Three Essays on Financial Markets and Monetary Policy

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The global financial crisis triggered by fallout from the sub-prime mortgage market in the U.S. has led economists to focus attention on the role of monetary policy in the crisis. The question of how monetary policy affects the financial sector is the key to the current debate over the role financial stability should play in the monetary policy decisions. As a contribution to this debate, my dissertation examines the link between monetary policy and three main financial sectors - the banking sector, the stock market, and the housing market.

The first essay examines whether the Federal Open Market Committee (FOMC) responded to changes in equity prices during the period 1966-2009. I distinguish the indirect response, where the FOMC reacts to equity prices only when equity prices affect its target variables, from the direct response, where the FOMC reacts to equity prices directly regardless of their effects on the target variables. In addition, the paper models the Federal Reserve’s reaction function as state dependent, hypothesizing that the FOMC may respond to changes in asset prices asymmetrically during different states of the economy. The results show that the FOMC did respond directly to equity price changes when asset prices were falling. During non-bust periods, the FOMC did not respond directly to equity prices. It used information on equity prices to forecast target variables.
The second essay investigates the effect of expansionary and contractionary monetary policy on the risk-taking behavior of low-capital and high-capital banks. Using quarterly data on federally insured banks spanning the period from 1991 to 2010, the paper shows that expansionary policy caused high capital banks to take more risk. Capital-constrained banks were not significantly affected by expansionary monetary policy. Contractionary monetary policy, however, is not effective in affecting the risk-taking behavior of both capital-constrained and unconstrained banks. The paper, therefore, confirms the hypothesis that expansionary policy is more effective in encouraging capital unconstrained banks to invest more in risky assets.

The third essay examines the role of monetary policy on housing bubbles in the last three decades. A spatial dynamic model is used to explicitly account for spatial cross-section dependence in the data. Using quarterly panel data on 48 contiguous U.S. states and District of Columbia, the paper discovers that the housing bubbles across the U.S. are mainly driven by the local or state specific factors during the period 1976 – 2000. However, the prolonged low interest rate since the 2001 recession contributed to the run-up in house prices across states.
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CHAPTER I

INTRODUCTION

The financial crisis that began in the summer of 2007 was the most severe since the Great Depression. The immediate cause was a downturn in the national housing market that followed a long period of rapid construction and rising home prices (Mishkin, 2009). These developments have created hardship for the families who are forced to leave their homes and have disrupted communities. It has also contributed to a major shock to the financial system, with sharp increases in credit spreads and large losses to financial institutions.

The Federal Reserve System (the Fed) was obligated to take a number of steps to contain the crisis as the subprime market disruption spread to other asset-backed securities and across the financial system. The Fed lowered the federal funds rate target from 51/4% in September 2007 to 1/4% in December 2008. Despite the substantial decline in the federal funds rate and interest rates on Treasury securities, the cost of credit to both households and businesses has generally risen. Since then interest rates on riskier debt instruments have risen sharply. Banks and other financial intermediaries have also sharply tightened credit standards for both household and business.

However, some researchers and financial commentators have linked stock market and housing price bubbles to excess liquidity in the financial system and excessive easy monetary policy (Taylor, 2009, Adrian and Shin, 2008). Opponent of this view have
taken the position that monetary policy was neither a principal cause of the asset price bubble nor the appropriate device for controlling the bubble in the financial markets (Mishkin, 2009, Bernanke, 2010). As a contribution to this ongoing debate, this dissertation explored the link between monetary policy and three major financial sectors – stock markets, banking sector and the housing market.

The first essay focused on addressing the question: What has been the response of the Federal Open Market Committee (FOMC) to movements in equity prices? In the previous studies there is no consensus whether the FOMC has adopted an unannounced policy goal of responding to the change in equity prices, or the FOMC consider stock price movements only to the extent that they impact on the primary monetary policy goals of price stability and output growth. The essay distinguishes the FOMC's reaction to forecasts of traditional goal variables, which may depend on equity prices, from the FOMC’s independent reaction to changes in equity prices. In addition, previous empirical studies implicitly assume that the response of FOMC to changes in equity prices is symmetric. Evidenced from different historical episodes, the Fed could respond differently depending on the state of the economy. The essay, thus, model the monetary policy reaction function as state dependent, to disentangle the asymmetric response of the Fed during the bust and non-bust periods.

A real-time data and Greenbook forecasts (GBF) or Survey of Professional Forecasts (SPF) of the target variables, either as regressors or as instruments, are used for the period 1966-2009. The regression results indicated that the FOMC did respond directly when the economy was in the state of asset bust. During the non-bust periods, the Fed was not responding to the change in equity prices. However, the Fed used the
stock market information in forecasting its policy targets regardless of the state of the economy.

The second essay contributes to the recent debate how monetary policy easing encourages banks to take excess risk. Most of the debates so far have focused on how low interest rate induced greater risk-taking through a search for yield (Rajan, 2005) or its effect on leverage (Bario and Zhu, 2008). But there could be an opposite risk-shifting effect when the banks operate with limited capital or excess liability. Furthermore, the empirical studies so far fail to distinguish the effects of contractionary and expansionary monetary policy on banks risk taking. It is unclear whether contractionary, expansionary policy or both drive banks risk-taking. This essay addresses these limitations by exploring the asymmetric response of capital-constrained and capital-unconstrained banks to the two monetary policy instances, i.e. expansionary and contractionary monetary policy. The response of well-capitalized banks to the change in monetary policy could be different from response of poorly-capitalized banks.

Using quarterly data on federally insured banks for the period 1991-2010, the result from the symmetric model indicated a positive link between federal funds rate and banks risk-taking. That means banks take more risk as the federal funds rate increases, and banks discourage to take more risk as interest rate falls. However, this positive linkage disappeared when the policy is disaggregated into expansionary and contractionary policy. In addition, the policy-asymmetric responses disappeared as the sample is divided into high capital and low capital banks. Well-capitalized banks responded more strongly to expansionary policy, while the poorly capitalized banks were not responding at all. The result also shows that contractionary policy didn't have any
significant effect on the risk-taking behavior of all banks independent of the level of capitalization.

The current financial turmoil, triggered by increasing defaults in the subprime mortgage market, has reignited the debate about the effect of monetary policy on boom-bust cycle of housing prices. The third essay examined the role of monetary policy on the boom and bust cycles of housing prices. Taylor (2007) showed that the exceptionally low short-term interest rate during the period 2003-2004 substantially contributed to the boom in the housing starts. It also led to an upward spiral of higher house price, falling delinquency and foreclosure rates, more favorable credit ratings and financing conditions, and higher demand for housing. As the short-term interest rates returned to normal levels, housing demand fell rapidly, bringing down both construction and house price inflation. A number of researchers and policy makers have been opposing Taylor’s (2007) view, including the current chairman of the Fed, Ben Bernanke and the former chairman, Alan Greenspan.

The above two opposing views were implicitly assume that the response of housing markets across the regions are the same. This is in fact based on the conventional view that monetary policy cannot be used to influence, control or target the economic conditions of particular regions. However, regional economic conditions can significantly influence the aggregate response to monetary policy actions (Carlino and Defina, 1999). The housing market across the states in east-coast, in the middle and west-coast are not only very heterogeneous but also interdependent across the neighboring states. I incorporated the three important factors – national, state or regional and spatial – in the analysis of the role of monetary policy on the housing boom-bust
cycle. Using quarterly panel data on 48 contiguous U.S. states and District of Columbia, the essay identified that how the change in the federal funds rate affected the growth in housing prices across the states. The results indicate that the housing bubble in the last three decades was mainly driven by the local or state specific factors, and the change in monetary policy didn’t have any significant effect. However, the recent housing boom was different in a sense that expansionary monetary policy had contributed to the run-up in the housing prices across the states.

In summary, these three essays concentrate on the dynamic relationship between the financial markets or institutions, and monetary policy. The first essay indicated that monetary authorities indeed had been taking into account the movement in equity prices after the bubble burst. The last two essays focused on the role of monetary policy on financial distress. Monetary policy easing had a significant impact on encouraging well-capitalized banks to take more risk. While the poorly capitalized banks were not significantly affected by the expansionary monetary policy. It is also found that the extended expansionary monetary policy since 2001 recession had a significant contribution on housing market boom, which subsequently burst after 2006.
CHAPTER II

HOW DID THE FEDERAL RESERVE RESPOND TO STOCK MARKETS?

2.1. Introduction

During the past two to three decades, the Federal Reserve has been largely successful at keeping inflation under control (Bernanke and Gertler, 2001). Although it is too early to say that inflation is no longer an issue of concern, it is quite plausible that the next battle facing the central bank is on a different front. The increase in financial instability, of which one important dimension is increased volatility of asset prices, has already been a concern of policy makers and researchers. In fact, there are obvious historical episodes that warrant such concern. For instance, the 1990 recession in the United States has been attributed to the preceding decline in real estate prices (Bernanke and Lown, 1991). Even the more recent rapid rise and subsequent decline in residential housing prices and stock prices have contributed to a major shock to the financial system. It leads to a sharp increase in credit spreads and large losses to financial institutions (Taylor, 2007). With these episodes in mind, it is normal for one to ask how the policy makers, i.e., the central bankers, respond to asset price variability.

A number of debates have been made on the appropriate role of equity prices on monetary policy deliberation. Two general arguments are considered in these debates. The first argument is that the central banks should not be independently concerned with
what is happening in the asset market; rather, the asset price variability provides information for predicting the main policy targets. The second argument is that the volatility in asset price could have a considerable impact on consumption and investment, and could affect the financial stability of the economy. Hence, central banks should be concerned about the asset market movement and thus respond to stock price variability. Most of these debates, however, revolved around policy prescriptions rather than policy actions. It is more important to understand the policy actions already undertaken for the future policy prescription. Using historical data this paper examines whether the central bank targets asset prices in addition to its inflation and output stabilization objective. It also examines whether asset prices only provide an informative role for monetary policy, by providing signals about expected inflation or output gap.

A recent study of this type was conducted by Fuhrer and Tootell (2008), who distinguish the Federal Open Market Committee’s (FOMC) reaction to forecasts of traditional monetary policy goals, which may depend on equity prices, from the FOMC’s independent reaction to changes in equity prices. They implicitly assume that the FOMC responds symmetrically when the economy is in different states (i.e., boom/bust). As Bordo and Jeanne (2002) pointed out, the response of the monetary authorities to asset price variability might be different depending on the state of the economy. During the boom period, the domestic private sector accumulates high levels of debt on the expectation of further rises in asset prices, while the assets themselves serve as collateral. During the asset market bust, the decline in the value of the collateral induces consumers to cut back expenditure. It also induces firms to reduce investment spending. The reduction in spending might lead to additional negative effects on asset prices, which may
further lead to financial instability. Yet the financial instability could build up in the environment of stable prices (Borio and Lowe, 2002). Thus to minimize the risk of financial instability, monetary authorities could consider the asset price as part of their target, independent of inflation and output gap.

The main objective of this paper is, therefore, to identify whether monetary policy has an independent concern for the movement in asset prices in different states of the economy (i.e., asset boom/bust). In addition, the paper addresses two important issues that are ignored by Fuhrer and Tootell (2008). First, the paper uses the real-time data set rather than the revised data. The revised data do not reflect the information available to the monetary authorities and they are, therefore, a poor guide to understand the authorities’ behavior (Orphanides, 2001). Thus, it is logical to evaluate monetary policy using information available to the monetary authorities at the time of the policy decision. Second, the paper addresses the existence of a weak instrument problem in the Instrumental Variable (IV) estimation used by Fuhrer and Tootell (2008).

By using the data for the period 1966-2009, this paper concludes that the Fed lowered the interest rate in response to decreases in asset prices when the economy was in an asset bust period. The Fed did not respond independently to the stock market in non-bust periods. This implies that the Fed was responding directly to stock market movement after the asset bubble reversal occurred, i.e., after the bubble burst. The Fed, however, used stock price as an indicator in forecasting the other targets, regardless of the state of the economy. These results are robust to alternative specifications and measurements of the variables used for estimation.
The remainder of the paper is organized as follows. Section 2.2 summarizes the literature explaining the relationship between asset price variability and monetary policy. In Section 2.3, the paper reviewed the standard framework of forward-looking interest rate (or Taylor) rules, including a discussion of the use of real-time data and the weak instrument problems. The asymmetric monetary policy reaction function is also specified in Section 2.3. Finally, the conclusion is made in Section 2.4.

2.2. Literature Review

The study of the role of asset prices in monetary policy has essentially led to an extension of the literature on monetary policy rules. Since Taylor (1993), monetary policy has been modeled as interest rate feedback rules whereby the Fed changes its policy instrument in response to variables in the economy, in particular, inflation and output variability. Taylor (1993) argues that his simple rule is a good representation of how the Fed sets its policy instrument. However, critics have shown that the so-called Taylor rule misses the inertial behavior of the interest rates. Moreover, a large volume of work on optimal policy rules as opposed to simple policy rules have been developed (for example, Clarida et al. 1999, 2000 and Woodford, 2001). Among the class of optimal policy rules, there is a division about how these rules are specified, especially when it comes to the possibility of the Fed’s reaction to asset price movements.

A monetary policy response to asset price developments can take two forms: either proactive, or reactive (Bordo and Jeanne, 2002). A reactive approach is consistent with an inflation targeting policy regime focusing on price stability. According to this
approach, the monetary authorities should wait and see whether the asset price reversal occurs. If it does occur, they should react to the extent that there are implications for inflation and output stability. This view is justified by Bernanke and Gertler (2000, 2001) who argued that it is desirable for central banks to focus on underlying inflationary pressures. Asset price becomes relevant only to the extent that it signals potential inflationary or deflationary forces. They concluded that as long as the monetary policy responds aggressively to inflation, there is no rationale for a direct response to asset prices. They also argued that trying to stabilize asset prices is problematic because it is nearly impossible to know for sure whether a given change in asset values results from fundamental factors, non-fundamental factors, or both.

