The Risk Management Approach of the Federal Reserve System - A Model for the European Central Bank? *

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Abstract

Uncertainty regarding the state of the economy and the reaction of private subjects to interest rate decisions is the greatest problem of each central bank. This paper investigates whether accounting for uncertainty in monetary policy as proposed by Alan Greenspan and conducted by the Federal Reserve System in years 2003 and 2004 can be used as a model for the European Central Bank. Greenspan's approach is shown to involve unusually expansive policy in some states. I find that the Fed, in contrast to the ECB, meets the conditions under which such a policy is likely to be successful. Consequently, implementing Greenspan's approach is connected with higher risk for the European than for the U.S. policy maker.

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1 Introduction

Monetary policy is always conducted under uncertainty. The central bank has to estimate the current state of economic activity with respect to growth and inflation. Moreover, it has to forecast its future development accounting for various possible reactions of private subjects to its policy decisions. Consequently, designing an effective and successful monetary policy under these conditions is a difficult and a widely discussed issue. Greenspan (2003, 2004) introduced a method that allows the policy maker to account for uncertainty and called this idea a "risk management approach". It focuses on avoiding scenarios defined as particularly dangerous for the economy. This paper investigates whether the strategy proposed by Alan Greenspan and implemented by the Federal Reserve System in years 2003 and 2004 can be used as a model for the European Central Bank.

Each interest rate decision may be followed by several different scenarios, depending on the actual state of the economy and inflation expectations of private subjects. In the standard procedure applied by most central banks, the decision which minimizes the expected value of the loss function is taken. In contrast, the strategy of Alan Greenspan is aimed primarily at eliminating scenarios identified as especially dangerous for the economy. Consequently, the decision which results in the minimal expected loss for the central bank may be rejected if it can lead to a low-probability scenario resulting, e.g., in a liquidity crisis. For instance, an unusually expansive policy of the Fed in 2003 and 2004 was aimed at preventing the deflation scenario. Although the risk management approach prevents some particularly undesirable scenarios from occuring, the risks of other disadvantageous scenarios can increase. For example, very low interest rates may decrease the risk of stagnation but increase the risk of high inflation in the following periods or affect the investment behavior of private banks. Therefore, the question arises when such an approach is likely to be successful.

The analysis is conducted in two steps. First, the consequences that Greenspan's approach

might have for monetary policy are discussed. Theoretical literature on this issue and a policy example presented in this paper indicate that the risk management approach involves an aggressive and expansive policy in some states. Standard models of interaction between the central bank and private subjects show that such a policy is usually inefficient since private subjects start to expect high inflation. Therefore, the second step of the analysis involves investigating, under which conditions expansive policy is less likely to be followed by permanently increased inflation expectations. Formulated hypotheses are tested for the Fed and the ECB.

The Fed is shown to have a price level target in its reaction function which, according to the literature on price level targeting, anchors inflation expectations and keeps them on a low and stable level. This reduces the probability of large and permanent increases in inflation expectations and, in turn, enables the central bank to conduct an expansive policy if it wishes to exclude dangerous scenarios as suggested by the risk management approach. Furthermore, all analyzed past periods of increased inflation expectations in the U.S. are shown to have been temporary and last no longer than a couple of months. Both findings suggest that periods of expansive monetary policy are not likely to be followed by permanent upward shifts of inflation expectations. This means that the Fed can implement an expansive policy for a couple of periods, when needed, with a relatively low risk. In result, this central bank can account for uncertainty as proposed by Alan Greenspan and is able to implement policy that this strategy may suggest.

The ECB, however, is found to target inflation and not the level of prices. Consequently, large and permanent increases in inflation expectations are more probable than in the case of a central bank with a price level target. Moreover, inflation expectations observed in the past do not include any periods of upward shifts. Therefore, it is much more difficult to assess the reaction of private subjects after observing expansive monetary policy than in the case of the Fed. Consequently, implementing Greenspan's approach is connected with higher risk for the

European than for the U.S. policy maker.

