The Fed and the Stock Market*

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Abstract

The Fed closely monitors the stock market and the stock market continuously forms expectations about the Fed decisions. What does this imply for the relation between the fed funds rate and the S&P500? We find that the answer depends on the conditions prevailing on the financial market. During periods of high (low) volatility in asset price inflation an unexpected 5% fall in the stock market index implies that the Fed cuts the interest rate by 19 (6) basis points while an unanticipated policy tightening of 50 basis points causes a 4.7% (2.3%) decline in the S&P500. The Fed reaction to asset price return is however statistically different from zero only in the high volatility regime, whereas the fall in asset price return following an interest rate rise is highly significant during normal times only.

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1 Introduction

The stock market boom of the late 1990s and its consequent bust has led to a resurgence of interest on the conduct of monetary policy in the face of crucial developments in the financial market. In a recent speech at the Meetings of the American Economic Association, the Fed Chairman Alan Greenspan (2004) offers his own view on the subject. *"Rules that relate the setting of the federal funds rate to the deviations of output and inflation from their respective targets, in some configurations, do seem capture the broad contours of what we did over the past decade and a half. And the prescriptions of formal rules can, in fact, serve as helpful adjuncts to policy [...]. But at crucial points, like those in our recent policy history – the stock market crash of 1987, the crises of 1997-98, and the events that followed September 2001 – simple rules will be inadequate as either descriptions and prescriptions of policy. Moreover, such rules suffer from fixed-coefficient difficulties"*.

From a theoretical point of view, Bordo and Jeanne (2002) forcefully argue that the linkages between asset prices, financial instability and monetary policy are inherently nonlinear. Using a model in which firms can only borrow against collateral and in which credit crunches occur if asset prices fall below a certain threshold, they show that the optimal policy response to asset price inflation is nonlinear, even though asset price stabilization is not a target of the Central Bank. Moreover, a policy that (pre-emptively) raises the interest rate in the anticipation of a credit crunch, dominates a purely reactive monetary policy that responds only to current inflation and real activity. Bernanke, Gertler and Gilchrist (1999), and Bernanke and Gertler (1989 and 1999) provide a possible microfoundation for such a nonlinearity and show that the magnitude of the effects of asset price fluctuations on the economy will strongly depend on the state of household and firms' balance sheets as measured by the degree and distribution of risk exposure.[1]

Despite the growing number of theoretical contributions, the empirical evidence on the nexus between monetary policy and asset prices is scant and to the best of our knowledge, there are no studies that, on one side allow for nonlinearities in the Central Bank response to asset price inflation and, on the other, explore the possibility that the stock market reaction to monetary policy innovations is state-dependent. Moreover, these two channels are often regarded as independent and there have been no attempts so far to build up a unified framework for disentangling and measuring simultaneously the two effects. This paper tries to fill the gap.

We develop a new identification strategy that explicitly incorporates the risks and condi-

[1] The idea is that agency problems make internal finance cheaper than external finance such that a raise in a firm's share price increases the available collaterals and reduces the marginal cost of external funds. Hence, firms are more likely to increase their borrowing and investment in normal times rather than in periods of financial distress when collateral constraints start to bind. This mechanism is referred to as financial accelerator.

tions prevailing on the financial market as emphasized by Bordo and Jeanne (2002), and Bean (2003). In practice, we use daily observations to construct a within-month measure of volatility in asset price returns. This is the threshold variable that governs the possible monetary regime shift in a four-variate Structural VAR (SVAR) in interest rate, asset price returns, output gap and inflation. The cut-off value is determined within the model: a change in stock market volatility can be used to identify different policy regimes.

Modelling monetary policy within an identified macroeconomic system - as opposed to the single equation used in earlier contributions - has two advantages. First, it allows to take explicitly into account the endogeneity problem due to the simultaneous relation between stock prices and interest rate changes. Second, it provides a joint estimate of the response of monetary policy to asset price and of the reaction of asset price to monetary policy. We check and confirm the robustness of our results using an alternative identification scheme based on a system of orthogonality conditions estimated with GMM.

A major finding of the paper is that US monetary policy over about the last twenty years can be characterized by two regimes. Using monthly observations, the estimates of the reaction function indicate that the periods of low financial volatility are associated with a monetary policy response to inflation and output gap only. In contrast, high volatility periods raise the scope for a significant interest rate reaction also to asset price inflation. As the regime in which monetary policy actively responds to asset prices is associated with asset price busts, our findings suggest that the policy of the Fed over the stock market can be described as reactive. On the asset price side, the S&P500 index appears relatively more reactive to monetary policy news in the high volatility regime, though the estimate of such a response is far less accurate than its counterpart during normal times.

The paper is organized in five parts. Section 2 presents some narrative evidence and the data, and shows that a number of key reduced-form statistics change quite dramatically with the state of the financial market. Section 3 describes a VAR model that can naturally accommodate such a nonlinearity and presents the relative estimates. The following part uses a system GMM and shows that the results are robust to an alternative identification strategy. The last section concludes.

2 Narrative evidence and descriptive statistics

Alan Greenspan (2004) identifies four outstanding episodes in the recent US monetary policy history. His speech will serve as a basis for our narrative evidence. All episodes are associated with adverse outcomes on the financial market and they include the stock market crash of late 1987, the first Iraq war at the end of 1990, the liquidity crisis following the Russian default in 1998, the new-economy bubble of the late 1990s and its relative bust whose consequences extend from early 2000 through late 2001.

Referring to the crash in October 1987, Greenspan (2004) observes *"We operated essentially in a crisis mode, responding with an immediate and massive injection of liquidity to help stabilize highly volatile financial markets"*. A similar reaction appears some years later when *"the weakening of demand already under way, some pullback of credit by lenders, and the spike in oil prices after Iraq's invasion of Kuwait were sufficient to produce a marked contraction of activity in the fall of 1990. [...] Policy eased gradually but persistently to counter the effects of these developments, with the funds rate falling to 3 percent by September 1992, its lowest level since the early 1960's."*.

