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Stock Market Uncertainty and Monetary Policy Reaction Functions of the Federal Reserve Bank

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Abstract

In this paper we examine the link between stock market uncertainty and monetary policy in the US. There are strong arguments why central banks should account for stock market uncertainty in their strategy. Amongst others, they can maintain the functioning of financial markets and moderate possible economic downswings. To describe the behavior of the Federal Reserve Bank, augmented forward-looking Taylor rules are estimated by GMM. The standard specification is expanded by a measure for stock market uncertainty, which is estimated by an exponential GARCH-model. We show that, given a certain level of inflation and output, US central bank rates are significantly lower when stock market uncertainty is high and vice versa. These results are achieved by using the federal funds rate from 1980:10 to 2007:7.

JEL Classification: E58, G01

Keywords: Monetary policy rules, financial markets, stock market uncertainty, EGARCH

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1 Introduction

Various episodes of financial turbulences were accompanied by decreasing short term interest rates. In particular, the US Federal Reserve Bank (Fed) and its former chairman Alan Greenspan received a great deal of praise for restoring confidence in financial markets by cutting central bank rates aggressively. Undoubtedly, the Fed achieved this goal several times and thereby moderated an economic downswing and encouraged a fast recovery of the US economy in times of extraordinary uncertainty.

However, prominent economists (e.g. Taylor (2007)) argue that asset price bubbles are likely to occur, when central banks provided too much liquidity. Accordingly, the relative long period of very low central bank rates, succeeding the burst of the dotcom bubble in 2001, has at least favored the recent housing price bubble. In the future, this sequence of events might repeat, because the Fed has cut interest rates dramatically in spite of increasing inflation, when stock market uncertainty has increased due to the latest housing slump and the ongoing financial markets turbulences. Generally, the impression prevails that central banks cut interest rates when financial markets are in turmoil and are more likely to raise interest rates, otherwise.

In this paper we examine, if the Fed systematically compensates enhanced stock market uncertainty by cutting the federal funds rate. Following Clarida et al. (1998, 2000) forward-looking Taylor rules are estimated to test this hypothesis. The standard specification is expanded by a measure for stock market uncertainty. The latter one is estimated by an exponential GARCH-model (Nelson (1991)). Our results show that it is useful to include financial uncertainty as an explanatory variable. Given a certain level of inflation and output, US central bank rates are significantly lower when stock market uncertainty is high and vice versa. Our results complement available evidence on stock market uncertainty, asset prices and monetary policy. E. g. D'Agostino et al. (2005) examine the reaction of the Fed to changes in asset price returns and vice versa. They show that the Fed reaction to asset price returns is statistically different from zero only in a high volatility regime whereas an unanticipated policy tightening causes a significant decline in the Standard & Poor's 500 stock market index (S&P 500) in normal times only.

There are possible reasons why central banks should include stock market uncertainty in their strategy. One reason is, that large and market-wide changes in asset prices can lead to liquidity- and solvency problems in the economy. If many or some system-relevant actors on financial markets are negatively affected by large and surprising movements in the market, functions of the financial system, e.g. the allocation of savings or capital, might be disordered. Another reason might be that excess volatility on financial markets makes economic agents uncertain about future income and can thereby aggravate a given economic downswing or even trigger an economic downswing by itself. Since investments and purchases of durable consumer goods can be seen as being largely irreversible, firms and households may then find it advantageous to postpone purchases until the future seems to be more certain (Hu (1995); Choudhry (2003)). Thus, excess stock market uncertainty can spill over into broader macroeconomic uncertainty in terms of output and inflation fluctuations. Central banks might try to compensate this by lowering the costs for credits.

The remainder of the paper is organized as follows. In the next section we discuss how to measure financial uncertainty for the US. Subsequently, we review the theoretical and empirical foundations of an augmented monetary reaction function. Section 4 describes the results. Finally we conclude.