Cecchetti et al. (2000), on the other hand, argued in favor of a more proactive response of monetary policy to asset prices. They claimed that asset price bubbles create distortions in investment and consumption, leading to extreme rises and subsequent declines in both output and inflation. Raising interest rates modestly as asset prices rise above what are estimated to be warranted levels would reduce the risk of asset reversal. Similarly, lowering interest rates modestly when asset prices fall below warranted levels helps to smooth these fluctuations by reducing the possibility of an asset price bubble forming, thus reduce the risk of boom-bust investment cycles.

The above proactive and reactive debate, which identifies how the Fed should systematically respond to asset price movements, has revolved more around analysis of policy prescriptions, rather than realized monetary policy actions. It is important to understand the policy actions already undertaken for the future policy prescriptions. A very limited number of studies use historical data identifying how the central banks
responded to asset price misalignments. Examples of such studies are Rigobon and Sack (2003), Chadha et al. (2004), and Fuhrer and Tootell (2008). Rigobon and Sack (2003) used an identification technique based on the heteroskedasticity of stock market returns to identify the reaction of the Fed to the stock markets. Their results indicated that monetary policy reacted significantly to stock market movements. Chadha et al. (2004) also examine whether asset prices and exchange rates are included in a standard interest rate rule using data for the United States, the United Kingdom, and Japan since 1979. Their results indicated that monetary policy makers respond independently to stock price misalignment and exchange rate variability. Their results also support the notion that in addition to the direct effect, both asset prices and exchange rates are used as information for setting interest rates.

Similarly, Fuhrer and Tootell (2008) distinguished the FOMC’s reaction to forecasts of traditional goal variables (i.e., inflation and output gap), which may depend on equity prices, from the FOMC’s independent reaction to changes in equity prices. By using the actual forward-looking variables examined by the FOMC (i.e., the “Greenbook forecasts"), they found little evidence to support the proposition that the FOMC responds independently to stock values. Rather, the FOMC uses stock price change for forecasting the usual monetary policy goal variables.

Fuhrer and Tootell (2008), however, implicitly assume that the FOMC responds symmetrically when the economy is in different states (i.e., boom/bust). They analyzed the response of monetary policy for the two sub-samples, Pre-Greenspan and Greenspan periods. Such a sample split, however, does not capture the state-dependent effects, which could vary within subsamples. The response of the monetary authorities to asset
price variability might be different depending on the underlying state of the economy. There is growing literature demonstrating that the effect of a liquidity shock on the economy, in particular for asset prices, is greater during asset price booms and busts in comparison to normal times. For example, Borio and Lowe (2002), Bordo and Jeanne (2002), and Detken and Smets (2004), among others, provide explanations that justify a tighter link between liquidity measures and asset prices during boom or bust periods.

During boom periods, rising asset prices strengthen banks' balance sheets, and as a result, banks' leverage falls. When banks target a certain leverage ratio, they want to increase their liabilities by borrowing more to buy new assets. These thereby lead to further an asset price rise, which will reignite the whole process. The exact same mechanisms will work in a comparable manner during bust periods. In such a situation the monetary authorities might intervene to stop the risk of a boom-bust cycle.

In summary, not only are there divergent views about whether monetary policy reacts to asset prices, but there is also another dimension to the problem – whether the reaction, if any, was symmetric in different states of the economy. A number of historical episodes (for example the 1987 and 1990 stock market crashes) for which the Fed was moving aggressively by reducing the short-term interest rate, motivated me to tackle these issues.

2.3. Monetary Policy Reaction Function

In this section I briefly review the standard framework analysis of forward-looking interest rate (or Taylor) rules, augmented by the stock price changes. This policy
rule allows for asset price to act as both information variables and monetary policy targets. The paper then discusses the state-dependent effects of asset price on monetary policy instrument. The main empirical results are reported under each sub-section.

2.3.1. Stock Market Augmented Taylor Rule

Following Clarida, Gali, and Gertler (CGG) (1998, 1999, and 2000), the following form of augmented forward-looking reaction function is specified as:

\[ i_t^* = \bar{r} + \Phi E_t X_{t+k} \]  

where \( i_t^* \) is the targeted nominal interest rate, \( X_{t+k} \) is the vector of targeting variables, i.e., inflation \( (\pi_t) \), output gap \( (y_t) \), and real GDP growth \( (\Delta y_t) \). \( \bar{r} \) is, by construction, the desired nominal rate when both inflation and output are at their target levels. \( \Phi \) contain parameter estimates of inflation, output gap, and real GDP growth.

The Taylor rule can also be estimated with a specification which allows for the possibility that the interest rate adjusts gradually to achieve its target level (Woodford, 1999). Following CGG, the actual observable interest rate \( i_t \) is assumed to partially adjust to the target as follows:

\[ i_t = (1 - \rho)i_t^* + \rho i_{t-1} + \varepsilon_t \]  

where \( \rho \in (0,1) \) captures the degree of interest rate smoothing. \( \varepsilon_t \) is an exogenous random shock and assumed to be i.i.d. Combining the partial adjustment, equation 2.2, with the target model (2.1) yields the policy reaction function as:

\[ i_t = \alpha + \Psi E_t X_{t+k} + \rho i_{t-1} + \varepsilon_t \]  

13
where \( \alpha = (1 - \rho)\tilde{\beta} \) and \( \Psi = (1 - \rho)\Phi \). This equation provides estimates of the coefficients on target variables and speed of adjustment (\( \rho \)).

The equity price augmented type of monetary policy rule is specified (Fuhrer and Tootell, 2008) as:

\[
i_t = \alpha + \Psi E_t X_{t+k} + \gamma S_{t-1} + \rho i_{t-1} + \varepsilon_t,
\]

where \( S_t \) is the asset price at period \( t \). To estimate this policy equation, we should substitute the unobserved (expected) target variables with realized values as follows:

\[
i_t = \alpha + \Psi X_{t+k} + \gamma S_{t-1} + \rho i_{t-1} + \nu_t,
\]

Where the error term, \( \nu_t = -\Psi[X_{t+k} - E_t X_{t+k}] + \varepsilon_t \), is a linear combination of the forecast error of inflation, output and the exogenous disturbances \( \varepsilon_t \).

The forecast of the variables, \( E_t X_{t+k} \), in equation 2.4 follow the process:

\[
X_{t+k} = \Theta I_t + \lambda S_{t-1} + \mu_t,
\]

where \( I_t \) is the information set used to forecast the policy variables. The main question addressed at this point is whether stock prices affect the federal funds rate directly, so that \( \gamma \neq 0 \) in equation 2.5; or indirectly, i.e., are used for forming forecasts of the variables \( X_{t+k} \) in equation 2.6, so that \( \lambda \neq 0 \).

Quarterly data from 1966:Q1 to 2009:Q1 are used. Following Fuhrer and Tootell (2008), the start of the sample is chosen because prior to this time the federal funds rate was not the effective policy instrument. The inflation rate (\( \pi_t \)) is measured as the annual
percentage change in GDP deflator. The output gap ($y_t$) is measured by the difference between real GDP and potential output, which is estimated by the Congressional Budget Office (CBO). The real GDP growth ($\Delta y_t$) is measured as the annual percentage change in real GDP. The Federal Funds rate is the nominal interest rate, obtainable from the Board of Governors of the Federal Reserve System. The percentage change in the S&P 500 price index is used as a measure of stock price, which are obtained from the EconStat data base.

The Greenbook forecasts (GBF) and the Survey of professional forecasts (SPF) of the target variables are obtained from the Federal Reserve Bank of Philadelphia. The Greenbook forecasts are prepared by the Fed staff and presented before each meeting of the Federal Open Market Committee (FOMC). The FOMC meets every six weeks and hence there are roughly 8 Greenbook forecasts available in a year. However, for the earlier part of the sample (i.e., 1966-1970), the FOMC meetings took place almost every month. Therefore there are twelve forecasts available within a year for that time period. For the period that Greenbook forecasts are made every six weeks, I use the forecasts closest to the middle of the quarter. For the early part of the sample when twelve Greenbook forecasts are available, I also choose the quarterly forecasts that were made in the second month of the quarter. The Greenbook forecasts are made available to the public with a five year delay, and hence my sample ends in the last quarter of 2003.

The median surveys of professional forecasts (SPFs) are also used as a proxy for the private sectors expectation about the future of the economy. This survey was

\[ \text{For robustness I also use the PCE chain-weight price index and consumer price index (CPI). The conclusions are not changed.} \]

\[ \text{For robustness the Dow Jones Industrial Average (DJIA) index and the NASDAQ composite price index are also used. The conclusions are not changed.} \]
originally conducted by the American Statistical Association/National Bureau of Economic Research and has been taken over by the Federal Reserve Bank of Philadelphia. The SPFs are performed near the end of the second month of each quarter. The SPF data span from the last quarter of 1968 to the last quarter of 2009.

Panel A of Table 2.1 presents parameter estimates of the baseline model (equation 2.4) for the full sample. The first column provides the Instrumental Variable (IV) estimates of the target variables when the Greenbook forecasts of the targets are used as instruments. These instruments include Greenbook forecasts of inflation, unemployment rate, and real GDP growth. Due to data limitation on Greenbook forecast of output gap, unemployment rate is used as alternative to output gap as of Fuhrer and Tootell (2008). Four lags of stock price changes are also included as instruments. The second column presents the IV estimates of the targets when SPFs are used as instruments, as alternative to the Greenbook forecasts. The results indicate that estimates of $\gamma$'s are not statistically different from zero at a 5% level of significance. This indicates that the Fed did not respond directly to the stock price changes. In line with the literature, the other traditional targets, i.e., inflation and output gap (measured by unemployment rate) are found to be positive and significant. The conclusion here is consistent with Fuhrer and Tootell's (2008) conclusion that the Fed did not directly target stock prices.

However, this paper addresses two related issues that are overlooked by Fuhrer and Tootell (2008). First, the paper deals with the existence of weak instrument problem in the IV estimation of the forward-looking policy reaction function. In fact, Fuhrer and

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3 The results reported in Table 2.1 employ one period ahead forecasting horizon (i.e. $k=1$). The results do not vary for the horizon $k=2, 3$ and $4$.

4 Due to the Orthogonality between regressors and the error term, the Instrumental Variable (IV) method of estimation is used.
Tootell (2008) partially disentangle "observational equivalent" or "weak identification" problem using FOMC forecasts as a more direct measure of information that enters the FOMC's policy decision.

As indicated in the first and second column, Panel A of Table 2.1, the Hansen's J-test doesn't indicate rejection of the overidentifying restriction. However, the validity of instruments not only depends on the exogeneity, but also on the "relevance" or the weakness of the instruments (Stock et al., 2002). The instruments are said to be "weakly identified" if the endogenous variables are weakly correlated with the instruments. When the instruments are weakly identified, the IV estimates, hypothesis tests, and confidence intervals are unreliable (Staiger and Stock, 1997, Andrews and Stock, 2005). The Cragg-Donald F-statistic is used to test the weakness of the instruments. Stock and Yogo (2005) proposed the F-statistic form of the Cragg and Donald (1993) statistic based on the null hypothesis: the instruments are weak. As reported in the first and second column of Panel A, I fail to reject the hypothesis at a 5% level of significance. Thus the inference drawn from these IV estimates suffered from a "weak identification" problem and, hence, is unreliable.

The second issue addressed in this paper is the use of real-time data rather than the revised data set that is used by Fuhrer and Tootell (2008). Most of these datasets are changing over time because of data revisions. For example, data on the real GDP reported at the first quarter of 2009 would be revised over the next couple of quarters. This data revision could come from the existence of measurement error or the availability of new information (Orphanides, 2001). Data revisions for inflation and the output gap both create differences between the data available to researchers and the data available to
policymakers. These differences are mainly caused by definitional changes and the data revisions themselves (Molodtsova et al., 2008). Another distinction is that real-time data are available to the policymakers, while not available to the public. Thus, this data incorporate information available to the FOMC at the time of policy decisions.

This paper uses the real-time data that are compiled by Croushore and Stark at the Federal Reserve Bank of Philadelphia (Croushore and Stark, 2001). These data sets have a triangular format with the vintage date on the vertical axis and dates on the horizontal axis. The term vintage denotes each date for which data is available as it appeared at the time. Because inflation and real GDP are not contemporaneously available, vintage dates are paired with the last available observation, generally one quarter earlier.

The third and fourth column of Panel A of Table 2.1 presents the parameter estimates using real-time data. Again stock prices are found to be statistically insignificant in affecting the monetary policy decision. The Hansen J-test doesn’t reject the overidentification restrictions and the Cragg-Donald F-statistic rejects the weak identification problem. Thus, the instruments are found to be valid in terms of both exogeneity and having a relatively strong correlation with the endogenous variables in the model. Thus, the estimated coefficients of stock price from real-time data are unbiased and more reliable than the estimates from the revised data set. As explained before, this makes sense since the FOMC didn’t have information about ex-post lags when making policy decisions. Rather the Fed had forecasts made by its staff and the real-time data at the time of policy decision.

As did Fuhrer and Tootell (2008), in addition to the full sample period under consideration, Table 2.1 also reports estimates for two sub-samples. Panel B and C
report the results for the pre-Greenspan era and the Greenspan era, respectively. The results are consistent and provide similar conclusions that the Fed did not independently respond to the stock price changes.