The narrative evidence from the late 1990's also appears to support the notion of a reactive monetary policy stance. Moreover, there seems to be a case for a different attitude of the Fed towards stock market busts and stock market booms. On the one hand, *"the 1998 liquidity crisis [...] prompted the type of massive ease that has been the historic mandate of a central bank. Crises are precipitated by the efforts of market participants to convert illiquid asset into cash. [This] causes prices of equity assets to fall, in some cases dramatically."*. On the other hand, Greenspan also argues that "*Nothing short of a sharp increase in short-term rates that engenders a significant economic retrenchment is sufficient to check a nascent bubble. The notion that a well-timed incremental tightening could have been calibrated to prevent the late 1990s bubble is almost surely an illusion. Instead, we [...] need to focus on policies to mitigate the fallout when it occurs and, hopefully, ease the transition to the next expansion.*"

This informal evidence is suggestive and important because it identifies a minimal set of requirements for our framework: a credible empirical model of the interaction between the Fed and the stock market must be able to track these episodes. Moreover, in his speech *"Risk and Uncertainty in Monetary Policy"*, Greenspan forcefully argues that during crucial events *"the central bank pursues a risk management approach"* according to which the costs and benefits of a policy action are weighted in the face of a pervasive uncertainty about the developments in the financial market.

We complement the narrative evidence above with some reduced form statistics that appears to corroborate the existence of important non-linearities in the joint behavior of monetary policy and asset returns. The idea is that different levels of volatility in financial markets can trigger off a different policy reaction to movements in asset price returns. The justification for this comes from Greenspan's speech. The stock market volatility can actually signal a situation -or a prospect- of financial distress such as to provide the policy makers with a simple, useful measure of uncertainty and risk. In *normal* times, which we define as times characterized by low volatility, the Fed may not react to stock market returns. In contrast, episodes of high volatility may require a significant interest rate intervention.

The data set consists of five series. Among them, four are assumed endogenous and one is assumed to govern the transition between regimes. The endogenous variables are stacked into a vector y_t and they are: the yearly inflation rate, π_t, the output gap, x_t, the Federal funds rate, i_t and the growth rate of the S&P 500 Index, q_t. The series q_t is computed at each point in time by first taking the within-month average of daily observations on the S&P 500 Index and then computing its growth rate. The threshold variable, z_t, is the within-month standard deviation of the daily growth rates of the S&P 500 Index.[2] The sample is 1985:08 - 2003:10.

Four episodes of high volatility clearly emerge from Figure 1. Interestingly, they correspond to the periods highlighted by Greenspan. The first event is associated with the months between the end of 1987 and the beginning of 1988 while the following period starts in the fall of 1990 and extends through early 1991. Financial markets become once more highly volatile between the end of 1997 and 1998. The fourth and more prolonged period lasts from the end of 1990's to the first two years of the new millennium.

In order to give a sense of the importance of regime changes in the identification and measurement of the response of the Fed to the stock markets, we report summary statistics and correlations for the four series conditional on the high/low volatility level. We set the threshold at $z^* = .0099$. At this stage we do not offer any justification for this value. In the following Section, we will rationalize it as the maximum likelihood estimate of the threshold level in a multivariate TAR model.

Summary statistics and correlations for each regime are reported in Tables 1 and 2. The stock market return, q_t, displays a negative mean of around -0.9 in the high volatility regime and a positive mean of about 1.8 in the low volatility regime. The reverse is true for the output gap series where a positive mean of x_t during high volatility periods turns negative when volatility is low. The standard deviations of the five series in Panel B show a marked differences across regimes in that they all peak during high volatility times.

Table 2 reports the correlation between the series over the full sample and over the two sub-samples. The asymmetries are confirmed. It is interesting to notice that high volatility is associated with falling asset price returns while low volatility is associated with increasing asset price return; the change in the correlation is remarkable and goes from 0.16 in the low volatility regime to -0.45 in the high volatility regime. The federal funds rate displays a positive correlation (0.10) with q_t when the stock market is characterized by low volatility while the correlation falls to zero when the volatility in stock market is high. The S&P 500

[2]Sources and definitions for the variables are detailed in the Appendix.

return has a negative (-0.17) correlation with inflation in the low volatility regime and a zero correlation with inflation in the high volatility regime.

These descriptive statistics are of course only suggestive. Nevertheless, some important asymmetries between the two Regimes seem to emerge and, more importantly, these asymmetries appear to characterize the interaction between monetary policy and the stock market. Next section develops a nonlinear econometric model to formally account for these observations.

3 Evidence from a Nonlinear Structural Model

This section presents some empirical evidence on the nonlinear relation between monetary policy and asset prices. The estimates are based on a Threshold Structural Vector Autoregressive (TSVAR) model.

3.1 The TSVAR Specification

We assume the following structural form:

$$\begin{cases} A_1 y_t = k_1 + \sum_{i=1}^{p} \theta_i^1 y_{t-i} + \varepsilon_t^1 & \text{if } z_t < r_1 \\ A_2 y_t = k_2 + \sum_{i=1}^{p} \theta_i^2 y_{t-i} + \varepsilon_t^2 & \text{if } z_t > r_1 \end{cases} \tag{1}$$

where $y_t = (y_{1t}, y_{2t}, \ldots, y_{kt})'$ is a $k-th$ dimensional vector time-series and $Cov(\varepsilon_t^i) = D_i$, with D_i being a diagonal matrix and the matrices A_i having ones on the main diagonal. z_t is the threshold variable whose level determines the switching between regimes[3]. A more compact representation is:

$$\begin{cases} A_1 y_t = \Theta_1 X_t + \varepsilon_t^1 & \text{if } z_t < r_1 \\ A_2 y_t = \Theta_2 X_t + \varepsilon_t^2 & \text{if } z_t > r_1 \end{cases} \tag{2}$$

where: $X_t = vec(1 \ y_{t-1} \ldots y_{t-p})'$ and $\Theta_j = (k_j, \theta_1^{(j)}, \ldots, \theta_p^{(j)})$.

The reduced form of the model is the standard TVAR model studied by Tsay (1998):

$$y_t = \begin{cases} \Phi_1 X_t + u_t^1 & \text{if } z_t < r_1 \\ \Phi_2 X_t + u_t^2 & \text{if } z_t > r_1 \end{cases} \tag{3}$$

where: $\Phi_i = A_i^{-1}\Theta_i$ and: $Cov(u_t^i) = \Sigma_i = A_i^{-1} D_i A_i^{-1}$.

Parameters in equation (3) can be estimated in two steps. For given r_1, the two equations are two separate multivariate linear regressions, whose coefficients, Φ_i and Σ_i can be obtained by OLS.

Estimates are:

$$\hat{\Phi}_i(r_1) = \left(\sum_t^{(i)} X_t X_t'\right)^{-1} \left(\sum_t^{(i)} X_t y_t'\right) \tag{4}$$

[3] At this level of generality we focus on a two regimes model only for expositional reasons. We will show below that the data appears to favor a two-regime specification.

and:

$$\hat{\Sigma}_i(r_1) = \frac{{}^{(i)}_{t}(y_t - X_t'\hat{\Phi}_i(r_1))(y_t - X_t'\hat{\Phi}_i(r_1))'}{n_i - k} \tag{5}$$

where ${}^{(i)}_{t}$ denotes summing over observations in regime i, and n_i denotes the number of observations in regime i.