2 A measure of stock market uncertainty

The main idea of this paper is the empirical validation of the assumption that the Fed responds to uncertainty in the US financial market by means of interest rate adjustments. Therefore, it is necessary to find a representative definition of the US financial market and an appropriate measure of the stock market uncertainty, which is unobservable. For the former objective the S&P 500 seems to be an adequate candidate. It contains the stocks of 500 large market capitalization corporations from the United States. We use the S&P 500 index instead of the Dow Jones index, because it is plausible to assume that its broader definition leads to a more accurate picture of the US financial market. Following the definition of uncertainty as a state of having limited knowledge where it is impossible to exactly describe the existing state or future outcome, we view the return $\Delta \log sp_t$ of the S&P 500 value sp_t at time $t \in T$ with $T = \mathbb{N}$ as a random variable X_t. We define stock market uncertainty as the standard deviation $\tilde{s}_t$ of the random variable X_t. According to Chebyshev's inequality the upper bound of the probability $P(|X_t - \mu_t| \geq c) \leq \tilde{s}_t^2/c^2$ rises in t with $\tilde{s}_t^2$ for any $c > 0$ and existing $E(X_t) = \mu_t$ and $V(X_t) = \tilde{s}_t^2$. Hence, the higher the uncertainty $\tilde{s}_t$, the higher the probability of deviating from an expected level μ_t.

A rise in stock market uncertainty represents stress in the financial sector. Financial stress is defined as a situation when many or some system-relevant actors on financial markets are negatively affected by large and surprising movements in the market and, therefore, functions of the financial system might be disordered. It is well known that the volatility in asset prices tends to insist at a higher level after a significant increase and sometimes even continues to rise afterwards. A possible explanation for the formation of clusters is a high frequency of news. In this case, stock market uncertainty would be the result of fundamentally justified fluctuations in asset prices. An alternative and a more feasible explanation is a changing degree of tension on the market, i.e the same news lead to different asset price changes, depending on the nervousness, i.e. the stock market uncertainty. This formation of volatility clusters can be interpreted as a sign for inefficiency on the financial market.

The fact that $\tilde{s}_t^2$ varies over t and shows volatility clusters must be considered in the estimation strategy. Engle (1982) introduced autoregressive conditional heteroskedasticity (ARCH) models, which are specifically designed to model and forecast conditional variances. These models were generalized as GARCH (generalized ARCH) by Bollerslev (1986). A further extension known as exponential GARCH (EGARCH) was proposed by Nelson (1991). We apply this framework in our analysis, because it allows for modeling leverage effects in financial markets. In our context this univariate time series model contains a mean and a variance equation as follows:

$$\Delta \log sp_t \quad = \quad \alpha_0 + \alpha_1 \Delta \log sp_{t-1} + e_t, \tag{1}$$

and

$$\log \tilde{s}_t^2 \quad = \quad \beta_0 + \beta_1 \log \tilde{s}_{t-1}^2 + \beta_2 \left| \frac{e_{t-1}}{\tilde{s}_{t-1}} \right| + \beta_3 \frac{e_{t-1}}{\tilde{s}_{t-1}}. \tag{2}$$

e_t is an error term, which follows by assumption a generalized error distribution (GED). The left-hand side of equation (2) is the log of the variance conditional on past variances $\tilde{s}_{t-1}^2$ and past errors e_{t-1}. This implies that the leverage effect is exponential, rather than quadratic, and that forecasts of the conditional variance are guaranteed to be nonnegative. The presence of asymmetric leverage effects can be tested by the hypothesis that $\beta_3 \neq 0$.

Founded by a regime shift in monetary policy in the US (see section 3) we use daily S&P 500 data of the database FERI from 1979:8 to 2007:7 at a first step. This sample which includes 7305 observations will be reduced to 7067 observations if one abandons trading free days. On the basis of this sample we generate monthly averages for the S&P 500 and estimate the EGARCH in a monthly frequency. Due to the model specification the adjusted regression sample for the monetary policy reaction function lasts from 1979:10 to 2007:7 and contains 334 observations.