2.3.2. State Dependent Monetary Policy Rule

2.3.2.1. Asset Asymmetry

To examine the asymmetric response of the Fed to the stock price change, I specified a stock market-augmented Taylor rule as in equation 2.4. The lags of change in stock prices interacted with the dummy variable, measuring the underlying state of the economy, are included in the model below:

\[ i_t = \alpha + \Psi E_t X_{t+k} + \gamma_1 u_{t-1} S_{t-1} + \gamma_2 \omega_{t-1} S_{t-1} + \gamma_3 (1 - u - \omega)_{t-1} S_{t-1} + \varepsilon_t \tag{2.7} \]

where \( \omega \) is the dummy variable taking the value of 1 for the period of asset boom; otherwise it has a value of zero. \( u \) is also the dummy having the value of 1 for the asset bust quarters; otherwise it takes the value of zero.

The forecast of variables \( X_{t+k} \) in equation 2.7 follows the following process:

\[ X_{t+k} = \Theta I_t + \lambda_1 u_{t-1} S_{t-1} + \lambda_2 \omega_{t-1} S_{t-1} + \lambda_3 (1 - u - \omega)_{t-1} S_{t-1} + \mu_t \tag{2.8} \]

The paper addresses two key questions: first, whether the stock price changes affect the federal funds rate directly, so that \( \gamma_i \neq 0 \), in equation 2.7, or indirectly, used as instruments for forecasting \( X_{t+k} \), so that \( \lambda_i \neq 0 \), in equation 2.8, \( i=1 \) (asset boom), \( i=2 \) (asset bust), \( i=3 \) (no boom/bust); and second, whether the response of the Fed to stock price movement depends on the state of the economy, so that the statistical significance of \( \gamma_i, s_i \) are different at different states of the economy.
Following Bordo and Jeanne (2002), the asset boom or bust periods are defined when the three-year moving average of the growth rate in the asset price falls outside a confidence interval defined by the first and second moment of the series. Given that $S_t$ is the growth rate in the stock price in period $t$ and $\bar{S}$ is the average growth rate over all the periods. Then if the average growth rate between year $t-2$ and year $t$ is larger than a threshold, i.e., \[ \frac{S_t + S_{t-1} + S_{t-2}}{3} > \bar{S} + \sigma, \] then a boom is assumed in period $t-2$, $t-1$ and $t$, where $\sigma$ is the standard error of the series. Conversely a bust is assumed in the periods $t-2$, $t-1$ and $t$ if \[ \frac{S_t + S_{t-1} + S_{t-2}}{3} < \bar{S} - \sigma. \]

Figure 1 below shows the stock price changes, with the boom and bust periods marked with dark and light shaded bars, respectively. As evidenced from the figure, my assumption or detection of periods with asset boom and bust coincide with known asset price boom and bust cycles. It captures the late 1970's boom-bust cycle, the 1987 stock price crash, the early 2000 bust, and the recent huge bust in stock prices.

Table 2.2 reports estimates of the target variables from asset asymmetric reaction function using real-time data. The first column presents the parameter estimates using Greenbook forecasts as instruments, as with Fuhrer and Tootell (2008). The second column reports the estimates using surveys of professional forecasts as instruments. The results from these two columns indicate that stock prices are statistically significant when the economy was in the state of asset bust. In the non-bust periods, the stock prices are found to be statistically insignificant in affecting the monetary policy decision. This implies that the FOMC targeted stock prices when the economy was in a state of asset bust. Specifically, as the stock price decreased by one percent in the period of asset bust,
the Fed reduced the federal funds rate by at least 0.13 percent. The FOMC did not respond to stock price changes when the economy was in a state of asset boom or normal periods. The coefficient of inflation is above one and the coefficient of output gap is above zero, which is consistent with the Taylor principle. The reported Hansen J-test and Cragg-Donald F-statistic imply the instruments not only pass the overidentification restrictions, but also are not weakly identified. Hence, the estimates of the target variables reported are reliable.

Figure 1: Stock Price Changes during Asset Boom and Bust Period

Orphanides (2003) proposed two specifications of forward-looking monetary rules using real-time data. The first replaces one-quarter lagged inflation by forecasts of inflation, but retains the one-quarter lagged output gap. The second adds the forecasted
rate of growth of the output gap to the specification. Due to the limitation of forecasts of output gap data, this paper presents the OLS estimation results from the first specification. According to Orphanides (2003), it is not necessary to use instrumental variable (IV) techniques since the real-time forecasts are based only on information available contemporaneously.

The last two columns of Table 2.2 present the OLS estimates of the parameters using GBFs and SPF as regressors. Similar to the IV estimation results, stock price is found to be significant in the state of asset bust. In the non-bust periods, the asset price is found to be statistically insignificant. Again from the OLS estimation the same conclusion is made, that the Fed did directly respond to the stock market when the economy was in the state of asset bust. The Fed did not independently respond to stock prices in the non-bust periods. In addition, the estimated coefficients of inflation and output gap are in line with the Taylor principle.

2.3.2.2. Economy Asymmetry

The Fed's response to the stock market may vary not only at different states of the asset market (i.e., asset boom and asset bust), but also at different states of the economy (i.e., recession/expansion). Since the Fed's response could be asymmetric based on the state of the economy, I also estimated a model recognizing the asymmetric response at the state of recession and expansion. Thus, the variant of equation 2.7 and 2.8 is specified as follows:

\[ i_t = \alpha + \Psi E_t X_{t-k} + \gamma_1 r_{t-1} S_{t-1} + \gamma_2 (1 - r)_{t-1} S_{t-1} + \epsilon_t \]

\[ X_{t+1-k} = \Theta I_t + \lambda_1 r_{t-1} S_{t-1} + \lambda_2 (1 - r)_{t-1} S_{t-1} + \mu_t \]
where \( r \) is a dummy variable equal to 1 for the recession quarters, and to 0 for non-recession quarters. Table 2.3 presents the estimation results of the economy asymmetry reaction function (i.e., equation 2.9) based on NBER recognition of recession/contraction and non-recession periods. Both the IV and OLS estimation results indicated that the Fed responded to the stock market when the economy was in the state of contraction. The Fed, however, did not target stock market during the non-recession periods.

2.4. Stock Price as Information Set

In addition to examining whether the Fed directly targeted stock prices, this paper also looked at whether the Fed used the stock market as information set in forecasting the main traditional targets. Table 2.4 presents the coefficient estimates for lagged stock prices and their p-values for the estimated forecasting equations (2.6), (2.8), and (2.10). The upper portion of the table presents those coefficients from symmetric specification. The first column reports the coefficients using revised data with Greenbook forecasts, as of Fuhrer and Tootell (2008). The lag of stock price turns out to be significant in forecasting the policy target variables, i.e., inflation and unemployment rate.\(^5\) It implies that the Fed did respond indirectly to stock price change, i.e., the Fed used stock price as part of the information set in forecasting the policy targets.

The lower portions of Table 2.4 provide the coefficients for lagged stock prices from asymmetric forecasting specifications. The first two columns under the lower portion present those coefficients using Greenbook forecasts. The estimated coefficients

\(^5\) Unemployment rate is used as alternative to output gap, as a policy target variable, due to data limitation on Greenbook forecast of output gap.
in forecasting policy targets are found to be statistically different from zero no matter what the state the economy was in. This implies that the Fed did use the change in stock price as an information variable in forecasting the policy targets irrespective of the state of the economy.

The last two columns in the lower panel of Table 2.4 present the coefficients of lagged stock prices using SPF's. Again the change in stock price is found to be statistically significant in forecasting inflation and unemployment rate. The change in stock price had a negative and significant impact in forecasting inflation when the economy experienced asset boom and bust. When the economy was in the state of asset boom, the increase in asset price signaled a decrease in price level. On the other hand, when the economy was at the state of asset bust, the decline in the asset price forecasted inflationary pressure. Similarly, the stock price change had a significant impact in the forecast of the unemployment rate. During the boom period, an increase in stock price forecasted a decrease in unemployment rate, whereas a decline in stock price signaled an increase in unemployment rate during the bust periods. From these results one can conclude that the Fed used stock price movements as information in forecasting the target variables regardless of the state of the economy.

2.5. Conclusion

The increase in financial instability, of which one important dimension is increased volatility of asset prices, has been the concern of policy makers and researchers. The question is how the monetary authorities responded to the volatility of
asset prices? Although previous studies try to answer this question, there is no consensus among the researchers. This paper distinguishes the indirect response, where the FOMC reacts to equity prices directly regardless of their effects on the target variables. In addition, the paper models the reaction function as state-dependent, hypothesizing that the FOMC may respond to changes in asset prices asymmetrically during different states of the economy. This is in fact supported by different episodes of the asset price crash in the 1990's and even the recent 2008 asset price bubble, where the Fed reduced the interest rate to a historical low since the Great Depression.

The results, which are based on quarterly data for the period from 1966 to 2009 show that the FOMC did respond indirectly to the stock price change regardless of whether the economy was experiencing an asset boom, bust, or a normal period. That means the Fed used the stock market information in forecasting its policy targets. In addition to the indirect response, the Federal Reserve responded directly to the change in stock price when the economy experienced asset busts. Specifically, the Fed reduced the interest rate, on average, at least by 13 points as the stock price decreased by one percentage point.

It is apparent that the Fed could inject liquidity and build business confidence by reducing the interest rate when the economy is in the state of asset bust or in state of recession. However, reversing business confidence could take time, and can’t be achieved in a short period of time. The possible instability, i.e., financial instability, created after the asset reversal could bring a lot of damage to the economy. It is, therefore, very important that the Fed should closely follow and respond to the stock markets before the asset burst or reversal occurs. It might be important to analyze and
estimate the threshold level of the change in stock price that the Fed should carefully watch and respond accordingly. That is beyond the scope of this study and part of future research.
Table 2.1
Instrumental Variable (IV) Estimation Results of Symmetric Monetary Reaction Function

<table>
<thead>
<tr>
<th>Sample</th>
<th>Parameters</th>
<th>Estimated Coefficients</th>
<th>Revised Data</th>
<th>Real-time Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>GBF</td>
<td>SPF</td>
</tr>
<tr>
<td></td>
<td>Inflation</td>
<td>2.015**</td>
<td>3.450**</td>
<td>2.024**</td>
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<tr>
<td></td>
<td>Real GDP Growth</td>
<td>0.638</td>
<td>0.983**</td>
<td>0.637</td>
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<td></td>
<td>Stock Price</td>
<td>0.108</td>
<td>-0.027</td>
<td>0.121</td>
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<tr>
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<td>Lag of Federal funds rate</td>
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<td>0.94**</td>
<td>0.87**</td>
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<tr>
<td></td>
<td>Hansen J-test</td>
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<td>0.14</td>
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<tr>
<td></td>
<td>Cragg-Donald F-statistic</td>
<td>6.62</td>
<td>2.37</td>
<td>21.67</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Panel A</td>
<td></td>
</tr>
<tr>
<td><em>Post-Greenspan</em></td>
<td>Unemployment rate</td>
<td>-1.608</td>
<td>-2.725**</td>
<td>-1.570</td>
</tr>
<tr>
<td>(1966-1987)</td>
<td>Inflation</td>
<td>3.052**</td>
<td>2.988**</td>
<td>2.892**</td>
</tr>
<tr>
<td></td>
<td>Real GDP Growth</td>
<td>0.123</td>
<td>0.413**</td>
<td>0.104</td>
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<td></td>
<td>Stock Price</td>
<td>0.191</td>
<td>-0.012</td>
<td>0.192</td>
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<tr>
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<td>Lag of Federal funds rate</td>
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<td>0.92**</td>
<td>0.90**</td>
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<tr>
<td></td>
<td>Hansen J-test</td>
<td>0.14</td>
<td>0.24</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>Cragg-Donald F-statistic</td>
<td>1.93</td>
<td>4.18</td>
<td>45.73</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Panel B</td>
<td></td>
</tr>
<tr>
<td><em>Post-Greenspan</em></td>
<td>Unemployment rate</td>
<td>-1.363</td>
<td>-1.067</td>
<td>-0.818</td>
</tr>
<tr>
<td>(1987-2009)</td>
<td>Inflation</td>
<td>2.333**</td>
<td>1.393**</td>
<td>2.273**</td>
</tr>
<tr>
<td></td>
<td>Real GDP Growth</td>
<td>1.063</td>
<td>0.307</td>
<td>0.745**</td>
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<td></td>
<td>Stock Price</td>
<td>0.154</td>
<td>0.180</td>
<td>0.145</td>
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<td>Lag of Federal funds rate</td>
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<td>0.85**</td>
<td>0.89**</td>
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<tr>
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<td>0.22</td>
<td>0.34</td>
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<td>Cragg-Donald F-statistic</td>
<td>2.66</td>
<td>6.31</td>
<td>32.51</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Panel C</td>
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</tbody>
</table>

** (P<0.05)

\[ i_t = \alpha + \Psi X_{t+1} + \gamma S_{t-1} + \rho i_{t-1} + \varepsilon_t, \quad X_{t+1} = (y_{t+1}, \Delta y_{t+1}, \pi_{t+1}) \] and \( \psi = (\beta, \delta, \theta) \),

where \( i_t \) is Federal funds rate. \( y_t \) is unemployment rate/output gap. \( \Delta y_t \) is Real GDP growth rate. \( \pi_t \) is Inflation rate. \( S_t \) is change in S&P 500 stock price index. \( \beta, \delta, \) and \( \theta \) are parameter coefficients of inflation, unemployment rate/output gap and Real GDP growth, respectively. Greenbook Forecasts (GBFs) or Survey of Professional Forecasts (SPFs) and four lags of change in stock prices are used as instruments. The critical values for the Cragg-Donald F statistic are: 20.27 at 5% and 10.77 at 10% based on relative bias and 33.51 and 15.07 based on relative size. The test rejects the null if the Cragg-Donald F-static exceeds the critical value.
## Table 2.2
Estimation Results of Asset Asymmetry Reaction Function

