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## Abstract

This paper 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 they 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 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 the economy was in the state of asset bust. During the non-bust periods, however, the FOMC did not respond directly to equity prices; rather it only used the information for forecasting the target variables.

***JEL** classification: E44, E52*
***Keywords**: Monetary policy, Asset Boom and Bust*

## 1. Introduction

During the past two to three decades, the Federal Reserve has been largely successful at keeping inflation under control (Bernanke and Gertler, 2002). 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, 1998). 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.

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 two summarizes the literature explaining the relationship between asset price variability and monetary policy. In Section three, 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 three. Finally, the conclusion is made in Section four.

## 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 (1999, 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 (2001), Bordo and Jenne (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 proceeds 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.

## 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.

### 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:

$$i_t^* = \bar{r} + \boldsymbol{\Phi} \boldsymbol{E}_t \boldsymbol{X}_{t+k} \quad (1)$$

where $i_t^*$ is the targeted nominal interest rate. $\boldsymbol{X}_{t+k}$ 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. $\boldsymbol{\Phi}$ 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:

$$i_t = (1-\rho) i_t^* + \rho i_{t-1} + \varepsilon_t \quad (2)$$

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, with the target model (1) yields the policy reaction function as:

$$i_t = \alpha + \boldsymbol{\Psi} \boldsymbol{E}_t \boldsymbol{X}_{t+k} + \rho i_{t-1} + \varepsilon_t, \quad (3)$$

where $\alpha = (1-\rho)\bar{r}$ and $\boldsymbol{\Psi} = (1-\rho)\boldsymbol{\Phi}$. 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:

$$i_t = \alpha + \boldsymbol{\Psi} \boldsymbol{E}_t \boldsymbol{X}_{t+k} + \gamma S_{t-1} + \rho i_{t-1} + \varepsilon_t, \quad (4)$$

where $S_t$ is the asset price at period $t$. The forecast of the variables, $\mathbf{X_{t+k}}$, in equation 4 follow the process:

$$\boldsymbol{X_{t+k}} = \theta + \sum_{j=1}^{4} \boldsymbol{\delta_j X_{t-j}} + \lambda S_{t-1} + \mu_t \, , \qquad (5)$$

The main question addressed at this point is whether stock prices affect the federal funds rate directly, so that $\gamma \neq 0$ in equation 4; or indirectly, i.e., are used for forming forecasts of the variables $\boldsymbol{X_{t+k}}$ in equation 5, so that $\lambda \neq 0$.

Quarterly data from 1966:Q1 to 2009:Q1 are used. Following Fuhrer and Tootell, 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.[1] 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.[2]

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.

[1] For robustness it is also calculated by the GDP chain-weight price index, the PCE chain-weight price index, and consumer price index (CPI).

[2] For robustness I also use the Dow Jones Industrial Average (DJIA) index and the NASDAQ composite price index.

The median survey of professional forecasts (SPFs) is also used as a proxy for the private sectors expectation about the future of the economy. This survey was 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 1 presents parameter estimates of the baseline model for the full sample.[3] 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. 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 Tootell 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 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 (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

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

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. 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 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, in addition to the full sample period under consideration, Table 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.

### 3.2. State dependent monetary policy rule

#### *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 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:

$$i_t = \alpha + \boldsymbol{\Psi E_t X_{t+k}} + \gamma_1 u_{t-1} S_{t-1} + \gamma_2 o_{t-1} S_{t-1} + \gamma_3 (1-u-o)_{t-1} S_{t-1} + \varepsilon_t, \qquad (7)$$

where $o$ 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 $\boldsymbol{X_{t+k}}$ in equation 7 follows the following process:

$$\boldsymbol{X_{t+k}} = \theta + \sum_{j=1}^{4} \boldsymbol{\delta_j X_{t-j}} + \lambda_1 u_{t-1} S_{t-1} + \lambda_2 o_{t-1} S_{t-1} + \lambda_3 (1-u-o)_{t-1} S_{t-1} + \mu_t \qquad (8)$$

This 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 7, or indirectly, used as instruments for forecasting $\boldsymbol{X_{t+k}}$, so that $\lambda_i \neq 0$, in equation 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' 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 $\mathrm{S_t}$ is the growth rate in the stock price in period $\mathrm{t}$ 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., $\frac{S_t + S_{t-1} + S_{t-2}}{3} > \bar{S} + \upsilon$, then a boom is assumed in period $t-2$, $t-1$ and $t$, where $\upsilon$ is the standard error of the series. Conversely a bust is assumed in the periods $t-2$, $t-1$ and $t$ if $\frac{S_t + S_{t-1} + S_{t-2}}{3} < \bar{S} - \upsilon$.