In the second step, the threshold is estimated as the value $\hat{r}$ that minimizes the total sum of squared residuals:

$$\hat{r} = \arg\min_{r_1} S(r_1) \tag{6}$$

where $S(r_1) = S_1(r_1) + S_2(r_1)$ and $S_i(r_1)$ is the trace of $(n_i - k)\hat{\Sigma}_i(r_1)$.

The resulting estimates are thus: $\hat{\Phi}_i(\hat{r})$ and $\hat{\Sigma}_i(\hat{r})$. Tsay (1998) provides the necessary technical assumptions to guarantee the consistency of the above estimator as the sample size, n, tends to infinity.

3.2 Identification

Having obtained estimates of the reduced form parameters, $\hat{\Phi}_i(\hat{r})$ and $\hat{\Sigma}_i(\hat{r})$, we can attempt to recover the parameters of the structural form.

By simply counting the number of free parameters in models (2) and (3), it is immediate to see that in order to have a just-identified model, $\frac{k(k-1)}{2}$ restrictions must be imposed on (2) in each regime.

3.3 The Reduced-form

We estimate a four variable TVAR with federal funds rate, stock returns, output gap and inflation modelled as endogenous variables. In other words, $y_t = [i_t, q_t, x_t, \pi_t]$. The threshold variable, z_t, represents a measure of asset price volatility and it governs the switch between monetary policy regimes. Standard lag length criteria select a reduced-form system (3) of order two. Moreover, two regimes seem to effectively describe the monetary policy stance of the Fed in the face of asset price volatility.[4]

The point estimate of the cut-off value for the threshold is 0.0099. Inspection of the path of the threshold variable in Figure 1 reveals that the first regime, which is represented by the thin line, consists of 144 observations and it is associated with low values of volatility in asset price return. Hence, we label it *low-volatility* regime. The second regime depicted by the thick and dotted line is made up of 77 observations and virtually corresponds to the narrative evidence on periods of financial distress reported in section 2. We label this sub-sample *high-volatility* regime.

[4]We also estimate a three-regime model and compare it to the performance of the two-regime model. The data appears to favor the latter.

The presence of two regimes in the parameters of the model is confirmed by the rejection of the linearity assumption. The likelihood ratio (LR) test for the null hypothesis of the validity of the linear model, which is distributed as a χ^2 with 46 degree of freedom, is equal to 142 and strongly rejects the null. An alternative test derived by Davies (1987) to take into account the presence of nuisance parameters, also rejects the null of linearity. Therefore, the presence of two regimes in the parameter of the model seems to be confirmed in the sample.

3.4 The Structural Form

Our goal is to recover the contemporaneous relations among the endogenous variables within each regime. In particular, we are interested in the interest rate reaction to movements in asset price return and in the response of the stock market to monetary policy news. To identify such responses we assume that, on the one hand, the interest rate can respond contemporaneously to inflation, output gap and asset return. On the other hand, inflation and the output gap can respond to the interest rate with a lag of (at least) one period. These assumptions line up with the identification of a monetary policy shock proposed by Christiano, Eichenbaum and Evans (1999). In a similar vein, asset price returns are allowed to respond contemporaneously to news about economic activity, though the reaction of output to movements in the stock market takes at least one period. This amounts to the following restrictions:

$$u_i \equiv \begin{pmatrix} u^i \\ u^q \\ u^x \\ u^\pi \end{pmatrix}_i = \begin{pmatrix} 1 & a_{12} & a_{13} & a_{14} \\ a_{21} & 1 & a_{23} & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & a_{43} & 1 \end{pmatrix}_i \begin{pmatrix} \varepsilon^i \\ \varepsilon^q \\ \varepsilon^x \\ \varepsilon^\pi \end{pmatrix}_i \equiv A_i \varepsilon_i \quad \text{with } i = 1, 2 \tag{7}$$

The response of monetary policy to movements in the stock market is computed as the cumulative changes in the interest rate following an innovation to asset price returns. The cumulative response is given by the sum of a_{12} and the coefficients on lagged asset price returns in the interest rate equation. The reaction of the stock market to monetary policy is measured on impact and it is captured by the parameter a_{21}. The distribution of the parameters can be calculated by montecarlo simulations, drawing residuals from the asymptotic distribution of the estimated covariance matrices in each regime. Given the threshold value, we then re-estimate the model and solve for the estimated coefficient over 10000 draws.

Table 3 presents the structural estimates of some key parameters. As far as the monetary policy reaction function is concerned, the *low volatility regime* in the second column is associated with a significant response to contemporaneous inflation and output gap. The cumulative response of interest rate to asset price return is however not statistically different from zero, thereby implying that a conventional Taylor rule in inflation and output gap does provide a reasonably good description of the Fed monetary policy during normal times.[5] On the financial market side, this regime is characterized by a highly significant response of the S&P500 Index to the federal funds rate. In particular, an unanticipated monetary policy tightening of 50 basis points leads on average to a contemporaneous decline in the stock returns of about 2.3%. The distributions of the parameters governing the relation between monetary policy and asset price inflation in the *low volatility regime* are displayed in the first row of Figure 3. The zero is outside any significant region of the parameter space only in the second column, which refers to the asset price response to monetary policy.

The third column of Table 3 reports the estimates for the regime associated with a *high within-month volatility* of the S&P500 Index. The response of monetary policy to inflation takes a negative value which is statistically different from the estimate of the low volatility regime whereas the response to the output gap does not vary significantly. The crucial difference is however that the interest rate reaction to an unanticipated asset price shock is now highly significant: an unexpected 5% fall in the S&P500 Index induces an interest rate cut of about 19 basis points. The asset price response to movements in the policy rate is large, though the point estimate is far less accurate relative to Regime 1. The second row of Figure 3 is the mirror image of the first row as the distribution of the monetary policy parameter is concentrated in the positive orthant while the distribution of the asset price coefficient is far more dispersed.

Interestingly, using daily observations over the 1990s, a different identification strategy and, most importantly, a linear model with a time-varying covariance matrix, Rigobon and Sack (2003) find that on a monthly basis the Fed moves the interest rate downward by 14 points in response to an asset price change of 5%. It is worth noting that Rigobon and Sack's estimate falls in between our estimate of the monetary policy response during normal times, 6 basis points, and our estimate of the Fed reaction in the high asset price volatility regime, 19 basis points. Turning to the asset price response to monetary policy, Rigobon and Sack (2004) report that an interest rate increase of 50 basis points implies a 3.4% decline in the S&P500 Index whereas Bernanke and Kuttner (2004) find a value of 2.6%. Our estimates imply a value of 2.3% and 4.7% for the low volatility regime and the high volatility regime respectively.