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Estimated Coefficients</th>
<th>IV</th>
<th>SPF as instruments</th>
<th>GBF as instruments</th>
<th>OLS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>GBF as instruments</td>
<td>SPF as instruments</td>
<td>GBF of as regressors</td>
<td>SPF of as regressors</td>
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<tr>
<td>Unemployment rate</td>
<td>-1.462**</td>
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<tr>
<td>Real GDP Growth</td>
<td>0.369</td>
<td>1.016**</td>
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<tr>
<td>Inflation</td>
<td>2.031**</td>
<td>2.34**</td>
<td>1.53**</td>
<td>1.33**</td>
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</tr>
<tr>
<td>output gap</td>
<td></td>
<td></td>
<td>0.57</td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td>Stock Price</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Asset Boom</td>
<td>-0.062</td>
<td>-0.11</td>
<td>0.073</td>
<td>0.031</td>
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<tr>
<td>Asset Bust</td>
<td>0.292**</td>
<td>0.225**</td>
<td>0.125**</td>
<td>0.167**</td>
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<tr>
<td>No Asset Boom/Bust</td>
<td>0.365</td>
<td>0.184</td>
<td>0.067</td>
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<tr>
<td>Lag of Federal funds rate</td>
<td>0.87**</td>
<td>0.90**</td>
<td>0.85**</td>
<td>0.85**</td>
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<td>Hansen J-test</td>
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<td>0.80</td>
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<tr>
<td>Cragg-Donald F-statistic</td>
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<tr>
<td>R²</td>
<td>0.79</td>
<td>0.84</td>
<td>0.85</td>
<td>0.83</td>
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</table>

** (P<0.05)

\[ i_t = \alpha + \Psi X_{t+1} + \gamma_1 u_{t-1} S_{t-1} + \gamma_2 \sigma_{t-1} S_{t-1} + \gamma_3 (1 - u - \sigma)_{t-1} S_{t-1} + \varepsilon_t, \]

\[ X_{t+1} = (y_{t+1}, \Delta y_{t+1}, \pi_{t+1}) \text{ and } \Psi = (\beta, \delta, \theta), \]

where \( i_t \): Federal funds rate, \( y_t \): unemployment rate/output gap, \( \pi_t \): Inflation rate, annual rate, \( S_t \): Percent change in S&P 500 stock price index. \( o \) and \( u \) are dummy for Boom and Bust periods, respectively. \( \beta, \delta, \) and \( \theta \) are parameter coefficients of inflation, output gap and Real GDP growth, respectively. \( \gamma_1, \gamma_2, \) and \( \gamma_3 \) are parameter coefficients of stock price change during the period of asset boom, asset bust and normal period, respectively. Greenbook Forecasts (GBFs) or Survey of Professional Forecasts (SPFs) and four lags of change in stock prices are used as instruments. The critical values for the Cragg-Donald F statistic are: 20.27 at 5% and 10.77 at 10% based on relative bias and 33.51 and 15.07 based on relative size. The test rejects the null if the Cragg-Donald F-static exceeds the critical value.
Table 2.3
Estimation Results of Economy Asymmetry Reaction Function

<table>
<thead>
<tr>
<th>Parameters</th>
<th>IV Estimated Coefficients</th>
<th>OLS Estimated Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GBF as instruments</td>
<td>SPF as instruments</td>
</tr>
<tr>
<td>Unemployment rate</td>
<td>-0.733**</td>
<td>-1.117**</td>
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<tr>
<td>Real GDP Growth</td>
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<td>0.750</td>
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<tr>
<td>Inflation</td>
<td>1.687**</td>
<td>2.800**</td>
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<tr>
<td>output gap</td>
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<tr>
<td>Stock Price</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recession</td>
<td>0.093**</td>
<td>0.056**</td>
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<tr>
<td>Non-recession</td>
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<tr>
<td>Lag of Federal funds rate</td>
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</tr>
<tr>
<td>Hansen J-test</td>
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<tr>
<td>Cragg-Donald F-statistic</td>
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<tr>
<td>R2</td>
<td>0.82</td>
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</table>

** (P<0.05)

\[ i_t = \alpha + \Psi X_{t+1} + \gamma_1 r_{t-1} S_{t-1} + \gamma_2 (1 - r)_{t-1} S_{t-1} + \varepsilon_t, X_{t+1} = (y_{t+1} \Delta y_{t+1} \pi_{t+1}) \] and \[ \Psi = (\beta \delta \theta) \] where \( i_t \) is Federal funds rate, \( y_t \) is unemployment rate/Output gap, \( \Delta y_t \) is Real GDP growth rate, \( \pi_t \) is Inflation rate, \( S_t \) is change in S&P 500 stock price index. \( \beta \), \( \delta \) and \( \theta \) are parameter coefficients of inflation, output gap and Real GDP growth, respectively. Greenbook Forecasts (GBFs) or Survey of Professional Forecasts (SPFs) and four lags of change in stock prices are used as instruments. The critical values for the Cragg-Donald F statistic are: 20.27 at 5% and 10.77 at 10% based on relative bias and 33.51 and 15.07 based on relative size. The test rejects the null if the Cragg-Donald F-statistic exceeds the critical value.
Table 2.4
Information Set and Stock Price Change

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Estimated Coefficients</th>
</tr>
</thead>
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<td><strong>Symmetric Model</strong></td>
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<td>Inflation</td>
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<tr>
<td>Unemployment rate</td>
<td>-0.0057**</td>
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<tr>
<td>Real GDP Growth</td>
<td>0.0212**</td>
</tr>
<tr>
<td><strong>Asymmetric Model</strong></td>
<td></td>
</tr>
<tr>
<td>Inflation</td>
<td></td>
</tr>
<tr>
<td>Asset Boom</td>
<td>0.006**</td>
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<tr>
<td>Asset Bust</td>
<td>0.054**</td>
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<tr>
<td>No Asset Boom/Bust</td>
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<tr>
<td>Recession</td>
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<tr>
<td>Non-recession</td>
<td>0.009**</td>
</tr>
<tr>
<td>Unemployment rate</td>
<td></td>
</tr>
<tr>
<td>Asset Boom</td>
<td>-0.003**</td>
</tr>
<tr>
<td>Asset Bust</td>
<td>-0.009**</td>
</tr>
<tr>
<td>No Asset Boom/Bust</td>
<td>-0.002**</td>
</tr>
<tr>
<td>Recession</td>
<td>-0.013**</td>
</tr>
<tr>
<td>Non-recession</td>
<td>-0.004</td>
</tr>
<tr>
<td>Real GDP Growth</td>
<td></td>
</tr>
<tr>
<td>Asset Boom</td>
<td>-0.002</td>
</tr>
<tr>
<td>Asset Bust</td>
<td>0.045**</td>
</tr>
<tr>
<td>No Asset Boom/Bust</td>
<td>-0.002</td>
</tr>
<tr>
<td>Recession</td>
<td>-0.059</td>
</tr>
<tr>
<td>Non-recession</td>
<td>-0.014</td>
</tr>
</tbody>
</table>

** (P<0.05)

Symmetric Model: \( \mathbf{X}_{t+1} = \mathbf{\Theta}_t + \lambda_1 r_{t-1} S_{t-1} + \lambda_2 (1-r)_{t-1} S_{t-1} + \mu_t \)

Asymmetric Model: \( \mathbf{X}_{t+1} = \mathbf{\Theta}_t + 1 \lambda_1 u_{t-1} S_{t-1} + \lambda_2 \sigma_{t-1} S_{t-1} + \lambda_3 (1 - \sigma_{t-1}) S_{t-1} + \mu_t \)

and \( \mathbf{X}_{t+1} = (y_{t+1}, \Delta y_{t+1}, \pi_{t+1}) \), where \( y_t \): unemployment rate/Output gap, \( \pi_t \): Inflation rate, annual rate, \( \Delta y_t \): Real GDP growth. \( \mathbf{\Theta}_t \) is a vector contains four lags of inflation, unemployment rate and real GDP growth, and GBF/SPFs of inflation, unemployment rate and real GDP growth. \( S_t \): Percent change in S&P 500 stock price index. \( \sigma \) and \( u \) are dummy for Boom and Bust periods, respectively. \( r = 1 \) a dummy for recession periods.
CHAPTER III

ASYMMETRIC BANK RISK TAKING AND MONETARY POLICY

3.1. Introduction

The financial crisis that began in the summer of 2007 was an extraordinarily complex event. Troubles in the credit markets negatively affected banks, liquidity evaporated in the interbank markets, and central banks intervened on a scale not often seen before. Many market observers and researchers claimed that the low interest rate is the main cause for this crisis. A low interest rate may encourage banks to take more risk in different ways. Low returns on investments, such as government bonds or risk-free assets, may increase incentives for asset managers to take on more risks for contractual, behavioral or institutional reasons (Rajan, 2005). Low interest rates can make banks take more risk through their impact on valuation, income, and cash flow (Adrian and Shin, 2008, Bario and Zhu, 2008).

Yet the question of how monetary policy affects banks’ risk-taking is the key to the current debate over what role financial stability considerations should play in the monetary policy decisions. Most of the debates so far have focused on how monetary policy easing can induce greater risk-taking through a search for yield or its effect on
leverage, a view this paper broadly supports. But there could be an opposite risk-shifting effect when the banks operate with limited capital or excess liability and a weaker capital regulation in the financial system (De Nicolo, 2010). The response of well-capitalized (high-capital or capital-unconstrained) banks to monetary policy easing could be different from the poorly capitalized (low-capital or capital-constrained) banks. The limited capital constraint could allow the high-capital banks to expand their loans and take more risk, responding to the fall in short term interest rate, while the poorly capitalized banks could do the opposite. Thus, the main objective of this paper is exploring the asymmetric response of high-capital and low-capital banks (called cross-sectional asymmetry) to the change in monetary policy.

Furthermore, the empirical studies so far fail to distinguish between the effects of the two policy instances (i.e., contractionary policy and expansionary policy) on banks' risk-taking response. It is unclear whether expansionary policy (a reduction in interest rate), or contractionary policy (a rise in interest rate), or both drive the empirical results. Recently, the Bank Lending Channel (BLC) literature identified the asymmetric loan supply response associated with the two policy instances for a given capital-constrained banks. According to this literature, expansionary policy has a weak effect on increasing the loan supply of capital-constrained banks, whereas contractionary policy has a strong effect on decreasing the loan supply of capital-constrained banks. Likewise, for the capital-unconstrained banks, expansionary policy has a strong stimulating effect on loan supply, and contractionary monetary policy has a weak or no effect on banks' loan supply (Kishan and Opeciela, 2000). This asymmetric response is observed not only in loan

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6 These include Borio and Zhu (2008), Adrian and Shin (2008), Altunbas et al. (2009), Diamond and Rajan (2009) and Taylor (2009).
supply, but also on the risk-taking response of loan-supplying institutions, i.e., banks (Borio and Zhu, 2008). Thus, this paper also compares the separate effects of contractionary and expansionary policy independently on risk-taking behavior of both low-capital and high-capital banks.

Using quarterly data on balance sheet items of federally insured banks spanning the period from 1991:Q1 to 2010:Q1, this paper analyzes how the change in federal funds rate affect banks’ risk-taking. The result from the symmetric model indicated a positive link between the interest rate and banks’ risk-taking, indicating that banks take more risks as the federal funds rate increases, and banks take fewer risks as the interest rate falls. However, this positive link between the change in the short-term interest rate and banks’ risk-taking disappeared when the policy is disaggregated into two: contractionary and expansionary policy. Specifically, expansionary policies were effective and encouraged banks to take more risk, while contractionary policies were ineffective in affecting the banks’ risk.

In addition, the above policy-asymmetric responses disappeared as the sample is divided based on the leverage ratio: high-capital and low-capital banks. Well-capitalized banks responded more strongly to expansionary policy, while the poorly capitalized banks did not respond at all. More particularly, a one percentage fall in the interest rate increased the high-capital banks’ risk ranging from 8 percent to 17 percent. The results also show that contractionary policy didn’t have any significant effect on the risk-taking behavior of all banks independent of the level of capitalization.
The next section presents the empirical methodology and the data used in the empirical analysis. The empirical results from symmetric and asymmetric specifications are presented in Section 3.3. Finally, Section 3.4 provides the conclusions of the paper.

3.2. Empirical Methodology and Data

Most of the mechanisms proposed so far in the literature point out a negative relationship between the monetary policy and banks’ risk. Indeed, monetary policy easing induces greater risk-taking through a search for yield (Rajan, 2005, Bario and Zhu, 2008), asset substitution (Fishburn and Porter, 1976), and its effect on leverage and asset valuation (Adrian and Shin, 2008, Altunbas et al, 2010). A “search for yield” argument goes as follows. Financial institutions with long-term commitments, such as insurance companies, need to match the yield they promised on their liabilities with what they obtain on their assets (Rajan, 2005). When interest rates are low, they are forced to invest in riskier assets to match the yield on their liabilities. If yields on safe assets remain low for a prolonged period, financial institutions will need to default on their long-term commitments. When interest rates are high, they can generate the necessary revenue by investing in safe assets.

A related mechanism operates through asset substitution. Under general conditions, a lower yield on safe assets will lead banks to decrease their portfolio holdings. Risk-neutral and risk-loving banks will increase their demand for risky assets until equilibrium returns and both types of investments are equalized. Risk-averse banks, however, could reallocate their portfolios and hold safer assets under most utility
functions (Fishburn and Porter, 1976). A complementary mechanism that a fall in the interest rate can encourage risk-taking is through leverage channel (Adrain and Shin, 2008). Banks react by buying or selling assets when faced with shocks to their profits and leverage. Monetary policy easing boosts asset prices and increases banks’ equity relative to corporate debt. Then banks respond to the fall in leverage by increasing the holding of risky assets (Adrian and Shin, 2008).