The estimation results in Table 1 are achieved via maximum likelihood upon the assumption that e_t follows a generalized error distribution. The

Table 1: Estimation results of the stock market volatility model (EGARCH)

α_0	α_1	β_0	β_1	β_2	β_3	ϑ
0.0073**	0.1866**	−0.8266*	0.2052**	−0.1164*	0.9042**	1.4728**
(0.0017)	(0.0580)	(0.4025)	(0.0776)	(0.0593)	(0.0568)	(0.1529)

Standard errors in parenthesis. ** and * indicate the rejection of the hypothesis of zero coefficients on a 99% and 95% level.

significantly estimated GED parameter $\hat{\vartheta} = 1.473$ indicates a fat-tailed distribution of the error, which is typical for financial time series. If the tail parameter $\vartheta = 2$ holds, the GED follows a normal distribution and in case of $\vartheta = 1$ a Laplace distribution. For $\vartheta < 2$ a fat-tailed distribution follows. The Ljung-Box statistic of the standardized residuals is not significant at any lag and leads to the conclusion of a correctly specified mean equation due to the absence of serial correlation. The same is true for the squared residuals and the p-values of the ARCH LM test. Hence, the variance equation appears to be correctly specified.

Based on the estimation results we calculate $\widehat{\tilde{s}}_t$ as a substitute for stock market uncertainty $\tilde{s}_t$. In order to calculate a target inflation rate π^* of the Fed, it is necessary to use a demeaned variable s_t for $\tilde{s}_t$ and $\widehat{s}_t$ for $\widehat{\tilde{s}}_t$.

On October 19, 1987 stock markets around the world crashed, shedding a huge value in a very short period. This event is also known as the Black Monday. A degree of mystery is associated with the 1987 crash; one explanation for the 1987 crash was selling by program traders. Another explanation was the fear of recession. Additionally, the Congress passed a law, that made it more difficult to take over companies via leveraged buy-out. In the following months estimated stock market uncertainty reaches an extraordinary peak (Figure 1). Due to the second Gulf War, stock market uncertainty shows a second peak in 1991, even though, the increase was moderate compared to 1987. In the following years, a relatively long period of below-average uncertainty can be observed. Even the Asian crisis did not initiate a remarkable increase of stock market volatility - it grew only marginally above the total sample average. This period of extraordinary low stock market volatility was potentially the outcome of exaggerated optimism concerning the future during this time. In 2001 when the New Economy Bubble busted, asset prices decreased sharply. Additionally, terrorists attacked the World Trade Center in New York on September 11th, arousing a high intensity of fear and uncertainty in financial markets. It is worth noticing, that estimated

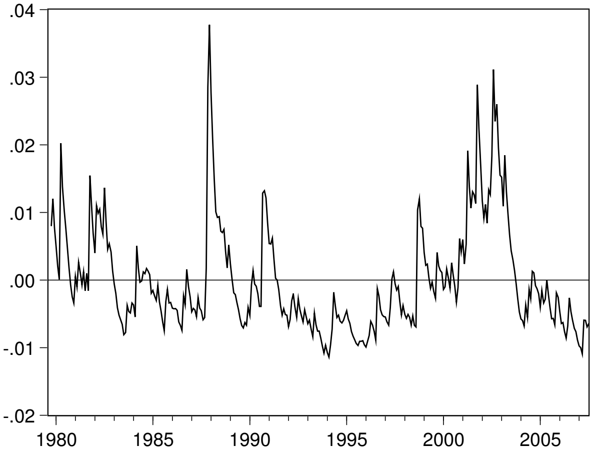

Figure 1: Estimated stock market uncertainty, demeaned

uncertainty seems to increase when asset prices drop. However, the increase in uncertainty occurs with a time lag of about 3 months.

3 An augmented monetary policy reaction function

As mentioned in most of the monetary policy literature, a Taylor rule seems to be the best approximation of a monetary policy reaction function. Our specification and estimation of an augmented Taylor rule follows Clarida et al. (1998, 2000). If a central bank intends to influence the economic situation, it uses the short term interest rate as a tool. To be able to influence real terms, there must be some kind of nominal wage and price rigidity so we assume that nominal wage and price rigidity exists. We further suppose that the central bank has a target for the nominal short term interest rate, r_t^*, that relies on the economic situation. In the Taylor rule we model the nominal target rate regarding the long run nominal interest rate, the inflation gap, the output gap and a measure of stock market uncertainty in each period. We include expected inflation because we agree with Clarida et al. (1998, 2000), that this reflects the actual way of monetary policy making. Additionally, incorporating expected inflation makes it easier to disentangle the link between the estimated coefficients and the central bank objectives.