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.

Figure 1: Stock Price changes during Asset Boom and Bust period

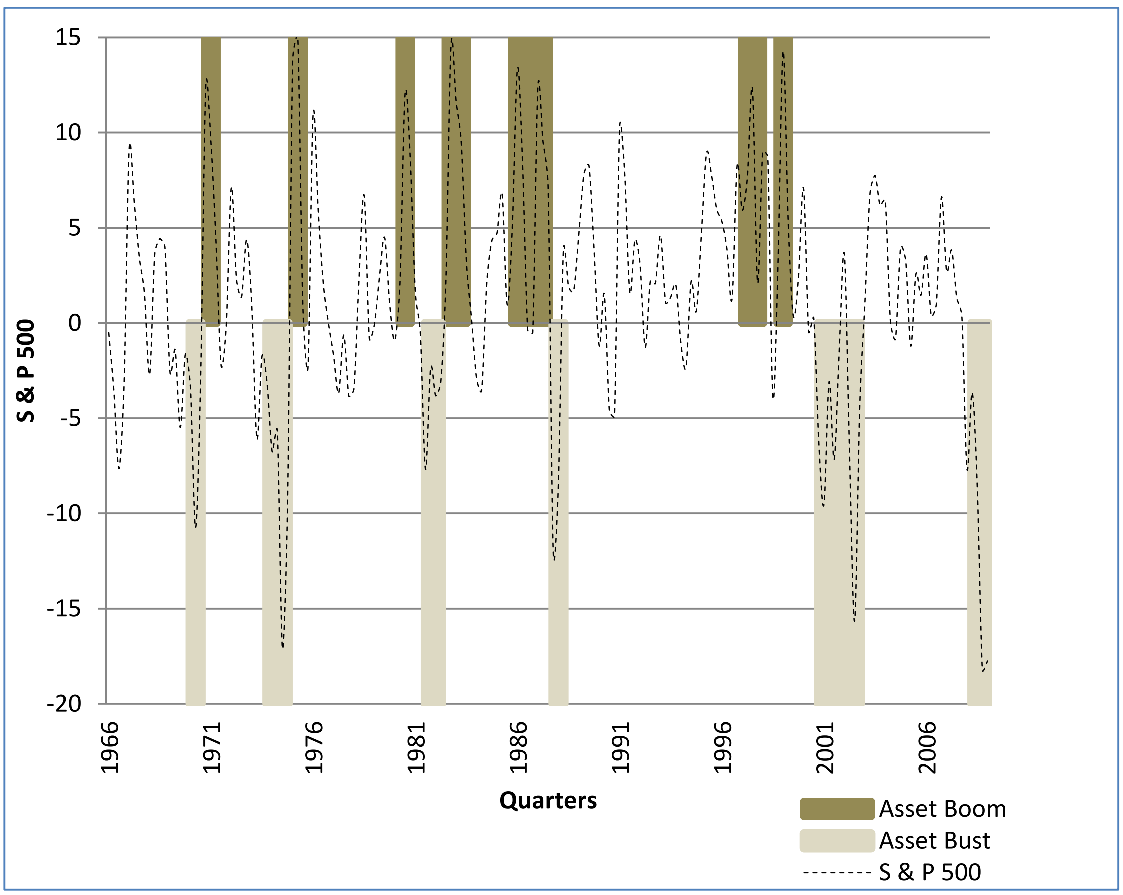


Table 2 reports estimates of the target variables from asset asymmetric reaction function using real-time data. The first column presents the parameter estimates using Greenbook forecasts as instruments, as with Fuhrer and Tootell (2008). The second column reports the estimates using surveys of professional 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 asst 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. Thus the estimation result reveals that the Fed independently responded to stock prices after the asset reversal occurred.

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 techniques since the real-time forecasts are based only on information available contemporaneously.

The last two columns of Table 2 present the OLS estimates of the parameters using GBFs and SPFs 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.