Asymmetric information is the key to this negative relationship between monetary policy easing and banks’ risk-taking. Risk-neutral leveraged banks behave like risk-loving agents since they do not internalize the losses they impose on depositors and investors. If investors were able to correctly price the bank’s risk-taking at the margin, the incentive to invest in an excessively risky portfolio would disappear. The higher private yield of riskier investments would be compensated for by the higher cost of the bank’s liabilities. However, since investors cannot observe the bank’s portfolio, excess risk-taking occurs even when the bank’s liabilities are priced correctly (Keely, 1990).

The charter value hypothesis, on the other hand, claimed a positive link between monetary easing and banks’ risk-taking. In the formal frameworks of this channel developed by De Nicolo (2010), a reduction in the policy rate leads to lower deposit rates passing through lending rates. Assuming a fully leveraged bank that is financed fully through deposits, a cut in the policy rate would increase the bank’s expected net return on all its assets by lowering the rate it has to pay on deposits. But this increase would be disproportionately larger for safer assets, since the bank’s investment in these assets means a higher probability that it will have to repay depositors. It follows that a reduction in the policy rate makes riskier assets relatively less attractive. This is
consistent with results in Altunbas et al. (2010), who use data from European and US banks, and find that increases in interest rates and negative Taylor rule residuals are positively associated with default risk measures.

To examine this link between monetary policy and banks' risk-taking, the following model was designed (Altunbas et al., 2010):

$$\Delta R_{i,t} = \beta_0 + \beta_1 \Delta R_{i,t-1} + \sum_{j=0}^{1} \beta_f \Delta i_{t-j} + \sum_{j=0}^{1} \beta_m M_{i,t-j} + \sum_{j=0}^{1} B_{i,t-j} + \epsilon_{i,t}$$

where $i = 1, \ldots, N$, and $t = 1, \ldots, T$, $N$ is the number of banks, and $T$ is the final year. $R_{i,t}$ represents bank risk by bank $i$ at period $t$. $i_t$ is the short-term interest rate. $M_i$ is the vector of macroeconomic variables and $B_{i,t}$ is the vector of bank-specific characteristics.

The link between monetary policy and bank risk could also be influenced by the balance sheet or bank-specific characteristics that summarize the ability and willingness of banks to supply additional loans (Lepetit et al., 2008, Konishi and Yasuda, 2004). In this paper, therefore, three variables are introduced to capture the bank-specific characteristics: ASSET (the log of total assets), LIQ (liquidity to total assets) and CAP (the capital-to-asset ratio). Well-capitalized banks and banks with a more liquid portfolio are more likely risky, given that all other things are equal (Kishan and Opeiela, 2000). The effect of ASSET on bank risk is negative because larger banks are more capable of managing risks (and thus less risky) than small banks (Lepetit et al., 2008 and Konish and Yasuda, 2004).

The macroeconomic condition of the economy could also affect the link between monetary policy and bank risk. Better economic conditions that are captured by nominal
GDP growth increase the number of projects that become profitable in terms of expected net present value, and thereby reduce the overall credit risk of the banks (Altunbas et al, 2009 and 2010). The overall profitability of banks, estimated by the slope of the yield curve, also affects their risk-taking behavior. Thus the steeper the yield curve, the greater the negative effect on bank risk, since their assets have a longer maturity than liabilities (Altunbas et al. 2010). According to Altunbas et al. (2010), the evolution of asset price and housing price are also introduced in the model to take into account the improvements in borrowers’ net worth and collateral. An increase in asset prices or housing prices increases the value of collateral and thus reduces the overall credit risk (Altunbas et al, 2010).

Quarterly data on balance sheet items of federally insured banks spanning the period from 1976 quarter 1 to 2010 quarter 1 are used. These data were obtained from the Report of Condition and Income (or Call Report) that all insured banks submit to the Federal Reserve. The data contains information for over 6000 banks operated each year across the country. All the banks, including merged or bankrupt banks, are considered as long as the balance sheet information is available. However, those banks having information of less than four quarters are dropped from the sample. Macroeconomic variables, i.e., the federal funds rate, nominal GDP, and ten-year government bond rate, are obtained from the Federal Reserve System database. The housing price index is obtained from the Federal Housing Enterprise Oversight (OFHEO). The S&P 500 price index is used as a measure of stock price, which is obtained from EconStat data base. The slope of the yield curve is calculated as the difference between the ten-year government bond yields and the short term interest rate, i.e., federal funds rate. The
deviation of the interest rate from the benchmark measure is calculated as the difference between the real short-term interest rate and the "natural interest rate," calculated using the Hodrick-Prescott filter.\footnote{Two additional benchmark measures have been used: (i) generated by "Taylor rule" with interest rate smoothing and (ii) generated by a standard "Taylor rule" using equal weights on output and inflation and no interest rate smoothing.}

The standard ex post measures of banks' risk, based on quarterly accounting data and calculated for each bank throughout the period, are used in this study. These measures are: (i) the standard deviation of the return on assets (SDROA); (ii) the standard deviation of the return on equity (SDROE); and (iii) the ratio of loan loss provisions to total loans (LLP). I also computed the insolvency risk measure Z-score (ZSCORE hereafter) which is developed by Boyd et al. (1993). The ZSCORE is a statistic indicating the probability of bankruptcy, which is calculated as: \[ \text{ZSCORE} = \frac{\text{ROA} + \text{EA}}{\text{SDROA}}, \] where ROA is net income-total asset ratio and EA is equity-asset ratio. Since the ZSCORE is negatively associated with the insolvency risk, I define the downside risk as being the negative value of the ZSCORE.

3.3. Empirical Results

This paper employs first difference to obtain the estimates of the model, as proposed by Arellano and Bover (1995) and Blundell and Bond (1998). The dynamic GMM estimator allows for a number of advantages. It exploits the time series element of the data and in differences, it controls for firm-specific effects, like the fixed-effect method. It also allows for the inclusion of lagged dependent variables as regressors and
controls for the endogeneity of explanatory variables (Roodman, 2006). The GMM method can be applied when: (1) N is large but T is small; (2) the explanatory variables are endogenous, and (3) unobserved firm-specific effects are correlated with other regressors. In fact, GMM estimators ensure efficiency and consistency provided that the models are not subject to serial correlation of order two and the instruments used are valid (which is tested with the Sargan test). This section reports banks’ risk-taking response to symmetric monetary policy using four different alternative measures of banks’ risk. It also reports the banks’ risk-taking response to asymmetric monetary policy (i.e., contractionary and expansionary monetary policy). In addition, the cross-section asymmetric responses of high-capital banks and low-capital banks to monetary policy are presented in this section.

3.3.1. Symmetric and Asymmetric Monetary Policy

The results for symmetric and asymmetric effects of monetary policy on risk-taking behavior of all the banks in the sample are contained in Table 3.1. The first two columns report the results using the negative of the change in ZSCORE as the dependent variable and measure of banks’ risk. As presented in the first column, the coefficients associated with the change in the federal funds rate are significant and positive, indicating that the lower interest rate discourages banks from taking more risk. This result is consistent with the other three alternative measures of banks’ risk. The overall quality of a loan portfolio indeed increases; thereby the banks’ risk falls, if interest rates are lower. This is consistent with the findings of Jimenez et al. (2009) and Altunbas et al. (2010). It is also consistent with the theoretical prediction of Dimoand and Rajan (2009) who indicate that
the drop in banks’ risk is probably reinforced by the reduction in bank funding liquidity cost after the decrease in the short-term interest rate.

Unlike the previous studies the paper also examines the effect of the asymmetric monetary policy on banks’ risk and thus divides the monetary policy into two: contractionary and expansionary monetary policy. In this study, an increase in the federal funds rate implies contractionary policy, whereas a decrease in the federal funds rate implies an expansionary policy. As reported in Table 3.1, most of the coefficients associated with an expansionary monetary policy are negative and significant, indicating that an expansionary monetary policy encouraged banks to take more risk, whereas the coefficient associated with a contractionary policy are insignificant across all the specifications. This implies that an expansionary monetary policy had been more effective and encourages banks to invest in risky assets. Specifically, a one percent reduction in the short-term interest rate increased banks’ risk-taking, on average, with a range of 0.3% to 18%. The reliability of the above results are tested and supported by the Sargen test and the second order auto-correlation test.

3.3.2. Cross-sectional Asymmetric Risk-taking

In order to exploit the different risk-taking behaviors of highly leveraged or low-capital banks and high-capital banks (i.e. cross-sectional asymmetry), the sample is classified based on banks’ leverage ratio. Banks with a capital leverage ratio below 8% are considered to be low-capital (capital-constrained) banks, whereas banks with a leverage ratio 8% and above are high-capital (capital-unconstrained) banks. My choice of a benchmark ratio as 8% is based on two considerations. First, 8% is the 25th
percentile for my sample and one can make the argument that a bank may be considered constrained if its leverage ratio is below the 25\textsuperscript{th} percentile. Second, 8\% is the minimum regulatory requirement based on a 100\% risk weight.

A comparison of the balance sheet items and bank-risk measures for high- and low-capital banks yields some noteworthy differences. Table 3.2 reports the mean of the balance sheet variables (ASSET, CAP and LIQ) and four alternative measures of banks' risk. While we cannot make definitive statements about the risk-taking behavior of banks by looking at the mean comparison test, the mean differences can help to understand the possible different behavior of the two groups of banks. As indicated by the t-test statistics, the mean of the alternative measures of banks' risk are all statistically different between the low- and high-capital banks. It also indicates that the mean value of the risk measures higher for high-capital banks as compared to low-capital banks. This comparison test also shows that the two groups of banks are significantly different in terms of their bank specific characteristics. The mean capital-to-asset ratio for low-capital banks is about 7\%, which is below our benchmark of 8\%. The high-capital banks are more liquidated and highly capitalized as compared to low-capital banks.

The asymmetric response of high-capitalized and low-capitalized banks to the change in monetary policy is analyzed by estimating the baseline model for the two groups of banks separately. Table 3.3 reports the effect of expansionary and contractionary monetary policy on low- and high-capital banks' risk-taking separately. The coefficients associated with expansionary monetary policy for low-capital banks are all insignificant, indicating that expansionary policy seems to have no stimulating effect for these banks to take more risk. Contractionary policy didn't have any significant
effect on capital-constrained banks either. This implies that no change in monetary policy had any significant effect on the risk-taking of capital-constrained banks.

However, all of the coefficients associated with expansionary monetary policy are negative and significant for high-capital banks. High-capital banks’ risk-taking increased on average with a range of 8% to 17% as the short-term interest rate declined by one percent. This indicates that high-capital banks were involved in risky investments during the period of expansionary policy. The fall in the short-term interest rate didn’t have a significant effect on the risk of capitalized banks. Thus, the results indicate that an expansionary monetary policy induced high-capital banks to invest in risk asset, while not significantly affecting the risk-taking behavior of low-capital banks. However, contractionary monetary policy didn’t have any significant impact on risk-taking behavior of either high- or low-capital banks.

In addition to the change in the monetary policy rate, balance sheet characteristics of banks have a significant effect on banks’ risk-taking. As indicated in Table 3.3, the banks’ size (ASSET) has a significant and positive effect on banks’ risk. It means that the bigger the bank is, either both high- and low-capital banks, the higher the incentive to take more risk, given that all other things are constant.

To summarize, during the period 1991 - 2010, monetary policy easing had a significant impact on encouraging low-capitalized banks to take more risk, while the capital-constrained banks weren’t significantly affected by the monetary policy easing. This confirms the hypothesis that expansionary policy induces capitalize-unconstrained banks to invest more in risky assets relative to safe assets. However, this result could be affected by the change in regulatory requirements in the banking system. In the
following section, I also explore the risk-taking behavior of capital-constrained and unconstrained banks before the capital regulations made in the late 1980s and the early 1990’s.

3.3.3. Banks’ Risk during the Pre-Basel/FDICIA Period

The cross-sectional response of banks to a monetary policy stance could be different depending on the capital regulation in the financial system. Some banking literature states that capital regulation is motivated by the need to avoid the risk-shifting incentives generated by improperly priced deposit insurance, since an unregulated bank may take excessive portfolio and leverage risk in order to maximize its shareholder value, at the expense of the deposit insurance (Kishan and Opiela, 2006; Koziol and Lawrenz, 2009). Two important changes in capital regulation took place in the period from 1988 to 1992. The Basel Accord I, which set capital-to-risk-weighted asset and leverage ratio requirements, was adopted in 1988 and phased in through the end of 1992. FDICIA was passed in 1991, strengthening enforcement and transparency of penalties associated with both the leverage and the new risk-weighted Basel requirements. Essentially, the regulatory capital literature emphasizes an increase in the effective capital constraint and describes the capital regulatory environment as being weak during the pre-Basel/FDICIA period relative to the post-Basel/FDICIA period (Berger et al., 1995). This section, therefore, explores the cross-sectional asymmetric response of banks to the two policy instances during the pre-Basel/FDICIA (i.e. 1976:Q1-1990:4) period.

Table 3.4 presents the estimation results of the baseline model for the pre-Basel/FDICIA period. Most of the coefficients of expansionary monetary policy are
negative and significant irrespective of the level of capitalization. This indicates that both capital-constrained and unconstrained banks were taking more risk during the period of expansionary policy. However, as I compare the qualitative difference between the coefficients of expansionary policy for low- and high-capital banks, I realize that the low-capital banks strongly respond to the fall in the interest rate. Specifically, a one-percentage fall in the short-term interest rate lead to an increase in risk-taking of low-capital banks by at least 1%, while the high-capital banks’ risk-taking increased by at least 0.1%. However, most of the coefficients associated with contractionary monetary policy are positive and significant for high-capital banks, while insignificant for low-capital banks. The results above clearly indicate the asymmetric response of banks is affected by the apparent differences in the effective capital constraint between the pre-Basel/FDICIA period and the post-Basel/FDICIA period.