Augmenting the Taylor rule by a measure of financial uncertainty yields

$$r_t^* = \overline{r} + \beta(E[\pi_{12,t}|\Omega_t] - \pi^*) + \gamma(E[y_t|\Omega_t] - y_t^*) + \xi E[s_t|\Omega_t]. \qquad (3)$$

$\overline{r}$ is the long run equilibrium rate, $\pi_{12,t}$ represents average inflation between t and $t+12$.[1] y_t is real output and y_t^* denotes potential output, calculated with perfectly flexible wages and prices. s_t represents stock market uncertainty and π^* stands for the tolerated inflation rate. Ω_t is the information set that is available to the central bank at time t. The central bank uses this set to form rational expectations, which is shown by the capital letter E. It is worth emphasizing that current variables are not supposed to be part of the information set in t.

The target for the ex-ante real interest rate is defined by $rr_t^* := r_t^* - E[\pi_{12,t}|\Omega_t]$. Therefore, equation (3) can be rewritten as

$$rr_t^* = \overline{rr} + (\beta - 1)(E[\pi_{12,t}|\Omega_t] - \pi^*) + \gamma(E[y_t|\Omega_t] - y_t^*) + \xi E[s_t|\Omega_t]. \qquad (4)$$

$\overline{rr} = \overline{r} - \pi^*$ represents the long run equilibrium real rate of interest, which is only determined by real variables. A variation of the target real interest rate is the result of a difference between expected inflation and tolerated inflation, expected output and potential output and expected stock market uncertainty.[2] Misalignments force a change in the target real interest rate. The values of β, γ and ξ are an important sign of the weight the central bank puts on inflation, output or stock market uncertainty.

Another important fact is the interest rate smoothing central banks seem to conduct. In order to reflect the smoothing strategy in the model we assume that the central bank adjusts the actual rate partially to the target.

$$r_t = (1 - \rho)r_t^* + \rho r_{t-1} + v_t \qquad (5)$$

In Equation (5) $\rho \in [0, 1]$ represents the degree of interest smoothing. The higher ρ, the higher the influence of the lagged rate on the actual rate and therefore the smoothing effect. We assume that v_t is an exogenous random shock that is i.i.d.[3]

[1] Assuming rational expectations, we work with observed instead of expected variables. The implied loss of observations is only problematic in case of small samples. For an alternative approach see e.g. Carstensen (2006).

[2] We do not explicitly assess the desired level of stock market uncertainty. By demeaning estimated stock market uncertainty, s_t, we minimize effects of stock market uncertainty on the estimates for the tolerated inflation rate.

[3] This is a reliable assumption, because we do not reject the overidentifying restrictions based on the J-statistics. Therefore, this shock is econometrically not important.

We define $\alpha := \bar{r} - \beta\pi^*$ and $x_t := y_t - y_t^*$. Combining the target model

$$r_t^* = \alpha + \beta E[\pi_{12,t}|\Omega_t] + \gamma E[x_t|\Omega_t] + \xi E[s_t|\Omega_t] \tag{6}$$

and equation (5) we obtain

$$r_t = (1-\rho)\{\alpha + \beta E[\pi_{12,t}|\Omega_t] + \gamma E[x_t|\Omega_t] + \xi E[s_t|\Omega_t]\} + \rho r_{t-1} + v_t. \tag{7}$$

We then eliminate the unobservable forecast variables, to derive the Taylor rule in terms of realized variables:

$$r_t = (1-\rho)[\alpha + \beta\pi_{12,t} + \gamma x_t + \xi s_t] + \rho r_{t-1} + u_t. \tag{8}$$