### *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 7 and 8 is specified as follows:

$$i_t = \alpha + \Psi \boldsymbol{E_t X_{t+k}} + \gamma_1 r_{t-1} S_{t-1} + \gamma_2 (1-r)_{t-1} S_{t-1} + \varepsilon_t, \qquad (7')$$

$$\boldsymbol{X_{t+k}} = \theta + \sum_{j=1}^{4} \boldsymbol{\delta_j X_{t-j}} + \lambda_1 r_{t-1} S_{t-1} + \lambda_2 (1-r)_{t-1} S_{t-1} + \mu_t \qquad (8')$$

where $r$ is a dummy variable equal to 1 for the recession quarters, and to 0 for non-recession quarters. Table 3 presents the estimation results of the economy asymmetry reaction function (i.e., equation 7') 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.

### 3.3. 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 4 presents the coefficient estimates for lagged stock prices and their p-values for the estimated forecasting equations (5) and (8). The upper portion of the table presents those coefficients from symmetric specification. The first column reports those 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. 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 4 provide the coefficients for lagged stock prices from asymmetric forecasting specifications. The first two columns under the lower portion presents those coefficients using Greenbook forecasts. The estimated coefficients 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 4presents the coefficients of lagged stock prices using SPFs. 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.

## 4. Conclusions

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 1: IV Estimation Results of Symmetric Monetary Reaction Function

| Sample | Parameters | Estimated Coefficients | | | |
|---|---|---|---|---|---|
| | | Revised Data | | Real-time Data | |
| | | GBF | SPF | GBF | SPF |
| **Full sample** | | Panel A | | | |
| **(1966-2009)** | Unemployment rate | -1.215** | -3.150** | -1.082** | -2.755** |
| | Inflation | 2.015** | 3.450** | 1.824** | 1.350** |
| | Real GDP Growth | 0.638 | 0.983** | 0.437 | 0.500 |
| | Stock Price | 0.108 | -0.027 | 0.221 | -0.132 |
| | Lag of Federal funds rate | 0.87** | 0.94** | 0.88** | 0.91** |
| | Hansen J-test | 0.12 | 0.14 | 0.21 | 0.35 |
| | Cragg-Donald F-statistic | 6.62 | 2.37 | 20.67 | 44.25 |
| **Post-Greenspan** | | Panel B | | | |
| **(1966-1987)** | Unemployment rate | -1.608 | -2.725** | -1.330 | -1.821** |
| | Inflation | 3.052** | 2.988** | 1.992** | 1.375** |
| | Real GDP Growth | 0.123 | 0.413** | 0.104 | 0.901** |
| | Stock Price | 0.191 | -0.012 | 0.078 | 0.157 |
| | Lag of Federal funds rate | 0.90** | 0.92** | 0.92** | 0.95** |
| | Hansen J-test | 0.14 | 0.24 | 0.56 | 0.24 |
| | Cragg-Donald F-statistic | 1.93 | 4.18 | 15.60 | 37.11 |
| **Post-Greenspan** | | Panel C | | | |
| **(1987-2009)** | Unemployment rate | -1.363 | -1.067 | -0.518 | -0.437 |
| | Inflation | 2.333** | 1.393** | 1.623** | 1.509** |
| | Real GDP Growth | 1.063 | 0.307 | 0.445** | 0.320 |
| | Stock Price | 0.154 | 0.180 | 0.145 | 0.113 |
| | Lag of Federal funds rate | 0.89** | 0.85** | 0.89** | 0.85** |
| | Hansen J-test | 0.21 | 0.22 | 0.34 | 0.21 |
| | Cragg-Donald F-statistic | 2.66 | 6.31 | 32.51 | 33.91 |

