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THE IMPACT OF SURPRISE POLICY ACTIONS ON INTEREST RATES: THE INFLUENCE OF CENTRAL BANK CREDIBILITY

Author: M.A.F. Dieters
Student number: 308620
Thesis supervisor: Dr. D.J.C. Smant
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PREFACE AND ACKNOWLEDGEMENTS

This thesis is written for everyone with an economical background who wishes to increase their knowledge on the implications of Central Bank credibility on the impact of (surprise) target rate changes on the term structure of interest rates. I have had the pleasure of doing research on this topic which significantly improved my knowledge on Central Bank behaviour, the creation of expectations of financial markets and how these are linked in the term structure of interest rates. I am certain that this contribution in my knowledge will be very much beneficial for my post- academic life.

I would like to thank my thesis supervisor Dave Smant for his contributions in theory and though. Research has been extensive and long, and I would to take the opportunity to thank him for his support during this time.

I also would like to thank family and friends whose contribution was not that of one within the academic field, but that of moral support, especially in times of crisis. In particular, I would like to thank my parents for their continuous support during my academic life.

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ABSTRACT

This paper argues that the impact of policy surprises on interest rates is to be held conditional to CB credibility. Following Barro and Gordon (1978) and Cukiermann (1992), among others, we hypothesise that uncredible CBs are accompanied by higher mean and volatility in interest rates, which might result in higher shocks to interest rates due to (surprise) policy actions. We therefore divide the environment in which financial markets response to policy actions in environments were the policymakers is assumed to be perceived as credible vis-à-vis an environment where he is perceived as being uncredible. CB credibility is measured by (1) *a policy rule*, (2) *the deviation of inflation from its target*, and (3) *inflation persistency*. In addition, this paper differentiates CB policy events in (1) events where a change in the target rate was made, and (2) FOMC meeting events without the occurrence of a target rate change (also see Zebedee *et al.* (2008)). Secondary, this paper investigates whether the state dependence of the business cycle, being economic expansions and recessions, changes the impact of anticipated and unanticipated target rate changes.

Analysing the entire Greenspan era, the results argue very much in favour of the literature. First, uncredible CBs are accompanied by higher mean interest rates. Second, the impact of anticipated target rate changes is zero for the credible CB environment, but negative for medium and long term maturities for uncredible CBs, as expected. Third, the impact of surprise target rate changes is uniformly higher for the uncredible CB vis-à-vis the credible CB. Third, if we allow for some flexibility on the part of the policymaker where she is allowed for some discretion about her policy the result are quite similar for both environments. Considering the state dependence of the business cycle, this paper finds that recessions are accompanied by lower mean interest rates than economic expansion, but that the impact of anticipated and unanticipated target rate changes is in general the same.

The results imply that a policymaker that wishes to increase interest rate and inflation stability, with lower mean interest and inflation rates should be open about her contingency plan and should sufficiently be able to anchor economic agents' expectations and should also perform according to this contingency plan. Second, the results for the influence of the business cycle might suggest that economic agents incorporate additional risk-premia in anticipated target rate changes for in both economic expansions and recessions for medium and long term rates. In addition, the impact of the disclosure of biases in expectations of future inflation rates (corresponding with surprise target rate changes) does not change conditional to the business cycle.

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CHAPTER 1 Introduction

Earlier studies like Cook and Hahn (1989), Roley and Sellon (1995), Pool and Rasche (2000), Kuttner (2001) and Pool et al. (2002), among others, have shown that Federal Reserve (henceforward Fed) target rate changes have a significant impact on short term interest rates, while lacking a significant impact on medium and long term interest rates. Pool and Rasche (2000) and Kuttner (2001) furthermore show that a decomposition into anticipated and unanticipated target rate changes results in the fact that unanticipated target rate changes cause significantly higher shocks in Treasury-bill rates throughout the yield curve, while leaving the impact of anticipated changes of no significance. Under the hypothesis that markets expect a CB to be credible towards realizing its long run policy goals – hence that policy surprises would not interfere with expectations of the intended policy in the long run – this impact on interest rates should not exist. One might therefore presume that the occurrence of shocks to medium and long term interest rates in response to policy surprises is the result of the lack of a CB's credibility of *perceived* commitment to his policy goals.

Barro and Gordon (1978) and Cukiermann (1992), among others, have shown that discretionary time inconsistent policies lead to higher mean and volatility of inflation and interest rates. They therefore suggest CBs to increase transparency to economic agents about the contingency plan and to make a CB accountable for their 'incentive-based' behaviour, through easily monitored and measurable "rule". This results in higher CB credibility and would minimize any forecast biases created due to the policy regime. Empirically this is supported by Pool *et al.* (2002) who find that surprise target rate changes have a significant impact on t-bill rates throughout the yield curve for the pre-1994 period, but for the short term maturities for the post-1994 period. The authors therefore suggest that post-1994 improvements on CB transparency – announcing policy actions immediately upon making them – have reduced the impact of uncertainty about future monetary policy on interest rates. This paper will take this one step further by arguing that a policymaker's actions towards a credible policy – proxied by a performance measure for commitment to the policy goals - would improve the monetary environment in which financial markets create expectations, resulting in smaller shocks to interest rates due to policy surprises.

To verify this finding, this paper analyzes whether an economic environment which is characterized by one where the Fed is assumed to be *perceived* as credible (uncredible) generates smaller (bigger) shocks to interest rates in the case of surprise policy events. In light of the "*Rules vs. Discretion*" literature and that related, we will try to create a state dependence for CB credibility that captures whether the policymaker might be perceived as being credible to the public by his performance to negate (or minimize) biases between expectations of economic agents and actual policy.[1] We will measure CB credibility by the policymaker's performance according to (1) a policy rule, (2) the deviation of inflation from its target, and (3) inflation persistency. In addition, this paper differentiates CB policy events in (1) events where a change in the target rate was made, and (2) FOMC meeting events without the occurrence of a target rate change. The rationale is that even though an actual target rate change had not occurred financial markets might have anticipated on one, creating a policy surprise event (also see Zebedee *et al.* (2008)).

[1] This literature will be discussed in section two.

This paper will first address recent literature on this subject and provide the theoretical foundation of our CB credibility measures in chapter two. This is followed by the research methodology concerning measuring the anticipation of CB target rate changes and the modeling and measurement of CB credibility in chapter three. Chapter four focuses on the data and data handling and chapter five will provide the results. In chapter six we will comment on the results and finally conclude.

CHAPTER 2 Literature Review

This section will describe the relation between rational expectations, CB credibility and the term structure of interest rates. The objective of this section is to provide theoretical insight on how the principal-agent problem between CB's and economic agents can result in credibility issues for a CB, which results in higher mean and volatility of inflation and interest rates. Ultimately, this paper will show that this results in bigger shocks to the yield curve due to surprise monetary policy actions, but that a policymaker's anchored commitment to his policy goals potentially reduces the impact.

This paper will first provide information on how the conduct of monetary policy affects expectations created by economic agents and how expectations are reflected in the yield curve. Section two than details the origin of CB credibility and its implications for expectations on future monetary policy and how this might influence the response to monetary policy actions as a result.

2.1 The term structure of interest rates

This paper will first address how the term structure of interest rates is created and how expectations on the development of important economic aggregates change the development of the future short term interest rate. The basis for the development of the term structure of interest rates will be the (rational) Expectations Hypothesis (EH) theory. This section will show that the conduct of monetary policy will have an important impact on the degree in which these assumptions can indeed be met. As such this section provides the introduction to the influence of the monetary policy environment to the (expected) development of the short term interest rate and, as a result, to the response in interest rates due to surprise policy events.

2.1.1 The Expectations Hypothesis theory (EHT)

Under the EHT the yield curve captures the short term interest rate and the expected development of future short term interest rates – being medium to long term interest rates. To an investor it should not matter whether to invest in a long term bond or a roll-over strategy investing in short term bonds for the long run. The long term interest rate should reflect the expected average of short term interest rates over the life of the long term bond. In this sense, the spread of (nominal) interest rates and (including) additional liquidity and/ or risk premia – primarily reflects expectations of the future development of the short term interest rate. As this is maturity dependant, the yield curve reflects whether markets expect the short term rate to increase (e.g. a steeper yield curve) or if it is expected to decline (e.g. an inverted yield curve). For example, under the assumption that U.S. Treasury bonds have no default rate while being highly liquid - hence does not incorporate a liquidity or risk premium - the resulting yield curve is a pure capture of expectations of the development of the (nominal) short term interest rate. In real terms, the market will correct for expectations of the future development in the inflation rate accordingly. A typical formulation of the EHT is the following

$$R_t^n = (1/k)\sum_{i=0}^{k-1} E_t i_{t+mi}^m + \theta_t \tag{2.1}$$

where

$$E_t i_{t+mi}^m \equiv E_t r_{t+mi}^m + E_t \pi_{t+mi}^m \tag{2.2}$$

In equations (2.1) and (2.2) R_t^n represents the long term *n*-period interest rate, i_{t+mi}^m represents the short term interest rate, r_{t+mi}^m represents the real interest rate, π_{t+mi}^m represents the inflation rate, E_t is the expectations operator and θ represents the term premium. As stated the term premium is assumed to be fixed, time-invariant but maturity dependant, e.g. $\theta_t^n = \theta_{t-1}^n$ but $\theta_t^n > \theta_t^{n-1} > 0$. Equation (2.2) adds the fact that expectations of the short term interest rate are formed by means of anticipating the future development of inflation and the future short term real interest rate. This formulation allows for the fact that when expectations of inflation ($E_t \pi_{t+n}$) increases economic agents will adjust nominal interest accordingly as to offset the negative (real) income effect of increasing inflation, thus keeping the real interest rate constant. Equation (2.2) therefore shows the importance of creating correct expectations of the future development of inflation and the (real) short term interest rates to make unbiased forecasts that alter the current short, medium and long term interest rate, hence change the term structure of interest rates.

To understand the effect of biased expectations on the possible rejection of the EHT, consider that the EHT is tested by estimating the model

$$E_t i_{t+n-m}^{(m)} - i_t^{(m)} = \alpha_1 + \beta_1 (f_t^{(m,n)} - i_t^{(m)}) + \varepsilon_t^{m,n} \tag{2.3}$$

where under the EHT the forward rate ($f_t^{(m,n)}$) calculated from the difference between a long term *n*-period interest rate and a short term *m*-period interest rate, should be equal to the expected (*n-m*)-period-ahead interest rate, when ε_t is N(o,σ^2). α_1 represents a constant time-invariant term-premium. The test for the presence of the EHT therefore is the *null*- hypothesis that β_1 is statistically not different from one. If $\beta_1 \neq 1$ this would imply the rejection of the EHT and/ or the contradiction of constant time-invariant risk premia.

Rejection of the EHT suggests that expectations are bound to incorporate a bias and/ or suggest that interest rate contains a time-varying risk premium. In general empirical results are supportive to the EHT for European countries, but however contradict this for the U.S..[2] The rejection of the EHT is

[2] Cook and Hahn (1990) and Cambell and Shiller (1991) provide most of the empirical results. Empirical studies that find evidence for European countries are Gerlach and Smets (1997), Hejazi et al. (2000), Ghazali and Low (2002), Boero and Torricelli (2002) and Musti (2006). Empirical studies that find evidence for rejection of the EHT for the U.S. are Mankiw *et al* (1986), Fama and Bliss (1987), Campbell and Shiller (1991), Lange *et al.* (2003), Cochrane and Piazzesi (2005), Downing and Oliner (2007), Brown et al. (2007), Sarno et al. (2007) and Beechey, *et al.* (2008). Empirical results depend on the methodology of choice, the specific country, the period of study and the instrument of choice. For example, evidence for the U.S. is found by Longstaff (2000) who uses overnight rates, and by Corte (2007) who uses repo rates. This acknowledges the general tendency of acceptation of the EHT at the very short end of the yield curve, but to contradict this for the medium and long end of the yield curve for the U.S.

argued to be largely influenced by uncertainty aspects in relation to unobserved monetary policy regime shifts and structural breaks in the economy. Under the EHT it is assumed that the real economy is stochastically stationary and can be represented by models that are known to all economic agents and that everyone behaves accordingly, while having complete information and perfects foresight. As it is likely that the real economy is however subject to structural changes in a dynamic and uncertain environment, it is therefore a flawed assumption which finds its origin mostly in simplicity arguments. The rejection of the EHT would therefore only imply the need for more sophisticated models. It is argued therefore that economic agents are rather expected to learn the different dynamic models that structure their economic environment (see for example Andolfatto *et al.* (2006)).[3]

Important to this paper is the occurrence of biases in expectations (or alternatively the presence of non-constant term premia) in relation - or rather conditional to - monetary policy. As Equation (2.1) and (2.2) showed expectations of inflation and short term interest rates are reflected into the term structure of interest rates. Through the transmission process the policymaker's (anticipated) change in the level of the policy instrument i_t will result in changes in intermediate targets, i.e. inflation and domestic production. It is therefore easily shown that expectations on the future behaviour of the policymaker in choosing his policy regime will influence economic agents' expectations today. As expectations of future monetary policy change so will expectations on the development of the future interest rate. It is therefore suggested that the creation of "unbiased" expectations, or the statement that term premia are fixed, is to be held conditional to a "state of the world", e.g. here the policy regime. Mankiw and Miron (1986) find evidence for the U.S. that the introduction of the Federal Reserve System has changed the degree in which economic agents make unbiased expectations, as the EHT is accepted for the period before the introduction of the Fed, but rejected for the period after. Kool and Thornton (2005), however, find that the EHT for the period after the introduction of the Fed is rejected for environments of extreme volatility in short term interest rates. In addition, Shiller *et al.* (1983) and Mankiw *et al.* (1989) argue that biased expectations are the result of interest rate smoothing by the Fed, e.g. the fact a policymaker's reaction to shocks of inflation and output is less than one-for-one, as the policymaker tries to slowly adjust interest rates to their desired levels. They argue that since the short term interest rate has not *moved in a predictable fashion* it suggests that in their attempt to increase interest rate stability this has *decreased the degree of "perfect-foresight-with-error" on the future behaviour of short term interest rates.* As the policymaker's contingency plan is unobserved, or non-transparent, a CB should improve the "foresight" of its policy to enhance the predictability of the future development of the short term interest rate. Conditional on the perceived future policy uncertainty, economic agents alter their 'allowance for risk' suggesting the possibility of time-variant or, potentially, "policy-variant"' term premia. The conditioning of the creation of expectations and expectations-models through increased policy transparency will lead to better expectations and expectations models, hence better foresight, which additionally reduces the risk and uncertainty premia absorption into the term structure of interest rates.

In relation to the latter, recent improvements in the transparency of monetary policy contingency plans, signalling and enhanced CB credibility has decreased uncertainty, reduced the mean and

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[3] This is also different from arguments for the liquidity preference or the preferred habitat theory, which implications are outside the boundaries of this paper.

volatility of inflation and interest rates, thereby improving financial stability (Cukiermann (1992)). It therefore remains crucial for a CB to engage in such transparent policies that the existence of any forecast biases are minimalized contributing to smaller shocks to the money market yield curve in response to (surprise) monetary policy actions (Barro and Gordon (1983)).

The question therefore becomes how financial markets create rational expectations and can make unbiased forecasts, and to what extent CB policy expectations contribute to that. The next section will try to answer this question.

2.1.2 Information, rational expectations and forecasts

Under the theory of rational expectations financial markets will behave according to the optimal forecast on the future development of the interest rate. As already suggested however, the question whether or not economic agents can make unbiased expectations is very much dependant on the difficulties they experience in correctly anticipating the behaviour of the monetary policymaker. For example, if economic agents are confronted with a non-transparent and ambiguous policymaker forecasting the correct development of (future values of) economic aggregates will be more difficult as the (expected) behaviour of the policymaker becomes more uncertain. If economic agents' lack the ability to correctly anticipate such a policymaker's behaviour it would be false to state that economic agents are bad or irrational forecasters. The alternative statement would be that economic agents are indeed rational forecasters, but that this is conditional to some "state of the monetary policy". This paper will elaborate on this statement later on. An important question therefore becomes how economic agents gather their information and how this information might contain biased data conditional to the policymaker's expected behaviour, e.g. the situation when this leads to incomplete information under non-perfect foresight.

A first problem in gathering unbiased information is that it can be costly, which - in a cost to benefit approach - might lead to lower incentives to search for complete information, hence leading to biased forecasts. The assumption therefore that economic agents have complete information is arbitrarily at the minimum and probably false. A second assumption is that expectations are created homogeneously across markets and that everyone behaves according to the same theory and models, which is a false assumption. Third, and perhaps most important, it is assumed that the real economy is stochastically stationary and that the "representative models" are indeed truly representative, which is also a false assumption. For example - in light of the policymaker's influence on the real economy - it is assumed that the policymaker has perfect control over the transmission process. It is assumed that the policy instrument (e.g. the federal funds target) is perfectly linked to the operational target (i.e. the short term interest rate) and directly influences the policy intermediate targets (i.e. the money stock), which results in the perfectly reaching the policy final targets (i.e. price stability and (real) output growth) and ultimately the policy goal. The relationship between the operational target and the final target is however rather complex, indirect, and in important aspects not fully understood. Therefore the fundamental assumptions of complete information and perfect foresight are very likely not being met. As a result, economic agents primarily depend on (simple) models that describe the (expected) behaviour of economic aggregates and the (expected) policymaker's actions that alter current and future (forecasted) values of these aggregates. As shown by Cukiermann (2001) and Andolfatto (2006) the degree in which this process is successful and generates the least biases is sometimes referred to as being dependant on the economic agent's *learning abilities*.

To this paper primarily important is the influence that monetary policy has for the rational EHT and how this might change economic agent's learning abilities. Consider the following example. If economic agents expect a policymaker to pursue an anti-inflationary policy in reaction to an exogenous inflation shock, they will anticipate a higher future interest rate that decreases current and future prices through the tightening of aggregate demand. If however the policymaker is not committed to this anti-inflationary policy, the result will be a biased expectation of the (future) rate of inflation and thus anticipate a lower real interest rate. If monetary policy is responsible for creating biased expectations, the alternative statement can be that the rational EHT is still present, but however conditional to the "state of the monetary policy", e.g. the *perceived* monetary credibility. To see how this might work, we take a simple example. According to Andolfatto (2006) the fact that the creation of unbiased inflation expectations is inherent to economic agents' learning experience, the adoption of new information - conditional to monetary policy - can be addressed by the following model:

$$\pi_t = \mu + z_t + e_t \tag{2.4}$$

with

$$z_t = \begin{cases} z_{t-1} & \text{w.p. } \phi \\ s_t & \text{w.p. } 1-\phi \end{cases} \tag{2.5}$$

where e_t is N(o, σ_e^2) and s_t is N(o, σ_s^2). Equation (2.4) assumes that inflation follows a stochastic process that incorporates learning. It is argued that recent monetary policy can be characterized by relatively infrequent display of "regime shifts" subject to relatively extensive "learning".[4] It is then assumed that inflation rates are determined by a long run (unconditional) mean μ and is subject to two types of shocks: a persistent component z (with probability (ϕ) close to unity); and a purely transitory component e_t. Here, z_t represents the current inflation regime. Crucially important to economic agents making unbiased forecasts then becomes the transparency of these "regime shifts" and the degree in which the economic environment provides "complete information". In an environment of "complete information" economic agents can directly observe the regime shock $z_t=\{z_t, z_{t-1},\ldots,z_0\}$. The rational one-period-ahead expected inflation rate forecast than becomes

$$E[\pi_{t+1} | z_t] = \mu + \phi z_t \tag{2.6}$$

Under "incomplete information" economic agents cannot directly observe the "regime shift", but only observe the history of inflation shocks $\pi_t=\{\pi_t, \pi_{t-1},\ldots\pi_0\}$. As a result they observe

[4] These "regime shifts" refer to the preferences of the monetary policy maker to either fight inflation or stimulates domestic growth. Relatively small regime shifts refer to the fact that monetary policy preferences are quite stable over time, e.g. the policymaker's preferences in targeting either variable does not change much or frequently over time. This would improve the "learning capabilities" of economic agents and improve the forecasting abilities, decreasing any forthcoming biases in expectations.

$$b_t \equiv E[z_t | \pi_t] \quad (2.7)$$

and

$$b_{t+1} = (1-\alpha)b_t + \alpha(\pi_t - \mu) \quad (2.8)$$

where b_t is the expected value of the "hidden" state variable z_t and conditional to π_t. Observations for b_{t+1} can be modeled by equation (2.9), where 0 < α < 1. The rational one-period-ahead inflation forecast is than given by

$$E[\pi_{t+1} | b_t] = \mu + \phi b_t \quad (2.9)$$

In comparing equation (2.9) with (2.6) it is easily seen that a lack in perfectly observing the monetary policy contingency plan results in more volatility in the creation of expectations. Under "complete information" the inflation forecast will solely depend on the persistent (observable) parameter z_t. If the chance of a regime shift is very small, e.g. ϕ approaches unity, expectations in such an environment are always stable, shifting occasionally when changes in the regime are observed or communicated by the (transparent) policymaker. The better economic agents can adopt newly acquired information into their expectations models the least volatile are forecasts made from private agents' probability distribution functions. Under "incomplete information", however, economic agents cannot disentangle the reasons for (sudden) exogenous shocks in inflation, but only observe the underlying stochastic process. Contrary to the situation of "complete information" economic agents will now also incorporate the "transitory shocks" into the dynamics of the inflation forecasts. As a result, inflation forecasts are the result of the probabilities assigned to possible sources for these shocks and economic agents will hedge the associated risk of being wrong. Economic agents' private probability distribution functions will be contaminated with (excess) volatility in expectations due to uncertainty, increasing the mean and volatility of (expected) future inflation and interest rates, as seen in equation (2.2). An additional implication is that under "incomplete information" economic agents are very much limited in adapting to new monetary policy regimes, which could very much damage the outcome of the policy transmission process.

Empirical results have shown that *differences in expectations between forecasters are large, predominantly between price setters and economists* (Mankiw et al. (2003)); *financial markets are inadequate in adopting new information for creating inflation expectations* (Ball and Croushore (1995) and Mehra and Mankiw (2003)); *forecasters generally underestimate inflation* (Mehra and Mankiw (2003)); *forecasters seem to make negative inflation forecast errors in relation to short term interest rates - they underestimate future inflation when interest rates are high* (Mankiw et al. (2003)). In other words they anticipate too much inflation pressure in the future when interest rates are relatively high, and vice versa; *expectations of inflation are underestimated in times of rising inflation, but also overestimated in times of falling inflation* (Dotsey and DeVaro (1995) and Delong (1997)). This implies that the money market yield curve is relatively too flat when inflation is increasing, but relatively to steep when inflation is falling; *forecast errors have predictive power and future forecast errors have predictive power for present forecast* errors (Mankiw *et al.* (2003)). This suggests that part of the knowledge that the forecast was wrong is not utilized in the forecast for future inflation expectations. In other words, there does not seem to be a learning experience. It might also imply that markets are incapable of 'learning', as the determinants for creating unbiased expectations are unobservable, for example due to monetary policy (Cukiermann (1992), Croushore (1997), Roberts (1997), Thomas (1999) and Mehra (2002)). This would suggest that financial markets are persistent in making forecast errors and implies the rejection of the rational EHT.

To this paper primarily important is the degree in which expectations on primary economic instruments are conditional to expectations on the future behaviour of the CB. Where this section has shown the general implications of "incomplete information" to expectations of inflation, the next section will show how monetary policy expectations influence the instrument set that alters the term structure of interest rates. The next section will than show how a policymaker's (lack of) commitment to the communicated policy goals alters the term structure of interest rates and will show how a policymaker's credibility potentially results in smaller shocks to the money market yield curve due to surprise policy actions.

2.2 Monetary policy, CB credibility and interest rates

The goal of this section is to provide a link between CB credibility and the expectations that economic agents create. It will be shown that the degree in which economic agents perceive the policymaker to be credible towards its commitment to its policy goals, decreases mean and volatility in inflation and interest rates. The result is that the creation of better expectations in a less uncertain (future) monetary environment will reduce the impact of surprise policy actions to interest rates.

First this section will link economic agents' expectations and their decision making to expectations that they have on the policymaker's actions. Second, we will link this to the policymaker's decision making and his optimization problem for choosing his policy. Third, we will show how a discrepancy in expectations by economic agents and the policymaker will result in increased uncertainty about future monetary policy, with negative outcomes for the anticipation process of policy actions. Fourth we will than show how the policymaker's efforts to commit himself to the policy goals for which it is accountable for will anchor economic agents' expectations, reducing inflation expectations and (additional) risk-premia in interest rates. As a result, the policymaker's commitment to a contingency "rule" will result in a smaller impact of surprise policy actions to interest rates, especially for medium and long term interest rates.