The remainder of the paper is organized as follows. Section 2 describes the idea of the risk management approach and presents an empirical example of its application focusing on the aggressiveness of monetary policy in the implementation period. Section 3 discusses the conditions, under which the policy maker realizes gains from aggressive monetary policy. Hypotheses derived from the discussion enable to test whether the Fed and the ECB meet these conditions and, consequently, whether these banks may account for uncertainty in a way proposed by Alan Greenspan without any increased risk of losses. Section 4 presents empirical results. Section 5 concludes.

2 Monetary Policy under Uncertainty

The following section illustrates the consequences that the new approach introduced by Greenspan (2003, 2004) might have for the central bank's decisions. The first part describes Greenspan's way of thinking about monetary policy and points out its possible consequences based on theoretical models. The second part presents an empirical example of the application of the risk management approach and analyzes the aggressiveness of monetary policy in the implementation period.

2.1 Idea

One of the most serious problems faced by monetary policy makers is the lack of full knowledge about the current state of the business cycle. Since the outcome of monetary policy depends on the true value of macroeconomic indicators, each interest rate decision may have several different consequences for the economy. Therefore, the policy maker faces a problem of accounting for uncertainty in such a way that the outcome of his decisions fulfills the objectives of the central bank and thus assures the preferred development of the economy.

The central bank estimates current values of target variables and makes forecasts of their future paths given each of the considered alternative monetary policy decisions. A state is defined as a set of current target variable values and their conditional forecasts. A scenario is defined as a set of future paths of target variables depending on a monetary policy decision and on the true state of the economy. Model estimation and forecast errors imply uncertainty about the true state of the economy which means that there are more than one possible states which have a positive probability to turn out to be true. Therefore, each decision considered by the central bank can result in several different scenarios. The outcome of each scenario can be quantified by costs and benefits it has for the economy and for the monetary policy maker which can be measured, for example, by the value of the central bank's loss function.

The standard procedure implemented by most central banks is aimed at minimizing the expected value of the loss function. Each decision may result in several different scenarios, dependent on the true state of the economy. The scenarios are characterized by their probabilities and values of the loss function. The expected loss is calculated for each of the considered interest rate steps and the decision implying the lowest expected costs for the economy is taken.[1] This procedure is very general and applies even for central banks with different objectives. In such cases, target variables may be weighted differently but the decision-making process is still similar. Alternatively, the central bank can consider only the most probable state. In this case, it has to compare the outcomes of several discussed decisions given the target variable paths having the highest probability.

In the approach proposed by Alan Greenspan, the central bank considers the outcome of discussed decisions for each scenario separately instead of looking only at the expected value of the loss function. This strategy is motivated by the fact that some scenarios may be very dangerous for the economy and imply extremely high costs for the policy maker. The objective of a central bank implementing the risk management approach is to avoid scenarios regarded

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[1]This approach corresponds to mean forecast targeting formalized by Svensson (2005).

as particularly disruptive for the economy, even if their probability is very low. Decisions that may lead to such outcomes are ruled out in the first place.[2] Note that central banks may take different decisions depending on how they weight costs occuring in various scenarios. For example, a central bank that has two targets: low inflation and high employment will probably attribute higher costs to a scenario with decreasing output than a central bank having a sole inflation target. Similar to the ordinary procedure, scenarios may be evaluated differently but the decision-making process is the same even if banks have different objectives.

Svensson and Williams (2005) developed so-called distribution forecast targeting, a theoretical framework for monetary policy decisions under uncertainty. The idea of their model is very similar to the risk management approach of Alan Greenspan.[3] A dicussed interest rate decision is assessed based on loss function realizations for the whole set of scenarios, each of them occuring in a particular state. Thus the whole distribution of each target variable for the set of states is analyzed. In contrast, mean forecast targeting corresponding to the ordinary procedure accounts only for the expected value of the target variable (and thus for the expected loss).

To illustrate the implications for monetary policy decisions, the authors conduct an exercise, in which the central bank is allowed to react differently in different states. They assume the following general form of a Taylor-type rule:

$$i_t = f_{ij_t} i_{t-1} + f_{\pi j_t} \pi_t + f_{yj_t} y_t \tag{1}$$

where i is the interest rate, π is the inflation, y is the output gap, j is the state and t denotes discrete time. The optimal parameters of the reaction function are derived for each of the

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[2]Similar interpretations of the risk management approach of Alan Greenspan include, e.g., Feldstein (2004) who relates this approach to the Bayesian theory of decision making where possible states of the economy are identified and subjective probabilities are assigned to each of them. Expected utility of each outcome can be calculated using these probabilities. The optimal policy is chosen as the one with the highest expected utility. A similar interpretation can be found in Bernanke (2004). Blinder and Reis (2005) provide a further discussion of possible interpretations of the risk management approach.