$\boldsymbol{i}_t = \alpha + \Psi E_t \boldsymbol{X}_{t+1} + \gamma \boldsymbol{S}_{t-i} + \rho \boldsymbol{i}_{t-1} + \varepsilon_t$, $\boldsymbol{X}_{t+k} = (y_{t+1}\ \Delta y_{t+1}\ \pi_{t+1})$ and $\psi = (\beta\ \ \delta\ \ \theta)$, where $i_t$ is Federal funds rate. $y_t$ is 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. Four quarterly lags of inflation, output gap, real GDP growth, stock price change, and federal funds rate 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: Estimation results of Asset Asymmetry Policy Reaction function

| Parameters | Estimated Coefficients | | | |
|---|---|---|---|---|
| | IV | | OL S | |
| | GBF as instruments | SPF as instruments | GBF of as regressors | SPF as regressors |
| Unemployment rate | -1.462** | -0.84 | | |
| Real GDP Growth | 0.369 | 1.016** | | |
| Inflation | 2.031** | 2.34** | 1.53** | 1.33** |
| output gap | | | 0.57 | 0.69 |
| Stock Price | | | | |
| Asset Boom | -0.062 | -0.11 | 0.073 | 0.031 |
| Asset Bust | 0.292** | 0.225** | 0.125** | 0.167** |
| No Asset Boom/Bust | 0.365 | 0.184 | 0.067 | 0.012 |
| Lag of Federal funds rate | 0.87** | 0.90** | 0.85** | 0.85** |
| Hansen J-test | 0.54 | 0.80 | | |
| Cragg-Donald F-statistic | 36.33 | 29.65 | | |
| $R^2$ | 0.79 | 0.84 | 0.85 | 0.83 |

** (P<0.05)

$$i_t = \alpha + \Psi E_t \boldsymbol{X}_{t+1} + \gamma_1 u_{t-1} S_{t-1} + \gamma_2 o_{t-1} S_{t-1} + \gamma_3 (1-u-o)_{t-1} S_{t-1} + \varepsilon_t ,$$

$\boldsymbol{X}_{t+1} = (y_{t+1} \ \ \Delta y_{t+1} \ \pi_{t+1})$ and $\Psi = (\beta \ \ \delta \ \theta)$, where $i_t$ : federal funds rate. $y_t$ : output gap/unemployment rate, $\pi_t$ : 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.

Table 3: Estimation Results of Economy Asymmetry Reaction Function

| Parameters | Estimated Coefficients | | | |
|---|---|---|---|---|
| | IV | | OL S | |
| | GBF as instruments | SPF as instruments | GBF of inflation as regressor | SPF of inflation as regressor |
| Unemployment rate | -0.733** | -1.117** | | |
| Real GDP Growth | 0.667 | 0.750 | | |
| Inflation | 1.687** | 2.800** | 1.873** | 1.429*** |
| output gap | | | 0.873** | 1.021** |
| Stock Price | | | | |
| Recession | 0.093** | 0.056** | 0.127** | 0.186** |
| Non-recession | 0.005 | 0.003 | 0.086 | 0.054 |
| Lag of Federal funds rate | 0.85 | 0.91 | 0.85 | 0.83 |
| Hansen J-test | 0.49 | 0.12 | | |
| Cragg-Donald F-statistic | 43.11 | 23.98 | | |
| R2 | 0.82 | 0.85 | 0.84 | 0.82 |

** (P<0.05)

$$i_t = \alpha + \Psi E_t \boldsymbol{X}_{t+1} + \gamma_1 r_{t-1} S_{t-1} + \gamma_2 (1-r)_{t-1} S_{t-1} + \varepsilon_t, \quad X_{t+1} = (y_{t+1} \;\; \Delta y_{t+1} \;\; \pi_{t+1})$$

and $\boldsymbol{\Psi} = (\beta \;\; \delta \;\; \theta)$ where $i_t$ : federal funds rate. $y_t$ : output gap/unemployment rate, $\pi_t$ : 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.

Table 4: Information Set and Stock Price Change

| Parameters | Estimated Coefficients | | | |
|---|---|---|---|---|
| | GBF | | SPF | |
| **Symmetric Model** | | | | |
| Inflation | | -0.018** | | -0.016** |
| Unemployment rate | | -0.005** | | -0.012** |
| Real GDP Growth | | 0.021** | | 0.057** |
| **Asymmetric Model** | | | | |
| | Asset Asymmetry | Economy Asymmetry | Asset Asymmetry | Economy Asymmetry |
| Inflation | | | | |
| Asset Boom | - 0.006** | | -0.011** | |
| Asset Bust | -0.054** | | -0.036** | |
| No Asset Boom/Bust | -0.007** | | -0.051** | |
| Recession | | - 0.054** | | -0.137** |
| Non-recession | | -0.009** | | -0.002** |
| Unemployment rate | | | | |
| Asset Boom | -0.003** | | -0.047** | |
| Asset Bust | -0.009** | | -0.021** | |
| No Asset Boom/Bust | -0.002** | | -0.0002** | |
| Recession | | -0.013** | | -0.0216** |
| Non-recession | | -0.003 | | -0.0068** |
| Real GDP Growth | | | | |
| Asset Boom | -0.002 | | -0.018 | |
| Asset Bust | 0.045** | | 0.001** | |
| No Asset Boom/Bust | -0.0019 | | 0.011 | |
| Recession | | 0.059 | | 0.001** |
| Non-recession | | -0.014 | | -0.013 |