2.2.1 The monetary policy objective

To link economic agents' rational expectations with monetary policy actions, we make use of a simple macro-economic framework that describes the relationship between a policymaker's policy targets $\{ y_t, \pi_t \}$ and a model that describes the policymaker's optimization objective for choosing the level of the operational target i_t. Following Kydland and Prescott (1979), Barro and Gordon (1983) and

Clarida *et al.* (1999) this concept will relate economic agent's actions in a decision rule, their expectations in an expectations function, and the policymaker's behavior in a policy "rule". This section will describe these components of the process respectively.

2.2.1.1 Economic agent's expectation-based decision rules

Consider a simple macro-economic framework which consists of a typical "IS"-curve - relating domestic production to the real-interest rate - and a "Philips"-curve - relating inflation with the unemployment rate

$$y_t = -\varphi[i_t - E_t\pi_{t+1}] + E_t y_{t+1} + g_t \qquad (2.10)$$

$$\pi_t = \lambda y_t + \beta E_t \pi_{t+1} + u_t \qquad (2.11)$$

where g_t and u_t are disturbance terms that obey, respectively

$$g_t = \rho g_{t-1} + \overline{g}_t \qquad (2.12)$$

$$u_t = \rho u_{t-1} + \overline{u}_t \qquad (2.13)$$

with $0 \leq \mu$ and $\rho \leq 1$. Here, y_t represents the output gap, $i_t - E_t\pi_{t+1}$ represents the real interest rate – being the interest rate, i_t, minus expectations of inflation of economic agents, $E_t\pi_t$. φ is a constant, representing the intertemporal elasticity of substitution, e.g. how consumers' relative choices for consumption changes as their relative prices change. Here, λ and β are both constants, representing the resp. the marginal cost that is reflected in inflation due to a rise in output, and the degree in which prise setters set current prices according to expectations on next period cost increases. In addition, $\overline{g}_t$ is N(o, $\sigma^2_{\overline{g}}$) and $\overline{u}_t$ is N(o, $\sigma^2_{\overline{u}}$).

Equation (2.10) shows that the present level of the output gap is inversely related to the real interest rate and positively related to expectations of future levels of the output gap. Equation (2.10) also shows the traditional view that a policymaker faced with higher inflation expectations in the future, e.g. $E_t\pi_{t+n}\uparrow$, should respond with a minimally equal increase in the interest rate, as to offset the rise in actual inflation, hence keeping the real interest rate constant. Equation (2.11) shows that the present level of inflation is positively related to resp. the output gap and expectations of the future level of inflation. This reflects the fact that economic agents' expectations of higher inflation in the future, for example price setters, will have them correct prizes today accordingly. Therefore a policymaker that wishes to decrease or stabilize current inflation rates needs to ensure that economic agents think inflation will not increase or even decrease in the future. In conventional theory the policymaker will therefore communicate that it anticipates an anti-inflationary policy, which would indicate that inflation is indeed under control for the medium to long term. However, the policymaker can easily deceive economic agents this way. Namely, equation (2.12) also shows the traditional trade-off between inflation and unemployment, where the latter is inversely related to the output gap. Note that from the view of the policymaker it is beneficial to make the public believe that it pursues an anti-inflationary policy, lowering $E_t\pi_{t+n}$, which would normally result in lower current inflation and output growth, and higher unemployment levels as a result. However, provided that economic agents have adapted their expectations of inflation to lower levels the policymaker now has the incentive to pursue an expansionary policy - and lower interest rates - to accommodate the otherwise lower level of y_t. Lower (real) interest rates will have an impact of the magnitude φ, which in the new situation would push output growth above its target level, providing an expansionary policy and increasing inflation above its target. The policymaker will now only incur a "cost" to inflation in the amount of λ, the marginal cost of his expansionary policy. In the typical case that $\beta > \varphi$, however, (while λ being relatively low) the benefits of the expansionary policy are greater than the costs. Rational agents will anticipate on this behaviour and will not take the policymaker's next period announcement of lower inflation as being "credible". Attributing the additional risk of the policymaker anticipating such a policy this actually increases future expected inflation rates. Provided that the CB is continuously positioned as "uncredible" the policymaker lacks the ability to anticipate a successful disinflationary policy in the future.

As it is primarily important to see how expectations on the future behaviour of the policymaker affect current aggregate activity we formulate equations (2.10) and (2.11) forward to get

$$y_t = E_t \sum_{i=0}^{\infty} \{-\varphi[i_{t+i} - \pi_{t+1+i}] + g_{t+i}\} \tag{2.14}$$

$$\pi_t = E_t \sum_{i=0}^{\infty} \{\beta^i \lambda y_{t+i} + u_{t+i}\} \tag{2.15}$$

Equations (2.14) and (2.15) now also express the influence of economic agents' expectations of the development of the future short term interest rate, e.g. the assumed operational instrument for CB policy. Thus, the determinants of making unbiased expectations of the future level of the short term interest rate in equation (2.1) incorporates present and future expectations of monetary policy, where, as a result, the CB's commitment to their communicated target values, i.e. the situation where $E\pi_t = \pi_t$, is primarily important. In an (increasingly) uncertain environment, with more volatile private agents' probability distribution functions, biased expectations of i_t and π_t will cause shocks to the money market yield curve - as shown by equation (2.1) - as markets will continuously have to correct their biased expectations. Attributing the risk of "being wrong" by incorporating risk-premia to medium and long term interest rates this increases both the mean and volatility of inflation and interest rates. Therefore, a CB's "credibility" of its commitment to its anti-inflationary policy will be crucial to make unbiased expectations of the development of the term structure of interest rates, reducing the mean and volatility of inflation and interest rates. The question therefore becomes how the policymaker "rationally" makes to best decision for himself, as he maximizes his own utility. As show by equations (2.10) and (2.11) there is a trade-off between increasing output growth and decreasing inflation. The next question therefore becomes how the policymaker will use this concept to change the aggregates from economic agents' decision functions (2.14) and (2.15) which best suits his preferences (e.g. the fact whether or not he finds it optimal to commit himself to the anti-inflationary policy that prevents output growth, or vice versa).

The important question for economic agents is therefore how the policymaker will choose the future level of i_t that will result in the expected changes in the target variable set $\{y_t, \pi_t\}$ in equations (2.14) and (2.15).[5] The next section will contribute to that question.

2.2.1.2 The policymaker's decision rule and optimization

To see how the monetary policy maker optimizes his decision we assume it behaves according to a social welfare function $S(y_t, \pi_t)$. The policy objective can be formulated as follows

$$\max -\frac{1}{2} E_t \left\{ \sum_{i=0}^{\infty} \beta^i \left[\alpha \left(y_{t+i} - k \right)^2 + \left(\pi_{t+i} - \pi^* \right)^2 \right] \right\} \tag{2.16}$$

where α is the relative weight the CB puts on output deviations, while β^i represents the fact that economic agents discount future expectations at a rate i_t. Here, k is a constant representing the target rate for the output gap, which is zero under the assumption that the policymaker is only interested in stabilizing output around its potential level, e.g. does not pursue a (surprise) expansionary policy. In addition it is assumed that the CB has an inflation target (π^*) of zero.

Equation (2.16) shows that the policymaker tries to optimize its policy by choosing the level of the policy instrument i_t, such that its targets for y_t and π_t are achieved through equations (2.10) and (2.11). Equation (2.16) states that the policymaker incurs a cost that increases with its departure of the level of output from its target rate (e.g. which satisfies reaching the equilibrium natural rate of unemployment) and additionally with inflation. In addition, the choice of π_t is designed to minimize the (expected) present value of costs, reflected by β^i, where $\beta^i \equiv \left[\frac{1}{(1+r)^t} \right] \Big\| I_0$. Here, r represents a (constant) real discount rate and I_0 is the initial information set, which is assumed to be available to all economic agents as well as to the policymaker. Each period the CB "chooses" the instrument set $\{y_t, i_t, \pi_t\}$, consisting of the target values for y_t and π_t and the policy instrument (i_t), to maximize the objective function (2.16) subject to equation (2.10) and (2.11). In each period both the policymaker and economic agents enter with the same information set I_0. Economic agents form expectations based on the fact that the policymaker will maximize its policy objective, conditional to the inflation equation (2.11). Secondary, it will choose the level of i_t which than satisfies equation (2.10). Simultaneously, economic agents form expectations on inflation ($E_t\pi_t$) with the same information set I_0. Most important, economic agents expect $E\pi_{t+n} = \pi_{t+n}$ to appear from the policy objective and the policy is therefore assumed to be "time consistent". However, realizing that the policymaker re-optimizes at the beginning of each period rational agents might anticipate the policymaker to renege on his or her announcement

[5] This paper will follow the rational that CBs "choose" the level of the target variable set $\{y_t, \pi_t\}$ and the policy instrument i_t that suits their incentive-based discretionary policy to maximize their objective function. It is therefore suggested that CBs have direct control over i_t, y_t and π_t,. Therefore, we will refer to both the target variable set and the policy instrument together as the 'instrument set'.

for π_{t+n}, given his or her potential incentive to increase output growth in contrast to decreasing inflation. The policymaker than chooses to "deceive" economic agents by not following up on his commitment to an anti-inflationary policy, thus pursuing a surprise inflationary policy. The more uncertain economic agents become of this commitment, the higher will be the volatility of expected future aggregates in equations (2.14) and (2.15) - and therefore risk-premia - and the less able they become in correctly anticipating the policymaker's actions on changing i_t. Decreased predictability of i_t will then result in higher mean and volatility of interest rates in the anticipation of target rate changes. As a result the impact of surprise policy actions will likely increase shocks to yield curve accordingly.

As stated, the degree in which rational agents will alter their expectations of inflation vis-à-vis the actions of the monetary policymaker will depend on her "credibility" to actually do what she communicates to do. As stated by equation (2.9), under discretion and given the level of ambiguity of the policymaker, the policy contingency plan that obeys equation (2.16) is not transparent and therefore the rational agent is lacked with complete information and perfect foresight under equation (2.1), to make unbiased expectations for $\{E_t y_{t+l}, E_t i_{t+i}, E_t \pi_{t+i}\}$ under equations (2.14) and (2.15). As such, the degree in which economic agents can rationally make unbiased expectations is conditional to the transparency and credibility of the communicated policymaker's contingency plan. Under discretion, the CB can therefore not credibly influence expectations of economic agents and, as a result, the CB will take expectations of economic agents as given. In the same way economic agents form expectations on a CB to choose the level of y_t and π_t which satisfies optimization. Clarida *et al.* (1999) show that the outcome of the CB's optimization process leads the policymaker to choose the instrument set $\{y_t, i_t, \pi_t\}$ according to

$$y_t = -\frac{\lambda}{\alpha}\pi_t \tag{2.17}$$

$$\pi_t = \alpha q u_t \tag{2.18}$$

$$i_t = \gamma_\pi E_t \pi_{t+1} + \frac{1}{\varphi} g_t \tag{2.19}$$

where[6]

$$q = \frac{1}{\lambda^2 + \alpha(1-\beta\rho)} \tag{2.20}$$

$$\gamma_\pi = 1 + \frac{(1-p)\lambda}{\rho\varphi\alpha} > 1 \tag{2.21}$$

$$E_t \pi_{t+1} = \rho\pi_t = \rho\alpha q u_t \tag{2.22}$$

Equation (2.10) showed that the CB should increase i_t as to contract demand below its capacity, reducing y_t. Equation (2.17) now shows that the amount in which it should do so is inversely related to the output-for-inflation trade-off (λ) and is positively related to the relative preference towards

[6] See for a detailed specification of the variables Clarida *et al.* (1999).

sustaining output growth (α). By setting $y_t = 0$ (e.g. a zero output gap) the policymaker achieves both its targets for output and inflation. The result from equation (2.17) is that there is a short run trade-off between inflation and output when $u_t > 0$, the situation where there is a so-called "cost push inflation".[7] When cost push inflation is present the policymaker's optimal policy is to incorporate targeting inflation which aims at a gradual convergence of inflation towards its target, hence to smooth inflation and therefore interest rates. Extreme inflation targeting is only optimal when $u_t = 0$ or $\alpha = 0$, which is generally not the case. This therefore acknowledges the fact that the policymakers chooses the level of ambiguity which allows him to choose the level of i_t which aims at interest rate smoothing, adding to financial stability. In addition, equation (2.19) again acknowledges the relation between future inflation expectations and interest rates. Higher inflation expectations will flatten the typical upward sloping yield curve as short term interest rates are expected to increase under the condition that inflation is "under control" for the medium to long run, keeping medium and long term interest rates at their current levels. Equation (2.21) shows that the policymaker should than increase interest rates more than one-for-one to an increase in expected inflation. Whether the policymaker will do so however depends on the policymaker's commitment to its policy goals, e.g. the anti-inflationary policy. The next section will therefore provide insight on how economic agents' expectations of a policymaker's commitment will alter the anticipation of inflation expectations in the term structure of interest rates, changing the way that short term shocks will affect expectations for medium and long term interest rates.

2.2.2 Discretionary time-inconsistent policies and expectations

As stated previously, at the beginning of each period the rational agent is aware of the fact that the policymaker might choose a level of ambiguity which satisfies his need for a surprise inflationary policy to lower unemployment at the cost of higher inflation. The problem at which we than arrive is the situation that $E\pi_{t+1} \neq \pi_{t+1}$, e.g. the situation where the policymaker's choice of π_t is different from the economic agents' forecast, $E\pi_{t+1}$, causing a so-called "inflation bias". The inflation bias therefore arises as a result of a policymaker's desire to push output above its potential level, represented by targeting $k > 0$ for the output gap, as opposed to zero in equation (2.16). Clarida *et al.* (1999) show that this results in the policymaker choosing the instrument set { y_t, i_t , π_t }

$$y_t^k = -\frac{\lambda}{\alpha}\pi_t^k + k \tag{2.23}$$

$$\pi_t^k = \pi_t + \frac{\alpha}{\lambda}k \tag{2.24}$$

where

$$y_t^k = y_t \tag{2.25}$$

[7] Cost push inflation relates to the increase of prices of goods or services or an increase in wages, which result in an increase of the general price level, e.g. inflation. An example is the price for oil, which is characterized by a lack of sufficient alternatives, which is an important factor for the level of real income of the public altogether. The same way, price setters will adjust current prices for (expected) increases in wages. The idea is that this is related to output as growth can lead to more scarcity of raw products or increases in expected prices and hence the demand from wage setter to increase current wages, which likely result in higher prices as price setter will try to accommodate these increases in wages through higher prices for their products.

$$\pi_t^k > \pi_t \tag{2.26}$$

The result of this strategy is therefore that the output gap is exactly the same as in the previous case, but however inflation systematically increases to a new equilibrium with the amount $\frac{\alpha}{\lambda}k$. Rational economic agents recognize the incentives of the policymaker to expand demand and forecast inflation based on equation (2.24), which now represents the "true intentions" of the policymaker, increasing their expectations of inflation with $\frac{\alpha}{\lambda}k$. Hence, they forecast inflation conditional to their expectations of the "true commitment" of the policymaker, implicitly represented by k. Since there is no long run trade-off between inflation and output (e.g. y_t converges to zero in the long run) the policymaker is left with an increased long-run equilibrium of inflation. An as "uncredible" perceived CB regime will therefore result in biased expectations for inflation (e.g. $E_t\pi_t \neq \pi_t$) with a higher mean and volatility, which will ultimately cause biased expectations in the development of the (future) short term interest rate i_t.

Binder (2000) argues that CB credibility is a key element in the link between policy actions and the development of long term interest rates, among other important economic indicators. He defines "CB credibility" as the fact that a CB does what it says it will do. In general, CB credibility is closely linked to a CB's performance to stabilize inflation, or more concrete; *credibility is achieved when a CB pursues a zero inflation target or alternatively its communicated target.*[8] Higher noise in monetary control – inherent to lower credibility – increases the mean and variance of monetary growth, which in turn increases the mean and volatility of (expected) inflation (also see Okun (1971), Logue and Willet (1976), Jaffe and Kleiman (1977), Kydland an Prescott (1979), Barro and Gordon (1983) and Cukiermann and Meltzer (1986)). The impact of mean and volatility of expected inflation ($E_t\pi_t$) for expectations of the future development of the short term interest rate (i_t) can be easily seen in Equation (2.1). Increasing values for $E_t\pi_t$ will correspond to increasing values for the short term interest rate, while increased uncertainty (e.g. higher volatility) will result in more widened probability density functions of the potential future level of the short term interest rate (e.g. medium to long term rates), increasing the attributed risk-premia in the yield curve. This also follows the rationale of Fellner *et al.* (1979) who already provided the link between rational expectations and CB credibility, promoting the "*credibility hypothesis*", which described that expectations are influenced by expectations on the future behaviour of policymakers. He states that: *„Inconsistent policies will lead to diffuse personal probability distributions with risk allowances playing a large role in their decision making, and states of the economy in which firm and credible policies condition the publics expectations lead to much more strongly peaked and widely shared personal probability distributions, concerning future events".* This implies that a 'state of the economy' which is characterized by a credible monetary policy maker will lead to reduced risk and uncertainty, resulting in better (e.g. less biased, with lower mean and variance) expectations, moreover, through the conditioning of heterogeneous expectations among economic agents and (forecasters') expectations models.

[8] For example, the European Central Bank (ECB) has explicitly stated an inflation target of 2%, while the Federal Reserve lacks an explicitly stated inflation target. Therefore, economic agents rely on an implicit inflation target, which may differ among groups of agents and may depend on the model to estimate the (implicit) value of the target.

Indeed, the investment in credibility among CBs worldwide has certainly showed the fruits of lower mean and volatility in inflation and interest rates, adding to financial stability in these countries (also see Bernanke (2006)). It can therefore easily be argued that the conditioning of expectations under a credible monetary policy will lead to a lower impact of (surprise) policy events, as under such a 'state of the world' rational economic agents with better foresight would make less biased forecasts of the future development of i_t, lowering volatility, and in addition do not incorporate relating risk-premia in the term structure of interest rates, lowering mean interest rates, as there is no uncertainty about future monetary policy. As the introduction of additional risk-premia can therefore be suggested to be conditional to the 'state of the world', e.g. here a policymaker's credibility, these conditional risk-premia might not solely contribute to a lower impact of surprise target rate changes on interest rates, but may also influence the acceptance of the rational EHT.

The issues of discretionary time-inconsistent policies have led to a strand of literature providing possible solutions to constrain the incentives of a policymaker. These mostly constitute of *institutional reform* (Persson and Tabellini (1990), Rogoff (1985), Lohmann (1992) and Waller (1992)); *contracts* (Walsh (1995)) and *legislative rules* (Canzoneri (1985) and Garfinkle and Oh (1993)). This paper will continue by addressing two additional widely documented and highly recommended solutions, namely *the adoption of an inflation target* and *the adoption of a policy "rule"*, as a means to attain the necessary transparency and credibility.

2.2.3 The influence of commitment

The previous section has shown how discretionary time-inconsistent policies *increase* the mean and volatility of inflation and interest rates. In contrast, this section will show how the ability to (easily) monitor and measure the policymaker's performance will *lower* the mean and volatility in inflation and interest rates. The improved transparency in the contingency plan and improved CB credibility through monitored and measurable performance will lower the attributed risk adjustments in future inflation and interest rate expectations. The goal of this section is to show which means to monitor and measure this commitment by a policymaker would provide such CB credibility.

2.2.3.1 Adopting and inflation target

The presence of discretionary policies and a potential inflation bias have lead to a greater need for openness and transparency about a CBs goals, expectations and procedures. A significant strand of literature has therefore promoted the idea of CB's adopting an explicitly stated inflation target.[9] By adopting an explicit inflation target a policymaker would (implicitly) constrain its policies' flexibility to pursue a policy that is not anti-inflationary as he will be held accountable for deviations from the policy target. This however also provides him (maybe even immediately) with the necessary credibility as he is expected to perform accordingly. Explicitly stating an inflation target would therefore provide the openness and transparency about a policymaker's expectations and intentions, providing an anchor for medium to long run expected inflation accordingly. In addition, this would also create a

[9] Important contributions are Bernanke *et al.* (1999a and 1999b), Woodford (2004), Santomero (2004a en 2004b), Bernanke and Woodford (2005), Walsh (2005), Hetzel (2007), McCallum (2007) and Dennis (2007), among others.

performance measure (ex-post) for the accountability of the policymaker for his "true commitment". As a result, expectations of the (future) development of the operational policy instrument i_t in equation (2.1) are significantly improved, reducing forecast biases. As suggested earlier, the conditioning of forecasts of future inflation rates and the development of the future short term interest rate will therefore lead to lower mean and volatility of both instruments. Indeed, the adoption of an inflation target has been crucial for lower inflation rates across countries, has institutionalized low inflation objectives and facilitated improved monetary policy (Bernanke (2006), Bernanke *et al.* (1999a and 1999b), Santomero (2004a en 2004b) and Levy (2007), among others).

Having an inflation target that anchors economic agents' expectations, we can consider that forward-looking economic agents expect inflation to develop with a limited and mean-reverting nature of fluctuations of inflation around its target as

$$E_t \pi_{t+n+1} = (1-\omega) E_t \pi_{t+n} + \varpi \pi^* \tag{2.27}$$

where ω is a constant and 0 < ω < 1, representing the "smoothing" character of the policymaker's inflation targeting process to stabilize shocks in inflation. Note that for n=0 it counts that $E_t \pi_t = \pi_t$. Higher values for ω will imply that the policymaker is perceived to be more actively targeting inflation, leading to a faster convergence of current inflation towards its target level, adding to his or her credibility as an inflation targeter. Even in the case of a large deviation of inflation from its target, or short run volatility in inflation, expectations for the medium and long run are sufficiently anchored for any choice of ω, while for ω close to unity it will count that $E_t \pi_{t+n} \approx \pi^*$, e.g. the inflation rate will converge towards its long run equilibrium target rate. The faster current inflation rates will converge, the more the policymaker will be perceived as an anti-inflation targeter. As the policymaker is successful in increasing inflation stability around the target she will be able to target inflation by the degree of ω =1. If, for example, if a policymaker does not adequately choose the level of i_t such that inflation pressure is discontinued (e.g. inflation is persistent over a subsequent period of time) the more likely will economic agents reflect this information in their expectations of future monetary policy, and hence for the development of future levels of inflation and interest rates accordingly. Consider, for example, that inflation follows the following stochastic process

$$\pi_t = a_1 \pi_{t-1} + a_2 \pi_{t-2} + \ldots a_n \pi_{t-n} + \eta_t \tag{2.28}$$

where inflation develops according to an autocorrelated process, with magnitude a_n. Higher levels of a_n imply that inflation is highly dependant on past levels of inflation (e.g. is highly persistent) which contradicts the fact that the policymaker is a credible anti-inflation targeter. Namely, when inflation increases a credible policymaker is expected to increase the level of i_t such that the real interest rate increases - contracting demand and reducing output growth - which should lead to lower levels of (expected) inflation. As a result, inflation will be correlated with past levels ($a_n > 0$) as the policymaker pursues financial stability and therefore smoothes shocks in inflation (and interest rates), but in the end inflation should still converge towards its target rate, decreasing the coefficients {a_1, a_2, a_n}, hence reducing inflation persistency. Therefore, the higher levels of the coefficients {a_1, a_2, a_n}, the less a CB will be perceived as being an anti-inflationary policy regime. Therefore, monetary policy regimes which show a high persistency in inflation can be perceived by economic agents as regimes with a low level of CB credibility, with, as a consequence, the adverse inherent property of increasing expected inflation in equations (2.2), (2.9) and (2.11) accordingly.

Under adoption of an inflation target, in choosing ω and π^* the policymaker will maximize its objective function by choosing i_t such that expected inflation converges to $E_t\pi_{t+n} = \pi_{t+n} = \pi^*$ and y_t=0. If the policymaker pursues a time-inconsistent discretionary policy this will show up by a decreasing ω over time, which will again transform rational agents' expectations formation to one that results in altering the level of k in equation (2.18). Since the policymaker knows this fact she will "choose" the target set {ω, y_t, i_t, π_t} which creates economic agents' expectations that k=0, resulting in $E_t\pi_{t+n} = \pi_{t+n} = \pi^* < E_t\pi_{t+n} = \pi_{t+n} + \frac{\alpha}{\lambda}k_{t+n}$. As $E_t\pi_{t+n}$ decreases because the policymaker is (continuously) perceived as being credible, R_t^n in equation (2.1) decreases, reducing the impact of inflationary shocks to interest rates as inflation expectations are sufficiently anchored. Short term surprise policy actions will therefore not influence medium to long term expectations as $E\pi_{t+n}^c = \pi^*$.