The error term in equation (8), $u_t := -(1-\rho)\{\beta(\pi_{12,t} - E[\pi_{t+12}|\Omega_t]) + \gamma(x_t - E[x_t|\Omega_t]) + \xi(s_t - E[s_t|\Omega_t])\} + v_t$, is a linear combination of the forecast errors of inflation, output, stock market uncertainty and the exogenous disturbance v_t. Central banks use the information in Ω_t, to decide how to set r_t in order to influence the right-hand side variables such as, for example, average one-year-ahead inflation $\pi_{12,t}$. Consequently, an endogeneity problem arises. To overcome this problem we use the generalized method of moments (GMM), which seems to be more efficient than other instrumental variable estimators in the presence of heteroskedasticity (Baum, Schaffer, and Stillman (2003)).[4] According to Hansen and Hodrick (1980) the composite disturbance term u_t has a MA$(n-1)$ representation on account of the rational expectation hypothesis. As the Taylor rule above uses $\pi_{12,t}$, $n = 12$ holds. In this case the GMM estimator of the parameter vector is a two-step nonlinear estimation procedure when the model is overidentified (Hansen (1982)). The final estimation uses more than 300 observations. Consequently, the difference between alternative GMM estimators vanishes, and the interpretation of the standard errors obtained from this regression seems to be unproblematic. The estimated standard errors are based on an asymptotic theory that apparently hold well in intermediate samples (Florens et al. (2001)).

Let z_t denote a vector of instruments known when r_t is set (i.e., $z_t \in \Omega_t$) and orthogonal to the exogenous monetary shock v_t (i.e., $E[v_t z_t] = 0$). Replace $\widehat{x}_t$ and $\widehat{s}_t$ for the unobservable output gap, x_t, and stock market uncertainty, s_t, respectively. Equation (8), in combination with the assumption that z_t entails valid instruments, implies the following set of orthogonality

[4]The time series used in this model specification seem to be $I(0)$ due to the highest p-Value of the augmented Dickey-Fuller test of 0.029. For the test procedures we take the sample from 1979:10 to 2007:7. Hence, the minimal number of included observations of the test procedures is 317 and the test is more than sufficiently selective.

conditions, which provides the basis for the estimation of the parameter vector $(\alpha, \beta, \gamma, \xi, \rho)$.

$$E\{[r_t - (1-\rho)(\alpha + \beta\pi_{12,t} + \gamma\widehat{x}_t + \xi\widehat{s}_t) - \rho r_{t-1}]z_t\} = 0 \tag{9}$$

The instruments, z_t, include lagged values of inflation, $\pi_{1,t}$, lagged values of the output gap, $\widehat{x}_t$, lagged interest rates, r_t, lagged stock market uncertainty, $\widehat{s}_t$, and lagged log differences of commodity prices o_t, which help to forecast inflation, the output gap and stock market uncertainty. Two assumptions make the instrumental variables orthogonal to the error term, u_t. First, the central bank does not make systematic forecast errors, i.e. we deal with rational expectations. Therefore, a linear combination of the forecast errors is orthogonal to any variable included in the information set of the central bank, Ω_t. It is reasonable to assume that the central bank has the opportunity to utilize lagged values for forecasts. Second, the central bank's interest rate decision is not influenced by lagged values of right hand side variables, except for the case that changes in lagged values alter forecasts of future inflation, output and stock market uncertainty. It other words, it is assumed that the central bank does not care about the past unless it is assumed to influence the future.

Finally we estimate the central bank's target inflation rate π^*. Given $\alpha := \overline{r} - \beta\pi^*$ and $\overline{r} = \overline{rr} + \pi^*$ we receive $\alpha := \overline{rr} + (1-\beta)\pi^*$, which implies

$$\pi^* = \frac{\overline{rr} - \alpha}{\beta - 1}. \tag{10}$$

If the sample is long enough, the sample average real rate is a good approximation of $\overline{rr}$. Knowing $\overline{rr}$, it is possible to calculate π^*.