Asymmetric Model: $$\boldsymbol{X}_{t+1} = \theta + \sum_{j=1}^{4} \boldsymbol{\delta_j X_{t-j}} + \lambda_1 u_{t-1} S_{t-1} + \lambda_2 o_{t-1} S_{t-1} + \lambda_3 (1-u-o)_{t-1} S_{t-1} + \mu_t$$ or

$$\boldsymbol{X}_{t+1} = \theta + \sum_{j=1}^{4} \boldsymbol{\delta_j X_{t-j}} + \lambda_1 r_{t-1} S_{t-1} + \lambda_2 (1-r)_{t-1} S_{t-1} + \mu_t$$

and $\boldsymbol{X}_{t+1} = (y_{t+1} \;\; \Delta y_{t+1} \;\; \pi_{t+1})$, where $y_t$ : output gap/unemployment rate, $\pi_t$ : inflation rate, annual rate, $\Delta y$ : real GDP growth. $S_t$ : percent change in S&P 500 stock price index. $o$ and $u$ are dummy for boom and bust periods, respectively. $\lambda^{\pi}$, $\lambda^{y}$, and $\lambda^{\Delta y}$ are parameter coefficients of stock price change in inflation, output gap, and real GDP forecasting equation. r is a dummy for recession periods.

## References

Andrews D.W.K, and Stock J.H, 2005. Inference with Weak Instruments. NBER Technical Report.

Bernanke B.S and Lown C.S., 1991. The Credit Crunch. Brookings papers on Economic activity, 2, 204-39.

Baum C.F., Schaffer M.E., and Stillman S., 2003. Instrumental Variables and GMM: Estimation and Testing. Stata Journal, 3: 1-31.

Bernanke B. and Gertler M., 1999. Monetary Policy and Asset Price Volatility. Federal Reserve Bank of Kansas City Economic Review, 84(4), 17-51.

Bernanke, B. and Gertler M., 2000. Monetary Policy and Asset Price Volatility. NBER Working paper, 7559.

Bernanke, B. and Gertler M., 2001. Should Central Banks Respond to Movements in Asset Prices? American Economic Review, 91(2), 253-257.

Borio, C., and Lowe P., 2002. Asset Prices, Financial and Monetary Stability: Exploring the Nexus. Monetary and Economics Department, BIS Working Paper, 114.

Bordo M., and Jeanne O., 2002. Boom-busts in asset prices, economic instability, and monetary policy. NBER working paper, 8966.

Bullard B. and Schaling E., 2002. Why the Fed Should Ignore the Stock Market? The Federal Reserve Bank of Dallas, March/April 2002.

Cecchetti S.G., G. Hans., J. Lipsky, and Wadhwani, S., 2000. Asset Prices and Central Bank Policy. International Center for Monetary and Banking Studies, Center for Economic Policy Research, London.

Chadha J., Sarno L., and Valente G., 2004. Monetary Policy Rules, Asset Prices, and Exchange Rates. IMF Staff Papers, 51(3), 529-551.

Clarida R., Gali, J. and Gertler M., 1998. Monetary Policy Rules in Practice: Some International Evidence. European Economic Review, 42, 1003-1067.

Clarida R., Gali, J. and Gertler M., 1999. The Science of Monetary Policy: A New Keynesian Perspective. Journal of Economic Literature, 37(4), 1661-1707.

Clarida R., Gali, J and Gertler M., 2000. Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory. Quarterly Journal of Economics, 115(1), 147-180.

Cragg J.G. and Donald S.G., 1993. Testing Identifiability and Specification in Instrumental Variable Models. Econometric Theory, 9, 222-240.