2.2.3.2 Rules versus discretion

Another strand of literature has argued that the CB should adopt an explicit "rule" which describes the policymaker's contingency plan. A policymaker that tries to show the public that she is indeed credible in her stated commitment can provide full transparency about this contingency plan, being the policy instruments, future expectations and the procedure to follow. The adoption of a simple "rule" which contains the key policy instrument set {y_t, i_t, π_t } and describes the policymaker's anticipated behaviour, e.g. the change in his policy instrument (i_t) in response to changes in the economic aggregate target set (y_t, π_t), conditional to his communicated (or otherwise observed) preferences for either target, would then easily provide the necessary anchor for the creation of expectations.

A significant strand of literature has contributed to the literature in both criticism and phrase for the adoption of such a "simple rule". Critical comments mostly relate to the fact that *rules put on too much constraints for the policymakers to translate its dynamic system into a "simple rule" in a dynamic, changing environment and that is therefore only feasible in low dynamic environments* (Kydland and Prescott (1979) and Barro and Gordon (1983); that *monetary policy objectives might change and that therefore any change in policy due to changes in its environment, or improved knowledge about its environment will alter the structure of these rules and that the rule should therefore fit the economic conditions at that time* (Lucas (1976), Kydland and Prescott (1979), Woodford (1999), McCallum (2004) and Hildebrand (2006)); that it therefore would *provide the necessary flexibility to adjust its policy as the policymaker sees fit (Bernanke (2006)); but that it should have a timeless characteristic such that prevailing (current) economic conditions cannot be exploited* (Woodford (1999)); and would solely have to *focus on policy parameters that are more easily to control (e.g. prices) instead of* *parameters that are more easily biased in their estimates, e.g. the output gap* (Edge *et al.* (2004)). Positive comments, however, are that it would *provide economic agents a firm anchor for the creation of their expectations*[10]; that commitment to a "rule" would *provide a performance measure which makes the policymaker accountable ex-post for its policy and simultaneously provides CB credibility* (Blinder and Reis (2005) and Taylor (2005)); that it therefore *would negate the systematic biases from naïve period-to-period optimization* (Woodford (2004)); that *empirical papers have sufficiently shown the analytical power of "rules" to analyze policy decision making* (Taylor (1999, 2002), Clarida *et al.* (2000), Feldstein *et al.* (2004), Blinder and Reis (2005) and Taylor (2005) and Qin (2008), among others); that *the fruits of such a commitment can be seen across countries, with lower mean and volatility of inflation and interest rates, as policymakers are being seen as credible inflation targeters that promote long run price stability* (Feldstein *et al.* (2004), Kohn (2004)); and that while "*one cannot blindly calculate interest rates from the instruments provided by the rule, that it is clear that these practical approaches possess the benefits of policy rule, being the means for policy evaluation, consistency over time, and accountability*" (Taylor (2005) and Blinder and Reis (2005)). As suggested by Blinder and Reis (2005) the most interesting times for evaluation are the times that policymakers perform "out-the-rule", e.g. the time that the policymaker uses the most discretion about its policy (also see Taylor (2005)).[11] A deviation of the policy instrument (e.g. the federal funds rate) from the implicit target - that would accommodate the markets expectations of the credible policy - might suggest that a CB's commitment to the contingency plan is "flawed", hence suggesting the potential lack in CB credibility as perceived by financial markets. The interesting question than becomes to what extent this perception on CB credibility has an impact on future policy expectations.

For example, consider the following simple Taylor-rule alike "*contingency plan*", that contains the instrument set $\{i_t, \pi_t, y_t\}$

$$i_t^* = r^* + \pi_t + \beta_\pi \left(\pi_t - \pi^*\right) + \beta_y y_t \tag{2.29}$$

where r^* represents the long run equilibrium real interest rate, π_t is inflation, π^* is the inflation target and y_t is the output gap measured by the deviation between actual real domestic production and its potential level. β_π and β_y are constants representing the policymakers preference for respectively the inflation and output gap. According to equation (2.29) a policymaker that promotes inflation stability and actively pursues an anti-inflationary policy will do so choosing $\beta_\pi > 1$ to accommodate an increase in inflation expectations by minimally an equal increase in the interest rate. The situation that $\beta_y < 1$ then implies that the policymaker's values targeting inflation more than targeting the output gap. This was already suggested by equations (2.21) and (2.33). The "rule" provides economic agents with an anchor for the creation of expectations on the development of interest rates. As the

[10] The representing literature is too heavily documented to name all that contributed, however, important contributions are Kydland and Prescott (1977, 1979), Fellner *et al.* (1979), Barro and Gordon (1983), Blinder (1998, 2000), Fischer (1990), Clarida *et al.* (2001), Woodford (1999, 2004)), McCallum (2004), and Blinder and Reis (2005).

[11] In Blinder and Reis (2005) performing "out-the-rule" relates to the difference in economic agents' expectations of the development of the (future) federal funds rate - which is implicitly provided by the rule - from the actual development of the federal funds rate. In other words, the situation where the CB chooses a different policy than is implied by the rule, which relates to a lack of commitment to the rule, e.g. implies the policymaker's uncredibility.

preferences for β_π, β_y and the target rate for inflation become known to economic agents the level of i_t can easily be anticipated, reducing any forecast biases and attributed risk-premia in interest rates as a result.

This simple "rule" will provide the monitor, e.g. economic agents, with the tools to make the policymaker accountable ex-post for its policy actions, as changes in β_π over time will signal its changed preferences for fighting inflation and will result in a potential loss in CB credibility. Simultaneously, a policymaker who behaves according to the "rule" will build up credibility, which negates the adverse effects of the alternative discretionary policy, as showed by equations (2.25) and (2.26). In realizing the fact that economic agents make forecasts for the development of the future short term interest rate according to equation (2.29), conditional to the information set I_0, the policymaker will optimize its decision by choosing i_t that meets economic agents' expectations of π_t and y_t according to equations (2.10) and (2.11). This is also shown by Clarida *et al.* (1999) who show that commitment to a policy rule yields choosing the instrument set { y_t, i_t , π_t } according to

$$y_t^c = -\frac{\lambda}{\alpha^c}\pi^c \tag{2.30}$$

$$i_t = \gamma_\pi^c E_t \pi_{t+1} + \frac{1}{\varphi} g_t \tag{2.31}$$

where

$$\alpha^c \equiv \alpha(1-\beta\rho) < \alpha \tag{2.32}$$

$$\gamma_\pi^c \equiv 1 + \frac{(1-p)\lambda}{\rho\varphi\alpha^c} > 1 + \frac{(1-p)\lambda}{\rho\varphi\alpha} \equiv \gamma_\pi \tag{2.33}$$

Equation (2.33) shows that - relative to the case of discretionary policy - under commitment to a policy rule the CB increases the nominal interest rate by a larger amount in response to a rise in expected inflation, represented by the higher coefficient $\gamma_\pi^c > \gamma_\pi$. This suggests that the policymaker is more likely to be being perceived as an active inflation targeter, given his or her relatively higher preferences to stabilize inflation, adding to her credibility. This therefore leads to lower future expected inflation vis-à-vis the case without commitment to a "rule". As rational agents are under such a condition confident that k = 0 ($\alpha^c < \alpha$), hence that $\pi_t^c = \pi_t$, it follows that $E_t\pi_t^c < \pi_t < \pi_t^c$. The result is therefore the same as with the adoption of an inflation target; the anchoring and conditioning of expectations and the lack of uncertainty related premia in private probability functions will lower the mean and volatility of (expected) inflation and (future) short term interest rates, decreasing its contribution to the term structure of interest rates (e.g. the situation where $R_t^n \downarrow$ and $\Delta R_t^n \downarrow$ as $E_t i_{t+n} = i^c$ and $E_t i_{t+n} \downarrow$, under $E\pi_{t+n}^c = \pi^*$, $E_t\pi_{t+n} \downarrow$ and $E_t \Delta\pi_{t+n} \downarrow$). More important, reduced uncertainty about future monetary policy will reduce (or even negate) the impact of surprise monetary policy actions to interest rates (e.g. the situation where this leads to ΔR_t^n =0 as $E_t i_{t+n} = i^c$ under $E\pi_{t+n}^c = \pi^*$).

This chapter has shown that the successful anchoring of expectations, while constraining the policymaker's incentives, decreases the uncertainty of future monetary policy. As the policymaker knows the adverse effects of a lack of commitment to the contingency plan - as she is being monitored and her performance can be measured - she will indeed follow through on her communicated contingency plan. As a result, economic agents' expectations vis-à-vis CB expectations will be affected with the least bias in forecasting the effects of future monetary policy on current and future economic aggregates. Therefore, the anchoring of expectations for inflation, under increased transparency on the (future) development of interest rates, will lead to probability distribution functions that will attribute lower term-premia to medium and long run policy uncertainties. It is therefore hypothesised that this favourable condition will lead to smaller shocks to interest rates due to policy surprises. If we could therefore disentangle the economic environment into one where a CB is perceived as being credible vis-à-vis one where a CB is being perceived as uncredible this could very well lead to the conclusion that CB credibility changes the way in which financial markets respond to (surprise) policy actions, e.g. the situation where CB credibility leads to lower mean and volatility in interest rates.

2.2.4 Target rate changes and interest rates

To finalize this chapter we conclude the formal description by showing how anticipated and surprise policy actions change interest rates, how this is hypothesised to be different for a credible vis-à-vis an uncredible policymaker state dependence and what their respective (hypothesised) effect will be.

According to the rational EHT anticipated policy actions should not affect interest rates as the as it would not alter future expectations.[12] Then, expectations of the future development of short term interest rates are largely (virtually only) based on expectations of anticipated target rate changes. Under the assumption that the overnight rate on Fed funds is the prime instrument for monetary policy, the spread between the short-term interest rate and the overnight rate incorporates expectations of future expected target rate changes. If we assume overnight rates to fluctuate around the target funds as a "stabilizing policy" implemented by the policymaker, then we can model the limited and mean-reverting nature of the fluctuations of the overnight rate federal funds around its target rate by the first-order stochastic difference as [13]

$$f_t - i_t^* = (1-w)(f_{t-1} - i_t^*) + \varepsilon_t \qquad (2.34)$$

were f_t and i_t^* respectively are the federal funds rate and the target funds rate. $E(\varepsilon_t) = 0$ and $0<w<1$ is a given constant. Note that in equation (2.34) fluctuations of the overnight rate are independent of target rate changes. Under the assumption of arbitrage longer-term interest rates are in line with expectations of future overnight rates, than the equilibrium relation between short-term

[12] This also follows the rationale of Kuttner (2001) and is supported by the outcome of the study.
[13] Also see Balduzzy *et al.* (1997)

interest rates and overnight rates can be expressed by a linear expectations-hypothesis term structure, namely [14]

$$R_t^n = (1/k)\sum_{i=0}^{k-1}\left(E_t f_{t+n}\right) + \theta \qquad (2.35)$$

where the yield R_t on *n*-days maturity loan at time *t* is the average of the future overnight federal funds rates f_{t+n} expected to prevail during the life of the security. Please recall equations 2.1 and 2.2, and slightly rewrite to resemble changes in expectations in overnight rates

$$\Delta R_t^n = (1/k)\sum_{i=0}^{k-1}\left(\Delta E_t f_{t+n}\right)_t \qquad (2.36)$$

which assumes a constant term premium and where

$$\Delta E_t f_{t+n} = \Delta E_t r_{t+mi}^m + \Delta E_t \pi_{t+mi}^m \qquad (2.37)$$

However now consider that

$$\Delta R_t^n = \left(\Delta i_t^* \middle| \Delta E_t f_{t+n}\right) \qquad (2.38)$$

and

$$\Delta i_t^* = \Delta i_t^E + \Delta i_t^U \qquad (2.39)$$

which implies that longer-term interest rates move with changes in the Fed target rate (only) conditional to the extent in which it changes expectations for future short-term overnight rates ($E_t f_{t+n}$), being changes in expectations in real interest rates ($\Delta E_t r_{t+mi}^m$) and expected inflation ($\Delta E_t \pi_{t+mi}^m$). In addition, Fed target rate changes are divided in expected target rate changes (Δi_{t+m}^E) and unexpected target rate changes (Δi_{t+m}^U). To see how the impact of anticipated and unanticipated target rate changes relates to the term structure of interest rates, we use a general implication of the EHT.

To link overnight rates to longer-term interest rates we apply equation (2.35), while taking equation (2.34) forward and taking summations according to (2.35) we find the relation between the anticipated target rate changes and interest rates under the rational EHT, namely

$$R_t^n - i_t^* = \left(\frac{1}{k}\right)E_t\left[\sum_{i=0}^{k-1}\left(i_{t+m}^* - i_t^*\right)\right] + \left[\frac{1-(1-w)^n}{wn}\right]\left(f_t - i_t^*\right) \qquad (2.40)$$

[14] Note that the term $E_t i_{t+mi}^m$ is replaced by the term $E_t f_{t+n}$, which resembles the (very) close relationship between (expected future) overnight rates and interest rates (also see Rudebusch (1995)).

$$\equiv E_t\left(\Delta i^E_{t+m}\right)+E_t\left(\Delta\left(f_t-i^*_t\right)\right)$$

where in equation (2.40) the spread $R^n_t - i^*_t$ contains information on expectations of future target rate changes $\left(i^*_{t+m} - i^*_t\right)$ and expectations on the development of the federal funds rate around its target $\left(f_t - i^*_t\right)$. As the last term $\left(f_t - i^*_t\right)$ is expected to be small in absolute values (zero in equilibrium, where the overnight rate is at its target rate), the result under the EHT is that (future) short-term interest rates move only with anticipated target rate changes $\left(E_t\left(\Delta i^E_{t+m}\right)\right)$ and the expected development of the overnight around its target $E_t\left(\Delta\left(f_t - i^*_t\right)\right)$, which incorporates the policy preferences for inflation targeting of the Fed.

Under the rational EHT it is expected that financial markets make unbiased expectations of future developments of either $\left(E_t\left(\Delta i^E_{t+m}\right)\right)$ and $E_t\left(\Delta\left(f_t - i^*_t\right)\right)$, where f_t primarily depends on expectations on future real interest rates and inflation rates (according to equation (2.37)), which is assumed to be conditional to the CB regime. Under the assumption of unbiased expectations, the impact of an anticipated target rate change on interest rates is expected to be zero, as policy performs as expected and hence does not alter any future expectations. However, in an uncertain environment it is argued that economic agents "hedge" the possibility of making biased expectations, which results in (relatively) too high anticipated target rate changes. The extent in which this "risk" is being hedged will determine its influence for short, medium and long term rates. While short term interest rates are thereby primarily influenced by liquidity effects of a target rate change, its impact on longer-term rates primarily depends on changes in expectations that alter future short term interest rates. Short term deviation from policy, does not necessarily imply that policy goals are not being met in the medium or long run. If markets however hedge this risk, this increases R^n_t and results in the fact that anticipated target rate changes are therefore relatively too high at that moment, which also reduces the "surprise" component of the target rate change. As financial markets become aware of the "unnecessary" hedge, the impact of the target rate change to interest rates reduces, being maturity dependent and expected to reduce as maturity increases, potentially being negative.

For surprise policy actions this is quite different. This paper hypothesizes that the effects of surprise policy actions are primarily influenced by changes in the perceived policy preferences and by private information of the CB.[15] Surprise contractionary policy, for example, can be perceived as information that economic agents have underestimated (expectations of) future inflation rates, resulting in an increase in $E_t\pi^m_{t+mi}$ and an increase in short, medium and long-term rates (e.g. R^n_t increases along the yield curve). Under the rational EHT the impact of the surprise target rate change will be limited to liquidity effects only for short to medium run maturities, with an assumed constant risk-premium, as long as long run expectations of π^m_{t+mi} are not affected by the policy decision.

This paper however hypothesises that the state dependence of CB credibility changes this perspective (also see Cambell1995)). The rationale is that the impact of both anticipated and

[15] Also see Romer and Romer (2000) and Ellingsen and Soderstrom (2001).

unanticipated target rate changes is hypothesised to be conditional to the (dynamic) environment in which financial markets create expectations, e.g. is conditional to CB credibility in this case. As shown in the previous sections (credible) uncredible policies are accompanied by (lower) higher risk attributions to interest rates ($E_t i^m_{t+mi}$) through (lower) higher expected future inflation, e.g. involves different perspectives on the development of both the terms for expected future target rate changes and changes in the development of (future) rates of real interest rates and inflation. A contractionary monetary policy under a credible CB environment will likely result an anticipated target rate change to have zero impact on interest rates as it would not change future inflation expectations (while no hedges against potential biases are assumed to be taken) resulting in an equal change in real interest rates in relation to changes in nominal interest rates, keeping R^n_t constant. The impact of the anticipated target rate change is therefore assumed to be zero along the entire yield curve. However, under an uncredible CB (with potentially high hedges against potential biases) an anticipated contractionary monetary policy can increase real interest rates ($E_t r^m_{t+mi}$) as nominal interest rates increase while expectations of inflation ($E_t \pi^m_{t+mi}$) decrease, due to a decrease in attributed risk-premia in longer-term inflation expectations, reducing $E_t \pi^m_{t+mi}$. As a result R^n_t decreases.[16] The impact of the anticipated target rate change is therefore assumed to be zero for short term interest rates, but can potentially be negative for longer term maturities.

As suggested surprise target rate changes are primarily influenced liquidity effects for the short run, and changes in expectations of future monetary policy and expected inflation rates in the medium to long run. Under a credible CB regime short term interest will move due to liquidity effects, while medium term interest rates are moved by changes in (short run) expectations of inflation. It is assumed that the credibility of the policymaker does not change long run inflation expectations, leaving the impact of a surprise target rate change to only (substantially) move short term interest rates and too some extent medium term interest rates. Under an uncredible CB however, hedges against biases in expectations will increase, increasing its impact along the entire yield curve. Increased inflation expectations, under a regime that is not perceived as a credible inflation targeter, will largely influence short, medium and long run interest rates. The impact of surprise target rate changes in uncredible CB environments are therefore expected to be significantly higher than in the case for credible CBs.

Controlling for the state dependence of CB credibility therefore yields the hypothesized impact of anticipated policy actions on interest rates of

$$\frac{\partial R^n_t}{\partial i^E_t} = \frac{\partial R^n_t}{\partial i^{E,C}_t} = 0 \quad \text{and} \quad \frac{\partial R^n_t}{\partial i^{E,UC}_t} < 0 \tag{2.41}$$

while for surprise policy actions this paper hypothesizes an effect of

$$\frac{\partial R^n_t}{\partial i^{U,C}_t} \leq \frac{\partial R^n_t}{\partial i^{U,UC}_t} \geq 0 \tag{2.42}$$

[16] Also see Gurkaynak, Sack, and Swanson (2005a).

where ∂i_t^C and ∂i_t^{UC} are respectively the changes in the target rate for the credible and uncredible state dependence of CB credibility.

CHAPTER 3 Methodology & Data

The previous section has shown how the anchoring of expectations for economic agents reduces potential biases in expectations that result from discretionary monetary policies. It has been shown that it is however necessary for economic agents to be able to monitor and measure a policymakers performance to attribute a level of CB credibility. This section will follow the rationale and theory of the previous section on how the policymaker can show her commitment to the policy goals, to create different performance measures that would link the policymakers perceived commitment to her policy goals to a policymaker's performance, to be able to attribute whether economic agents will perceive the policymaker to be credible or not.

This paper will first address the methodology concerning the measurement of surprise target rate changes in section one. Section two will then address the methodology concerning the measurement of CB credibility and will address how this paper will accommodate the influence of CB credibility in measuring the response to surprise target rate changes.

3.1 Measuring the impact of surprise target rate changes

In order to measure the market response to both the anticipated and unanticipated target rate change we estimate the following model

$$\Delta R_{s,t,m} = \alpha + \beta_1 \Delta TR^e{}_t + \beta_2 \Delta TR^u{}_t + \varepsilon_t \qquad (3.1)$$

where $\Delta R_{s,t,m}$ represents the change in money market yields for our risk-free government security (*s*) with maturity *m*, while day-*t* corresponds with the day of the market response to the target rate change and $E(\varepsilon_t) = 0$. $\Delta TR^e{}_t$ and $\Delta TR^u{}_t$ resp. represent the day-*t* anticipated and unanticipated target rate change, while ε_t represents the error term which is expected to be zero.

As shown by Kuttner (2001), under the assumption that no other event other than the CB target rate change has been anticipated the change in a day-*t-1* futures rate ($f^0{}_{s,t-1}$) and the day-*t* futures rate ($f^0{}_{s,t}$) captures the markets' unanticipated target rate change. That is

$$\Delta TR^u{}_t = \frac{m}{m-t}(f^0{}_{s,t} - f^0{}_{s,t-1}) + \mu^0{}_{s,t} \qquad (3.2)$$

for all but the first day of the month, where $f^0{}_{s,t-1}$ is substituted by $f^0{}_{s-1,m}$. Here, $\Delta TR^u{}_t$ represents the surprise target rate change, $f^0{}_{s,t}$ represents the current spot-month future rate from which its change during a *t*-day time interval is magnified by the amount of days affected by the surprise change. $\mu^{0}_{s,t}$ represents the change in spot rates which is not due to the anticipation to the target rate change, which is assumed to be zero.

For estimating policy expectations Kuttner (2001) and Faust, Swanson, and Wright (2004) use current one-month federal funds futures, Poole and Rasche (2000) and Bomfim (2003) use the one-month-ahead federal funds futures, Cochrane and Piazzessi (2002) use the one-month Eurodollar deposit rate, Ellingsen and Soderstrom (2004) use the three-month T-bill rate, and Rigobon and Sack (2002) use the three-month Eurodollar futures rate. Gürkaynak *et al.* (2007) analyzed the ability of these financial instruments to capture expectations of future monetary policy. They find that federal funds futures dominate all the other securities in forecasting monetary policy at horizons until six months. For longer horizons, the predictive power is very similar. In the decomposition of target rate changes, we will therefore use current one-month federal funds future rates.

Data on the federal funds rates and federal fund target rate changes are observed from Thomson Datastream and the Federal Reserve website.[17] For the response in short term money market yields to CB policy surprises we use data from Thomson Datastream, where the response is measured by daily changes in the 3-month, 6-month and 1-year Treasury bill. For the medium and long run we use data from the Federal Reserve H.15 Selected Interest Rates. These are daily changes for 2-year, 5-year and 10-year Treasury notes, and 30-year Treasury bonds, consistent with Kuttner (2001). As stated, the Federal Reserve only introduced federal funds futures in October 1988, which limits us to perform a full analysis of the Greenspan period. Settlement prices of the federal funds futures are collected via Reuters Datastream (code CFFCS00). The funds futures rate is than calculated as 100 minus the settlement price.

For the period before 1994 we assume that all announcements on target rate changes are made on the first day after the meeting (also see Zebedee *et al.* (2008)). For the period after 1994 the announcement date will be the day of the meeting. Announcements usually come around 14:15 p.m. Eastern time (19:15 GMT), unless specifically stated otherwise.[18] Data on federal funds futures settlement prices is collected around 2:00 p.m. Central time (3:00 p.m. Eastern time). This implies that the surprise target rate change is measured from the change in the federal funds futures rate of day-*t* from day-*t-1*. Data on Eurodollar deposits rates are collected at 9:30 a.m. Eastern time (14:15 GMT). The surprise target rate change is therefore measured by the Eurodollar deposit rate change of day-*t+1* from day-*t*. Data on the interest rate changes are observed as day-*t* closing (bid) rates and the response is therefore measured by the change of day-*t* from day-*t-1*. Data on the 3- month (average) CFNAI-index is directly observed from the Federal Reserve website.

To test the robustness of the findings we additionally publish the results for 1-month Eurodollar deposit rates.[19] Daily changes in the 1-month Eurodollar deposit rate are observed from the Federal

[17] In addition, values for target rate changes are cross-checked with studies from Thornton (2000, 2005), Thornton and Wheelock (2000), Kuttner (2001) and Zebedee *et al.* (2008).

[18] For the period before 1994 we use 14:15 p.m. ET of the day after the meeting as the timing of the announcement in line with Kuttner (2001) and for the post-1994 observation we use data from Zebedee *et al.* (2008) which includes the specific time of the announcements.

[19] Since Eurodollar deposit rates are quoted at the European market which is closed when the Fed announces its target rate change daily changes will capture a somewhat pure unanticipated target rate change, as closing prices reflect markets' expectations of day-*t+1* target rate changes, while the next day change will resemble the shock of the surprise target rate change.

Reserve (series ED1M). The unanticipated target rate change for Eurodollar deposit rates are measured by[20]

$$\Delta TR^u{}_t = (i_{t+1} - i_t) + \mu_t \tag{3.3}$$

where i_t represents the Eurodollar deposit rate on the day of the target rate change and $E(\mu_t) = 0$.