Following Florens et al. (2001), we create a second category of models. Here we work with lagged values of output and lagged stock market uncertainty as explanatory variables. In this case only expected inflation is endogenous. Furthermore, all of the stock market uncertainty-augmented Taylor rules are compared to standard Taylor rules which abstract from stock market uncertainty. Following Siklos et al. (2004) it is further tested if stock market uncertainty is a valuable instrumental variable for the standard specifications.

In general we use monthly data of the database FERI. The US consumer price index (CPI) is used to measure inflation. Current and lagged inflation rates are calculated as $\pi_{1,t} := 12 \cdot \log(\text{CPI}_t/\text{CPI}_{t-1})$. Average one-year-ahead inflation is defined as $\pi_{12,t} := \log(\text{CPI}_{t+12}/\text{CPI}_t)$. A seasonally adjusted index of industrial production is used to measure output. To obtain a measure for the output gap, $\widehat{x}_t$, industrial production is detrended by a linear and quadratic trend based on an OLS estimation from 1979:10 to 2007:7.[5]

As discussed in Clarida et al. (1998), there was a fundamental shift in the way the Fed conducted monetary policy in 1979. Thus, we start in 1979:8 which is the first full month when chairman Paul Volcker was in charge of US monetary policy. Since one-year-ahead inflation is targeted by the central bank, right hand side variables are only employed up to 2007:7. Accounting for the dynamics of the model, the estimation sample is 1980:10 to 2007:7 and includes 322 observations. The instrumental variables sample is from 1979:10 to 2007:7.

4 Results

Two specifications of Taylor rules are estimated. In our preferred specification the monetary policy reacts to expected inflation, actual output and actual stock market uncertainty. Here, all right hand side variables are endogenous. The second category of monetary policy reaction functions assumes that the central bank reacts to lagged output and stock market uncertainty. Here, only future inflation is endogenous. In both cases, standard Taylor rules are estimated for comparison.

Table 2 summarizes the results of our preferred specification. It is shown that a standard rule, which does not account for stock market uncertainty, yields plausible and significant results for all coefficients. The estimated monetary policy reaction function features a strong degree of interest rate smoothing; the coefficient for expected inflation, β, is significantly above one (not directly shown in Table 2), and the coefficient for the output gap, γ, is 0.316. Also the expected inflation target ($\pi^* = 3.14$) is quite reasonable.

The second estimation is based on the same specification, but lagged stock market uncertainty is included in the instrument vector. Even though this seems to be a moderate change, some coefficients are substantially different from the first estimation: The weight of the output gap is larger and the constant is insignificant. Furthermore, β is not significantly larger than one, so the Taylor principle is not fulfilled. The third estimation includes stock market uncertainty not only as an instrument but also as an explanatory variable for the federal funds rate. All coefficients have plausible values and are statistically significant at the 95% level. The coefficient for stock

[5]The output gap, $\widehat{x}_t = y_t - \widehat{\beta}_0 - \widehat{\beta}_1 t - \widehat{\beta}_2 t^2$, is not calculated from logarithmic production, because we do not want to stabilize the variance of the output gap by a Box-Cox-Transformation. In our approach the Taylor rule should explicitly contain volatility. Therefore, we include stock market uncertainty as well.

Table 2: Fed reaction functions, endogenous output gap and stock market uncertainty

ρ	α	β	γ	ξ	π^*	J	BIC
Standard							
0.961**	-16.545**	7.099**	0.316*	-	3.14	21.69	-1.306
(0.011)	(4.101)	(1.371)	(0.138)	-		{0.83}	
Including stock market uncertainty as instrument							
0.976**	-2.296	2.654**	0.494**	-	2.96	24.90	-1.383
(0.008)	(2.771)	(0.871)	(0.179)	-		{0.94}	
Including stock market uncertainty as instrument and explanatory variable							
0.969**	-14.378**	6.602**	0.564**	-341.065*	3.03	21.99	-1.388
(0.010)	(3.788)	(1.276)	(0.166)	(143.501)		{0.97}	