[5] Unlike the response on inflation and output gap, there is apparently less consensus in the empirical literature about whether monetary policy may respond to asset prices contemporaneously, as specified in Rigobon and Sack (2003), or with some lags, as specified in Bernanke and Gertler (1999). Table 3 reports the sum of the interest rate responses to contemporaneous and lagged asset price return. It is worth noticing however that the only significant coefficient in the reaction of the Fed to the stock market is the second lag of asset price return in the high volatility regime.

4 An alternative identification: System GMM

This section uses GMM and shows that the results obtained with the TSVAR model are robust to the identification and the method of estimation. The GMM estimates are based on a two-equation system made up of an interest rate reaction function and a stock market equation. An advantage of the bivariate system is that we do not need to specify explicitly a process for inflation and output gap, which leads to a more parsimonious model of the following form:

$$\begin{aligned} i_t &= \alpha_1 E_{t-1}(\pi_t) + \alpha_2 x_t + \alpha_3 q_{t-1} + \rho i_{t-1} + \varepsilon_t^i \\ q_t &= \alpha_4 x_t + \alpha_5 i_t + \varepsilon_t^q \end{aligned} \tag{8}$$

The first equation is a conventional Taylor-type rule augmented with a financial market indicator.[6] The second equation relates asset price returns to contemporaneous movements in output gap and interest rate and can be interpreted as the reduced form of the structural equation that relates asset prices to the stream of future expected discounted dividends. Our empirical specification follows the one employed by Bernanke and Gertler (1999).

Prior to estimation we replace expected values with actual values. The disturbance term is then a linear combination of forecast errors and therefore is orthogonal to any variable in the information set available at time $t-1$. The list of instruments includes six lags of inflation, output gap, the fed funds rate, the first difference of asset price and its volatility.

To address the issue of monetary policy regime switches we conduct two experiments. In the first, we estimate recursively the two-equation-system (8) using the observations corresponding to times in which the threshold variable is *not below* a given moving cut-off value. We start from a value of 0.012 for the asset price volatility and we then expand the subsample by moving the threshold *down* by 0.001 step. In the second experiment, we go in the opposite direction and we consider only the observations associated to times in which asset volatility is *below* the moving cut-off value. We start from a value of 0.008 for the asset price volatility and we then expand the subsample by moving the threshold *up* by the same steps as before.

As the process of the federal funds rate has a near-unit root, an unrestricted version of the system (8) produces very imprecise estimates. To fix the problem, we restrict $\rho = 1$ and for consistency we specify the stock market equation in first differences. The restricted model produces far more accurate and stable estimates. Figure 4 depicts the monetary policy response to movements in the asset prices under the two experiments. The estimate associated with the observations not below the value of 0.012 for the asset price volatility is significant and equal to 0.02. As the sub-sample expands because of a lower threshold value, the point estimate

[6] Results are robust to using a forward-looking specification with the nominal interest rate responding to the forecast of inflation twelve-months ahead.

declines and the confidence band becomes larger. In the limit, which virtually corresponds to the full sample at the very right-end side of the panel, the monetary policy response to asset price is estimated as low as 0.008 and the confidence interval virtually includes zero. Panel B is the mirror-image of Panel A in that the point estimate increases with the value of the threshold. The Fed response to the stock market is however not statistically different from zero in most sub-sample and in the limit case is equal to 0.008.

A similar patter emerges from Figure 5, which displays the reaction of asset price returns to monetary policy news. The first experiment in Panel A shows that lower values of the threshold are actually associated with lower and less accurate point estimates. The stock market response to movements in the interest rate is significant and just below the value -6 using the observations not below the threshold value of 0.012. As soon as the sample size increases however, the point estimate gets larger and more accurate up to a value of -2.9. More importantly, the confidence band shrinks when the included observations approach the full sample, thereby confirming the result of the SVAR that the data points in the low volatility regimes are helpful to identify this parameter. In analogy with the result in Figure 4, Panel B is the mirror image of Panel A also in Figure 5 as the stock market response declines with an increase in the threshold value. The point estimate is never statistically different from zero and in the limit it converges to a coefficient of -2.9.

Despite the difference in the method of estimation, the results using a recursive system GMM bear out the findings from the Nonlinear SVAR model. Specifically, the monetary policy response to movements in the stock market is larger during periods of high volatility than during periods of low volatility of asset price returns. Moreover, the Fed reaction is statistically different from zero only in the high volatility regime. Some point estimates, especially those on the interest rate reaction function, are somewhat sensitive to the change in the method of estimation. The size of these differences appear however neither quantitatively important nor unreasonable given the sampling uncertainty.

Several authors have estimated the monetary policy response to movements in the stock market over some post-1979 samples using single equation GMM. Bernanke and Gertler (1999) augment an otherwise conventional Taylor rule with the lag of asset price returns and they do find that the Fed does not react to the stock market. Chadha, Sarno and Valente (2004) report a set of statistically significant coefficients that range from 0.011 to 0.037 depending on the specification of the interest rate reaction function and the measure of asset price, with their favorite estimate being 0.015. The presence of nonlinearities documented in this paper and neglected in earlier contributions appear a reasonable candidate to reconcile the different estimates obtained using some linear model of the monetary policy reaction function.

5 Conclusions

Modelling and identifying the interaction between monetary policy and the stock market is complicated by two factors. The first is a standard endogeneity problem according to which the Central Bank may react to movements in asset price returns while asset price returns are sensitive to the interest rate set by the monetary authorities. The second is the existence of nonlinearities such that the magnitude of these reactions possibly depend on the state of the financial market. This paper develops an empirical nonlinear model and two alternative identification strategies to confront these issues.

Using US monthly data over the last two decades, we find that during periods of high volatility in asset price returns: an unanticipated 5% fall of the stock market index implies a statistically significant interest rate cut of 19 basis points; a monetary policy tightening of 50 basis points translates into a 4.7% decline of the S&P500, though this response is not statistically different from zero. In contrast, during normal times: the Fed significantly reacts to inflation and output gap only, and it does not respond to asset price returns. Specifically, an unexpected interest rate rise of 50 basis points induces a significant fall in the stock market index of about 2.3%. GMM estimates of a two-equation system made up of an interest rate reaction function for the Central Bank and an asset price equation for the market yield a similar picture.