Croushore D., and Stark T., 2001. A Real-time Data Set for Macroeconomists. Journal of Econometrics, 105, 111-130.

Detken C. and Smets F., 2004. Asset Price Booms and Monetary Policy. European Central Bank Working Paper, 364.

Filardo J., 2000. Monetary Policy and Asset Prices. Federal Reserve Bank of Kansas City Economic Review, Third Quarter, 85(3), 11-37.

Fuhrer J., and Totell G., 2008. Eyes on the prize: How did the fed respond to the stock Market? Journal of Monetary Economics, 55, 796-805.

Gali J. and Gertler M., 1999. Inflation Dynamics: A structural Econometric Analysis. Journal of Monetary Economics, 44, 195-222.

Goodhart C. and Hofmann B., 2007. House prices, Money, Credit, and the Macro-economy. Oxford Review of Economic Policy, forthcoming.

Hansen, C., Hausman J.A., and Newey W.K., 2004. Many Insturments, Weak Instruments and Econometric Practice. Working paper, M.I.T.

Judd and Rudebush, 1998. Taylor's Rule and the Fed: 1970-1997. Economic Review, Federal Reserve Bank of San Francisco, 3-16.

Kleibergen F. and Mavroeidis S., 2008. Weak Instrument Robust Tests in GMM and the New Keynesian Phillips Curve. Working paper, Brown University.

Ma A., 2002. GMM estimation of the New Keynesian Phillips Curve. Economics Letters, 76, 411-417.

Mavroeids S., 2005. Identification Issues in Forward-Looking Models Estimated by GMM, with an Application to the Phillips Curve. Journal of Money, Credit, and Banking, 37(3), 421-448.

Molodtsova T., Nikolsko-Rzhevskyy A., and Papell D.H., 2008. Taylor Rules with Real-time Data: A Tale of Two Countries and One Exchange Rate. Journal of Monetary Economics, 55, 563-579.

Newey W.K, 2004. Many Weak Moment Asymptotic for Continually Updated GMM Estimator. Department of Economics, M.I.T.

Newey W.K., and Windmeijer F., 2005. GMM with Many weak Moment conditions. Department of Economics, M.I.T.

Orphanides A., 2001. Monetary Policy Rules Based on Real-time data. American Economic Review, 91, 964-985.

Rigobon R. and Sack B., 2001. Measuring the Reaction of Monetary Policy to the Stock Market. The Quarterly Journal of Economics, 118(2), 639-669.

Semmler W., and Zhang W., 2007. Asset Price Volatility and Monetary Policy Rules: A Dynamic Model and Empirical Evidence. Economic Modeling 24, 411-430.

Sooreea R., 2007. Does U.S. Monetary Policy React to Asset Prices? Implications of Stock Market Bubbles, Volatility and Productivity. Indian Journal of Economics and Business, 6(2), 277-298.

Staiger D. and Stock J.H., 1997. Instrumental Variables Regression with Weak Instruments. Econometrica, 65, 557-586.

Stock J.H., Wright J.H., and Yogo M., 2002. A Survey of Weak Instruments and Weak Identification in Generalized Method of Moments. Journal of Business and Economic Statistics, 20, 518-529.

Stock J.H., and Wright J.H., 2000. GMM with Weak Instruments," Econometrica, 68, 1055-1096.

Stock J.H., and Yogo M., 2005. Asymptotic Distributions of Instrumental Variables Statistics with Many Weak Instruments. In Identification and Inference for Econometric Models: Festchrift in Honor of Thomas J. Rothenberg, Ed. By D.W.K. Andrews and J.H. Stock. Cambridge, UK: Cambridge University Press.

Svensson L., 1999. Inflation Targeting as a Monetary Policy Rule. Journal of Monetary Economics, 43(3), 607-654.

Taylor J., 1993. Discretion versus Policy Rules in Practice. Carnegie-Rochester Conference Series on Public Policy, 39, 195-214.

Violi R., 2006. Asset Prices and Monetary Policy Rules: Should we Forsake Financial Markets Stabilization. Monetary Policy, Profits and Finance, Forthcoming.

Woodford M., 1999. Optimal Monetary Policy Inertia. NBER working pape, 7261.

Woodford M., 2001. The Taylor Rule and Optimal Monetary Policy. American Economic Review, 91, 232-237.