The Taylor rate is estimated for 1980:10 - 2007:7. - The instruments are x_{t-1},..., x_{t-6}, x_{t-9}, x_{t-12}, $\pi_{1,t-1}$,..., $\pi_{1,t-6}$, $\pi_{1,t-9}$, $\pi_{1,t-12}$, o_{t-1},..., o_{t-6}, o_{t-9}, o_{t-12}, r_{t-1},..., r_{t-6}, r_{t-9}, r_{t-12}, and the same lags of stock market uncertainty in the latter cases. - Estimates are obtained by GMM with correction of MA(12) autocorrelation. - Optimal weighting matrix obtained from first two-stage least squares parameter estimates. - Standard errors in parenthesis. - ** and * indicate the rejection of the hypothesis of zero coefficients on a 99% and 95% level. - p-values in curly brackets. - Estimates of π^* assume that long run equilibrium real interest rate is equal to the sample average of $rr = 2.60$.

market uncertainty is negative, i.e. given certain levels of output and inflation expectations, the federal funds rate is significantly lower when stock market uncertainty is high and vice versa. The estimated level for target inflation has the very reasonable value of approximately 3%. Compared to other estimates, the weight on the output gap is highest ($\gamma = 0.564$). The J-statistic assesses the validity of the instrument vector. The hypothesis that the instruments are orthogonal to the composite error term can not be rejected for all estimations at plausible significance levels.

Table 2 also shows a statistic which can be used to compare the forecast quality of the estimations. Since we estimate a nonlinear GMM model we use the Bayesian Information Criterion ($BIC(k)$) with k parameters in an equation to compare the fitted values across equations, i.e.

$$BIC(k) := \log \widehat{\sigma}_k^2 + \frac{k \cdot \log T}{T} \quad , \quad \widehat{\sigma}_k^2 = \frac{1}{T} \sum_{t=1}^{T} \widehat{u}_t^2. \tag{11}$$

It can be seen that the augmented Taylor rule shows the best fit.

The second category of Taylor rules assumes that the central bank stabilizes future inflation but reacts on lagged output and stock market uncertainty (Table 3). The results are very similar to those in Table 2. All estimated policy rules show a high degree of interest rate smoothing and significant coefficients for output and future inflation. If stock market uncertainty is included only as an instrument, α is not statistically different from zero and β is not statistically above one. Once stock market uncertainty is also considered as explanatory variable both shortcomings disappear; α is statistically different from zero and the Taylor principle is fulfilled. The output gap coefficients, γ, lie in between 0.299 and 0.570. Again, (lagged) stock market uncertainty significantly influences the federal funds rate negatively. All estimated values for target inflation, π^*, are plausible. Comparing the latter category of monetary policy reaction functions, the augmented specification, which includes stock market uncertainty also as an explanatory variable, yields the best results; the $BIC(k)$ is smaller than in all other specifications. Again, the p-values of the J-statistic indicate that the instruments are orthogonal to the composite error term.

Table 3: Fed reaction functions, exogenous output gap and stock market uncertainty

ρ	α	β	γ	ξ	π^*	J	BIC
Standard							
0.961**	-16.557**	7.101**	0.299*	-	3.14	21.64	-1.304
(0.011)	(4.109)	(1.373)	(0.135)	-		{0.83}	
Including stock market uncertainty as instrument							
0.975**	-2.241	2.637**	0.479**	-	2.96	24.78	-1.378
(0.008)	(2.775)	(0.872)	(0.178)	-		{0.94}	
Including stock market uncertainty as instrument and explanatory variable							
0.973**	-15.667**	7.015**	0.570**	-348.409*	3.04	22.53	-1.386
(0.009)	(4.339)	(1.478)	(0.174)	(148.324)		{0.96}	

The Taylor rate is estimated for 1980:10 - 2007:7. - The instruments are $x_{t-1},\ldots, x_{t-6}, x_{t-9}, x_{t-12}, \pi_{1,t-1},\ldots, \pi_{1,t-6}, \pi_{1,t-9}, \pi_{1,t-12}, o_{t-1},\ldots, o_{t-6}, o_{t-9}, o_{t-12}, r_{t-1},\ldots, r_{t-6}, r_{t-9}, r_{t-12}$, and the same lags of stock market uncertainty in the latter cases. - Estimates are obtained by GMM with correction of MA(12) autocorrelation. - Optimal weighting matrix obtained from first two-stage least squares parameter estimates. - Standard errors in parenthesis. - ** and * indicate the rejection of the hypothesis of zero coefficients on a 99% and 95% level. - p-values in curly brackets. - Estimates of π^* assume that long run equilibrium real interest rate is equal to the sample average of $rr = 2.60$.