To measure the expected target rate change we subtract resp. model (3.2) and (3.3) for Federal Funds futures and Eurodollar deposit rates from the actual target rate change to measure the anticipated target rate change. This results in

$$\Delta TR^e{}_t = \Delta TR_t - \Delta TR^u{}_t \tag{3.4}$$

where $\Delta TR^e{}_t$ represents the expected target rate change and ΔTR_t represents the actual target rate change.

Estimating a somewhat identical model to 3.1 Kuttner (2001) showed that β_1 is not significantly different from zero for all maturities, while β_2 is only significant different from zero for short term maturities. This suggests that policy surprises seem to have no significant impact to medium and long term interest rates. As argued however, this paper hypothesises that the influence of CB credibility will change this perspective. As financial markets become more uncertain about the long run commitment to the policy goals, the bigger will be the impact of surprise target rate changes. The result will be that under a credible CB β_1 and β_2 are expected to approach zero for longer-term maturities, while in the situation where the CB is perceived as being uncredible β_1 will approach zero and is potentially negative for medium and long term maturities, while β_2 will be significantly different from zero for all maturities.

Our next step is to develop an objective measure for the perception of a policymaker to be credible or not. We will develop a binary variable to discriminate between the "state dependence" of CB credibility to control for the environment in which the response to the target rate change has occurred.

3.2 Measuring Central Bank credibility

This section will address the three different approaches to address the perception of financial markets on CB credibility. The previous chapter has shown that a policymaker can show commitment to the policy goals through her performance of (1) to perform according to the monetary policy rule, (2) attaining a level of inflation at the communicated (implicit) target level, and (3) achieving low levels of inflation persistency. The next sections will address these measurements of CB credibility respectively.

[20] Equation (3.3) represents a simplified and approximation of the actual spread. Eurodollar deposit rates should be adjusted for (additional) risk-premia. However, this does not change the results significantly.

3.2.1 CB credibility implied by a policy "rule"

This section will address the methodology to measure CB credibility by a federal funds rate bias. We will create a monetary reaction function that incorporates federal funds rate smoothing and contains the instrument set $\{i_t, \pi_t, y_t\}$, as detailed in section 2.2.3.2. The rational is to estimate the monetary reaction function for the Greenspan era that best fits the expectations of economic agents. As the actual contingency plan, e.g. "rule" is not observed, the best action for economic agents is to observe the "inflation regime" at play, as also suggested by Andolfatto (2006). As this will provide the anchor for the creation of expectations on the future development of the federal funds rate, the next step would then be to measure the difference between the estimated target rate for the federal funds rate - that incorporates economic agents expectations - vis-à-vis the actual federal funds rate that incorporates the policymakers "true commitment" to her (implicitly) communicated contingency plan.

Please recall the policy contingency plan from equation (2.31) that contained the instrument set $\{i_t, \pi_t, y_t\}$. We assume, however, that economic agents are forward-looking and therefore write equation 2.31 forward and rearrange to get the following forward-looking policy "rule"

$$i_t^* = r_E^* - (\beta - 1)\pi^* + \beta E_t \pi_{t+k} + \gamma E_t y_{t+q} \qquad (3,5)$$

where i_t^* denotes the day-*t* nominal federal funds target rate and $r_E^* = i_E^* - \pi^*$, where i_E^* represents the long run equilibrium nominal funds rate. By construction r^* denotes the desired real interest rate where inflation and output are at their target levels, π_{t+k} denotes the percent change in the price level for time *t+k* (expressed in annual rates), π^* is the target for inflation and y_{t+q} is a measure of the output gap for time *t+q* with the output gap being defined as the deviation of real domestic production from potential domestic production. E_t is the expectations operator. In addition, the equilibrium real interest rate and target inflation rate are expected to be constant.[21]

Since data on inflation and domestic production are published after quarter-*t*, data on $E_t \pi_{t+k}$ and $E_t y_{t+q}$ are not known to CBs or financial markets in real-time. The suggestion from Orphanides (2003) and Qin (2008) that data from the Federal Reserve Greenbook about future inflation and economic (domestic) growth will provide the solution is unfortunately false in this situation. Considering Greenbook data, the results should be based on expectations of financial markets and not on expectation from CBs. More important, if a CB is not transparent or is perceived as uncredible, financial markets are unlikely to either know or use the data. Vintage data however does provide real-time observations, but lacks expectations data. As we lack real-time data, this paper therefore assumes that next quarter expectations are measured by the day-*t+1* observation of the data, hence that $E\pi_{t+1} = \pi_{t+1}$. In addition, although the forward looking approach implies that k=1 and q=1, it is however suggested by most authors that financial markets use present quarterly data on domestic production (e.g. $q=0$) in anticipating future policy.[22] This paper therefore applies k=1 and q=0.

[21] This is consistent with Clarida *et al.* (2001)

[22] Also see Clarida *et al.* (2001) and Qin (2008).

One important component however in the conduction of monetary policy is the partial adjustment of the federal funds rate towards its target, also referred to as funds rate smoothing. CB's are expected not to directly change federal funds rate towards its target rate, but however adjust them smoothly to their anticipated target. Under interest rate smoothing, CBs still might be credible for their commitment to the main economic variables, however choose to slowly adjust rates towards their target, different from what the contingency plan would suggest. This suggests that shocks of inflation and output are only *partially* accounted for. As previously stated, the prime reason for this behaviour is the increase in financial stability as the economic environment is than characterized by both lower inflation and interest rate volatility.

Due to interest rate smoothing, we expect the actual federal funds rate for quarter-*t* (i_t) to evolve around its target value with a degree of inertia:

$$i_t = (1-p)i_t^* + p(L)i_{t-n} + \varepsilon \tag{3.6}$$

where $p(L) = p_1 + p_2L + \ldots + p_nL^{n-1}$ measures the autoregressive nature of the federal funds rate, while $p \equiv p(1)$. The magnitude of p reflects the degree of interest rate smoothing. Higher (lower) values of p imply that CBs are slower (faster) in adjusting the federal funds rate towards its target rate. Consistent with other research and manipulating model (3.7) we than formulate the monetary reaction function as

$$i_t = (1-p)\left(\alpha + \beta E_t\pi_{t+k} + \gamma E_t y_{t+q}\right) + p(L)i_{t-n} + \varepsilon_t \tag{3.7}$$

where $\alpha = r_E^* - (\beta - 1)\pi^*$. Here, α reflects a linear combination of the equilibrium real interest rate and the inflation target rate, and is equal to the equilibrium real interest rate when the inflation target is zero. In line with other research, this paper will use the number of lags n=2.[23] In addition, since both the inflation target and the federal funds rate target are of interest, we adjust model (3.7) to allow for estimation of both variables. Following Clarida *et al.* (2001) we assume that the equilibrium real interest rate (r_E^*) is measured by the sample average real interest rate ($\bar{r}$), hence that the equilibrium nominal funds rate target (i_E^*) is represented by $i_E^* = \bar{r} + \pi_E^*$. The following model will be estimated:

$$i_t = (1-(p_1+p_2))[(i_E^* - \pi_E^*) - (\beta-1)\pi_E^* + \beta E_t\pi_{t+k} + \gamma E_t y_{t+q}] + p_1 i_{t-1} + p_2 i_{t-2} + \varepsilon_t \tag{3.8}$$

where $p_1 + p_2 \equiv p$ and $i_t^* = [(i_E^* - \pi_E^*) - (\beta-1)\pi_E^* + \beta E_t\pi_{t+k} + \gamma E_t y_{t+q}]$, which provides the basis for our CB credibility measure.[24] Note therefore that both the target federal funds rate (i_t^*) and the target inflation rate (π_E^*) are implied target rates estimated using equation (3.8).

[23] See for example Clarida, Gali and Gertler (2000) and Qin (2008).

[24] We apply GMM-estimation to estimate model (3.9). We use 2SLS estimation with identity weighting matrix and GMM robust standard errors, under a HAC specification with Bartlett Kernel with a fixed Newey-West bandwidth selection. The instruments contain four lags of the federal funds rate, inflation, output gap, the interest rate spread between the 30 and 10-year risk-free government securities and M2 money growth, consistent with Clarida et al. (2000), among others.

Our credibility measure (c_{rule}) is equal to the deviation of the expected level of the federal funds rate implied by the "rule" and the actual level of the federal funds bias. This credibility measure therefore measures the extent to which the policymaker meets the expectations of financial markets. A positive (negative) value will imply a credible (uncredible) CB regime environment, as the Fed minimally targets a federal funds rate that promotes its commitment to the contingency plan. The rationale is that economic agents cannot actually observe the "actual" contingency plan, nor can they create the "best" contingency plan.[25] The best action for them, as also suggested by Kydland and Prescott (1979), Barro and Gordon (1983), Clarida *et al.* (1999) and Andolfatto (2005) is to simply observe the current regime and create expectations accordingly. This therefore suggests that we expect a CB to have *private information*, meaning that they have access to better information and are therefore better in formulating the policy rule. Than CB credibility implies that the policymaker chooses to either comply with their (implicitly) stated policy rule, or to ignore this an to choose an alternative policy.

As stated, it is expected that environments with a negative (positive) credibility will be characterized by bigger (smaller) shocks to the yield curve. To control for environments which meet either CB credibility condition, we apply two different measures. The first measure suggests that financial markets expect the CB to be committed to the "rule" and that a lower federal funds rate than the rate suggested by the rule immediately will be perceived as the policymaker being uncredible, as the policymaker's actions clearly where not adequate (enough). The second measure however allows for some tolerance or flexibility. This comes from the previously stated suggestion that the CB may not have perfect control over economic aggregates and the transmission process, which might alter the course of, for example, inflation in a different direction than anticipated, and would than require the CB to change its policy to counter the unanticipated movement in inflation. While in the previous case the policymaker may than be perceived as being uncredible, this scenario provides him some room in case the contingency plan is not functioning as expected. As such, the policymaker is provided with some flexibility to "manoeuvre" inflation around its target rate without incurring a loss to credibility.[26] This second measure, however, also suggests that a federal funds rate which is higher than the upper boundary will also imply that the policymaker is perceived as being uncredible. This would suggest that higher than expected federal funds rates also result in a loss in credibility. The rational is that while the CB accommodates the anti-inflationary policy, it might contract the economy too much resulting in a loss in future economic growth, or even a recession. This is contradictory to the policy goal of creating an economic environment which stimulates economic growth. A forthcoming complication may than become that in order to accommodate economic growth in the future the CB has to lower interest rates which might cause spurious increases in inflation rate in the long run. Therefore, to avoid this the policymaker simply has to keep the federal funds rate within its credibility boundary. Also note that any differences between the results will provide information whether financial markets are more likely to

[25] Obviously, the contingency plan has to contain the necessary coefficient value that minimally supports the anti-inflationary regime, or alternative the regime that would have the perception that it indeed creates inflation stability, while stimulation output growth. If this is met, the next scenario is that it fits the ideal situation that the policymaker performs according to the contingency plan that is suggested by the rule. A federal funds rate bias than reduces such likeliness, and alternatively creates the perception of the policymaker not being credible.

[26] For a similar methodology also see Mendonca (2009). However, here we use the rationale that federal funds rate levels within one standard deviation from the federal funds target rate will provide evidence for a policymaker to "stabilize inflation". This boundary will than consist of the implied federal funds rate plus and minus one standard deviation.

associate higher than implied fund rates with CB credibility than flexibility to allow it fluctuate around the target rate.

To control for the 'state of the world' two dummy variables (δ_{NOFLEX} and δ_{FLEX}) will be created for the state dependence of CB credibility, respectively with and without the flexibility to be able to keep the federal funds rate between a flexibility bound from its implied target rate. The baseline computation becomes

$$c_{FFB} = i_t - i^* \tag{3.09}$$

with the resulting dummies identified by the discrimination in allowed flexibility according to

$$\delta_{NOFLEX} = \begin{Bmatrix} \delta_{NOFLEX}^{CRED} & = 1 & if \;\; c_{FFB} \geq 0 \\ \delta_{NOFLEX}^{UNCRED} & = 0 & if \;\; c_{FFB} < 0 \end{Bmatrix} \tag{3.10}$$

and

$$\delta_{FLEX} = \begin{Bmatrix} \delta_{FLEX}^{CRED} & = 1 & if \;\; (0 + \sigma_i) \geq c_{FFB} \geq (0 - \sigma_i) \\ \delta_{FLEX}^{UNCRED} & = 0 & if \;\; (0 + \sigma_i) < c_{FFB} < (0 - \sigma_i) \end{Bmatrix} \tag{3.11}$$

where i_t^* is the quarterly implied federal funds target rate estimated by equation 3.5 and i_t represents the quarterly effective federal funds rate.[27]

To analyze the impact of CB credibility to the response to surprise target rate changes we simply sample the state of the world in which the response to target rate changes has occurred. This will be done according to the state dependencies of δ, namely δ_{NOFLEX} [δ_{NOFLEX}^{CRED} , δ_{NOFLEX}^{UNCRED}] and δ_{FLEX} [δ_{FLEX}^{CRED} , δ_{FLEX}^{UNCRED}].

Our sample covers the entire Greenspan period (1987Q4 until 2005Q4). For the estimation of the Federal Funds Bias (FFB) (model 3.4) we use real-time Vintage data for observations of inflation, which is data on core Personal Consumption Expenditure (PCE) (series PCONX[28]). The output gap is measured by the difference in actual domestic production (Bureau of Economic Analysis (BEA)) minus potential domestic production (Congressional Budget Office (CBO)). For the estimation of the monetary reaction function we apply GMM-estimation.[29] Figure A.1 in the Appendix provides an overview of the data used. Consistent with Clarida *et al.* (2001), among others, the instruments this

[27] The quarterly (effective) Federal Funds rate is actually a 4-months averaged rate.

[28] Source: Federal Reserve website. Unfortunately the PCONX data only starts its Vintage observation at 1996, which slightly biases the real-time observations. However, as far as this can be verified by fluctuations over time, the differences should be minimal as also corrections made over time are minimal. As is it suggested by other authors, see for example Qin (2008), that Alan Greenspan favoured to use data core PCE, we however have to make the stated assumption.

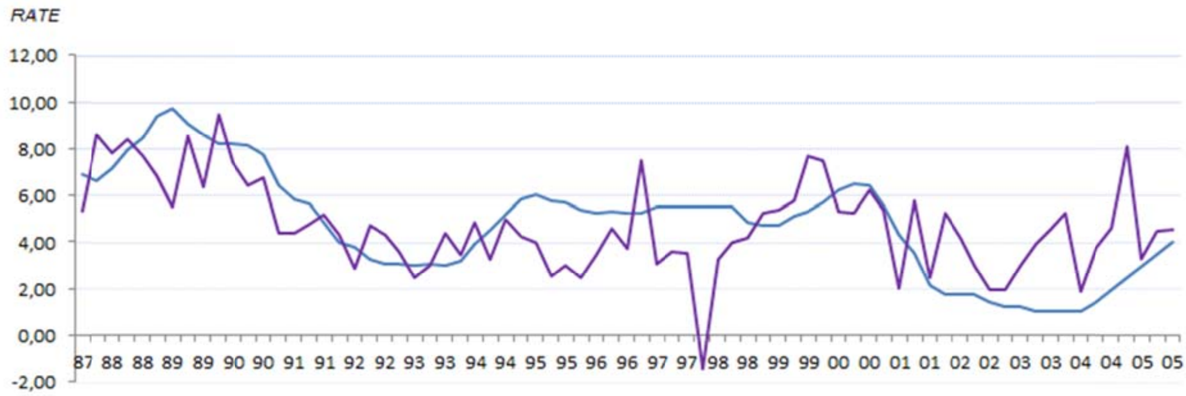
[29] We use 2SLS estimation with identity weighting matrix and GMM robust standard errors, under a HAC specification and Bartlett Kernel with a fixed Newey-West bandwidth selection.

paper uses are four lags of the federal funds rate, inflation, the output gap, M2 money growth, the spread between the short (3-month) and long term (10-year) risk-free interest rate, and the Consumer Price Index (CPI). The latter is chosen as a substitute for the Clarida *et al.* (2001) Commodity Price Index (YGFL) as this series has been discontinued. Therefore, similar to Giacomini and Rossie (2006), we use data on CPI observed from the International Monetary Fund (IMF), where inflation is the annualized differenced natural log of the CPI index.[30] Also similar to Giacomini and Rossie (2006) the 3-month and 10-year interest rates are represented by the constant maturity adjusted government security rate, respectively TCMNOMM3 and TCMNOMY10, observed directly from the Federal Reserve website. We use a series that is observed on a monthly basis, where the first observation for the first-month-of-the-quarter observation represents the quarterly observed rate. Differencing both results in the spread. Figure 3.1 provides an overview of the development of c_{FFB}.

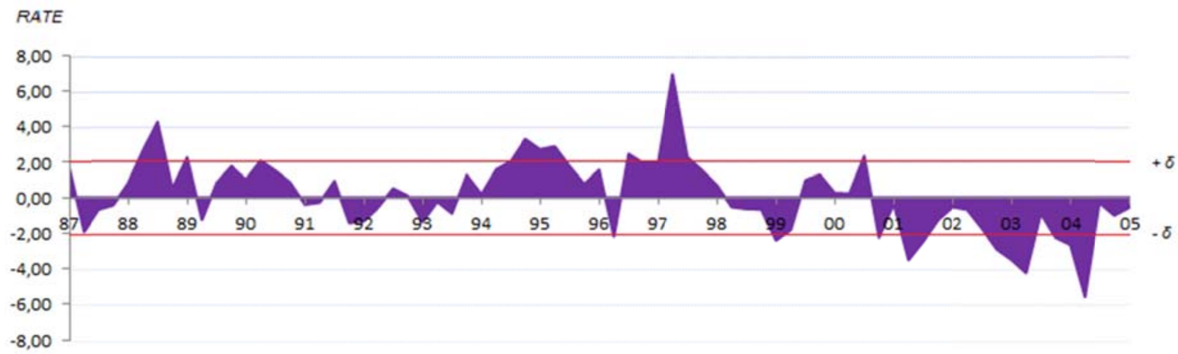
Figure 3.1

The Federal Funds Bias (FFB)

Panel A The actual federal funds rate versus the implicit federal funds target rate



Panel B The FFB accompanied by the boundaries for CB credibility flexibility



Notes:
[a] Panel A in Figure 3.1 shows the development of the actual federal funds rate (i_t) and the implied target federal funds rate (i^*). Panel B shows the resulting federal funds bias (FFB), measured by the actual federal funds rate minus the (implied) federal funds rate, according to equation (3.9), where the target FFR is observed from estimating equation (3.8). The horizontal red lines represent the CB credibility bound, being observations of the federal funds bias (FFB) within the (zero) mean and one standard deviation (σ=2,06) of the FFB. Note that credibility is attributed by a positive value of the FFB, or alternatively by values within one standard deviation of the mean bias.

Source: *Federal Reserve, CBO and authors calculations*

[30] CPI index for all items all urban consumers (U.S. city average) observed from the IMF website.

3.2.2 CB credibility implied by the inflation bias (IB)

A common methodology to measure the IB is to measure the difference in expectations of the future rate of inflation from CBs versus that of economic agents. Identical expectations would suggest that economic agents expect the CB to be trustworthy in their forecast and to come through on their contingency plan for the medium and long run. A secondary approach is to measure the difference between CB forecasts and actual values for inflation rates. This provides an ex-post performance measure for CB credibility, to follow through on their ex-ante made forecasts. Following the rationale of Orphanides (2003) it is however primarily important to use real-time data. The problem with both methodologies is that they do not provide a real-time analysis for this paper as Federal Reserve forecasts are obtained through the Greenbook dataset, which is only available to the public after five years. As such, at the time of the response to policy events economic agents would not have had this specific information.

This paper's methodology relies on the findings in section two. This paper therefore hypothesises that economic agents anchor their expectations for the policymakers' behaviour by the development of inflation from a target rate for inflation. As stated in section two, uncredible policymakers are characterized by their lack in actively fighting or stabilizing inflation rates, leading to higher inflation than its (implicit) target. As the policymaker remains unsuccessful in providing inflation rates lower around its target rate, even under the condition of smoothing shocks in inflation, economic agents will perceive the policymaker as being uncredible. Any economic environment which is characterized by the policymaker not performing according (close) to its target increases uncertainty and will result in the loss of CB credibility.

Our benchmark for the market's perception of CB credibility is therefore the performance to achieve the target rate for inflation (also see Mendoza (2009)). However, as in the case for the performance according to the policy rule, we will incorporate flexibility which allows the policymaker to achieve inflation rates within a certain flexibility boundary. As long as she performs within this boundary, no loss in CB credibility is hypothesised to occur. Our baseline model therefore becomes

$$c_{IB} = E\pi_{t+n} - \pi_E^* \tag{3.12}$$

with the resulting dummies identified by the discrimination in allowed flexibility according to

$$\delta_{NOFLEX} = \begin{Bmatrix} \delta_{NOFLEX}^{CRED} & =1 & if & c_{IB} \leq 0 \\ \delta_{NOFLEX}^{UNCRED} & =0 & if & c_{IB} > 0 \end{Bmatrix} \tag{3.13}$$

and

$$\delta_{FLEX} = \begin{Bmatrix} \delta_{FLEX}^{CRED} & =1 & if & (0+\sigma_i) \geq c_{IB} \geq (0-\sigma_i) \\ \delta_{FLEX}^{UNCRED} & =0 & if & (0+\sigma_i) < c_{IB} < (0-\sigma_i) \end{Bmatrix} \tag{3.14}$$

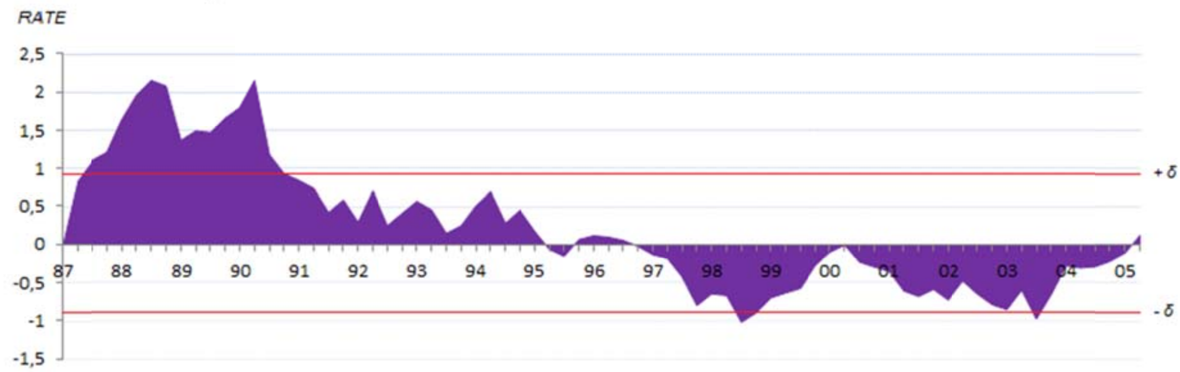
where $c_{IB,t}$ represents an inflation bias in the policymaker's performance, while π_E^* represents the (equilibrium) implicit target inflation rate. Unfortunately, the Fed has never explicitly stated an inflation target. We therefore rely on an implicit (equilibrium) inflation target (π_E^*) which will be observed directly from the estimation of model (3.8).

To analyze the impact of c_{IB} we sample the "state of the world" in which the response to a target rate change has occurred according to the state dependencies of δ, namely δ_{NOFLEX} [δ_{NOFLEX}^{CRED}, δ_{NOFLEX}^{UNCRED}] and δ_{FLEX} [δ_{FLEX}^{CRED} , δ_{FLEX}^{UNCRED}].

For the measurement of the Inflation Bias (IB) we use the difference between the actual next quarter expected inflation rate (series PGDP from the Survey of Professional Forecasters (SPF)) and the implied inflation (equilibrium) target rate (directly observed from model 3.4). The reason that we use the PGDP series instead of the PCONX series is that the success of the estimation of the MRF is based on the data used by the policymaker (e.g. the preference for core PCE), while the success of the IB is based on data used by forecasters (e.g. real-time forecasted price levels). Figure 3.2 provides an overview of the development of c_{IB}.

Figure 3.2

The Inflation Bias (IB)



Notes:

[a] The Inflation Bias (IB) is measured by the difference in the expected inflation rate ($E\pi_{t+n}$) and the implied (equilibrium) inflation target rate (π_E^*), according to equation (3.12). The target rate for inflation is estimated using equation (3.8). The horizontal red lines represent the boundaries for CB credibility, being observation within one standard deviation of the (zero) mean IB. Note that credibility is attributed by a positive value of the IB, or alternatively by values within one standard deviation(σ=0,84) of the mean bias.