In summary, in the pre-Basel/FDICIA period, when the capital constraints were weak, contractionary policy was ineffective for low-capital banks, but expansionary policy increased the risk of these banks. In the post-Basel period, marked by a stronger effective constraint, expansionary policy increased the risk of high-capital banks, but contractionary policy was ineffective for both low- and high-capital banks. It implies that the capital regulation made in the late 1980’s and early 1990’s (i.e. Basel I and FDICA) were not effective in reducing the risk-taking behavior of high-capital banks.
3.4. Conclusion

The recent financial crisis that started in the summer of 2007 has drawn the attention of researchers and policy makers to examine the link between monetary policy and banks' risk-perceptions and attitude (Adrian and Shin, 2008, Borio and Zhu, 2008 and Altunbas et al., 2010). Most of the researches so far support the view that monetary policy easing induces greater risk-taking by banks through a search for yield, or its effects on leverage. This paper broadly supports this view. But, there could be an opposite risk-shifting effect when the banks operate with sufficient capital or limited liability and the appropriate regulation in the financial system. The response of well-capitalized banks to the change in policy rate could be different from the response of poorly capitalized banks. Due to the capital constraint, the poorly capitalized banks could respond aggressively to the lower interest rate. Furthermore, the empirical studies so far fail to distinguish the effects on contractionary and expansionary monetary policy on banks' risk. It is unclear whether contractionary policy, expansionary policy, or both drive the negative link between monetary policy and banks' risk.

This paper empirically explores the risk-taking response of low-capital and high-capital banks (cross-sectional asymmetry) during the two policy instances (policy-asymmetry). The results show that expansionary monetary policy had the expected effect on high-capital banks. That is, expansionary policy increased the risk of high-capital banks, but didn't have significant effect on the risk of low-capital banks. Contractionary monetary policy didn't have any significant impact on the risk-taking behavior of both high- and low-capital banks. This asymmetric response may change in nature and
intensity due to the changes in regulatory capital constraints. Accordingly this paper also identified these differences and finds that both high- and low-capital banks that increased their risk were responding to the fall in the short-term interest rate during the pre-Basel/FDICIA period. Again during the pre-Basel/FDICIA period, contractionary monetary policy was effective in increasing the risk of high-capital banks, but not the low-capital banks. This is consistent with the argument that the regulatory capital constraint was weak during the pre-Basel/FDICA period, allowing the low-capital banks to respond strongly to expansionary policy.

The above result implies that monetary policy should carefully consider the overall capitalization of the banking system and the capital regulation in formulating monetary policy. The capital constraints imposed by Basel II, which is currently being implemented by some banks (i.e., core banks), may encourage even greater volatility in loans over the business cycle (Kashyap and Stein, 2004). If Basel II does create more constrained banks during recessions and better capitalized banks during expansions, my analysis suggests that countercyclical policy may be even more difficult. The change brought about by Basel II might result in banks reallocating their capital and consequently, adjusting the way they organize their balance sheets and the way they react to monetary policy shocks. Thus, it could be worthy to identify the implication of these new regulations on the risk-taking behavior of banks.
Table 3.4
Estimation Results for Pre-Basel Period for Low and High Capital Banks, 1976:1-1990:4

<table>
<thead>
<tr>
<th>Explanatory Variables</th>
<th>Low-Capital Banks</th>
<th>High-Capital Banks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$-\Delta \text{SCORE}$</td>
<td>$\Delta \text{LLP}$</td>
</tr>
<tr>
<td>$\Delta \text{SCORE}_{t-1}$</td>
<td>-0.038**</td>
<td>-0.088**</td>
</tr>
<tr>
<td>$\Delta \text{LLP}_{t-1}$</td>
<td>-0.360**</td>
<td>-0.328**</td>
</tr>
<tr>
<td>$\Delta \text{SDROA}_{t-1}$</td>
<td>-0.043**</td>
<td>-0.381**</td>
</tr>
<tr>
<td>$\Delta \text{SDROE}_{t-1}$</td>
<td>-0.556**</td>
<td>-0.341**</td>
</tr>
<tr>
<td>$\Delta t^* \text{EXPA}$</td>
<td>-0.330**</td>
<td>-0.428**</td>
</tr>
<tr>
<td>$\Delta t^* \text{CONT}$</td>
<td>0.087</td>
<td>0.280</td>
</tr>
<tr>
<td>$\text{ASSET}$</td>
<td>-0.587**</td>
<td>0.966**</td>
</tr>
<tr>
<td>$\text{LIQ}$</td>
<td>-0.002</td>
<td>0.005</td>
</tr>
<tr>
<td>$\text{CAP}$</td>
<td>-0.518**</td>
<td>0.391**</td>
</tr>
<tr>
<td>$\text{CONSTANT}$</td>
<td>0.556**</td>
<td>-0.243**</td>
</tr>
<tr>
<td>Sargen test</td>
<td>0.66</td>
<td>0.80</td>
</tr>
<tr>
<td>2nd order serial correlation</td>
<td>0.23</td>
<td>0.43</td>
</tr>
</tbody>
</table>

** (P<0.05)

The model is given by the following equation:

$$
\Delta R_{it} = \beta_0 + \beta_1 \Delta R_{i,t-1} + \sum_{j=0}^{1} \beta_j \Delta i_{t-1} + \sum_{j=0}^{1} \beta_j M_{t-1} + \sum_{j=0}^{1} B_{i,t-1} + \varepsilon_{i,t}
$$

where $i = 1,...,N$, and $t = 1,...,T$, $N$ is the number of banks, and $T$ is the final year. $R_{i,t}$ represents bank risk by bank $i$ at period $t$. $i$ is the short term interest rate. $M_{t}$ is the vector of macroeconomic variables (which includes: $\Delta \ln(\text{GDPN})$, YIELD and GAP) and $B_{i,t}$ is the vector of bank-specific characteristics that includes: ASSET, LIQ and CAP. The results reported here are qualitatively similar when the change in stock price (SP500) and the change in housing price index (HPI) are included in the model.
Table 3.2
Mean Comparison Test

<table>
<thead>
<tr>
<th>Variable</th>
<th>High-Capital Banks (CAP ≥ 8)</th>
<th>Low-Capital Banks (CAP &lt; 8)</th>
<th>T-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZSCORE</td>
<td>-15.953</td>
<td>-25.224</td>
<td>86.561**</td>
</tr>
<tr>
<td>LLP</td>
<td>0.325</td>
<td>0.0243</td>
<td>4.423*</td>
</tr>
<tr>
<td>SDROA</td>
<td>0.004</td>
<td>0.004</td>
<td>18.094**</td>
</tr>
<tr>
<td>SDROE</td>
<td>0.000</td>
<td>0.001</td>
<td>14.795**</td>
</tr>
<tr>
<td>ASSET</td>
<td>11.368</td>
<td>11.738</td>
<td>50.608**</td>
</tr>
<tr>
<td>CAP</td>
<td>11.974</td>
<td>7.037</td>
<td>-4.877**</td>
</tr>
<tr>
<td>LIQ</td>
<td>5.665</td>
<td>5.556</td>
<td>3.680**</td>
</tr>
<tr>
<td>N</td>
<td>522701</td>
<td>179057</td>
<td></td>
</tr>
</tbody>
</table>

** Significant at 1% (*) and 5% (**) level.

The four bank risk measures are: ZSCORE, LLP, SDROA, and SDROE. SIZE is a log of total assets, CAP the capital-to-total asset ratio, LIQ the liquidity-to-total assets ratio, LLP the loan loss provisions/total loans, SDROA is the standard deviation of ROA, and SDROE is the standard deviation of ROE, where ROA is net income-total asset ratio and ROE is net income-to-total asset ratio.

** Significant at 1% (*) and 5% (**) level.
Table 3.3
Estimation Results for High and Low Capital Banks, 1991:1-2010:1

<table>
<thead>
<tr>
<th>Explanatory Variables</th>
<th>Low-Capital Banks</th>
<th></th>
<th></th>
<th>High-Capital Banks</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-AZSCORE</td>
<td>ALLP</td>
<td>ASDROA</td>
<td>ASDROE</td>
<td>AZSCORE</td>
<td>ALLP</td>
</tr>
<tr>
<td>AZSCORE$_{i,t-1}$</td>
<td>-0.023**</td>
<td></td>
<td></td>
<td></td>
<td>-0.090**</td>
<td></td>
</tr>
<tr>
<td>ALLP$_{i,t-1}$</td>
<td></td>
<td>-0.241**</td>
<td></td>
<td></td>
<td>-0.385**</td>
<td></td>
</tr>
<tr>
<td>ASDROA$_{i,t-1}$</td>
<td></td>
<td></td>
<td>-0.230**</td>
<td></td>
<td>-0.304**</td>
<td></td>
</tr>
<tr>
<td>ASDROE$_{i,t-1}$</td>
<td></td>
<td></td>
<td></td>
<td>-0.161**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta i \times EXPA$</td>
<td>0.145</td>
<td>-0.041</td>
<td>-0.076</td>
<td>0.042</td>
<td>-0.170**</td>
<td>-0.089**</td>
</tr>
<tr>
<td>$\Delta i \times CONT$</td>
<td>-0.071</td>
<td>0.027</td>
<td>0.044</td>
<td>-0.025</td>
<td>0.087</td>
<td>0.041</td>
</tr>
<tr>
<td>ASSET</td>
<td>0.079**</td>
<td>0.176**</td>
<td>0.089**</td>
<td>0.086**</td>
<td>0.184**</td>
<td>0.156**</td>
</tr>
<tr>
<td>LIQ</td>
<td>-0.009</td>
<td>-0.009</td>
<td>-0.002</td>
<td>-0.004</td>
<td>0.005</td>
<td>-0.018**</td>
</tr>
<tr>
<td>CAP</td>
<td>0.259**</td>
<td>0.081**</td>
<td>0.013**</td>
<td>0.047**</td>
<td>0.140</td>
<td>-0.032</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>-2.381**</td>
<td>-2.442**</td>
<td>1.234**</td>
<td>-1.139**</td>
<td>-5.805</td>
<td>-1.592</td>
</tr>
<tr>
<td>Sargen test</td>
<td>0.18</td>
<td>0.29</td>
<td>0.20</td>
<td>0.13</td>
<td>0.16</td>
<td>0.37</td>
</tr>
<tr>
<td>2nd order serial</td>
<td>0.31</td>
<td>0.46</td>
<td>0.69</td>
<td>0.27</td>
<td>0.73</td>
<td>0.55</td>
</tr>
</tbody>
</table>

** (P<0.05)

The model is given by the following equation:

$$
\Delta R_{i,t} = \beta_0 + \beta_1 \Delta R_{i,t-1} + \sum_{t=0}^{\infty} \beta_t \Delta i_{t+j} + \sum_{t=0}^{\infty} \beta M_{i,t+j} + \sum_{t=0}^{\infty} B_{i,t+j} + e_{i,t}
$$

where $i = 1, \ldots, N$, and $t = 1, \ldots, T$, $N$ is the number of banks, and $T$ is the final year. $R_{i,t}$ represents bank risk by bank $i$ at period $t$. $i_t$ is the short-term interest rate. $M_t$ is the vector of macroeconomic variables (which includes: $\Delta \ln(GDPN)$ YIELD and GAP) and $B_t$ is the vector of bank-specific characteristics that includes: SIZE, LIQ, and CAP. The results reported here are qualitatively similar when the change in stock price (SP500) and the change in housing price index (HPI) are included in the model.
### Table 3.1
Estimation Results of Symmetric and Asymmetric Specifications, 1991:1-2010:1

<table>
<thead>
<tr>
<th>Explanatory Variables</th>
<th>Dependent Variable/Risk Measures</th>
<th>(-\Delta ZSCORE)</th>
<th>(\Delta LL)</th>
<th>(\Delta SDROA)</th>
<th>(\Delta SDROE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-\Delta ZSCORE_{t-1})</td>
<td></td>
<td>-0.076**</td>
<td>-0.075**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\Delta LL_{t-1})</td>
<td></td>
<td>-0.491**</td>
<td>-0.492**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\Delta SDROA_{t-1})</td>
<td></td>
<td>-0.491**</td>
<td>-0.492**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\Delta SDROE_{t-1})</td>
<td></td>
<td></td>
<td></td>
<td>-0.179**</td>
<td>-0.191**</td>
</tr>
<tr>
<td>(\Delta i)</td>
<td></td>
<td>0.188**</td>
<td>0.044**</td>
<td>0.004**</td>
<td>0.001**</td>
</tr>
<tr>
<td>(\Delta i*EXP)</td>
<td></td>
<td>-0.187**</td>
<td>-0.092**</td>
<td>-0.001</td>
<td>-0.003**</td>
</tr>
<tr>
<td>(\Delta i*CONT)</td>
<td></td>
<td>0.170</td>
<td>0.016</td>
<td>0.003</td>
<td>-0.007</td>
</tr>
<tr>
<td>ASSET</td>
<td></td>
<td>0.302**</td>
<td>0.213**</td>
<td>0.161</td>
<td>0.151</td>
</tr>
<tr>
<td>LIQ</td>
<td></td>
<td>-0.003**</td>
<td>-0.004**</td>
<td>0.002**</td>
<td>-0.002**</td>
</tr>
<tr>
<td>CAP</td>
<td></td>
<td>0.355**</td>
<td>0.021**</td>
<td>0.0282</td>
<td>0.021**</td>
</tr>
<tr>
<td>Sargent Test</td>
<td></td>
<td>0.31</td>
<td>0.36</td>
<td>0.55</td>
<td>0.61</td>
</tr>
<tr>
<td>2nd order serial</td>
<td></td>
<td>0.15</td>
<td>0.17</td>
<td>0.09</td>
<td>0.14</td>
</tr>
<tr>
<td>correlation</td>
<td></td>
<td>** (P&lt;0.05)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The model is given by the following equation:
\[
\Delta R_{i,t} = \beta_0 + \beta_1 \Delta R_{i,t-1} + \sum_{j=0}^{\infty} \beta_j \Delta i_{t-j} + \sum_{j=0}^{\infty} \beta_m M_{t-j} + \sum_{j=0}^{\infty} B_{i,t-j} + \varepsilon_{i,t}
\]

where \(i = 1, ..., N\) and \(t = 1, ..., T\), \(N\) is the number of banks, and \(T\) is the final year. \(R_{i,t}\) represents bank risk by bank \(i\) at period \(t\). \(i_1\) is the short term interest rate. \(M_i\) is the vector of macroeconomic variables (which includes: \(\Delta \ln(GDP)\), \(YIELD\) and \(GAP\)) and \(B_{i,j}\) is the vector of bank-specific characteristics that includes: \(ASSET\), \(LIQ\), and \(CAP\). The results reported here are qualitatively similar when the change in stock price (SP500) and the change in housing price index (HPI) are included in the model.
CHAPTER IV

HOUSING BUBBLES ACROSS U.S. STATES AND MONETARY POLICY: EVIDENCE FROM A SPATIAL DYNAMIC MODEL

4.1. Introduction

The global financial crisis triggered by fallout from the sub-prime mortgage market in the U.S. has led economists to focus attention on the role of monetary policy in the recent boom and bust behavior of housing prices. Some argue that the Federal Reserve System interest rate policy, especially the low rates during the period 2001-2005, was responsible for the housing price boom (Iacoviello, 2005, Taylor, 2007, Ioannidou et al., 2007 and Jarocinski and Smets, 2008.). On the other hand, in his speech at the 2010 Economic Association Annual Conference, the Federal Reserve Chairman Ben Bernanke argued that it is difficult to blame either monetary policy or the broader macroeconomic environment for the housing bubble. Although not universally held, this view has gained acceptance from many researchers and observers (Vargas-Silva, 2008, Greenspan, 2009, Dokko et al., 2009).