Our results therefore suggest that the nexus between monetary policy and asset price is better described as nonlinear because of specific, historically limited episodes. This finding limits the benefits of using single equation linear Taylor rules as a description of US monetary policy over long periods characterized by different and variable financial market conditions. In particular, at crucial times like the stock market crash of 1987, the crises of 1997-98, and the burst of the high-tech bubble at the end of the 1990's, the Fed appears to respond also to asset price return in an effort to mitigate the negative effects of the bust on economic activity. We provide narrative evidence that also supports the notion of a reactive monetary policy stance.

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Appendix: the Data

The data used in the empirical part are as follows:

FFR: Effective Federal Funds Rate
Source: Board of Governors of the Federal Reserve System H.15

CPI: Consumer Price Index For All Urban Consumers: All Items (SA) Index 1982-84=100
Source: BLS

S&P 500 Composite Stock Price Index
Source: Daily Press

Industrial Production Index (SA) Units: Index 1997=100
Source: Board of Governors of the Federal Reserve System G.17

The yearly inflation rate, π_t, is the year-to-year growth rate of the CPI index.

The output gap, x_t is the HP cycle computed from the Industrial Production Index.

The growth rate of the S&P 500 Index is computed by taking the within-month average of daily observations on the S&P 500 Index and then computing the growth rate.

The threshold variable, z_t, is the within-month standard deviation of the daily growth rates of the S&P 500 Index.