Source: *Federal Reserve, CBO and authors calculations*

3.2.3 CB credibility implied by inflation persistency (IP)

For our next proxy for CB credibility we will measure the autoregressive nature of inflation, namely inflation persistency (p_t). We will estimate inflation persistence by an AR(n) model via OLS. Here we define inflation persistence as the long run effect of a shock of inflation. The rationale follows section two, which argues that if inflation is persistent, e.g. does regress towards its mean inflation (or rather target) rate, this will provide the market with the perception that the policymaker is not committed to the policy goal to stabilize inflation, hence suggesting uncredible policy.

To control for the fact that the inflation process has significantly changed the last decennia, both due to inflation persistency and the relation with the output gap, we control for this by incorporating the output gap as endogenously explained variable (also see Calstrom (2007)). The following model will be estimated

$$\pi_t = \mu + \gamma E_t y_t + \phi_1 \pi_{t-1} + \phi_2 \pi_{t-2} + ... + \phi_n \pi_{t-n} + \varepsilon_t \qquad (3.15)$$

where π_t denotes inflation at present time *t*, π_{t-n} denotes the lagged inflation rate for the *t-n*th quarter, μ represents the constant term, while $E(\varepsilon_t) = 0$. Consistent with Carlstrom (2007) we set *n*=4 for the number of lags of inflation. The proxy for CB credibility is simply the sum of the coefficients (SUM) from the autoregressive process (also see Bordo (2004)), hence

$$c_{IP} = \sum_{i=1}^{k} \phi_i \qquad (3.16)$$

For $p \in (-1,1)$, the cumulative effect of the inflation shock is $1/(1 - c_{IP,t})$ which implies that the persistency of inflation increases as c_{IP} becomes larger. As the resulting persistency is either smoothed or not taken care of by the policymaker, this persistency is expected to maintain in the long run. As a result, financial markets will correct current nominal interest rates to adjust for the (expected) increase in future inflation rates, increasing long term rates accordingly. As c_{IP} becomes larger, increased uncertainty about future inflation persistency will likely cause the unanticipated component of target rate changes to be significantly influenced, increasing shocks to longer term nominal interest rates in response to monetary policy surprises. Therefore a higher value of c_{IP} implies lower CB credibility (also see Andrews and Chen (1994), Benatti (2008) and Pivetta (2007)).

Other than in the previous two cases, this credibility measure will not be differentiated for CB flexibility. The rationale is that the policymaker already has the “flexibility” to deviate from the target, provided we use four lags of inflation to measure inflation persistency, and would therefore have to make up for the “loss” of extra inflation created over the subsequent periods. Persistency in inflation therefore suggests that the policymaker has forfeited on her commitment and has not made up for this “loss”. Therefore the state dependency dummy for CB credibility using inflation persistency is identified only as

$$\delta_{NOFLEX} = \left\{ \begin{array}{c} \delta_{NOFLEX}^{CRED} = 1 \quad if \;\; c_{IP} \leq \overline{\phi}_{\pi} \\ \hline \delta_{NOFLEX}^{UNCRED} = 0 \quad if \;\; c_{IP} > \overline{\phi}_{\pi} \end{array} \right\} \qquad (3.17)$$

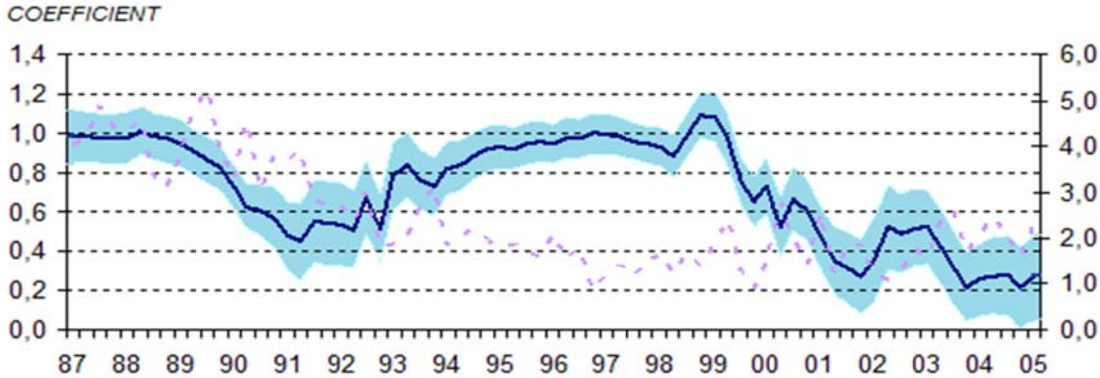
To analyse the impact of δ_{NOFLEX} we will now sample the response to policy events according to the state dependencies of δ_{NOFLEX} only, namely δ_{NOFLEX} [δ_{NOFLEX}^{CRED} , δ_{NOFLEX}^{UNCRED}].

For the measurement of Inflation Persistence (IP) we use the real-time Vintage data on core PCE (series PCONX) and for real domestic production (series ROUTPUT). The output gap is than measured by the difference between actual and potential GDP, where potential GDP is measured by the HP-trend (λ equals 1600) of real domestic production. Figure 3.3 provides an overview of the development of c_{IP}.

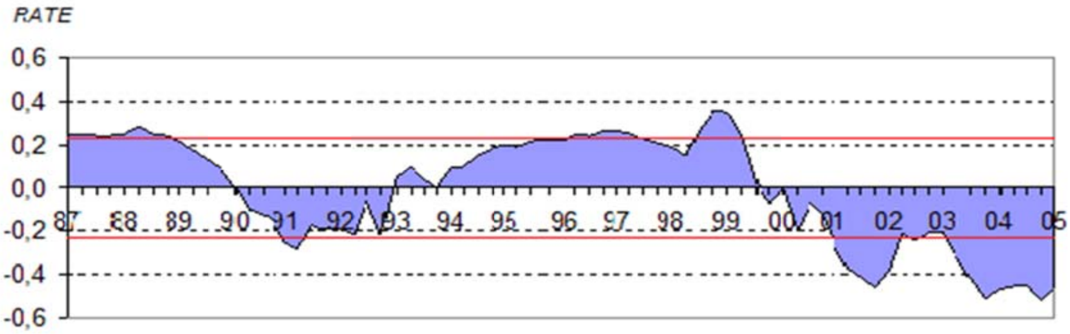
Figure 3.3

The Inflation Persistency (IP) coefficient and the resulting IP bias

Panel A The development of the IP coefficient



Panel B The IP bias accompanied by the boundaries for CB credibility



Notes:

[a] Panel A in Figure 3.3 shows the development of inflation persistency (IP) measured by the sum of the serial correlation coefficients (SUM) based on equation (3.16), where inflation is the natural logarithm of annualized quarterly changes in core PCE and the output gap is defined as the annualized quarterly difference of actual (real) domestic production from its potential level. The coefficients are calculated using 10-year rolling regressions. The purple dotted line provides information on the development of actual inflation rates for comparison only. Panel B shows the resulting IP bias measured by the difference in IP and the mean IP of 0.73, based on model 3.17. We use this value as it seems to be able to distinguish periods of relatively high inflation persistency versus periods of relatively low inflation persistency. The red lines in Panel B represent the credibility boundaries for attributing CB credibility for observations for the IP bias that lie within plus and minus one standard deviation of a zero mean IP bias.

Source: *Federal Reserve, CBO and own calculations*

3.2.4 A comparison of the dummy variables for CB credibility

A comparison of the CB credibility measures - and thereby their identification of CB credibility for different episodes during the Greenspan era - shows at first sight that they are not perfectly aligned in their attribution of credibility to the policymaker. The FFB- measure predominantly shows indifference to either regime for the episode 1987-94, while the IB- measure shows a transition from an uncredible policymaker to a credible policymaker in this period, which is somewhat supported by the IP- measure under the allowance for flexibility for CB credibility to the policymaker. Low (real) interest rates during the eighties might have caused spurious increases in inflation and therefore the inflation bias, which increased inflation persistency in the late eighties. The policymaker might have been perceived as credible during most of the 1988-91 period where federal funds rates were higher than the implicit target rate. However, with increasing inflation in 1989-90 real interest rates did not increase until 1991, but did (somewhat) lower inflation persistency in the subsequent periods. As a result, the decline in inflation rates from 1990-93/94 has reduced inflation persistency while Greenspan (somewhat) kept the federal funds rate around the implicit target rate. It can therefore be argued that Greenspan was perceived as credible in the late eighties to first- nineties and has therefore significantly reduced inflation pressure and expectations of future inflation rates accordingly. Unfortunately, the results of his credible policy are then only observed until after a 2-3 years when both inflation and inflation persistency levels are significantly reduced to adequate levels, e.g. around the target rate with relatively low inflation persistency.

The second period of interest is the period 1994-2000. While the FFB- measures indicates a period of a credible CB from 1994-98 (or 1994-01 with the flexibility of CB credibility), which is largely supported by the IB- measure, the IP- measure indicates that it is one of a lack of CB credibility. While Greenpan's efforts to stabilize and decrease inflation rates by means of targeting a federal funds rate higher than its implied target from 1994-98, his regime suffered from relatively high inflation persistency, while inflation rates plunged. One explanation however is that the IB- measure relies on forecast data for (future) inflation rates, while the IP-measure is based on Vintage real-time inflation rates observations. While financial markets therefore might have forecasted lower (future) inflation rates that reduced the inflation bias, actual inflation rates that were made public real-time would still argue that inflation rates had a relatively high persistency. With federal funds rates above and around its target rate, and forecasted inflation rates at and under its target rate, it would however be likely that Greenspan's policy were to be perceived as being credible.

The third period of interest is the period 2000-05. While the FFB- measure shows that Greenspan kept the level of the federal funds rate below its target level, (forecasted) inflation rates were well below its target level, while inflation persistency dropped significantly. However, this might be due to the economic slowdown [after 2001] where financial markets might have expected Greenspan to pursue a (highly) expansionary policy in order to keep the economy going, while inflation rates were expected to decrease as a result of a reduction in demand. Important therefore might be that the decline in real interest rates did not increase expected inflation until 2004. Lower expected inflation and relatively low inflation persistency may strongly suggest that Greenspan was perceived as being a credible policymaker, provided that lower than implied federal funds rates where necessary to stimulate economic growth.

Table 3.1 provides a Pearson correlation matrix (with a Phi- coefficient as output) of the three dummy variables, and the *p*-values of the Likelihood ratio Chi-square test for independence. It shows that the credibility measures are only slightly to moderately correlated, but that the *null*-hypothesis for independence between the credibility measures is uniformly rejected. Note that the FFB and IP dummies have the highest correlation (phi- coefficient = 0,40), while both (more strongly) inflation-based measures (e.g. the IB- and IP- dummies) are only slightly correlated (phi- coefficient = 0,23). Additionally, the IB dummy is equally correlated with both the FFB- and IP- dummy variable. Interestingly, while the performance according to a policy rule does rely on the performance to stabilize inflation around its target, observations that would intuitively imply that the policymaker is successful in doing so (e.g. higher federal funds rate than the target rate) is not very much correlated with the (objectives/) effects of such a policy (e.g. does not imply that inflation will be below its target). The effects might only be visible in the longer-run.

Table 3.1

Correlation between the dummy variables for CB credibility

DUMMY	Correlation Matrix					
	FFB		IB		IP	
FFB	1,00		0,23	(0,05)	0,40	(0,00)
IB	0,23	(0,05)	1,00		0,23	(0,05)
IP	0,40	(0,00)	0,23	(0,05)	1,00	

Notes:

[a] The FFB, IB and IP respectively represent the dummy variables with the value “0” for an uncredible regime and “1”for a credible regime. Presented values are Phi- coefficients. In addition, *p*-values of the Likelihood ratio Chi- square test are in parenthesis.

Source: *Authors calculations*

To complete the comparison, Table 3.2 provides the correlation matrix when using the option for flexibility for CB credibility.

Table 3.2

Correlation between the dummy variables for CB credibility with flexibility for credibility

DUMMY	Correlation Matrix					
	FFB		IB		IP	
FFB	1,00		0,03	(0,78)	0,11	(0,35)
IB	0,03	(0,78)	1,00		0,21	(0,07)
IP	0,11	(0,35)	0,21	(0,07)	1,00	

Notes:

[a] See Table 3.1. The FFB and IB dummies are however now adjusted for flexibility for CB credibility, according to equations 3.12 and 3.15.

Source: *Authors calculations*

Table 3.2 shows that the correlation between the dummy variables has become weaker. Additionally, the *p*-values for the tests of independence suggest only significance at the 10%- confidence level for the IP and IB dummies.

A note however on the correlation between the dummy variables is that the three measures rely on different suggestions within the literature on how one can measure CB credibility. Low correlation between the three measures therefore does not suggest that they are wrong, or that only one might be correct, but they simply reflect different perceptions of CB credibility. As it is unknown which performance measure (e.g. rule, bias, or persistency) economic agents prefer above another, only the level of the impact of surprise policy actions to interest rates when controlling for either three perception of credibility, can possibly argue in favour of one measure above the other. This is moreover supported by the fact that - for the environment without the flexibility for credibility – all three dummies do not move independent of each other, e.g. the performance measures are related to each other in their opinion whether or not the CB can indeed be perceived as being credible or not.

3.3 The influence of the business cycle

One of the problematic situations economic agents and CBs faces is an economic environment where it would be increasingly difficult to correctly anticipate CB actions. The easiest example is the situation of external events, such as a (sudden) crisis. Under a non-transparent and ambiguous policymaker it would then be increasingly difficult for economic agents to correctly anticipate CB target rate changes and anticipate future policy actions, which result in bigger surprise target rate changes and also higher responses to surprise target rate changes. This case is somewhat different from the case of CB credibility. Even if the CB is perceived as being credible the uncertain nature of the "state of the world' would still allow short term surprises to have an impact on medium and long term interest rates. To verify this fact, we hypothesise that differentiating responses to policy actions for economic recession vis-a-vis economic expansion would stylize this difference. For example, Basistha and Kurov (2008) have analyzed the influence of the economic environment on the response in stock market returns due to monetary shocks. They find that the impact of monetary shocks on the size of the response in stocks returns in times of economic recessions is almost twice as large as in times of good economic conditions. This suggests that the business cycle influences the behaviour of financial markets in their response to monetary policy actions.

To control for the business cycle this paper uses a 3-month moving average of the CFNAI- index to address whether it can be expected that the economy is in a recession or in an economic expansion, in line with the Federal Reserve Background release and the Chicago Fed Letter (2002). The main reason to use the CFNAI-index is that it contains real-time data, different from for example data on GDP, which only becomes available ex-post to the (surprise) policy event.[31] According to the Fed Background Release a recession is defined as the situation when the 3-month moving average falls below -0,7 and defined as an economic expansion when it reaches the value 0,2. Consistent with Evans *et al.* (2002) and Basistha and Kurov (2008) the recession period is therefore the period when

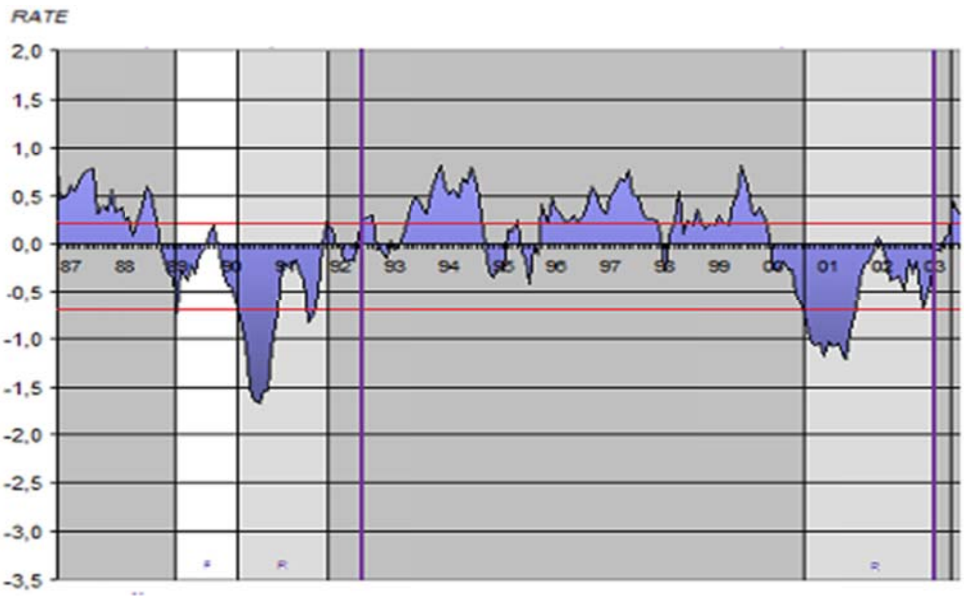
[31] As a means of comparison, figure A.6 in the Appendix provides a detailed overview of the development of real GDP and the resulting discrimination between an economic expansion and a recession.

the CFNAI-index falls below the value -0,7 until it reaches the value 0,2, while an economic expansion is the period when the CFNAI-index is higher than 0,2 until it falls below the value -0,7.

To analyse the impact of CB credibility we will sample the responses to (surprise) policy actions according to the state dependencies of δ_{CYCLE}, namely "0" (for a recession) and "1" (for an expansion). Figure 3.4 provides a detailed overview of the development of the 3- month CFNAI-index and the resulting differentiation for δ_{CYCLE}. Figure 3.4 shows the resulting recession periods in the Greenspan era, being 10/03/1990 until 12/23/1992 and 03/20/2001 until 10/18/2003. Other periods are therefore denoted as periods of economic expansion.

Figure 3.4

State of the U.S. economy by the development of the 3-month moving average of the CFNAI index and the timing of recession dates



Notes:

[a] Figure 3.4 shows the development of the 3-month CFNAI- index moving average. The horizontal red lines represent the Fed thresholds for the timing of the start and end of a recession by means of the statistical truning point of a business cycle. A recession begins when the 3-month CFNAI- index moving average breaks through the -0,7 barrier, while it has ended when the index breaks through the 0,2 barrier. The vertical lines represent the start end end of the recession periods accordingly. As this paper values the true real-time observation for recession and economic expansion dates known to financial markets, we also show a purple vertical line that represents the end of recessions as they were made public by the National Bureau of Economic Research (NBER). The arguments is that NBER publications sometimes lead the statistical end of a recession times by the 3-month CFNAI- index moving average. The result is that the real-time observation should be represented by the official publication by the NBER instead of financial markets still anticipating on real-time observations from the CFNAI- index.

CHAPTER 4 Results

This chapter will show the results of our study. As stated CB credibility is measured by the policymaker's performance according to (1) *a policy rule*, (2) *the deviation of inflation from its target, and* (3) *inflation persistency*. This paper will first address the impact of CB credibility by using each credibility measure in their respective order as above. Section two will than show the results when the impact of surprise policy actions is also measured from the outcome of Fed meeting days in general, without the necessity that a target rate change had actually occurred.

4.1 CB credibility and Federal Reserve surprise target rate changes

4.1.1 CB credibility measured by the Federal Funds Bias (FFB)

Table 4.1 provides the results for the response in Federal funds futures rates while applying the state dependency for CB credibility using model 3.11, the case without allowing for flexibility for the policymaker. The table shows that the response to surprise target rate changes is significantly higher for both the Eurodollar and Fed fund futures case. In addition, the coefficient for the anticipated target rate change is close to zero as expected, but is moreover only significant in an uncredible environment for the long term maturities. The R^2 is uniformly relatively high, but higher for the uncredible CB environment. In addition, the standard errors of the regressions are uniformly relatively low, but lower for the credible CB environments for short term maturities, and higher for medium to long term maturities.

As expected, the coefficient for the unanticipated target rate change in the credible CB environment quickly decreases and approaches zero as maturity increases. In contrast, the coefficient in the uncredible state dependence remains relatively high. This might indeed suggest that the response to surprise target rate changes in the uncredible CB environment suffers from higher (future) expected inflation rates, increasing longer-term interest rates accordingly. As expected, credible CB suffer far less altered inflation expectations as it is assumed that the policymaker is credible as an anti-inflation targeter, reducing the impact of surprises on longer-term interest rates. Under the assumption that private information on behalf of the Fed introduces increased (future) inflation expectations, credible policymakers will suffer less interest rate volatility from short-term price shocks that are incorporated in the term structure of interest rates.

An interesting fact is that the intercept - representing the (expected) mean change in the interest rate when both the anticipated and the unanticipated target rate changes are zero (e.g. the average change in the interest rate) - is uniformly negative for the credible CB, but positive for the uncredible CB for medium and long-term interest rates. This is however only the case for Eurodollar deposit rates, while the coefficients lack statistical significance except for the credible CB for 3- and 6-month maturity. As such, even in the absence of a target rate change, the average interest rate increases. Another interesting fact is that the coefficient for the anticipated target rate change for the long term maturities is significantly negative, as suggested. This might indeed suggest that in an uncertain environment financial markets reduce risk- premia for long term interest rates when the policymaker performs as expected. In other words they correct themselves for anticipating a too high premium. In contrast, as expected, the impact of the anticipated target rate change is uniformly roughly zero in the credible CB environment, but however not significant.

Table 4.1

Response to Fed target rate changes with CB credibility measured by the Federal Funds Bias (FFB)

Panel A: Response in eurodollar deposit rates

	CREDIBLE					UNCREDIBLE				
	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.
3-month	-2,27 ***	0,06	0,45 *	0,53	7,3	-2,14 *	0,05 **	0,89 *	0,88	3,6
	(1,18)	(0,04)	(0,07)			(0,58)	(0,02)	(0,06)		
6-month	-1,93	0,08 ***	0,46 *	0,53	7,5	-1,49 **	0,01	0,90 *	0,84	4,1
	(1,22)	(0,04)	(0,07)			(0,66)	(0,02)	(0,06)		
12-month	-1,50	0,09 **	0,42 *	0,51	7,3	-0,40	-0,05 ***	0,89 *	0,76	4,9
	(1,20)	(0,04)	(0,07)			(0,81)	(0,03)	(0,08)		
2-year	-1,20	0,08 ***	0,31 *	0,37	7,2	1,18	-0,06	0,81 *	0,58	6,8
	(1,18)	(0,04)	(0,07)			(1,12)	(0,04)	(0,11)		
3-year	-0,75	0,06	0,25 *	0,28	7,3	0,26	-0,06	0,71 *	0,47	7,3
	(1,20)	(0,04)	(0,07)			(1,20)	(0,04)	(0,12)		
5-year	-0,50	0,03	0,19 *	0,16	7,7	-0,14	-0,06	0,72 *	0,51	6,9
	(1,26)	(0,05)	(0,07)			(1,13)	(0,04)	(0,11)		
7-year	-0,42	0,02	0,13 ***	0,08	7,8	0,33	-0,12 *	0,65 *	0,53	6,1
	(1,27)	(0,05)	(0,07)			(0,99)	(0,04)	(0,10)		
10-year	-0,38	0,01	0,09	0,04	7,4	0,38	-0,11 *	0,58 *	0,54	5,3
	(1,22)	(0,04)	(0,07)			(0,88)	(0,03)	(0,09)		
30-year	-0,85	0,00	0,05	0,02	6,7	-1,11	-0,14 *	0,50 *	0,67	4,3
	(1,09)	(0,04)	(0,06)			(0,83)	(0,03)	(0,07)		

Panel B: Response in federal funds futures rates

	CREDIBLE					UNCREDIBLE				
	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.
3-month	-2,99 *	0,01	0,69 *	0,62	6,6	-2,41 *	0,01	0,89 *	0,82	4,4
	(1,05)	(0,04)	(0,09)			(0,81)	(0,03)	(0,08)		
6-month	-2,67 **	0,03	0,71 *	0,64	6,6	-2,09 **	0,00	0,89 *	0,76	5,2
	(1,06)	(0,04)	(0,09)			(0,96)	(0,04)	(0,10)		
12-month	-2,12 **	0,04	0,67 *	0,64	6,4	-0,30	-0,08 ***	0,93 *	0,69	5,9
	(1,02)	(0,04)	(0,09)			(1,08)	(0,04)	(0,11)		
2-year	-1,56	0,04	0,49 *	0,46	6,7	1,48	-0,08	0,83 *	0,49	7,9
	(1,08)	(0,04)	(0,09)			(1,46)	(0,06)	(0,15)		
3-year	-1,03	0,03	0,40 *	0,35	7,0	0,71	-0,08	0,74 *	0,40	8,4
	(1,13)	(0,04)	(0,09)			(1,54)	(0,06)	(0,16)		
5-year	-0,73	0,01	0,30 *	0,19	7,6	0,01	-0,08	0,72 *	0,41	8,1
	(1,22)	(0,05)	(0,10)			(1,49)	(0,06)	(0,15)		
7-year	-0,53	0,00	0,22 **	0,10	7,7	0,52	-0,14 **	0,66 *	0,42	7,1
	(1,24)	(0,05)	(0,10)			(1,32)	(0,05)	(0,14)		
10-year	-0,42	0,00	0,15	0,06	7,4	0,39	-0,12 **	0,56 *	0,39	6,4
	(1,19)	(0,05)	(0,10)			(1,19)	(0,05)	(0,12)		
30-year	-0,82	0,00	0,06	0,01	6,6	-1,11	-0,16 *	0,48 *	0,45	5,6
	(1,06)	(0,04)	(0,09)			(1,39)	(0,05)	(0,13)		

Notes:

[a] Panel A and B show the results for estimating model 3.5, while adjusting the sample according to the state dependence of CB credibility by using model 3.11. Panel A than shows the results when surprise target rate changes are measures by 1-month Eurodollar deposit rates to allow us to estimate the entire Greenspan period, while Panel B applies federal fund futures rate which contain observations for the period 10/20/1988 until 12/13/2005 only. For the Eurodollar deposit rates the sample contains 90 observations of Federal Reserve target rate changes for all maturities except the 30-year bond which contains 75 observations. The state dependence for CB credible than leads to 46 observations for a credible regime for all maturities, while the sample contains 44 observations for an uncredible regime except for the 30-year bond which contains 29 observations. For the Federal Funds Futures the sample contains 81 observations for Federal Reserve target rate changes for all maturities but the 30-year bond which contains 66 observations. The state dependence for CB credibility leads to 45 observations for a credible regime for all maturities, while the sample contains 36 observations for an uncredible regime for all maturities but the 30-year bond which contains 21 observations.