Most of the literature so far has focused on the link between monetary policy and the housing market and implicitly assumes that the responses of housing markets across the regions or states are the same. This view basically follows the conventional wisdom that monetary policy cannot be used to influence, control, or target the economic conditions of particular regions. The reverse, however, is not necessarily true (Carlino and Defina, 1999, Frantanton and Schuh, 2003). Regional economic conditions can
significantly influence the aggregate response to monetary policy actions. This is mainly due to the fact that the prevailing economic conditions vary across regions when monetary policy actions are taken. In addition economic sensitivity to monetary policy varies across regions (Carlino and Defina, 1999). Carlino and Defina (1999) provided evidence on heterogeneous dynamic responses of real income to a monetary policy tightening across U.S. states. They found that in some states, such as Indiana, Arizona, and Michigan, income declines on average by 2%, whereas in other states, such as Wyoming, New York and Texas, income declines only by about 0.5%. Both estimates deviate significantly from the national average of 1.2%.

Similarly, the distributions of housing prices have been uneven across the U.S. states and vary over time. In the last four-year period, i.e., 2005-2009, the real housing price indexes decreased more than 10% per year in several states on both east and west coasts, notably California, Florida, Nevada, and Massachusetts. However, during the same period the housing prices have shown an increase of about 2% in states like Wyoming, North Dakota, Washington, New Mexico and Tennessee. When we compared the growth in housing prices in the last four years with the average growth since 2001, we found that states like New York have grown more than three times the national average, while other states, like Michigan, have declined to 31% less than the national average. Thus, this heterogeneous distribution of housing price across the states and over time could affect the response of the housing price to monetary policy shock.

From the perspective of the current debate, an important question is whether the widespread, but not homogenous, housing bubble is caused by the monetary policy shock, rather than caused by other regional or state-specific factors, known as a “local
"Local bubbles" are local factors or circumstances that are specific to each geographic market, whereas monetary policy is the likely suspect of the "national" factor, which is the same across the nation (Frantanton and Schuh, 2003). This paper, therefore, mainly examines the role of monetary policy (national factor) on the housing bubble across the U.S. controlling for other local or state-specific factors.

Perhaps a similar study is found in Negro and Otrok (2007) who study the effects of monetary policy on regions in the U.S. using quarterly state level data from 1986 to 2005. They use a dynamic factor model to distinguish the relative importance of the common or national component in housing price movements from local or state-specific shocks. They find that historical movement in house prices across the U.S. states were mainly driven by the local component. However, the dramatic increase in house price during the period 2001-2005 was different and more of a national phenomenon. This paper differs from Negro and Otrok (2007) both in terms of methodology and focus. First, this paper directly examines the effect of monetary policy on the regional housing prices after controlling for state-specific factors. Second, the paper uses a spatial dynamic model which helps to control not only the regional heterogeneity, but also the spatial heterogeneity or interdependence of housing prices across neighborhood states. By controlling the three components—national, local and spatial—the paper provides more reliable results.

Spatial autocorrelation is a phenomenon where values of a variable show a regular pattern over space (Anselin, 1998). One reason house prices are spatially correlated is that property values in the same neighborhood capitalize shared location amenities (Basu
and Thibodeau, 1998). Housing markets in the same neighborhood might also be subject to the same common externality, which is unmeasured (Wilhelmsson, 2002). Then, ignoring spatial autocorrelation in analyzing the response of the housing market would overstate or understate the effect of other factors, such as monetary policy, which is the main variable of interest.

Using quarterly panel data on 49 contiguous U.S. states for the period 1976:Q1 to 2009:Q4, the paper shows how the change in the federal funds rate affects the growth in housing price across the states. The results indicate that the housing bubble in the last three decades was mainly driven by the local or state-specific factors, and the change in monetary policy didn't have significant effect on the housing bubble across the states. However, the recent housing boom was different in a sense that expansionary monetary policy had contributed to the run-up in the housing price across the states. Specifically, as the short-term interest rate fell by one percent, the housing prices were growing, on average, by less than five percent across the states.

The remainder of the paper is constructed as follows. Section 4.2 briefly explains the empirical methodology and the data used in the analysis. The empirical results from both the dynamic spatial lag model and the dynamic spatial error model are presented in Section 4.3. Finally, the conclusion of the paper is provided in Section 4.4.

4.2. Estimation Methodology and Data

The standard micro-housing model relates the market value of a property to a set of characteristics that determine the property value. Recently the micro-housing
literature addressed the issue of correlation of housing prices across the neighboring space (e.g., Basu and Thibodeau, 1998, and Cohen and Coughlin, 2008). On the other hand, the macro-housing literature relates the housing market with the aggregate economic activities (e.g. Taylor, 2007, Jarocinski and Smets, 2008, and Jan Dokko, 2009).

This paper is the middle way that uses a set of both the national and state level macroeconomic characteristics that could affect the housing price. A standard housing price model is specified following Case and Sheller (2003). Personal income, unemployment rate, mortgage rate and housing permits are the fundamental factors that affect housing prices across the states (Case and Sheller, 2003, Kohn and Bryant, 2010). The crime rate and the weather condition across the states could also have a significant impact on housing prices across the states (Saiz, 2007, Capozza et al., 2002).

To exploit the existence of spatial correlation or interdependence of housing prices among the neighborhood states, the paper uses a dynamic spatial model first introduced by J. Paul Elhorst (2003). A dynamic spatial model can take two forms: spatial lag dependence (known as spatial lag) and spatial error dependence, known as spatial error model (Anselin, 1998). Spatial lag dependence refers to the assumption of correlated errors that arise because of spatial spillover effects between observations of the dependent variable. That means, for example, the housing price in New Jersey is highly affected by the housing price in New York. Spatial error dependence refers to the assumption of correlated errors as occur among the independent variables. It can also arise from the spatial correlation between non-observable explanatory (or latent variables) (LeSage, 1997) or omitted variables (whilemsson, 2002). Housing markets in
the same neighborhood might also be subject to the same common externality, which is unmeasured. That means there might be some unobservable factors that affect the housing price both in New York and New Jersey. To account for both types of interdependence this paper models the housing price in the two forms, i.e., dynamic spatial lag model and dynamic spatial error model.

A dynamic spatial lag model is specified as:

\[
\Delta \log H_t = \phi \Delta \log H_{t-1} + \rho W \Delta \log H_t + \lambda \Delta i_{t-1} + X_{t-1} \beta + \varepsilon_t
\]

(4.1)

where

\[
W = \begin{bmatrix}
0 & w_{ij} & w_{i1} \\
 w_{ji} & 0 & w_{j1} \\
 w_{mi} & w_{mj} & 0
\end{bmatrix}
\]

(4.2)

and \( H \) is an \( N \times 1 \) vector of house price for every U.S. state \((s=1,\ldots,N)\) in year \( t \) \((t=1,\ldots,T)\). \( W \) represent an \( N \times N \) spatial weighting matrix with zeros on the diagonal and the element \( w_{ij} \) represents the spatial correlation between the two spatial units \( i \) and \( j \).

Then, \( \rho \) captures the overall strength of interdependence of housing price among the neighboring states. \( \phi \) is the coefficient for the temporal lag that captures the interdependence of the housing price over time. \( i_t \) represents the federal funds rate used as a monetary policy instrument and the main national factor and \( \lambda \) captures the effect of monetary policy on state level housing prices. \( X \) is an \( N \times K \) matrix of \( K \) independent variables that includes, the states or local factors that vary across the state (i.e., unemployment rate, real personal income, population, and crime rate), other national
factors (30-year mortgage rate and inflation rate), and fixed state and period effects (i.e., state and year dummies). \( \beta \) is a vector of coefficients and \( \varepsilon_{it} \) is an \( N \times 1 \) vector of residuals.

The spatial weight matrix \( W \), as given in equation 4.2, is a block diagonal matrix defined for a single quarter. It is constructed using two alternatives. The first is a distance contiguity weight matrix where the elements \( w_{ij} \) measure the (standardized) distance between the two states \( i \) and \( j \). The second is a standardized binary contiguity weights matrix, where the element \( w_{ij} = 1 \) for states \( i \) and \( j \) that share a border, and \( w_{ij} = 0 \) for states that don’t have a shared boarder. In either case, as is commonly done in spatial econometrics research, I row-standardize the resulting matrix by dividing each cell in a row by that row’s sum.

A dynamic spatial error model is specified as follows:

\[
\Delta \log H_t = \phi \Delta \log H_{t-1} + \lambda \Delta i_{t-1} + X_{t-1} \beta + \varepsilon_t 
\]

\[
\varepsilon_t = \delta W \varepsilon_t + \mu_t 
\]

where \( \mu_t \) is normally distributed with a zero mean and constant variance, and \( \delta \) is the spatial error correlation coefficient which indicates the possible interdependence of an observable factor that affects the housing price across the neighboring states. All other notations are the same as in the spatial lag dependent model.

I estimated the models by maximum likelihood using MATLAB code written by Paul Elhost (2005), and R.J. Franzese and J.C. Hayes (2006). The likelihood function for the spatial-lag model involves only one complicating modification of the likelihood for
the standard linear additive model. To see this, express the simple spatial-lag model in vector form, with the stochastic component of the left-hand side as:

\[ \Delta \log H = \rho W \Delta \log H + X \beta + \epsilon \Rightarrow \epsilon = (I - \rho W) \Delta \log H - X \beta = \Lambda \Delta \log H - X \beta \quad 4.5 \]

Then, the likelihood function for the stochastic component, \( \epsilon \), is the usual linear normal likelihood:

\[ L(\epsilon) = \left( \frac{1}{\sigma^2 2\pi} \right)^{NT} \exp \left( \frac{-\epsilon' \epsilon}{2\sigma^2} \right), \]

which in this case, will produce likelihood in terms of \( \Delta \log H \) as follows:

\[ L(\epsilon) = | \Lambda | \left( \frac{1}{\sigma^2 2\pi} \right)^{NT} \exp \left( \frac{-\epsilon' \epsilon}{2\sigma^2} (A \Delta \log H - X \beta)'(A \Delta \log H - X \beta) \right). \quad 4.7 \]

This resembles the typical linear normal likelihood, although the transformation from \( \epsilon \) to \( \Delta \log H \) is not by the usual factor, 1, but by \( | \Lambda | = | I - \rho W | \). The maximum likelihood is then calculated numerically (Elhorst, 2003).

The paper uses panel data for 49 contiguous U.S. states for the period 1976:Q1 to 2009:Q4. The housing price data for each state comes from the Office of Federal Housing Enterprise Oversight (OFHEO). OFHEO estimates and publishes quarterly house price indexes (HPI) for single-family detached properties. OFHEO use the data on conventional conforming mortgage transactions obtained from the Federal Home Loan Mortgage Corporation (Freddie Mac) and the Federal National Mortgage Association (Fannie Mae). The real housing price index data are obtained by deflating the nominal HPI using the core PCE inflation, which measures inflation in the personal consumption expenditure basket, less food and energy.
The state level per capita personal income, population, unemployment rate, and housing permit data are obtained from the U.S. Bureau of Census. The real per capita personal income data are computed by deflating the nominal per capita income using PCE inflation. Housing permit refers to the number of new, privately owned housing units authorized by each state. The crime rates (i.e., murder rate and burglary rate, per 100,000 populations) are obtained from the FBI's Uniform Crime Reports Series. Data on weather conditions (i.e., average January temperature and July mean relative humidity) are obtained from the United States Department of Agriculture Economic Research Service Natural Amenities Scale database. The national or aggregate level variables such as the Federal Funds rate, and inflation as measured by the GDP deflator were taken from the Federal Reserve Bank of St. Louis database (FRED). The 30-year mortgage rate is obtained from the U.S. Bureau of Census. The distance between the capital cities of the 49 contiguous U.S. states is obtained from the Regional Economic Information System database.