Figure 1: The Regimes and the Threshold Variable

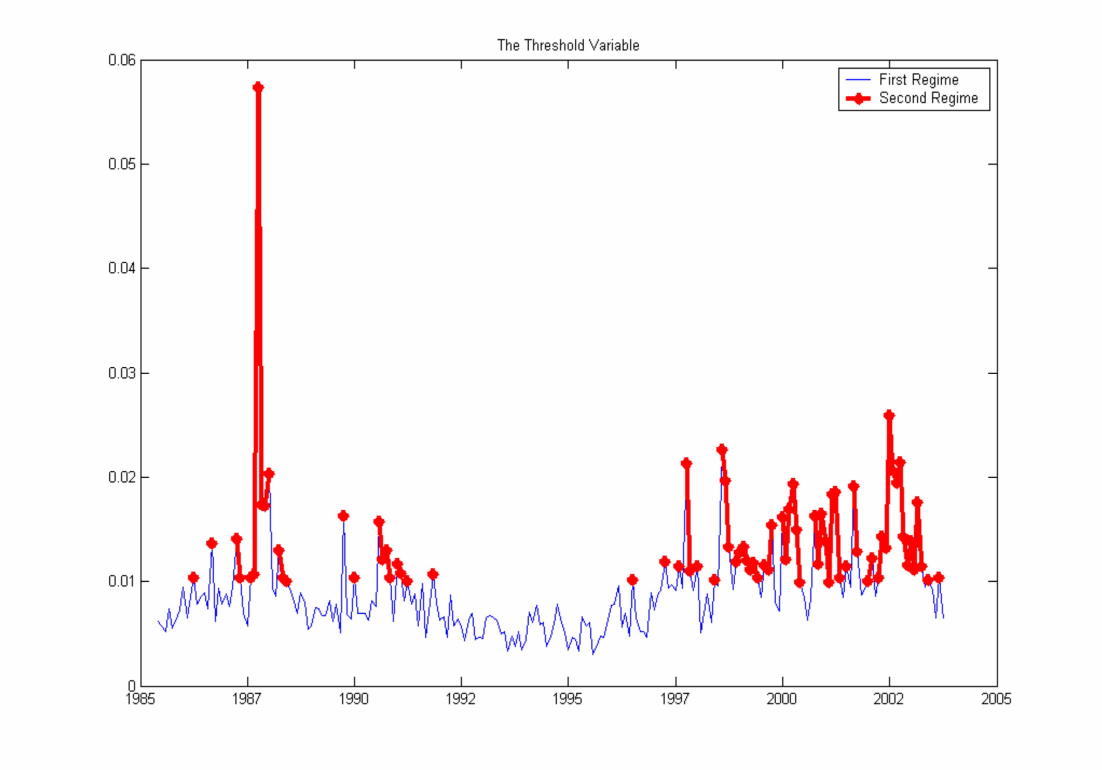


Figure 2: The Series and the Monetary Policy Regimes

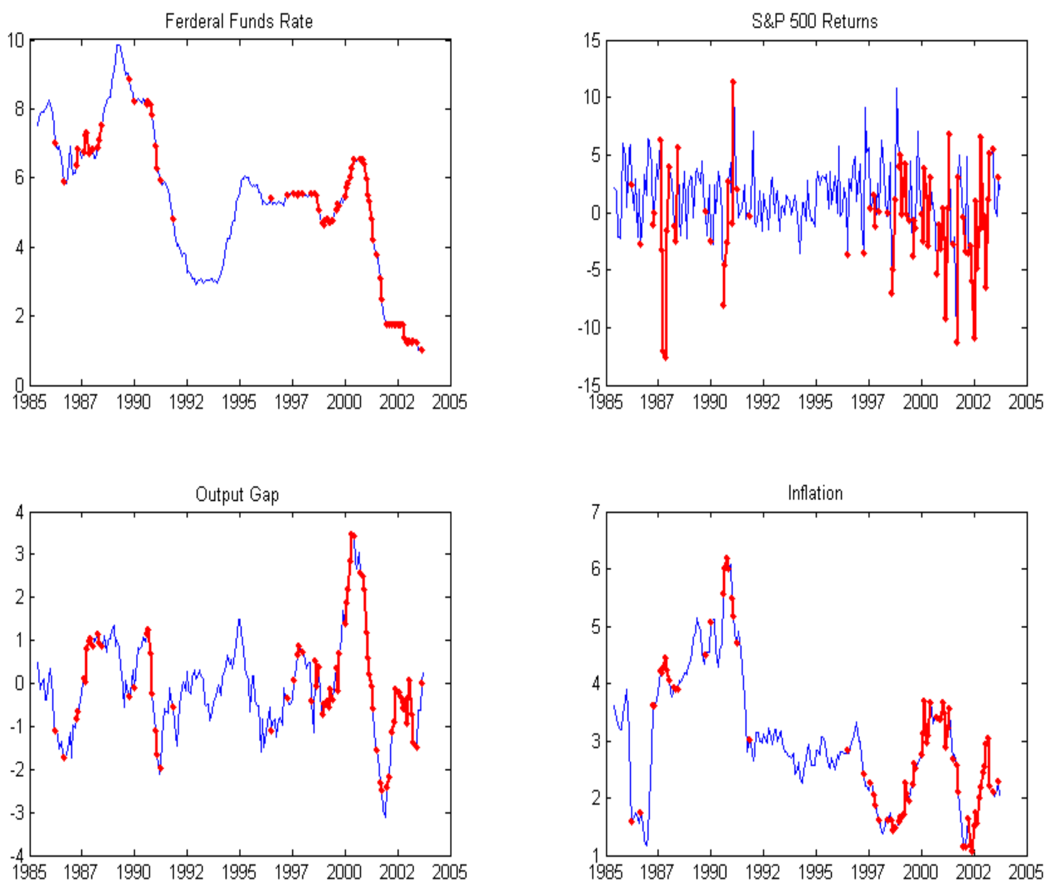
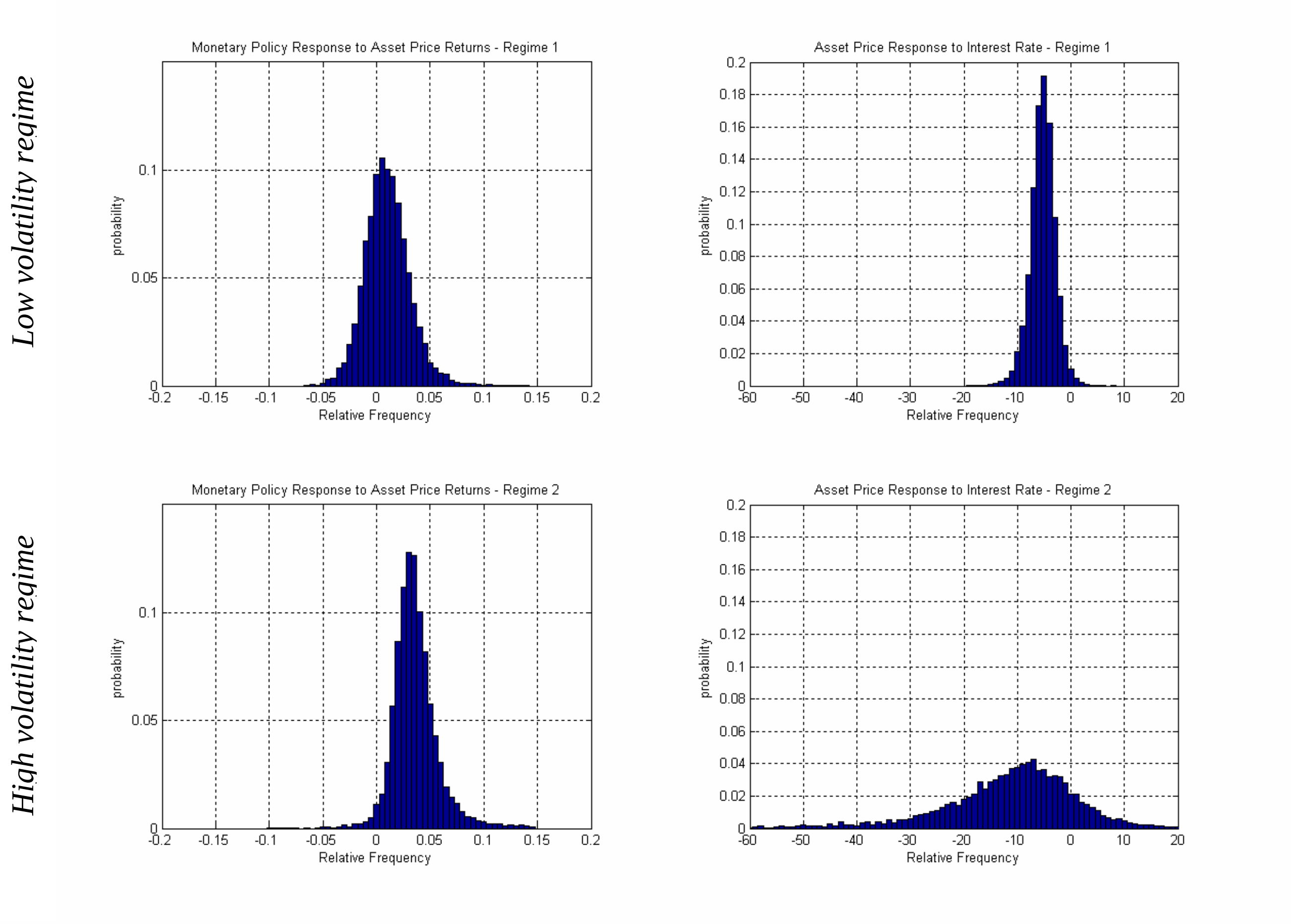


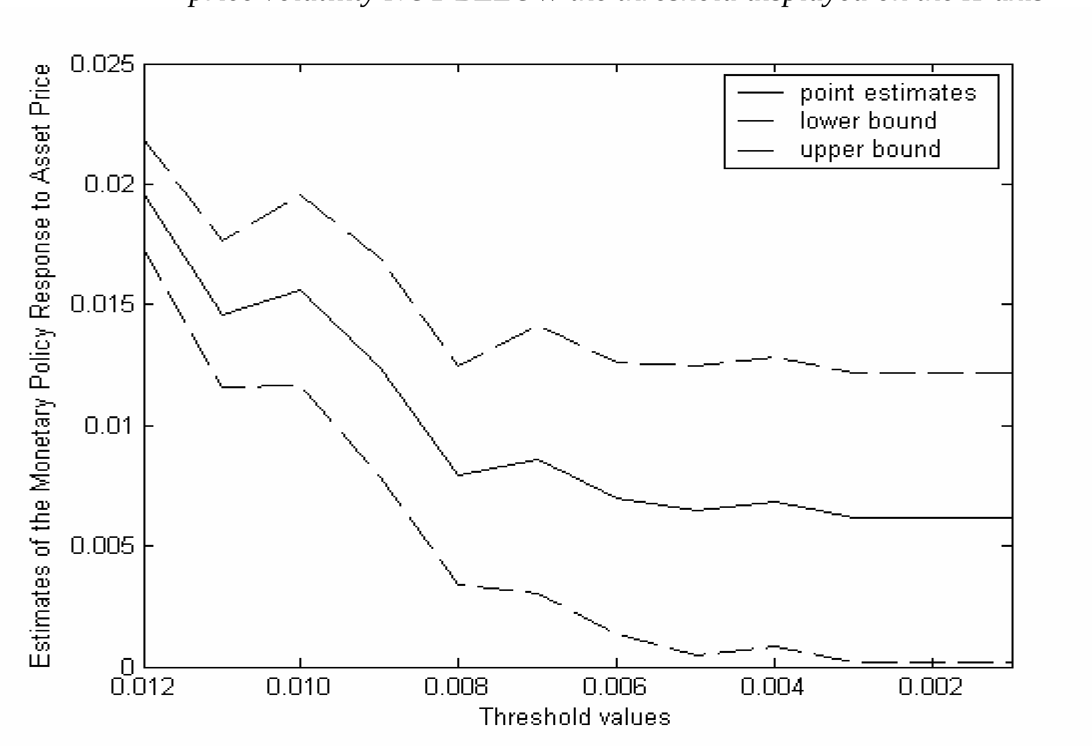
Figure 3: Distributions of Selected Structural Parameters