[b] A *, ** and *** respectively represent statistical significance at the 99%, 95% and 90% confidence level. Standard errors are in parenthesis.

If we adjust the situation to the case where the policymaker is allowed for flexibility (e.g. using model 3.12) the results are in general the same.[32] However, for the credible state dependence the intercept is somewhat higher (more negative) for all maturities, but only significant for the 3-month, 6-month, 1-year and 30-year maturity for both the Eurodollar and Federal funds futures rates, and for the 5-year maturity only for the Eurodollar case. For the uncredible state dependence the intercept is also higher (more positive) and now also significant for the 2-yr (Eurodollar and Fed futures), 3-yr (Eurodollar) and 30-yr bonds (Eurodollar). In addition, the coefficient for the unanticipated component of the target rate change is also somewhat higher and significant for all maturities. However, the coefficients for the uncredible state dependence are not significant for the intercept and both the anticipated and the unanticipated target rate changes. The exception to this is the 30-yr bond in the Eurodollar case where all coefficients are significant at the lowest level, while the intercept is highly positive, in favour of the theory. The response to the unanticipated target rate change is however highly negative, in contrast to the theory.

The results therefore suggest that a differentiation of the response environment to the state dependence of CB credibility significantly changes the consensus on the impact of surprise target rate changes. It shows that uncredible CBs suffer from bigger shocks to the yield curve due to surprise target rate changes vis-à-vis credible CBs. Uncredible CBs are accompanied by higher mean and volatility of interest rates, while in general CB actions in such an environment result in relatively high shocks to interest rates. Alternatively, the results show that a CB that provides an anchor for economic agents by communicating a (simple) policy rule, while showing commitment to this rule, will benefit from lower mean and volatility in interest rates, potentially increasing financial stability altogether.

4.1.2 CB credibility measured by the Inflation Bias (IB)

Table 4.2 provides the results for estimating model 3.5 when CB credibility is measured by the inflation bias while using the outcome of model 3.14. The results are comparable to the results from Table 4.1, with the exception that the intercept in the uncredible CB environment remains negative for all maturities, but is still however higher (less negative). In addition, the coefficient for the surprise response in the credible CB environment not only approaches zero but also becomes negative for the long term maturities and is statistically significant for the 30-year maturity.

The results for the case when we include the possibility of flexibility for the policymaker (e.g. using model (3.15) do not change the general results.[33] One observation that can be made is that this method seems less able to capture the suggested implications of state dependency for CB credibility vis-à-vis the case without CB flexibility. The coefficients for the response to surprise target rate changes increases for credible CB environments, but somewhat decrease for uncredible policies,

[32] Detailed results are available upon request. For Fed fund future rates the sample contains 52 observations for credible CB regimes for all maturities except for the 30-year bond which contains 43 observations. For uncredible regimes the sample contains 10 observations for all maturities except for the 30-year bond which contains only 4 observations. For Eurodollar deposit rates the sample contains 61 observations for credible regimes for all maturities except the 30-year bond which contains 52 observations. For uncredible regimes the sample contains 10 observations for all maturities except for the 30-year bond which contains only 4 observations.

[33] Detailed results are available upon request. For Fed fund future rates the sample contains 54 observations for credible CB regimes for all maturities except for the 30-year bond which contains 39 observations. For uncredible regimes the sample contains 27 observations for all maturities. For Eurodollar deposit rates the sample contains 55 observations for credible regimes for all maturities except the 30-year bond which contains 40 observations. For uncredible regimes the sample contains 35 observations for all maturities.

while the latter still remains significantly higher. In addition, this is accompanied by lower R^2 and (somewhat) lower significance levels. However, for the federal fund futures rate the value of the intercept for the uncredible state dependence is positive for all maturities, while being negative for the credible state dependence, as the theory from section two suggests. The intercept however remains insignificant. Therefore the general implication of the results for the credible vis-à-vis the uncredible policymaker remain the same.

Table 4.2

Response to Fed target rate changes with CB credibility measured by the Inflation Bias (IB)

Panel A: Response in eurodollar deposit rates

	CREDIBLE					UNCREDIBLE				
	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.
3-month	-3,61 **	0,05	0,50	0,48	7,5	-1,25	0,06 ***	0,59 *	0,73	5,4
	(1,33)	(0,04)	(0,09)			(0,81)	(0,04)	(0,06)		
6-month	-3,13 **	0,06	0,44 *	0,49	6,7	-0,82	0,03	0,64 *	0,69	6,3
	(1,20)	(0,04)	(0,08)			(0,94)	(0,04)	(0,07)		
12-month	-1,84	0,03	0,35 *	0,32	7,4	-0,91	0,02	0,63 *	0,68	6,3
	(1,32)	(0,04)	(0,09)			(0,95)	(0,04)	(0,07)		
2-year	-0,16	0,04	0,19 ***	0,11	8,5	-0,18	-0,01	0,58 *	0,64	6,2
	(1,51)	(0,05)	(0,11)			(0,93)	(0,04)	(0,06)		
3-year	0,48	0,03	0,14	0,06	8,5	-0,28	-0,03	0,51 *	0,52	6,7
	(1,52)	(0,05)	(0,11)			(1,01)	(0,04)	(0,07)		
5-year	-1,09	0,01	0,07	0,02	8,4	0,30	-0,06	0,49 *	0,48	6,8
	(1,49)	(0,05)	(0,10)			(1,03)	(0,04)	(0,07)		
7-year	-1,23	-0,02	0,00	0,01	7,3	0,56	-0,09 ***	0,42 *	0,39	7,1
	(1,31)	(0,04)	(0,09)			(1,07)	(0,04)	(0,07)		
10-year	-1,11	-0,02	-0,05	0,02	6,5	0,63	-0,09 **	0,37 *	0,36	6,7
	(1,15)	(0,04)	(0,08)			(1,01)	(0,04)	(0,07)		
30-year	-3,60 *	-0,06	-0,16 **	0,29	4,7	0,17	-0,11 *	0,32 *	0,35	6,1
	(1,20)	(0,03)	(0,06)			(0,93)	(0,04)	(0,06)		

Panel B: Response in federal fund futures rates

	CREDIBLE					UNCREDIBLE				
	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.
3-month	-3,31 **	0,02	0,70 *	0,56	6,9	-2,30 *	0,01	0,80 *	0,80	4,8
	(1,23)	(0,04)	(0,11)			(0,74)	(0,04)	(0,07)		
6-month	-2,87 **	0,03	0,62 *	0,57	6,2	-2,30 **	-0,01	0,90 *	0,77	5,7
	(1,11)	(0,04)	(0,10)			(0,88)	(0,04)	(0,09)		
12-month	-1,51	0,00	0,54 *	0,43	6,7	-2,00 **	-0,02	0,91 *	0,79	5,4
	(1,21)	(0,04)	(0,11)			(0,84)	(0,04)	(0,08)		
2-year	0,17	0,01	0,34 **	0,18	8,2	-1,28	-0,03	0,80 *	0,68	6,1
	(1,46)	(0,05)	(0,13)			(0,94)	(0,04)	(0,09)		
3-year	-0,20	0,01	0,26 ***	0,10	8,3	-1,01	-0,06	0,73 *	0,58	6,6
	(1,49)	(0,05)	(0,14)			(1,02)	(0,05)	(0,10)		
5-year	-0,80	-0,01	0,18	0,05	8,2	-0,61	-0,08	0,67 *	0,48	7,2
	(1,47)	(0,05)	(0,14)			(1,14)	(0,06)	(0,11)		
7-year	-0,98	-0,03	0,08	0,03	7,3	-0,22	-0,11 ***	0,60 *	0,40	7,4
	(1,30)	(0,04)	(0,12)			(1,14)	(0,06)	(0,12)		
10-year	-0,89	-0,03	0,02	0,03	6,5	-0,17	-0,10 ***	0,51 *	0,34	7,1
	(1,16)	(0,04)	(0,11)			(1,10)	(0,05)	(0,11)		
30-year	-3,47 **	-0,05	-0,16 ***	0,24	4,9	-0,49	-0,10 ***	0,41 *	0,27	6,5
	(1,24)	(0,04)	(0,08)			(1,04)	(0,05)	(0,10)		

Notes:

[a] Panel A and B show the results for estimating model 3.5, while adjusting the sample according to the state dependence of CB credibility by using model 3.14. For the Eurodollar deposit rates the sample contains 90 observations of Federal Reserve target rate changes for all maturities except the 30-year bond which contains 75 observations. The state dependence for CB credible than leads to 35 observations for a credible regime for all maturities, except for the 30-yr bond which contains 22 observations. The sample contains 55 observations for an uncredible regime except for the 30-year bond which contains 53 observations. For the Federal Funds Futures the sample contains 81 observations for Federal Reserve target rate changes for all maturities but the 30-year bond which contains 66 observations. The state dependence for CB credibility leads to 35 observations for a credible regime for all maturities, expect for the 30-yr bond which contains 22 observations. The sample contains 46 observations for an uncredible regime for all maturities, except for the 30-year bond which contains 44 observations.

[b] A *, ** and *** respectively represent statistical significance at the 99%, 95% and 90% confidence level. Standard errors are in parenthesis.

4.1.3 CB credibility measured by Inflation Persistency (IP)

Table 4.3 provides the results for the estimation of model 3.5 where model 2.18 is used for the state dependency of CB credibility. The results are quite the same as in the previous cases, hence not changing the overall implications of CB credibility. The exception is that for the federal funds futures case mean interest rates remain negative and relatively high for all maturities for both the credible and uncredible CB environment. The intercept however remains statistically insignificant for the medium and long run, with the exception of the 30-year bond for the credible CB environment, which is also relatively very high and very much smaller than in the uncredible environment.

Table 4.3

Response to Fed target rate changes with CB credibility measured by Inflation Persistency (IP)

Panel A: Response in eurodollar deposit rates

	CREDIBLE					UNCREDIBLE				
	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.
3-month	-2,27 **	0,08 **	0,49 *	0,69	5,4	-2,23 ***	0,04	0,68 *	0,56	6,9
	(0,97)	(0,03)	(0,05)			(1,12)	(0,05)	(0,10)		
6-month	-2,72 *	0,09 *	0,49 *	0,69	5,5	-0,82	0,00	0,67 *	0,51	7,3
	(0,99)	(0,03)	(0,05)			(1,17)	(0,05)	(0,10)		
12-month	-1,69	0,05	0,47 *	0,55	6,9	-1,03	0,01	0,63 *	0,50	6,9
	(1,23)	(0,04)	(0,07)			(1,12)	(0,05)	(0,10)		
2-year	-0,65	0,06	0,35 *	0,32	8,4	-0,05	-0,01	0,60 *	0,51	6,5
	(1,50)	(0,05)	(0,08)			(1,05)	(0,04)	(0,09)		
3-year	-0,84	0,05	0,28	0,22	8,7	-0,25	-0,03	0,53 *	0,43	6,7
	(1,55)	(0,05)	(0,09) *			(1,08)	(0,04)	(0,09)		
5-year	-1,20	0,03	0,21 **	0,13	8,7	0,17	-0,07	0,54 *	0,44	6,6
	(1,55)	(0,05)	(0,09)			(1,06)	(0,04)	(0,09)		
7-year	-1,23	0,00	0,13	0,06	7,9	0,29	-0,09 ***	0,48 *	0,38	6,9
	(1,41)	(0,05)	(0,08)			(1,11)	(0,05)	(0,10)		
10-year	-0,97	0,00	0,09	0,04	7,4	0,17	-0,08 **	0,42 *	0,36	6,3
	(1,32)	(0,04)	(0,07)			(1,02)	(0,04)	(0,09)		
30-year	-4,61	-0,09	-0,05	0,05	7,0	-0,33	-0,10 *	0,37 *	0,38	5,5
	(2,53) ***	(0,07)	(0,09)			(0,89)	(0,04)	(0,08)		

Panel B: Response in federal funds futures rates

	CREDIBLE					UNCREDIBLE				
	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.
3-month	-2,31 *	0,03	0,67 *	0,79	4,5	-4,13 *	0,00	1,19 *	0,69	6,1
	(0,79)	(0,03)	(0,06)			(1,04)	(0,04)	(0,15)		
6-month	-2,81 *	0,04	0,66 *	0,76	4,8	-3,07 *	-0,02	1,19 *	0,66	6,5
	-0,85	(0,03)	(0,06)			(1,10)	(0,05)	(0,16)		
12-month	-1,70	0,00	0,66 *	0,65	6,1	-2,85 *	-0,01	1,15 *	0,69	5,8
	(1,07)	(0,04)	(0,08)			(1,00)	(0,04)	(0,14)		
2-year	-0,58	0,01	0,50 *	0,39	7,9	-1,57	-0,02	1,01 *	0,59	6,2
	(1,40)	(0,050	(0,10)			(1,07)	(0,05)	(0,15)		
3-year	-0,71	0,00	0,42 *	0,29	8,3	-1,42	-0,04	0,90 *	0,50	6,7
	(1,46)	(0,05)	(0,11)			(1,14)	(0,05)	(0,16)		
5-year	-0,95	-0,01	0,35 *	0,21	8,3	-1,13	-0,06	0,81 *	0,39	7,3
	(1,46)	(0,05)	(0,11)			(1,25)	(0,05)	(0,18)		
7-year	-1,02	-0,04	0,24 **	0,13	7,6	-0,93	-0,09 ***	0,80 *	0,38	7,3
	(1,35)	(0,05)	(0,10)			(1,24)	(0,05)	(0,18)		
10-year	-0,79	-0,04	0,18 ***	0,09	7,2	-0,98	-0,08 ***	0,69 *	0,35	6,7
	(1,27)	(0,04)	(0,09)			(1,14)	(0,05)	(0,16)		
30-year	-4,63 ***	-0,11	0,00	0,07	7,0	-1,27	-0,08 ***	0,48 *	0,25	6,0
	(2,48)	(0,08)	(0,11)			(1,02)	(0,04)	(0,14)		

Notes:

[a] Panel A and B show the results for estimating model 3.5, while adjusting the sample according to the state dependence of CB credibility by using model 3.18. For the Eurodollar deposit rates the sample contains 90 observations of Federal Reserve target rate changes for all maturities except the 30-year bond which contains 75 observations. The state dependence for CB credible than leads to 44 observations for a credible regime for all maturities, except the 30-year bond which contains 29 observations. The sample contains 46 observations for an uncredible regime for all maturities. For the Federal Funds Futures the sample contains 81 observations for Federal Reserve target rate changes for all maturities but the 30-year bond which contains 66 observations. The state dependence for CB credibility leads to 44 observations for a credible regime for all maturities except the 30-year bond which contains 29 observations. The sample contains 37 observations for an uncredible regime for all maturities.

[b] A *, ** and *** respectively represent statistical significance at the 99%, 95% and 90% confidence level. Standard errors are in parenthesis.

4.2 CB credibility and Federal Reserve meeting day surprises

4.2.1 CB credibility measured by the Federal Funds Bias (FFB)

Table 4.4

Response to Fed meeting days with CB credibility measured by the Monetary Reaction function (MRF)

Panel A: Response in eurodollar deposit rates

	CREDIBLE					UNCREDIBLE				
	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.
3-month	-1,63 *	0,05	0,48 *	0,51	5,7	-2,17 *	0,06 *	0,82 *	0,78	3,5
	(0,61)	(0,03)	(0,05)			(0,40)	(0,02)	(0,05)		
6-month	-1,30 **	0,07 **	0,49 *	0,53	5,7	-1,43 *	0,02	0,84 *	0,75	3,8
	(0,61)	(0,03)	(0,05)			(0,42)	(0,02)	(0,06)		
12-month	-0,76	0,09 *	0,45 *	0,53	5,5	-0,69	-0,03	0,81 *	0,62	4,7
	(0,58)	(0,03)	(0,05)			(0,53)	(0,03)	(0,07)		
2-year	-0,69	0,06 ***	0,35 *	0,38	5,5	0,05	-0,03	0,71 *	0,38	6,8
	(0,59)	(0,03)	(0,05)			(0,76)	(0,04)	(0,10)		
3-year	-0,36	0,05	0,29 *	0,30	5,6	-0,40	-0,04	0,64 *	0,31	7,2
	(0,60)	(0,03)	(0,05)			(0,80)	(0,04)	(0,11)		
5-year	-0,30	0,01	0,23 *	0,18	6,0	-0,49	-0,05	0,64 *	0,33	6,9
	(0,64)	(0,03)	(0,05)			(0,77)	(0,04)	(0,10)		
7-year	0,01	0,01	0,16 *	0,10	5,8	-0,14	-0,10 *	0,60 *	0,33	6,2
	(0,62)	(0,03)	(0,05)			(0,70)	(0,04)	(0,09)		
10-year	0,00	0,00	0,11 **	0,06	5,6	-0,08	-0,09 *	0,51 *	0,33	5,5
	(0,60)	(0,03)	(0,05)			(0,62)	(0,03)	(0,08)		
30-year	-0,32	0,00	0,08 ***	0,03	5,1	-0,32	-0,12 *	0,44 *	0,44	4,7
	(0,55)	(0,03)	(0,04)			(0,66)	(0,03)	(0,08)		

Panel B: Response in federal funds futures rates

	CREDIBLE					UNCREDIBLE				
	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.
3-month	-1,88 *	0,02	0,72 *	0,58	5,4	-1,91 *	0,01	0,88 *	0,77	3,6
	(0,57)	(0,03)	(0,06)			(0,43)	(0,02)	(0,06)		
6-month	-1,62 *	0,04	0,75 *	0,63	5,1	-1,57 *	-0,01	0,89 *	0,70	4,2
	(0,55)	(0,03)	(0,06)			(0,51	(0,03)	(0,07)		
12-month	-1,04	0,04	0,70 *	0,63	4,9	-0,54	-0,08 **	0,91 *	0,62	4,9
	(0,52)	(0,03)	(0,06)			(0,60)	(0,03)	(0,09)		
2-year	-0,84	0,04	0,52 *	0,43	5,4	0,20	-0,06	0,78 *	0,36	7,2
	(0,57)	(0,03)	(0,07)			(0,88)	(0,05)	(0,13)		
3-year	-0,48	0,03	0,43 *	0,34	5,4	-0,17	-0,07	0,70 *	0,28	7,6
	(0,58)	(0,03)	(0,07)			(0,93)	(0,06)	(0,14)		
5-year	-0,43	0,00	0,33 *	0,19	6,0	-0,46	-0,07	0,70 *	0,30	7,3
	(0,63)	(0,04)	(0,07)			(0,89)	(0,05)	(0,13)		
7-year	-0,08	0,00	0,24 *	0,12	5,8	-0,12	-0,13 *	0,62 *	0,29	6,6
	(0,61)	(0,03)	(0,07)			(0,81)	(0,04)	(0,12)		
10-year	-0,05	-0,01	0,18 **	0,07	5,6	-0,15	-0,11 **	0,52 *	0,26	5,9
	(0,59)	(0,03)	(0,07)			(0,72)	(0,04)	(0,11)		
30-year	-0,36	0,00	0,08 ***	0,02	5,1	-0,26	-0,16 *	0,50 *	0,41	4,6
	(0,54)	(0,03)	(0,04)			(0,76)	(0,04)	(0,10)		

Notes:

[a] Panel A and B show the results for estimating model 3.5, while adjusting the sample according to the state dependence of CB credibility by using model 3.11. However, now we include Federal Reserve meeting days where not necessarily a target rate change has occurred, but may be anticipated. As a result, for the Eurodollar deposit rates the sample now contains 183 observations of Federal Reserve target rate changes for all maturities except the 30-year bond which contains 152 observations. The state dependence for CB credible than leads to 98 observations for a credible regime for all maturities, while the sample contains 85 observations for an uncredible regime except for the 30-year bond which contains 54 observations. For the Federal Fund Futures the sample contains 169 observations for Federal Reserve target rate changes for all maturities but the 30-year bond which contains 138 observations. The state dependence for CB credibility leads to 96 observations for a credible regime for all maturities, while the sample contains 73 observations for an uncredible regime for all maturities but the 30-year bond which contains 42 observations.

[b] A *, ** and *** respectively represent statistical significance at the 99%, 95% and 90% confidence level. Standard errors are in parenthesis.

Table 4.4 provides the results for the response in interest rates to meeting day surprises controlled for the state dependency of CB credibility using model 3.11, the case without CB flexibility. The general conclusions from the results are quite the same as the results for the response in the target rate change only. The response to surprise target rate changes is significantly higher for uncredible CB environments vis-à-vis uncredible CB environments. Second, for the uncredible CB environment the impact of the anticipated target rate change is negative and significant for medium to long term maturities, while being zero (however not significant) for the credible CB environment, as expected. However, the intercept shows some indifference to whether mean interest rates are higher in uncredible CB environments.

If we allow for CB flexibility according to model 3.12 the general conclusions are somewhat different.[34] While for the credible CB environment the results are generally in line with other results, the results for the uncredible CB environment are almost uniformly insignificant with unexpected signs. This might indicate that the allowance for flexibility for policymakers to be able to deviate from the target without suffering from credibility, lacks the ability to grasp the implications of uncredible CBs, or that it might require an alternative measure.

An interesting outcome of the results is that the response to surprise meeting day actions - considering possible target rate changes - has an almost equal effect on interest rates as actual changes in the target.

4.2.2 CB credibility measured by the Inflation Bias (IB)

Table 4.5 provides the results for the response in interest rates to Fed meeting day surprises controlled for the state dependency of CB credibility using model 3.14. The results are virtually the same to the responses to target rate changes and quite the same as the other results in general, hence not changing the overall implications of CB credibility.

If we allow for CB flexibility according to model 3.15, the general conclusions still remain the same.[35] However, in this case CB flexibility seems to improve the significance levels of the coefficients for the credible CB environment, in contrast to our FFB measure. For both the Eurodollar and the Fed fund futures, the significance levels for the medium and long term bonds improve for the credible environment, while the coefficient is also higher and significant at the highest level for all maturities, except for the 30-year bond where the coefficient is significant at respectively the 90% and 95% significance level for the Eurodollar and the Fed fund futures case. For the credible environment, the R^2 is also higher for the short term bonds, but is however lower for the medium to long run maturities. For the uncredible environment the R^2 is lower for all maturities. In addition, while the intercept for the uncredible environment without flexibility changes from negative to positive the intercept now already becomes positive at respectively the 2- and 7-year maturity for the Eurodollar and Fed fund futures case, in line with economic theory.

[34] Detailed results are available upon request. For the Eurodollar case the state dependence for CB credible now leads to 98 observations for a credible regime for all maturities, while the sample contains 85 observations for an uncredible regime except for the 30-year bond which contains 54 observations. The state dependence for CB credibility leads to 96 observations for a credible regime for all maturities, while the sample contains 73 observations for an uncredible regime for all maturities but the 30-year bond which contains 42 observations.

[35] Detailed results are available upon request. For the Eurodollar case the state dependence for CB credible now leads to 98 observations for a credible regime for all maturities, while the sample contains 85 observations for an uncredible regime except for the 30-year bond which contains 54 observations. For the Federal Fund Futures case the state dependence for CB credibility leads to 120 observations for a credible regime for all maturities, except the 30-year bond which contains 93 observations. The sample contains 49 observations for an uncredible regime for all maturities but the 30-year bond which contains 45 observations.