[3]The authors use a wide term of uncertainty, a so-called "mode" uncertainty, which can be interpreted not only as the uncertainty about the state of the economy but also as the paramenter uncertainty. For the sake of simplicity, mode uncertainty is interpreted here only as uncertainty about the true state of the economy.

analyzed states which are first assumed to be observable. The model where the coefficients may depend on the state j_t in period t is compared with the original and smoothed Taylor rules, where the coefficients are constrained to be the same in all states.[4] The results show that the coefficients in most of the states in the state-dependent rules are higher than the coefficients in the constant-coefficient rules. This means that the central bank with a more flexible reaction function reacts more aggressively to the changes in output and inflation in most states. The authors consider also the case of unobservable states, which is more realistic and closer to the actual idea of the risk management approach.[5] In general, implementing the risk management approach has a consequence that the responses to shocks may be more aggressive than it is the case for ordinary monetary policy.

2.2 Implementation: A Policy Example

The theoretical excercise cited in the previous section shows that the central bank which applies the risk management approach and is determined to avoid scenarios regarded as particularly disruptive for the economy may need to conduct aggressive policy in some states. This section presents an empirical example of the application of Greenspan's strategy and analyzes the policy aggressiveness in the implementation period.

An example of aggressive interest rate decisions resulting from applying the risk management approach is illustrated by the policy of the Fed in years 2003 and 2004. Greenspan (2004) states that the primary objective of the policy in this period was to avoid a deflation scenario. In the first half of 2003 the interest rates were at 1.25% and well below the neutral rates. Moreover, the baseline model indicated an improving business cycle. The optimal decision

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[4]In the comparison the unconditional mean of the period loss, $E[L_t]$, is used as the intertemporal loss function, where $L_t = Y_t' \Lambda_t Y_t$ with $Y_t = D_t[X_t\ x_t\ i_t]'$ and Λ_t is a symmetric and positive semidefinite matrix. X_t is a vector of predetermined variables (the state), x_t is a vector of forward-looking variables and i_t is a vector of the central bank's instruments.

[5]In this case, the central bank cannot observe the current state but has to use a subjective probability distribution of modes based on the observations of economic variables. The case of unobservable states is extended in Svensson and Williams (2006) where the central bank and the private sector update their subjective distributions of modes.

given this forecast was to increase the interest rates or at least keep them unchanged in order to avoid possible inflationary pressures coming from the growing economic activity. On the other hand, further stagnation of the U.S. economy was identified as a low-probability state. In this case, higher interest rates could lead to deflation. The Fed considered avoiding of extremely high costs generated in the case of deflation as its priority and decided to reduce the interest rates. The risk of an inflationary pressure was accepted in order to assure the elimination of the deflation risk.

The remainder of this section presents three empirical exercises showing that the policy of the Fed in 2003 and 2004 resulting from accounting for uncertainty was particularly aggressive in comparison to the neutral policy, the decisions of the Fed in other periods and to the policy of the ECB in the same period. To assess how expansive the policy in the considered period was, actual interest rate decisions are compared with the rates resulting from the original and smoothed Taylor rules. The original Taylor rule, first proposed in Taylor (1993), is probably the most popular method of approximating monetary policy decisions of a central bank. It takes the following form:

$$i_t^* = r + \pi_t + \alpha(\pi_t - \pi^*) + \beta y_t \tag{2}$$

where i_t^* is the interest rate in month t suggested by the rule, r is the long-run interest rate, π_t is the inflation rate and π^* is the targeted inflation. The output gap y_t is computed as $y_t = x_t - x_t^p$ where x_t is the logarithm of the output and x_t^p the logarithm of the potential output, both multiplied by 100.