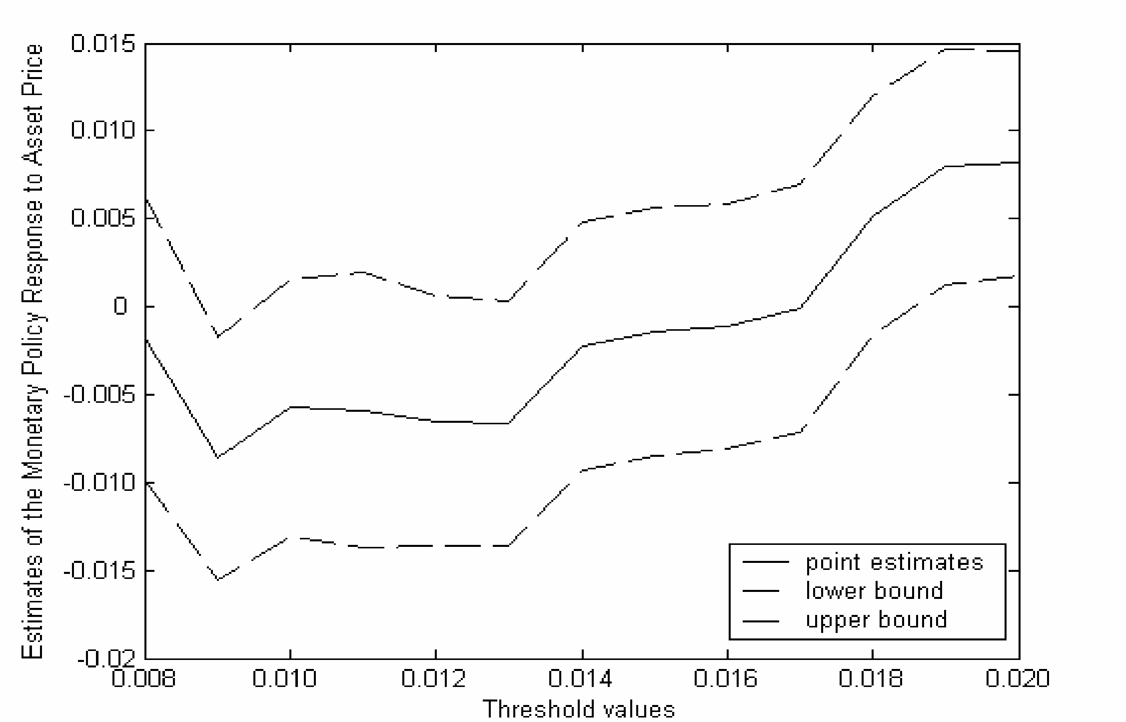
Notes: Monthly data. Sample: 1985:8 – 2003:10. The policy instrument is the federal funds rate and asset price returns are measured as the first (log) difference of the Standard and Poor's 500 stock market index. Estimates are based upon 10000 bootstrap repetitions.

Figure 4: GMM Rolling Estimates of the Monetary Policy Response to Asset Prices

Panel A: Estimates based on the observations associated with a value of the asset price volatility NOT BELOW the threshold displayed on the X-axis



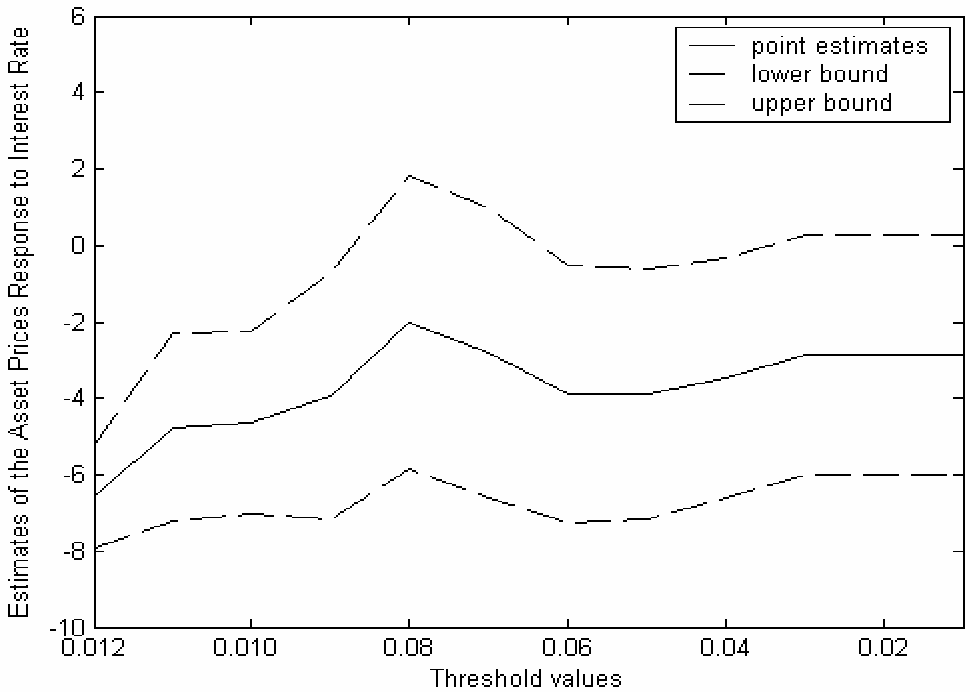
Panel B: Estimates based on the observations associated with a value of the asset price volatility BELOW the threshold displayed on the X-axis