Table 4.5

Response to Fed meeting days with CB credibility measured by the Inflation Bias (IB)

Panel A Response in eurodollar deposit rates

	CREDIBLE					UNCREDIBLE				
	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.
3-month	-2,35 *	0,06 ***	0,50 *	0,45	5,7	-1,42 *	0,06 **	0,59 *	0,67	4,6
	(0,67)	-0,03	(0,07)			(0,47)	(0,03)	(0,04)		
6-month	-2,12 *	0,07 **	0,46 *	0,48	5,0	-0,72	0,03	0,65 *	0,66	5,1
	(0,59)	(0,03)	(0,06)			(0,52)	(0,03)	(0,05)		
12-month	-1,09	0,03	0,37 *	0,30	5,7	-0,60	0,02	0,63 *	0,65	5,0
	(0,68)	(0,03)	(0,07)			(0,51)	(0,03)	(0,05)		
2-year	-0,34	0,03	0,20 **	0,08	7,1	-0,32	0,00	0,57 *	0,58	5,3
	(0,84)	(0,04)	(0,08)			(0,54)	(0,03)	(0,05)		
3-year	-0,44	0,03	0,15 ***	0,04	7,3	-0,29	-0,02	0,50 *	0,47	5,6
	(0,87)	(0,04)	(0,09)			(0,57)	(0,03)	(0,05)		
5-year	-0,60	0,01	0,09	0,02	7,1	-0,06	-0,06	0,47 *	0,41	5,9
	(0,84)	(0,04)	(0,08)			(0,60)	(0,03)	(0,05)		
7-year	-0,51	-0,02	0,02	0,00	6,3	0,30	-0,08 **	0,40 *	0,34	5,8
	(0,75)	(0,03)	(0,08)			(0,59)	(0,04)	(0,05)		
10-year	-0,52	-0,02	-0,03	0,01	5,7	0,37	-0,08 **	0,35 *	0,31	5,5
	(0,67)	(0,03)	(0,07)			(0,56)	(0,03)	(0,05)		
30-year	-1,28	-0,03	-0,12 **	0,11	4,2	0,30	-0,10 *	0,31 *	0,31	5,0
	(0,67)	(0,03)	(-0,05)			(0,52)	(0,03)	(0,05)		

Panel B Response in federal funds futures rates

	CREDIBLE					UNCREDIBLE				
	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.
3-month	-2,25 *	0,03	0,69 *	0,51	5,4	-1,56 *	0,00	0,84 *	0,76	4,0
	(0,64)	(0,03)	(0,08)			(0,43)	(0,03)	(0,06)		
6-month	-2,02 *	0,03	0,64 *	0,55	4,6	-1,31 **	-0,01	0,92 *	0,72	4,7
	(0,55)	(0,03)	(0,07)			(0,50)	(0,03)	(0,07)		
12-month	-0,96	0,00	0,56 *	0,39	5,3	-1,03 **	-0,02	0,92 *	0,75	4,4
	(0,63)	(0,03)	(0,08)			(0,47)	(0,03)	(0,06)		
2-year	-0,21	0,01	0,33 *	0,12	6,9	-0,74	-0,03	0,80 *	0,62	5,1
	(0,82)	(0,04)	(0,11)			(0,55)	(0,04)	(0,07)		
3-year	-0,33	0,01	0,25 **	0,07	7,2	-0,54	-0,05	0,72 *	0,53	5,5
	(0,86)	(0,04)	(0,11)			(0,58)	(0,04)	(0,08)		
5-year	-0,47	-0,01	0,19 ***	0,04	7,0	-0,50	-0,08 ***	0,65 *	0,42	6,0
	(0,83)	(0,04)	(0,11)			(0,64)	(0,04)	(0,08)		
7-year	-0,40	-0,03	0,10	0,02	6,3	-0,09	-0,10 **	0,57 *	0,35	5,9
	(0,74)	(0,04)	(0,10)			(0,63)	(0,04)	(0,08)		
10-year	-0,41	-0,03)	0,03	0,02	5,7	-0,03	-0,09 **	0,49	0,30	5,6
	(0,67)	(0,03)	(0,09)			(0,60)	(0,04)	(0,08)		
30-year	-1,20 ***	-0,03	-0,10	0,07	4,3	-0,10	-0,09 **	0,38 *	0,23	5,2
	(0,68)	(0,03)	(0,07)			(0,56)	(0,04)	(0,07)		

Notes:

[a] Panel A and B show the results for estimating model 3.5, while adjusting the sample according to the state dependence of CB credibility by using model 3.11. For the Eurodollar case the state dependence for CB credible now leads to 75 observations for a credible regime for all maturities except for the 30-year bond which contains 46 observations. The sample contains 108 observations for an uncredible regime except for the 30-year bond which contains 106 observations. For the Federal Fund Futures case the state dependence for CB credibility leads to 75 observations for a credible regime for all maturities, except the 30-year bond which contains 46 observations. The sample contains 94 observations for an uncredible regime for all maturities but the 30-year bond which contains 92 observations.

[b] A *, ** and *** respectively represent statistical significance at the 99%, 95% and 90% confidence level. Standard errors are in parenthesis.

4.2.3 CB credibility measured by Inflation Persistency (IP)

Table 4.6 provides the results for the response in interest rates to Fed meeting day surprises controlled for the state dependency of CB credibility using model 3.18. The results and implications again remain the same in general. However, an improvement is the fact that the intercept is now positive for the medium and long term maturities, but however not significant. The intercept is however uniformly higher for uncredible CB environments. Also note that the impact of the anticipated component of the target rate change is uniformly negative for medium and long term rates in the uncredible CB environment, as expected.

Table 4.6

Response to Fed meeting days with CB credibility measured by Inflation Persistency (IP)

Panel A: Response in Eurodollar deposit rates

	CREDIBLE					UNCREDIBLE				
	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.
3-month	-1,98 *	0,08 *	0,50 *	0,70	4,1	-1,66 *	0,04	0,68 *	0,50	5,7
	(0,47)	(0,02)	(0,04)			(0,62)	(0,04)	(0,07)		
6-month	-2,00 *	0,09 *	0,51 *	0,70	4,3	-0,56	0,00	0,66 *	0,49	5,6
	(0,50)	(0,02)	(0,04)			(0,61)	(0,03)	(0,07)		
12-month	-1,18 **	0,05 ***	0,49	0,55	5,5	-0,43	0,00	0,61 *	0,47	5,3
	(0,63)	(0,03)	(0,05)			(0,58)	(0,03)	(0,07)		
2-year	-1,06	0,05	0,35 *	0,26	7,2	0,23	-0,01	0,58 *	0,46	5,1
	(0,84)	(0,04)	(0,07)			(0,56)	(0,03)	(0,07)		
3-year	-1,04	0,04	0,28 *	0,18	7,4	0,18	-0,03	0,51 *	0,38	5,4
	(0,86)	(0,04)	(0,07)			(0,58)	(0,03)	(0,07)		
5-year	-1,31	0,03	0,21 *	0,11	7,4	0,53	-0,07 **	0,51	0,23	5,9
	(0,85)	(0,04)	(0,07)			(0,59)	(0,03)	(0,07) *		
7-year	-1,07	-0,01	0,14 **	0,06	6,6	0,75	-0,09 **	0,44 *	0,31	5,6
	(0,77)	(0,04)	(0,06)			(0,60)	(0,03)	(0,07)		
10-year	-0,92	-0,01	0,10 ***	0,04	6,2	0,67	-0,08 **	0,39 *	0,30	5,2
	(0,72)	(0,03)	(0,06)			(0,66)	(0,03)	(0,07) *		
30-year	-1,60 ***	-0,02	0,03	0,01	5,5	0,47	-0,10 *	0,33 *	0,29	4,7
	(0,91)	(0,04)	(0,05)			(0,51)	(0,03)	(0,06)		

Panel B: Response in federal funds futures rates

	CREDIBLE					UNCREDIBLE				
	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.
3-month	-2,03 *	0,02	0,68 *	0,78	3,5	-1,94 *	0,00	1,07 *	0,56	5,4
	(0,40)	(0,02)	(0,04)			(0,62)	(0,04)	(0,11)		
6-month	-2,10 *	0,04 **	0,68 *	0,75	3,9	-1,28 **	-0,03	1,11 *	0,59	5,2
	(0,44)	(0,02)	(0,05)			(0,60)	(0,04)	(0,11)		
12-month	-1,24 **	0,00	0,68 *	0,63	4,9	-0,99 ***	-0,01	1,05 *	0,61	4,7
	(0,57)	(0,03)	(0,06)			(0,54)	(0,03)	(0,10)		
2-year	-1,05	0,00	0,51 *	0,33	6,9	-0,22	-0,01	0,87 *	0,47	5,2
	(0,79)	(0,04)	(0,08)			(0,60)	(0,04)	(0,11)		
3-year	-1,01	0,00	0,42 *	0,23	7,2	-0,11	-0,03	0,80 *	0,40	5,5
	(0,82)	(0,04)	(0,09)			(0,63)	(0,04)	(0,11)		
5-year	-1,23	-0,02	0,35 *	0,17	7,2	0,07	-0,06	0,72 *	0,31	5,9
	(0,82)	(0,04)	(0,09)			(0,67)	(0,04)	(0,12)		
7-year	-1,00	-0,04	0,25 *	0,11	6,5	0,33	-0,08 **	0,66 *	0,28	5,8
	(0,74)	(0,04)	(0,08)			(0,66)	(0,04)	(0,12)		
10-year	-0,86	-0,04	0,18 **	0,07	6,1	0,26	-0,08 **	0,59 *	0,27	5,3
	(0,69)	(0,04)	(0,07)			(0,61)	(0,04)	(0,11)		
30-year	-1,61 ***	-0,04	0,08	0,03	5,4	0,04	-0,08 **	0,39 *	0,18	4,8
	(0,90)	(0,04)	(0,07)			(0,55)	(0,03)	(0,10)		

Notes:

[a] For both the Eurodollar and the Federal funds futures case the state dependence for CB credible leads to 88 observations for a credible regime for all maturities, except the 30-year bond which contains 57 observations. For the Eurodollar case the sample contains 95 observations for an uncredible regime for all maturities. For the Federal Fund Futures the sample contains 81 observations for an uncredible regime for all maturities.

[b] A *, ** and *** respectively represent statistical significance at the 99%, 95% and 90% confidence level. Standard errors are in parenthesis.

4.3 The influence of the macro-economic environment to the response to policy surprises

This section will provide the results of the estimation of the impact of surprise policy actions on interest rates, conditional to the state dependence of the business cycle. This paper will first provide the results for the estimation result when using actual target changes only, followed by the estimation results when using data for meeting day surprises in general.

4.3.1 The state dependence of the business cycle and surprise target rate changes

Table 4.7 provides the results for estimating the impact of (surprise) policy actions conditional to the state dependence of the business cycle. It shows that the impact of surprise policy changes is almost uniformly higher for economic expansions vis-à-vis recessions. In addition, the coefficients for the impact of surprise target rate changes are moreover significant across interest rates, in contrast to the coefficients for the anticipated target rate change, which are (almost) uniformly not significant. At a first glance, there does not seem to be a very large difference between the two state dependencies of the business cycle.

Interesting however is the negative and statistically significant intercept in the expansionary state dependence for the 3-month (for Eurodollar and Fed funds futures rates), 6-month and 12-month (for Fed funds futures rates) interest rates, while medium to long run interest rates are positive on average, but not significant (e.g. the spread increases). It seems that mean interest rates for short term interest rates are not very much different in an economic expansion vis-à-vis a recession, but that medium to long term rates are however (almost) uniformly (very much) lower during recession, as expected.

Also note that the coefficient for the anticipated target rate change is not very much different for the expansionary vis-à-vis the recession periods, where the impact changes from positive for short term interest rates to negative for medium to long term interest rates. The exception to this latter statement is the state dependence of a recession for the Eurodollar case, where the coefficient remains positive. However, the coefficients are uniformly insignificant, with the exception of the 30-year maturity bond for the Eurodollar case.

The results might imply that economic agents do not incorporate additional risk-premia due to expected biases in expectations relatively more in either situation from the other. In addition, the disclosure of private information on future inflation expectations does not relatively change its impact on future short term interest rate expectations in either state dependence. In contrast to expected, the results imply that economic expansions during the Greenspan era are accompanied by (average) increasing interest rates. However, the results do imply that interest rates are relatively lower in the case of a recession than for economic expansions as expected.

Table 4.7

Response to Fed target rate changes conditional to the state dependence of the business cycle

Panel A: Response in eurodollar deposit rates

	EXPANSION					RECESSION				
	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.
3-month	-2,05 **	0,04	0,59 *	0,55	6,3	3,55	0,25 **	0,67 *	0,65	6,1
	(0,92)	(0,04)	(0,07)			(3,49)	(0,10)	(0,11)		
6-month	-1,16	0,03	0,54 *	0,46	6,8	0,21	0,15	0,62 *	0,68	5,9
	(1,00)	(0,04)	(0,08)			(3,36)	(0,10)	(0,11)		
12-month	-1,05	0,03	0,47 *	0,39	6,8	-0,87	0,06	0,57 *	0,58	7,3
	(1,00)	(0,03)	(0,08)			(4,15)	(0,12)	(0,13)		
2-year	0,12	0,02	0,39 *	0,27	7,4	-1,47	0,02	0,42 *	0,40	8,2
	(1,08)	(0,04)	(0,09)			(4,65)	(0,13)	(0,15)		
3-year	-0,08	0,00	0,30 *	0,17	7,6	-1,28	0,01	0,37 *	0,33	8,5
	(1,11)	(0,04)	(0,09)			(4,84)	(0,14)	(0,15)		
5-year	0,33	-0,04	0,26 *	0,12	8,0	1,54	0,09	0,40 *	0,34	7,7
	(1,17)	(0,05)	(0,09)			(4,40)	(0,13)	(0,14)		
7-year	0,20	-0,06	0,20 ***	0,07	8,1	0,63	0,02	0,30 **	0,34	6,6
	(1,19)	(0,05)	(0,10)			(3,76)	(0,11)	(0,12)		
10-year	0,26	-0,06	0,16 ***	0,07	7,5	1,35	0,04	0,27 **	0,29	6,2
	(1,10)	(0,04)	(0,09)			(3,52)	(0,10)	(0,11)		
30-year	-0,56	-0,08 ***	0,16 ***	0,12	6,8	-0,31	0,02	0,14	0,11	6,2
	(1,05)	(0,04)	(0,08)			(3,66)	(0,10)	(0,12)		

Panel B: Response in federal funds futures rates

	EXPANSION					RECESSION				
	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.
3-month	-3,50 *	0,03	0,87 *	0,59	6,0	0,63	0,10	0,79 *	0,79	4,8
	(0,90)	(0,04)	(0,11)			(2,75)	(0,08)	(0,09)		
6-month	-2,84 *	0,03	0,82 *	0,51	6,7	-2,93	0,00	0,74 *	0,80	4,6
	(1,00)	(0,04)	(0,13)			(2,65)	(0,08)	(0,09)		
12-month	-2,28 **	0,03	0,75 *	0,48	6,6	-4,33	-0,12	0,71 *	0,74	5,8
	(0,98)	(0,04)	(0,012)			(3,29)	(0,10)	(0,11)		
2-year	-0,72	0,02	0,55 *	0,27	7.6	-4,26	-0,12	0,54 *	0,53	7,3
	(1,13)	(0,05)	(0,14)			(4,18)	(0,13)	(0,14)		
3-year	-0,57	0,00	0,44 *	0,17	7,8	-3,74	-0,11	0,47 *	0,44	7,8
	(0,15)	(0,05)	(0,15)			(4,48)	(0,14)	(0,14)		
5-year	-0,25	-0,02	0,31 ***	0,07	8,5	-0,64	-0,02	0,50 *	0,44	7,1
	(1,26)	(0,05)	(0,16)			(4,03)	(0,12)	(0,13)		
7-year	-0,25	-0,05	0,27	0,05	8,5	-1,29	-0,08	0,38 *	0,44	6,1
	(1,27)	(0,05)	(0,16)			(3,49)	(0,11)	(0,11)		
10-year	-0,16	-0,05	0,20	0,04	7,9	-0,20	-0,03	0,33 *	0,36	5,9
	(1,17)	(0,05)	(0,15)			(3,37)	(0,10)	(0,11)		
30-year	-1,04	-0,06	0,14	0,05	7,1	-1,09	-0,02	0,17	0,12	6,1
	(1,15)	(0,05)	(0,14)			(3,62)	(0,11)	(0,12)		

Notes:

[a] For both the Eurodollar case the state dependence of the business cycle leads to 62 target rate change observations within an expansionary economy for all maturities, except the 30-year bond which contains 49 observations. For the Federal fund futures rates the sample contains 53 observations within an expansionary for all maturities except the 30-year bond which contains 40 observations. For both the Eurodollar and Fed funds futures rates the sample contains 28 observations within a recession period for all maturities except the 30-year bond which contains 26 observations.

[b] A *, ** and *** respectively represent statistical significance at the 99%, 95% and 90% confidence level. Standard errors are in parenthesis.

4.3.2 The state dependence of the business cycle and meeting day surprises

Table 4.8 provides the results for estimating the impact of surprise policy action conditional to the state dependence of the business cycle. The result are more in line with our expectations for the anticipation of Fed meeting days vis-à-vis the case where only actual target rate changes are applied. The first noticeable difference is the (almost) uniform increase in mean interest rates for economic expansions vis-à-vis recessions. The intercept is positive for medium to long run interest rates (however uniformly insignificant) for economic expansions and negative (significant for medium run interest rates) for recessions, as expected. Note that the usage of meeting days as opposed to actual target rate changes has improved significance levels for the intercept. In addition, the negative impact of anticipated target rate changes is now significant for long term maturities in economic expansions and also negative and significant for the 7-year maturity for recessions.[36]

Table 4.8

Response to Fed meetings conditional to the state dependence of the business cycle

Panel A: Response in Eurodollar deposit rates

	EXPANSION					RECESSION				
	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.
3-month	-1,57	0,04	0,59 *	0,48	5,2	-1,45 ***	0,12 *	0,54 *	0,70	4,7
	(0,50)	(0,03)	(0,06)			(0,83)	(0,04)	(0,05)		
6-month	-0,72	0,02	0,55 *	0,43	5,3	-1,87 **	0,10 **	0,58 *	0,74	4,5
	(0,51)	(0,03)	(0,06)			(0,81)	(0,04)	(0,05)		
12-month	-0,39	0,01	0,48 *	0,38	5,2	-1,44	0,04	0,55 *	0,62	5,8
	(0,50)	(0,03)	(0,06)			(1,04)	(0,05)	(0,06)		
2-year	0,27	0,01	0,40 *	0,24	5,9	-2,28 ***	-0,01	0,41 *	0,39	7,1
	(0,57)	(0,03)	(0,06)			(1,27)	(0,06)	(0,07)		
3-year	0,26	-0,01	0,32 *	0,15	6,2	-2,17 ***	-0,02	0,36 *	0,31	7,2
	(0,60)	(0,03)	(0,07)			(1,29)	(0,06)	(0,07)		
5-year	0,53	-0,05	0,27 *	0,11	6,5	-2,10 ***	-0,01	0,32 *	0,29	6,8
	(0,62)	(0,03)	(0,07)			(1,22)	(0,06)	(0,07)		
7-year	0,62	-0,06 ***	0,20 *	0,07	6,4	-1,61	-0,04	0,25 *	0,27	5,9
	(0,61)	(0,03)	(0,07)			(1,05)	(0,05)	(0,06)		
10-year	0,60	-0,07 **	0,16 **	0,07	5,9	-1,39	-0,04	0,21 *	0,22	5,5
	(0,57)	(0,03)	(0,07)			(0,99)	(0,04)	(0,06)		
30-year	0,20	-0,09 *	0,15 **	0,11	5,3	-0,80	0,00	0,14 **	0,14	5,0
	(0,53)	(0,03)	(0,06)			(1,14)	(0,05)	(0,06)		

Panel B: Response in federal funds futures rates

	EXPANSION					RECESSION				
	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.	INTERCEPT	ANTICIPATED	UNANTICIPATED	R^2	S.E.
3-month	-1,89 *	0,01	0,86 *	0,50	5,1	-1,81 *	0,04	0,73 *	0,81	3,7
	(0,50)	(0,03)	(0,09)			(0,66)	(0,04)	(0,05)		
6-month	-1,38 *	0,01	0,82 *	0,47	5,2	-2,24 *	0,02	0,76 *	0,82	3,8
	-0,52	(0,03)	(0,09)			(0,68)	(0,04)	(0,05)		
12-month	-0,89 ***	0,01	0,74 *	0,44	5,0	-1,86 **	-0,05	0,77 *	0,73	4,9
	(0,50)	(0,03)	(0,08)			(0,88)	(0,05)	(0,06)		
2-year	-0,08	0,01	0,55 *	0,23	6,0	-2,63 **	-0,09	0,60 *	0,48	6,5
	(0,59)	(0,03)	(0,10)			(1,17)	(0,06)	(0,09)		
3-year	0,07	-0,01	0,46 *	0,15	6,3	-2,48 **	-0,08	0,52 *	0,38	6,8
	(0,62)	(0,04)	(0,11)			(1,22)	(0,06)	(0,09)		
5-year	0,21	-0,04	0,34 *	0,08	6,7	-2,39 **	-0,08	0,48 *	0,38	6,4
	(0,66)	(0,04)	(0,11)			(1,44)	(0,06)	(0,08)		
7-year	0,34	-0,06	0,27 **	0,06	6,5	-1,85 ***	-0,10 ***	0,38 *	0,35	5,6
	(0,65)	(0,04)	(0,11)			(1,00)	(0,05)	(0,07)		
10-year	0,35	-0,06 ***	0,21 **	0,05	6,1	-1,59	-0,08	0,30 *	0,27	5,3
	(0,60)	(0,04)	(0,10)			(0,95)	(0,05)	(0,07)		
30-year	-0,13	-0,07 ***	0,14	0,05	5,3	-0,90	-0,02	0,18 **	0,15	4,9
	(0,55)	(0,03)	(0,09)			(1,14)	(0,05)	(0,07)		

Notes:

[a] For both the Eurodollar case the state dependence of the business cycle leads to 127 meeting day observations within an expansionary economy for all maturities, except the 30-year bond which contains 110 observations. For the Federal fund futures rates the sample contains 113 observations within an expansionary for all maturities except the 30-year bond which contains 96 observations. For both the Eurodollar and Fed funds futures rates the sample contains 56 observations within a recession period for all maturities except the 30-year bond which contains 42 observations.

[b] A *, ** and *** respectively represent statistical significance at the 99%, 95% and 90% confidence level. Standard errors are in parenthesis.

[36] This is also supported by a Wald-test for the *null*-hypothesis that the coefficient for the anticipated target rate change is smaller than one cannot be rejected.

CHAPTER 5 Summary and conclusions

Research like Pool and Rasche (2000) and Kuttner (2001) show that Federal Reserve target rate changes have a significant impact on short term interest rates, while leaving the impact on medium and long term interest rates insignificant. Furthermore, “surprise” target rate changes cause significantly higher shocks in Treasury-bill rates throughout the yield curve, while leaving the impact of anticipated changes of no significance. This paper argues that the impact of “surprise” policy actions is however conditional to the perception of economic agents on the credibility of the Federal Reserve. This paper argues that under such a condition, the response to surprise policy actions will incorporate a higher risk-premia in the response to policy actions, which results in bigger shocks to interest rates due to policy surprises.

Following Barro and Gordon (1978), Kydland and Prescott (1979) and Cukiermann (1992), it has been argued that the perception of a CBs commitment to its policy goals has a significant impact on the creation of future expectations of inflation and interest rates. They argue that discretionary time-inconsistent policies will increase the mean and volatility of inflation and interest rates. Clarida *et al* (1999) show however that when a policymaker is credible towards a commitment to an anti-inflationary this will reduce the (additional) uncertainty-related premia in inflation and interest rates.

To verify this finding this paper applies three measures for CB credibility which follow directly from the “*Rules versus Discretion*” discussion and those close linked. Primary important is that our CB credibility measures are a real-time performance measure that states whether or not the policymaker can be perceived as being committed to a “*policy contingency plan*” that incorporates economic agents’ expectations. We therefore create three measures of CB credibility, being (1) *the deviation of the federal funds rate from an implicit target funds rate*, (2) *the deviation of inflation from an implicit target rate for inflation,* and (3) *by the persistency of inflation*.