4.5. Estimation Results

This section reports three sets of empirical results. The first set of results provides evidence on the relative importance of national versus regional or state shocks in driving house price movements across the U.S. states over the last three decades. The second sets of results provide answers for the question of whether the prolonged expansionary policy since 2001 was behind the housing boom in the period 2001-2007. These results are obtained by using a standardized contiguity distance weights matrix.
Table 4.1 presents estimation results using the entire sample 1976:Q1-2009:Q4. The first two columns provide estimates of the spatial lag model (i.e., equation 4.1), which includes a time-lag of the dependent variable to account for temporal dependence, as with the standard dynamic panel model. State and year dummies are also included to account for regional and period heterogeneity. The period dummies provide a flexible way to model common trends and/or common (random) shocks in the housing market. Another sort of spatially correlated domestic factor is captured by including a spatially weighted dependent variable. Again, the estimated coefficient on the spatial lag gives an estimate of the strength of interdependence in housing prices across the neighboring states, assuming that a shock in housing price in one state would affect house price in other closest neighboring states.

The first column of Table 4.1 reports the results in the case where only the national factors are included in the regression. A spatial-lag coefficient is statistically positive and significant, implying that an increase in neighbor state house price leads to an immediate increase in a given state house price. The sign of \( \rho \) here provides information about the sign of interdependence; however, the magnitude would change for preferred specifications. The coefficient of the main national factor, i.e., the federal funds rate, is negative and statistically significant, indicating that the change in monetary policy was one of the factors behind the historical movement in housing prices across U.S. states.

In the next model (column 2 of Table 4.1), I control for a state-level macroeconomic performance by adding real per capita income, unemployment rate, population, murder rate, and housing permit. As in other markets, the demand and supply
factors in each state could affect the housing price. The real per capita income, which is heterogeneous across the states, could affect the affordability of households given the level of mortgage interest rates (McCarthy and Peach, 2004). Thus, in the states where the per capita income is relatively high, households bid up those prices simply because they can afford them. The unemployment rate is also very heterogeneous across the states, and thus its effect on the demand for housing would be different across the states. In the U.S. states where unemployment is high, the housing price is expected to be relatively low. If so, I would expect a negative coefficient estimate for the unemployment variable. The demand for housing is certainly affected by the number of people residing in each state. The relatively more populated states would have more demand for houses, and thus would be expected to have a positive effect on housing prices. The crime rate is also very volatile across the region. It is expected to have a relatively lower demand, and thus price, for housing for the states where the murder rate is high. The number of housing permits by state governments would positively affect the supply of housing (and thus the price of house) that is expected to vary across the states.

As reported in column 2 of Table 4.1, the significant effect of monetary policy (shown in model 1 or column 1) disappears when the local or state level factors are controlled. Among the state level factors the coefficients associated with real per capita income and housing permit are insignificant. As expected, the unemployment rate and murder rate had a negative and significant impact on housing prices across the U.S. states. The coefficient of state level population turns out to be positive and significant as expected.
The last two columns of Table 4.1 presented estimates of spatial error model. As of the spatial lag model, first I control only the national or macro-aggregate variables. As indicated in the third column, the coefficient of change in the federal funds rate is found to be negative and significant. However, as I control for more macroeconomic variables that vary across the states, the coefficient of short-term interest rate turns out to be insignificant, whereas the state-level variables such as unemployment rate, murder rate, and population become significant. The coefficient of the spatial-error is still positive and significant, indicating that there are unobservable, spatially correlated factors that affect the housing price across the neighboring space.

To understand whether the recent expansionary policy was behind the housing boom in the period 2001-2007, both the spatial lag and spatial error model are re-estimated for the two sub-sample periods 1976-2000 and 2001-2007. Evidenced from the results reported in Table 4.2, the change in federal funds rate is insignificant across all the four alternative estimations. This indicates that monetary policy didn’t have any significant effect on the ups and downs of housing prices across the U.S. states during the period 1976 – 2000.

As indicated in Table 4.3, coefficients of the change in the federal funds rate are negative and significant across all the four estimations, i.e., even after the introduction of the regional variations. Specifically, as the short-term interest rate increases, the housing prices increased across the U.S. states. Both spatial and temporal-lag coefficients in all the four different specifications are significant, indicating that the housing price is not only correlated over time but also across the neighboring space. That means, as housing price increases, the housing price in the closest neighboring states increase as well.
To summarize, the historical movement in housing prices across the U.S. states were mainly driven by local or state-specific factors. However, the recent housing boom in the period 2001-2007 was different. The expansionary monetary policy has a non-negligible impact on housing prices across the U.S. states, but the impact was small relative to the size of the housing boom. Moreover, the housing prices across the states were highly spatially correlated and, thus, the results after controlling for the spatial interdependent provide reliable results.

4.5. Conclusion

This paper examines the effect of the monetary policy shock on the housing bubble across the U.S states, after controlling for both regional and spatial heterogeneity across the neighboring states. I used a spatial dynamic model that helps to capture both temporal and spatial interdependence in housing prices. Using quarterly data spanning from 1976 - 2009, the historical bubbles in housing prices across the 49 contiguous U.S. states were mainly driven by the state-specific factors. The important national factor, i.e., monetary policy, was not behind the movement in housing prices across the states. However, in the recent period, i.e., 2001-2007, the expansionary monetary policy had a significant impact on increasing housing prices across the states. Indeed, the state or local factors had an important contribution in housing price in those (housing) boom periods.
Table 4.1
Estimation Results of Dynamic Spatial Model for the Period 1976 – 2009

<table>
<thead>
<tr>
<th>Explanatory Variable</th>
<th>Spatial Lag Model (a)</th>
<th>Spatial Lag Model (b)</th>
<th>Spatial Error Model (a)</th>
<th>Spatial Error Model (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporal lag($H_{t-1}$)</td>
<td>0.051**</td>
<td>0.038**</td>
<td>0.157**</td>
<td>0.115**</td>
</tr>
<tr>
<td>Spatial lag($WH_t$)</td>
<td>0.130**</td>
<td>0.109**</td>
<td>0.495**</td>
<td>0.441**</td>
</tr>
<tr>
<td>Spatial error($WE_t$)</td>
<td>0.081**</td>
<td>0.072</td>
<td>-0.041**</td>
<td>0.981</td>
</tr>
<tr>
<td>$\Delta$ Federal funds rate($i_{t-1}$)</td>
<td>-0.081**</td>
<td>1.637</td>
<td>0.057</td>
<td>0.008</td>
</tr>
<tr>
<td>log House permit at $t-1$</td>
<td>0.038**</td>
<td>0.109**</td>
<td>0.157**</td>
<td>0.115**</td>
</tr>
<tr>
<td>log Real per Capita Income at $t-1$</td>
<td>0.072</td>
<td>1.637</td>
<td>0.057</td>
<td>0.008</td>
</tr>
<tr>
<td>Unemployment rate at $t-1$</td>
<td>-0.081**</td>
<td>-0.041**</td>
<td>0.981</td>
<td>-0.033</td>
</tr>
<tr>
<td>log Population at $t-1$</td>
<td>0.029**</td>
<td>0.981</td>
<td>0.008</td>
<td>0.041**</td>
</tr>
<tr>
<td>log Murder rate at $t-1$</td>
<td>-2.876**</td>
<td>-1.187**</td>
<td>0.845</td>
<td>-1.187**</td>
</tr>
<tr>
<td>constant</td>
<td>29.250**</td>
<td>11.440**</td>
<td>4.060</td>
<td>0.522</td>
</tr>
<tr>
<td>LR test</td>
<td>705.97</td>
<td>945.61</td>
<td>1373.78</td>
<td>1419.10</td>
</tr>
<tr>
<td>Observations</td>
<td>6468</td>
<td>6468</td>
<td>6468</td>
<td>6468</td>
</tr>
</tbody>
</table>

** (P<0.05)

The Spatial Lag Model is: $\Delta \log H_t = \phi \Delta \log H_{t-1} + \rho \Delta W \Delta \log H_t + \lambda \Delta i_{t-1} + X_{t-1} \beta + \epsilon_t$,

The Spatial Error Model is: $\Delta \log H_t = \rho W \Delta \log H_t + \lambda \Delta i_{t-1} + X_{t-1} \beta + \epsilon_t$,

$\epsilon_t = \delta W \epsilon_t + \mu_t$

where $H$ is the growth of housing price calculated as the log difference (i.e. $\Delta \log HPI$). All regressions include fixed period and unit effects; those coefficient estimates are suppressed to conserve space. The weight matrix is $W$ constructed using the distance between the capital cities of each state. All the spatial weights matrices are row-standardized.
Table 4.2
Estimation Results of Dynamic Spatial Model for the Period 1976 – 2000

<table>
<thead>
<tr>
<th>Explanatory Variable</th>
<th>Spatial Lag Model (a)</th>
<th>Spatial Lag Model (b)</th>
<th>Spatial Error Model (a)</th>
<th>Spatial Error Model (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporal lag ($H_{t-1}$)</td>
<td>0.001**</td>
<td>0.008**</td>
<td>0.026**</td>
<td>0.035**</td>
</tr>
<tr>
<td>Spatial lag ($WH_t$)</td>
<td>0.407**</td>
<td>0.448**</td>
<td>0.654**</td>
<td>0.609**</td>
</tr>
<tr>
<td>temporal error ($We_t$)</td>
<td></td>
<td></td>
<td>0.094</td>
<td>0.115</td>
</tr>
<tr>
<td>$\Delta$ Federal funds rate ($i_{t-1}$)</td>
<td>-0.094</td>
<td>0.115</td>
<td>-0.037**</td>
<td>-0.072</td>
</tr>
<tr>
<td>log House permit at $t - 1$</td>
<td>2.375</td>
<td>0.002</td>
<td></td>
<td>0.015</td>
</tr>
<tr>
<td>$\Delta$ Real per Capita Income at $t - 1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unemployment rate at $t - 1$</td>
<td>-0.408**</td>
<td>-0.207**</td>
<td>0.011**</td>
<td>0.057**</td>
</tr>
<tr>
<td>log Population at $t - 1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>log Murder rate at $t - 1$</td>
<td>-0.691**</td>
<td>-0.233**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>constant</td>
<td>12.010**</td>
<td>17.350**</td>
<td>28.660</td>
<td>25.789</td>
</tr>
<tr>
<td>LR test</td>
<td>1555.04</td>
<td>1058.08</td>
<td>1579.07</td>
<td>1349.50</td>
</tr>
<tr>
<td>Observations</td>
<td>4900</td>
<td>4900</td>
<td>4900</td>
<td>4900</td>
</tr>
</tbody>
</table>

** (P<0.05)

The Spatial Lag Model is:

$$\Delta \log H_t = \phi \Delta \log H_{t-1} + \rho \Delta W \Delta \log H_t + \lambda \Delta i_{t-1} + X_{t-1} \beta + \varepsilon_t$$

The Spatial Error Model is:

$$\Delta \log H_t = \rho W \Delta \log H_t + \lambda \Delta i_{t-1} + X_{t-1} \beta + \varepsilon_t,$$

$$\varepsilon_t = \delta W \varepsilon_t + \mu_t$$

where $H$ is the growth of housing price calculated as the log difference (i.e. $\Delta \log$ HPI). All regressions include fixed period and unit effects; those coefficient estimates are suppressed to conserve space. The weight matrix is $W$ constructed using the distance between the capital cities of each state. All the spatial weights matrices are row-standardized.
Table 4.3  
Estimation Results of Dynamic Spatial Model for the Period 2001 – 2007

<table>
<thead>
<tr>
<th>Explanatory Variable</th>
<th>Spatial Lag Model</th>
<th>Spatial Error Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(a)</td>
<td>(b)</td>
</tr>
<tr>
<td>Temporal lag( $H_{t-1}$)</td>
<td>0.587**</td>
<td>0.499**</td>
</tr>
<tr>
<td>Spatial lag( $WH_t$)</td>
<td>0.503**</td>
<td>0.495**</td>
</tr>
<tr>
<td>Spatial error( $W\varepsilon_t$)</td>
<td></td>
<td>0.643**</td>
</tr>
<tr>
<td>$\Delta$ Federal funds rate( $i_{t-1}$)</td>
<td>-0.043**</td>
<td>-0.041**</td>
</tr>
<tr>
<td>log House permit at $t-1$</td>
<td>0.835</td>
<td>0.221</td>
</tr>
<tr>
<td>log $\Delta$ Real per Capita Income at $t-1$</td>
<td>-0.641**</td>
<td>-0.279**</td>
</tr>
<tr>
<td>log Population at $t-1$</td>
<td>0.008**</td>
<td>0.001**</td>
</tr>
<tr>
<td>log Murder rate at $t-1$</td>
<td>-0.935**</td>
<td>-0.533**</td>
</tr>
<tr>
<td>constant</td>
<td>1.520</td>
<td>2.999**</td>
</tr>
<tr>
<td>LR test</td>
<td>916.38</td>
<td>1108.68</td>
</tr>
<tr>
<td>Observations</td>
<td>1568</td>
<td>1568</td>
</tr>
</tbody>
</table>

** (P<0.05)

The Spatial Lag Model is:
\[ \Delta \log H_t = \phi \Delta \log H_{t-1} + \rho \Delta W \Delta \log H_t + \lambda \Delta i_{t-1} + X_{t-1} \beta + \varepsilon_t \]

The Spatial Error Model is:
\[ \Delta \log H_t = \rho W \Delta \log H_t + \lambda \Delta i_{t-1} + X_{t-1} \beta + \varepsilon_t, \]
\[ \varepsilon_t = \delta W \varepsilon_t + \mu_t \]

where $H$ is the growth of housing price calculated as the log difference (i.e. $\Delta \log$ HPI). All regressions include fixed period and unit effects; those coefficient estimates are suppressed to conserve space. The weight matrix is $W$ constructed using the distance between the capital cities of each state. All the spatial weights matrices are row-standardized.
REFERENCES