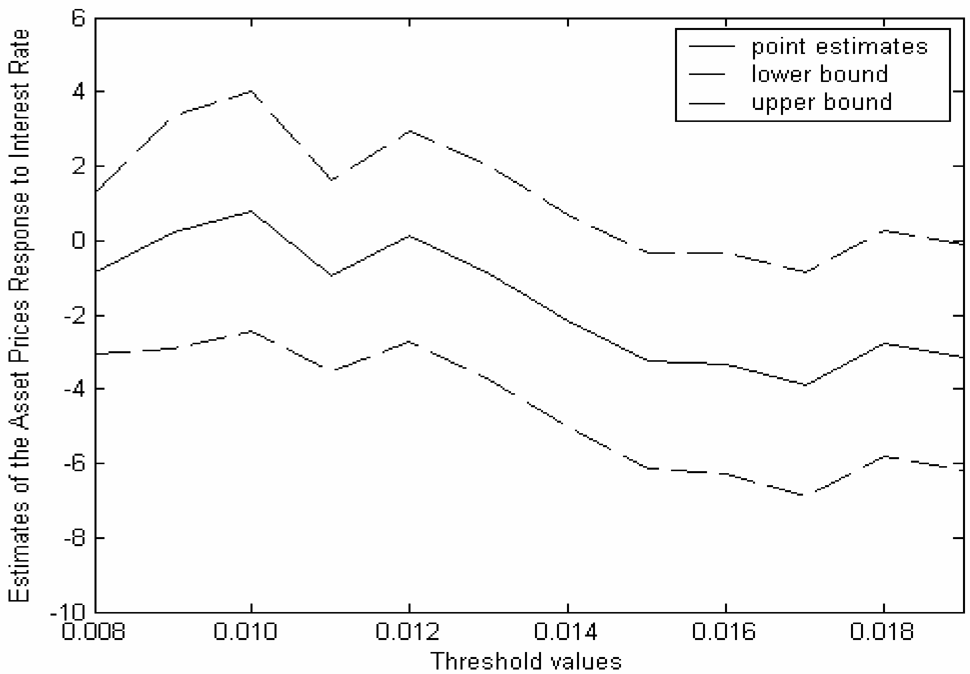
Notes: Monthly data. Sample: 1985:8 – 2003:10. Standard errors are computed using a four lag Newey-West covariance matrix estimates. See previous Tables for variable construction. The instrument set includes six lags of inflation, output gap, the fed funds rate, the first difference of asset price and its volatility.

Figure 5: GMM Rolling Estimates of the Asset Price Response to Interest Rate

Panel A: Estimates based on the observations associated with a value of the asset price volatility NOT BELOW the threshold displayed on the X-axis



Panel B: Estimates based on the observations associated with a value of the asset price volatility BELOW the threshold displayed on the X-axis



Notes: Monthly data. Sample: 1985:8 – 2003:10. Standard errors are computed using a four lag Newey-West covariance matrix estimates. See previous figures for variable construction. The instrument set includes six lags of inflation, output gap, the fed funds rate, the first difference of asset price and its volatility.

Table 1: Descriptive Statistics

Panel A – Mean

	Full sample	***Regime 1*** *Low volatility*	***Regime 2*** *High volatility*
Federal funds rate	5.3799	5.6071	4.9549
Asset price return	**0.8479**	**1.8043**	**-0.9406**
Output gap	-0.0694	-0.1246	0.0338
Inflation	3.0038	3.0478	2.9215
Variance of asset price return	**0.0094**	**0.0068**	**0.0142**

Panel B – Standard Deviation

	Full sample	***Regime*** *Low volatility*	***Regime 2*** *High volatility*
Federal funds rate	2.1089	2.0531	2.1592
Asset price return	**3.5638**	**2.5040**	**4.4714**
Output gap	1.0893	0.9753	1.2760
Inflation	1.0947	0.9841	1.2791
Variance of asset price return	0.0053	0.0017	0.0062

Notes: Monthly data. Full sample: 1985:8 – 2003:10. Inflation is measured as the change in the consumer price index and the output gap is the HP cycle of the Industrial Production index. The policy instrument is the federal funds rate and asset price returns are measured as the first (log) difference of the Standard and Poor's 500 stock market index. The volatility of asset prices is the within-month standard deviation of the first difference of the S&P's 500.

Table 2: Sample Correlations

full sample

	Federal funds rate	Asset price return	Output gap	Inflation	Variance of asset price return
Federal funds rate	1	0.084	0.375	0.618	-0.059
Asset price return		1	-0.148	-0.047	**-0.455**
Output gap			1	0.324	0.096
Inflation				1	-0.046
Variance of asset price return					1

Regime 1 – low asset price volatility

	Federal funds rate	Asset price return	Output gap	Inflation	Variance of asset price return
Federal funds rate	1	0.109	0.337	0.584	0.135
Asset price return		1	-0.138	-0.172	**0.157**
Output gap			1	0.359	-0.186
Inflation				1	-0.081
Variance of asset price return					1

Regime 2 – high asset price volatility

	Federal funds rate	Asset price return	Output gap	Inflation	Variance of asset price return
Federal funds rate	1	-0.042	0.468	0.672	0.030
Asset price return		1	-0.130	0.007	**-0.453**
Output gap			1	0.295	0.178
Inflation				1	0.014
Variance of asset price return					1

Notes: Monthly data. Full sample: 1985:8 – 2003:10. Inflation is measured as the change in the consumer price index and the output gap is HP cycle of the Industrial Production index. The policy instrument is the federal funds rate and asset price returns are measured as the first (log) difference of the Standard and Poor's 500 stock market index. The volatility of asset prices is the within-month standard deviation of the first difference of the S&P's 500.

Table 3: Point Estimates of Selected Structural Parameters

	Regime 1 *Low asset price Volatility*	***Regime 2*** *High asset price volatility*
Monetary Policy Response to		
Inflation	0.135***	-0.096***
Output gap	0.100***	0.120**
Asset price return	0.011	0.037***
Asset Price Response to		
Interest rate	-4.692***	-9.414

Notes: Monthly data. Sample: 1985:8 – 2003:10. Inflation is measured as the change in the consumer price index and the output gap is the HP cycle of the Industrial Production index. The policy instrument is the federal funds rate and the asset price return is measured as the first (log) difference of the Standard and Poor's 500 stock market index. The volatility of asset price changes is the within-month standard deviation of the first difference of the S&P's 500. The third and the fourth rows refer to the contemporaneous reactions of monetary policy to inflation and output gap whereas the entry for asset price return refers to the cumulative reaction. The last row reports the contemporaneous response of asset price return to the interest rate. The point estimates are the median of 10000 bootstrap repetitions. The superscript ***, ** and * denote the rejection of the one-side null hypothesis that the true coefficient is zero at the 1 percent, 5 percent and 15 percent significance levels, respectively.