Second, we test whether the state dependence of the business cycle changes the impact of anticipated and unanticipated target rate changes. The rationale follows from the stated literature in the fact economic agents might incorporate additional risk-premia in interest rates due to expected biased expectations on future monetary policy and (therefore) the future development of important economic aggregates, predominantly expectations of future inflation.

The results argue very much in favour of the stated theory. Uniformly the results show that uncredible CB environments are characterized by a higher mean and volatility in interest rates, while credible CBs have significantly lower mean in and shocks to interest rates as a result of surprise policy actions. Furthermore, under a credible CB the impact of the "surprise” component reduces to zero for the medium and long run maturities, while remaining significant and relatively high for all maturities under an uncredible CB regime. This might indeed suggest that uncredible regimes are characterized by economic agents expect higher future levels of inflation and incorporate these expectations accordingly in the term structure of interest rates. In contrast, the credible CB environment is characterized by (significantly) lower responses to surprise target rate changes, which might indicate that the credible policymaker is expected to neutralize any biases in expectations of (future) expectations of inflation (being disclosed from “*private information*”) in the medium to long run, as expected. Third, uncredible CB environments are characterized by negative responses to anticipated target rate changes for medium to long run interest rates. The negative impact of anticipated target rate changes for uncredible CBs might suggest that economic agents indeed incorporate additional risk- premia in interest rates, which are negated after the observation of the actual policy action. This might therefore suggest that term premia are not constant, but are moreover to be held conditional to the state of the environment, e.g. here CB credibility.

In addition, economic agents seem to value the outcome of Federal Reserve meetings in general – without the necessity of an actual target change to be having made - of equal importance as actual CB target rate changes, as the impact of the anticipated an unanticipated component of the policy surprise is virtually equal in both cases. In contrast, allowing for flexibility on CB credibility does not change the general outcome of the study.

The results for the impact of the state dependence of the business cycle indicate that mean interest rates are lower for recessions than for economic expansions, as expected. Additionally, for both economic expansions and recessions, the impact of both the anticipated and unanticipated target rate change is significant and virtually equal for both state dependencies. Both state dependencies are characterized by a negative coefficient for the anticipated component of the target rate changes, which might imply that additional risk- premia in interest rates due to expected biases in future expectations are not conditional to the business cycle. The same way, the relatively high coefficient for surprise policy actions might indicate that changes in expectations of future inflation rates are also not conditional to the state dependency of the business cycle.

In general it can therefore be argued that the impact of surprise policy actions is conditional to CB credibility. This changes the perspective on how the policymaker's transparency on her contingency plan alters financial stability altogether, promoting the argument in favour of "rules" rather than "discretion". A policymaker that creates openness about her contingency plan and communicates a "simple" rule or an explicit inflation target that can act as an anchor for creating expectations will greatly benefit from lower mean and volatility in interest rates.

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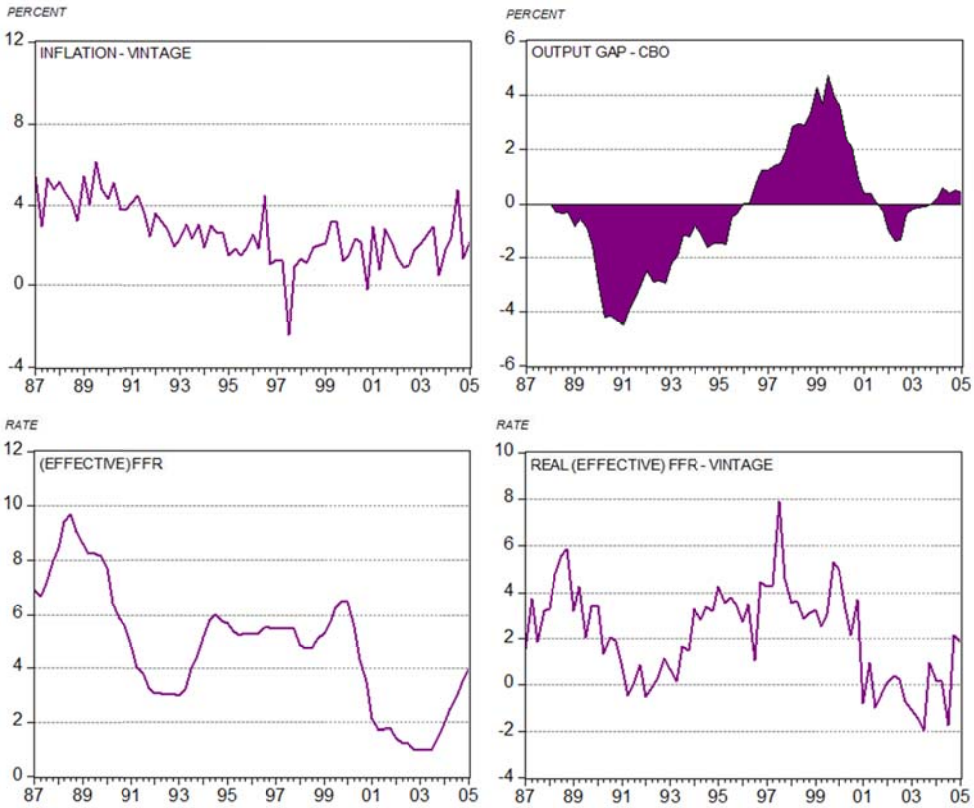
APPENDIX

Figure A.1
The development of inflation, the output gap and the (real) federal funds rate

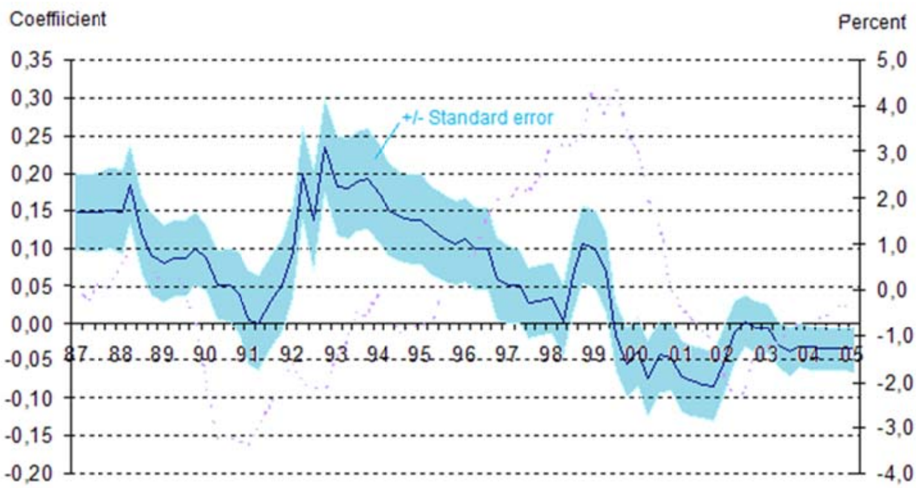


Notes:

[a] For a detailed specification of the variables, please visit the data description in Chapter 3.

Source: *Federal Reserve, CBO and authors calculations*

Figure A.2
The output gap coefficient



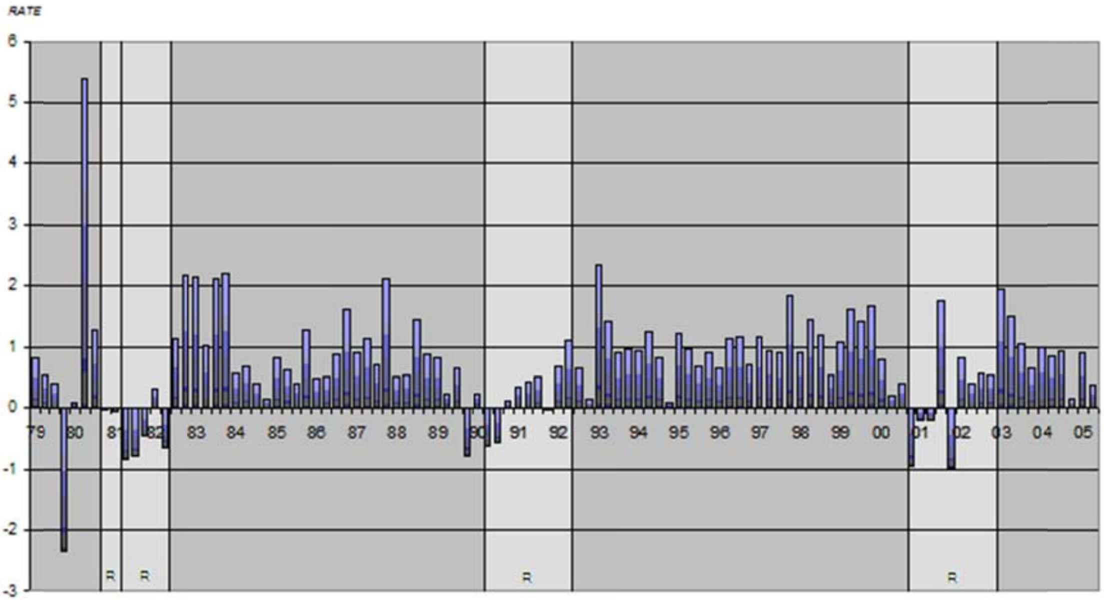
Notes:

[a] Figure A.2 shows the output gap coefficient for a regression of inflation on the output gap and 4 lags of inflation. The output gap is defined as the annualized quarterly difference of actual (real) domestic production from its potential level. The coefficients are calculated using 10-year rolling regressions, where the coefficient for quarter-*t* is based on data from *t*-39 to *t*. This is compared to the natural logarithm of the output gap (purple dotted line).

Source: *CBO and authors calculations*

Figure A.3

State of the U.S. economy by development of real GDP growth and the timing of recession dates



Notes:

[a] Figure A.3 shows the development of quarterly real domestic production growth, measures by the log of real domestic production minus previous quarter real domestic production. Data is real-time Vintage data from the Federal Reserve. Data is corrected for the indexation changes and missing observations are provided by means of linear interpolation between its one quarter leading and lagging observation. The black vertical lines show the statistical start of a recession provided the Federal Reserves general rule of thumb that a recession has started the first month of two consecutive quarters of negative real domestic production growth. Unfortunately no statistical measure is present for timing the end of a recession. We therefore apply the results from figure 3.4 as an indication of the end dates of each recession. This provides the first recession as being 1981Q2 until 1981Q3. The second recession statistically becomes immediately after the NBER had already announced the 1980-81 recession as being over. The figure shows that the official dating of the recession as being 1980-81 is missed because of the lack of a consecutive negative observation for 1980Q3 when the Vintage data shows a positive value of 0,09. Figures 10 and 11 point out that there would be reason for financial markets to believe that the economy was still in a recession, provided a level of confidence in present real-time data. This would point the end date of the recession at March 1983. Given the timing of the consecutive recessions, we time the recession as being 1981Q2 until 1983Q1. The second recession is dated from 1990Q4 until 1992Q4 and the third recession is dates as 2001Q2 until 2003Q3.

Source: *Federal Reserve and own calculations*

Table A.1
Federal Reserve policy actions for meeting days and target rate changes divided into the actual, expected and unexpected policy actions.

Date	Meeting	Actual	Eurodollar Deposit Rates		Federal Funds Futures	
			Expected	Unexpected	Expected	Unexpected
11/04/1987	0	-18,75	13,25	-32,00	NA	NA
12/17/1987	0	0,00	0,00	0,00	NA	NA
01/06/1988	0	0,00	0,00	0,00	NA	NA
01/28/1988		-18,75	-6,75	-12,00	NA	NA
02/11/1988		-12,50	-18,50	6,00	NA	NA
03/30/1988	0	25,00	25,00	0,00	NA	NA
05/09/1988		25,00	18,00	7,00	NA	NA
05/18/1988	0	0,00	0,00	0,00	NA	NA
06/22/1988		50,00	57,00	-7,00	NA	NA
07/19/1988		18,75	24,75	-6,00	NA	NA
08/08/1988		6,25	6,25	0,00	NA	NA
08/09/1988		37,50	18,50	19,00	NA	NA
08/17/1988	0	0,00	6,00	-6,00	NA	NA
09/21/1988	0	0,00	-6,00	6,00	NA	NA
10/20/1988		12,50	12,50	0,00	12,50	0,00
11/02/1988	0	0,00	-6,00	6,00	-2,00	2,00
11/17/1988		6,25	13,25	-7,00	-0,75	7,00
11/22/1988		6,25	6,25	0,00	-0,75	7,00
12/15/1988	0	31,25	19,25	12,00	26,25	5,00
01/05/1989		31,25	37,25	-6,00	31,25	0,00
02/09/1989	0	6,25	0,25	6,00	5,25	1,00
02/14/1989		25,00	19,00	6,00	21,00	4,00
02/23/1989		25,00	12,00	13,00	11,00	14,00
02/24/1989		18,75	6,75	12,00	4,75	14,00
03/29/1989	0	0,00	12,00	-12,00	7,00	-7,00
05/04/1989		6,25	6,25	0,00	4,25	2,00
05/17/1989	0	0,00	-7,00	7,00	1,00	-1,00
06/06/1989		-25,00	-19,00	-6,00	-26,00	1,00
07/07/1989		-25,00	-19,00	-6,00	-20,00	-5,00
07/27/1989		-25,00	-19,00	-6,00	-19,00	-6,00
08/10/1989		-6,25	0,75	-7,00	-8,25	2,00
08/23/1989	0	0,00	6,00	-6,00	4,00	-4,00
10/04/1989	0	0,00	0,00	0,00	0,00	0,00
10/18/1989		-25,00	-32,00	7,00	-29,00	4,00
11/06/1989		-25,00	-25,00	0,00	-28,00	3,00
11/15/1989	0	0,00	6,00	-6,00	0,00	0,00
12/20/1989		-25,00	-7,00	-18,00	-15,00	-10,00
02/08/1990		0,00	0,00	0,00	0,00	0,00
03/28/1990		0,00	6,00	-6,00	0,00	0,00
05/16/1990		0,00	0,00	0,00	-1,00	1,00
07/04/1990		0,00	0,00	0,00	0,00	0,00
07/13/1990		-25,00	-18,00	-7,00	-16,00	-9,00
08/21/1990	0	0,00	-7,00	7,00	-3,00	3,00
10/03/1990	0	0,00	0,00	0,00	0,00	0,00
10/29/1990		-25,00	-25,00	0,00	-23,00	-2,00
11/14/1990		-25,00	-25,00	0,00	-27,00	2,00
12/07/1990		-25,00	6,00	-31,00	-11,00	-14,00
12/18/1990	0	-25,00	7,00	-32,00	-9,00	-16,00
01/08/1991		-25,00	0,00	-25,00	-15,00	-10,00
02/01/1991		-50,00	-12,00	-38,00	-24,00	-26,00
02/07/1991	0	0,00	0,00	0,00	1,00	-1,00
03/08/1991		-25,00	-6,00	-19,00	-12,00	-13,00
03/27/1991	0	0,00	6,00	-6,00	2,00	-2,00
04/30/1991		-25,00	-12,00	-13,00	-8,00	-17,00
05/15/1991	0	0,00	0,00	0,00	0,00	0,00
07/04/1991	0	0,00	0,00	0,00	2,00	-2,00
08/06/1991		-25,00	-6,00	-19,00	-16,00	-9,00
08/21/1991	0	0,00	7,00	-7,00	1,00	-1,00

09/13/1991		-25,00	-19,00	-6,00	-21,00	-4,00
10/02/1991	0	0,00	-13,00	13,00	-1,00	1,00
10/31/1991		-25,00	-25,00	0,00	-20,00	-5,00
11/06/1991		-25,00	-19,00	-6,00	-13,00	-12,00
12/06/1991		-25,00	-13,00	-12,00	-14,00	-11,00
12/18/1991	0	0,00	0,00	0,00	-6,00	6,00
12/20/1991		-50,00	-19,00	-31,00	-24,00	-26,00
02/06/1992	0	0,00	0,00	0,00	2,00	-2,00
04/01/1992	0	0,00	0,00	0,00	-2,00	2,00
04/09/1992		-25,00	-7,00	-18,00	-4,00	-21,00
05/20/1992	0	0,00	-6,00	6,00	-5,00	5,00
07/02/1992		-50,00	-19,00	-31,00	-18,00	-32,00
08/19/1992	0	0,00	0,00	0,00	-1,00	1,00
09/04/1992		-25,00	-7,00	-18,00	-5,00	-20,00
10/07/1992	0	0,00	0,00	0,00	2,00	-2,00
11/18/1992	0	0,00	0,00	0,00	4,00	-4,00
12/23/1992	0	0,00	0,00	0,00	-1,00	1,00
02/04/1993	0	0,00	0,00	0,00	2,00	-2,00
03/24/1993	0	0,00	0,00	0,00	0,00	0,00
05/19/1993	0	0,00	0,00	0,00	2,00	-2,00
07/08/1993	0	0,00	0,00	0,00	0,00	0,00
08/18/1993	0	0,00	0,00	0,00	0,00	0,00
09/22/1993	0	0,00	0,00	0,00	0,00	0,00
11/17/1993	0	0,00	0,00	0,00	0,00	0,00
12/22/1993	0	0,00	0,00	0,00	-1,00	1,00
02/04/1994	0	25,00	13,00	12,00	16,00	9,00
03/22/1994	0	25,00	25,00	0,00	29,00	-4,00
04/18/1994		25,00	7,00	18,00	15,00	10,00
05/17/1994	0	50,00	50,00	0,00	45,00	5,00
07/06/1994	0	0,00	12,00	-12,00	2,00	-2,00
08/16/1994	0	50,00	44,00	6,00	40,00	10,00
09/27/1994	0	0,00	6,00	-6,00	8,00	-8,00
11/15/1994	0	75,00	56,00	19,00	66,00	9,00
12/20/1994	0	0,00	12,00	-12,00	11,00	-11,00
02/01/1995	0	50,00	50,00	0,00	40,00	10,00
03/28/1995	0	0,00	-6,00	6,00	0,00	0,00
05/23/1995	0	0,00	3,00	-3,00	-1,00	1,00
07/06/1995	0	-25,00	-6,00	-19,00	-18,00	-7,00
08/22/1995	0	0,00	-3,00	3,00	-2,00	2,00
09/26/1995	0	0,00	-3,00	3,00	-4,00	4,00
11/15/1995	0	0,00	0,00	0,00	-1,00	1,00
12/19/1995	0	-25,00	-10,00	-15,00	-14,00	-11,00
01/31/1996	0	-25,00	-25,00	0,00	-18,00	-7,00
05/21/1996	0	0,00	0,00	0,00	-1,00	1,00
07/03/1996	0	0,00	0,00	0,00	5,00	-5,00
08/20/1996	0	0,00	3,00	-3,00	1,00	-1,00
09/24/1996	0	0,00	7,00	-7,00	13,00	-13,00
11/13/1996	0	0,00	0,00	0,00	-1,00	1,00
12/17/1996	0	0,00	0,00	0,00	0,00	0,00
02/05/1997	0	0,00	0,00	0,00	2,00	-2,00
03/25/1997	0	25,00	19,00	6,00	21,00	4,00
05/20/1997	0	0,00	7,00	-7,00	9,00	-9,00
07/02/1997	0	0,00	0,00	0,00	1,00	-1,00
08/19/1997	0	0,00	0,00	0,00	-1,00	1,00
09/30/1997	0	0,00	0,00	0,00	0,00	0,00
11/12/1997	0	0,00	0,00	0,00	2,00	-2,00
12/16/1997	0	0,00	0,00	0,00	1,00	-1,00
02/04/1998	0	0,00	0,00	0,00	-1,00	1,00
03/31/1998	0	0,00	0,00	0,00	0,00	0,00
05/19/1998	0	0,00	-3,00	3,00	2,00	-2,00
07/01/1998	0	0,00	0,00	0,00	1,00	-1,00
08/18/1998	0	0,00	0,00	0,00	-1,00	1,00
09/29/1998	0	-25,00	-34,00	9,00	-31,00	6,00
10/15/1998		-25,00	-4,00	-21,00	-5,00	-20,00
11/17/1998	0	-25,00	-6,00	-19,00	-19,00	-6,00
12/22/1998	0	0,00	0,00	0,00	0,00	0,00

02/03/1999	0	0,00	0,00	0,00	1,00	-1,00
03/30/1999	0	0,00	0,00	0,00	0,00	0,00
05/18/1999	0	0,00	-6,00	6,00	1,00	-1,00
06/30/1999	0	25,00	32,00	-7,00	29,00	-4,00
08/24/1999	0	25,00	28,00	-3,00	22,00	3,00
10/05/1999	0	0,00	7,00	-7,00	1,50	-1,50
11/16/1999	0	25,00	19,00	6,00	17,00	8,00
12/21/1999	0	0,00	0,00	0,00	0,00	0,00
02/02/2000	0	25,00	29,00	-4,00	28,50	-3,50
03/21/2000	0	25,00	25,00	0,00	27,00	-2,00
05/16/2000	0	50,00	47,00	3,00	46,00	4,00
06/28/2000	0	0,00	10,00	-10,00	2,00	-2,00
08/22/2000	0	0,00	0,00	0,00	0,00	0,00
10/03/2000	0	0,00	0,00	0,00	0,00	0,00
11/15/2000	0	0,00	0,00	0,00	0,00	0,00
12/19/2000	0	0,00	0,00	0,00	-5,50	5,50
01/03/2001	0	-50,00	-4,00	-46,00	-21,00	-29,00
01/31/2001	0	-50,00	-51,00	1,00	-50,50	0,50
03/20/2001	0	-50,00	-60,00	10,00	-52,50	2,50
04/18/2001		-50,00	3,00	-53,00	-8,00	-42,00
05/15/2001	0	-50,00	-47,00	-3,00	-42,50	-7,50
06/27/2001	0	-25,00	-36,00	11,00	-33,50	8,50
08/21/2001	0	-25,00	-26,00	1,00	-27,00	2,00
09/17/2001		-50,00	-43,00	-7,00	-37,50	-12,50
10/02/2001	0	-50,00	-47,00	-3,00	-41,50	-8,50
11/06/2001	0	-50,00	-42,00	-8,00	-39,50	-10,50
12/11/2001	0	-25,00	-25,00	0,00	-26,00	1,00
01/30/2002	0	0,00	-3,00	3,00	-1,50	1,50
03/19/2002	0	0,00	2,00	-2,00	2,00	-2,00
05/07/2002	0	0,00	0,00	0,00	0,00	0,00
06/26/2002	0	0,00	1,00	-1,00	2,00	-2,00
08/13/2002	0	0,00	0,00	0,00	-3,00	3,00
09/24/2002	0	0,00	-1,00	1,00	-2,00	2,00
11/06/2002	0	-50,00	-28,00	-22,00	-34,00	-16,00
12/10/2002	0	0,00	1,00	-1,00	0,00	0,00
01/29/2003	0	0,00	-1,00	1,00	-0,50	0,50
03/18/2003	0	0,00	-4,00	4,00	-2,50	2,50
05/06/2003	0	0,00	1,00	-1,00	-1,50	1,50
06/25/2003	0	-25,00	-36,00	11,00	-37,50	12,50
08/12/2003	0	0,00	0,00	0,00	0,00	0,00
09/16/2003	0	0,00	0,00	0,00	0,00	0,00
10/18/2003	0	0,00	0,00	0,00	0,00	0,00
12/09/2003	0	0,00	1,00	-1,00	0,00	0,00
01/28/2004	0	0,00	0,00	0,00	0,00	0,00
03/16/2004	0	0,00	0,00	0,00	0,00	0,00
05/04/2004	0	0,00	0,00	0,00	1,00	-1,00
06/30/2004	0	25,00	24,00	1,00	26,00	-1,00
08/10/2004	0	25,00	24,00	1,00	23,00	2,00
09/21/2004	0	25,00	25,00	0,00	25,00	0,00
11/10/2004	0	25,00	24,00	1,00	24,50	0,50
12/14/2004	0	25,00	23,00	2,00	25,00	0,00
02/02/2005	0	25,00	25,00	0,00	25,00	0,00
03/22/2005	0	25,00	24,00	1,00	25,00	0,00
05/03/2005	0	25,00	25,00	0,00	24,50	0,50
06/30/2005	0	25,00	25,00	0,00	25,00	0,00
08/09/2005	0	25,00	26,00	-1,00	25,00	0,00
09/20/2005	0	25,00	24,00	1,00	21,50	3,50
11/01/2005	0	25,00	25,00	0,00	9,50	15,50
12/13/2005	0	25,00	25,00	0,00	25,00	0,00

Notes:

[a] Policy surprises are divided in “meetings day surprises” and “surprise target rate changes”. Policy actions are measured in basis points.

Sources: Federal Reserve website. Additional literature: Thornton (2000, 2005), Thornton and Wheelock (2000), Kuttner (2001), Zebedee *et al.* (2008) and authors calculations