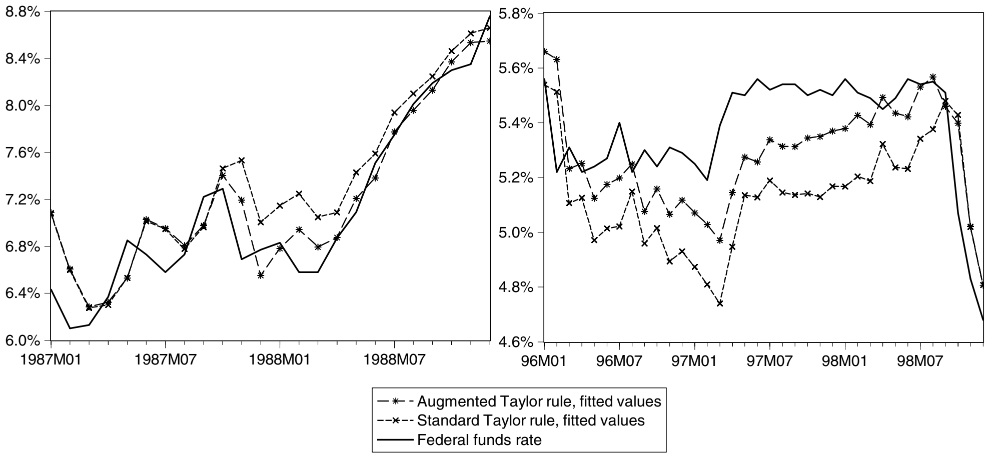

Figure 2: Federal funds rate and fitted values

Figure 2 illustrates that an augmented Taylor rule can explain the federal funds rate better than a standard rule in periods of extraordinary financial certainty or uncertainty. Due to the sharp increase in stock market uncertainty following the Black Monday, the Fed cut interest rates by roughly 80 basis points. Only the stock market uncertainty augmented Taylor rule can explain this monetary reaction. The right hand side graph shows fitted and actual values of the federal funds rate during the period of extraordinary certainty on financial markets. The fitted central bank rate is up to 20 basis point larger when stock market uncertainty is included. Again, this resembles reality much closer.

5 Conclusions

In this paper we examine the link between financial markets and the interest rate policy of the Fed. Because we use stock market uncertainty instead of asset prices or returns on assets, we do not have to judge if a certain level of asset prices deviates from fundamentals or not. To get an estimation of stock market uncertainty, we apply an EGARCH model on the US S&P 500. The estimated volatility is very high in well-known times of extraordinary uncertainty, e.g. after the stock market crash in 1987 or the burst of the dotcom bubble in 2001.

To describe the behavior of the Fed, augmented forward-looking Taylor rules are estimated by GMM. The results show that it is useful to include stock market uncertainty as an explanatory variable. All coefficients are negative and significantly different from zero. Given a certain level of the inflation and output gap, US central bank rates are significantly lower when stock market uncertainty is high and vice versa. These results are achieved by using the federal funds rate from 1980:10 to 2007:7, so we show that pacifying financial markets by interest rate cuts is part of the Fed reaction function since the early eighties.

In our view there are strong arguments for cutting interest rates in times of excess volatility on financial markets and vice versa. However, we can not conclude how sensitive such a reaction should be and leave this question for further research. Apart from that, monetary policy must be successful in terms of price stability in the medium run. All results indicate an inflationary target of approximately 3% over the whole sample. Facing the increasing frequency of asset price bubbles and the recent increase in inflation in the US, it will, however, eventually turn out that the Fed was too expansive at least in recent times.

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