The central bank is usually reluctant to conduct drastic interest rate changes. The smoothed Taylor rule is used to account for this fact (like, e.g., in Goodfriend (1991) or Rudebusch (2006)). Consider the rule of the following form:

$$i_t = \delta i_{t-1} + (1 - \delta)i_t^* + \epsilon_t \tag{3}$$

$$i_t^* = r + \pi_t + \alpha(\pi_t - \pi^*) + \beta y_t.$$

7

The central bank chooses the interest rate (i_t) as a linear combination of the current interest rate (i_{t-1}) and the interest rate suggested by the original Taylor rule (i_t^*). Both rules are widely used in the literature in order to estimate the policy maker's reaction function or to approximate the neutral monetary policy. For example, Clarida, Gali, and Gertler (1998) and Gerdesmeier, Mongelli, and Roffia (2007) compare monetary policies of several central banks and apply the smoothed Taylor rule for this purpose. Clarida, Gali, and Gertler (2000) use it to track different periods in the U.S. monetary policy while Peersman and Smets (1999) and Taylor (1999) show that it can serve as a benchmark for analyzing monetary policy in the euro area.

The first exercise includes a comparison of interest rate decisions with the neutral policy rates approximated by the original and smoothed backward-looking Taylor rules for the Fed and the ECB. The parameters α and β in the equations 2 and 3 are assumed to be 0.5 (as estimated in Taylor (1993)), the long run interest rate r is assumed to equal $r = 2$ and the target inflation rate $\pi^* = 2$.[6] The Taylor rates are compared with the actual official interest rates and the 3-month market interest rates. Since the official interest rates are only one of several monetary policy instruments, the results for the 3-month market interest rates allow to account for the overall impact of the conducted policy. Figures 1 and 2 present the ratio of the actual interest rates to the neutral policy interest rates. Figure 1 regards the official interest rates and Figure 2 the market interest rates. Subfigures (a) present the results for the original and (b) for the smoothed Taylor rules. If monetary policy is neutral, the actual interest rate is close to the Taylor rate and thus the ratio of both values equals one. The ratio falls below 1 in periods of expansion and increases above 1 in phases of contraction. One can see that the years after 2001 were characterized by a rather expansive monetary policy in both currency areas which is related to the worldwide economic slowdown. However, the policy of the Fed in years 2003 and 2004 is characterized by an extraordinary aggressiveness.

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[6]The results are robust to other assumptions about r and π^*. I considered also the following cases: (r=2, π^*=1) and (r=1, π^*=1).

The U.S. interest rates were very low in comparison to the neutral policy rates - around 30% of the original and 40% of the smoothed Taylor rates. The policy in this period was particularly expansive in comparison to the policy of the ECB and to other periods.

The second exercise involves estimating the parameters of the original and smoothed forward-looking Taylor rules for the Fed and the ECB. The actual interest rates are compared with the estimated Taylor rates. This approach allows to drop assumptions about the parameters α and β, the long run interest rate r and the target inflation π^* (equations 2 and 3). Following Clarida, Gali, and Gertler (2000) and Gerdesmeier, Mongelli, and Roffia (2007), the rule is estimated by GMM using the lagged interest rate, the inflation and the output gap as instruments. Similar to the first exercise, the rules are estimated using both, the official and market interest rates. Figures 3 and 4 present the estimation results for both central banks (detailed results are reported in Tables A.1 and A.2 in Appendix A) for the official and market interest rates, respectively. Subfigures (a) and (b) regard the original and subfigures (c) and (d) the smoothed Taylor rules (labelled "Original TR" and "Smoothed TR", respectively). The upper lines denote the actual and the estimated interest rates while the lower line denotes the estimation error defined as the difference between the actual and the estimated values. A negative estimation error means that the implemented policy was expansive in comparison to the estimated Taylor rates. I find that the results for the original Taylor rule include very high estimation errors for the Fed in years 2003 and 2004. In this period, the actual interest rate was up to 2 percentage points lower than the estimated Taylor rate which is very unusual compared with other periods and with the results for the ECB. It shows, consistently with the results of the first exercise, that the policy of the U.S. central bank in 2003 and 2004 which accounted for uncertainty and tried to avoid deflation was unusually expansive. The results for the smoothed Taylor rule do not depict a similar pattern. This is due to the fact that the interest rate series is very persistent (estimated coefficients for the lagged interest rate are very high) and most interest rate changes can be explained with their past values.
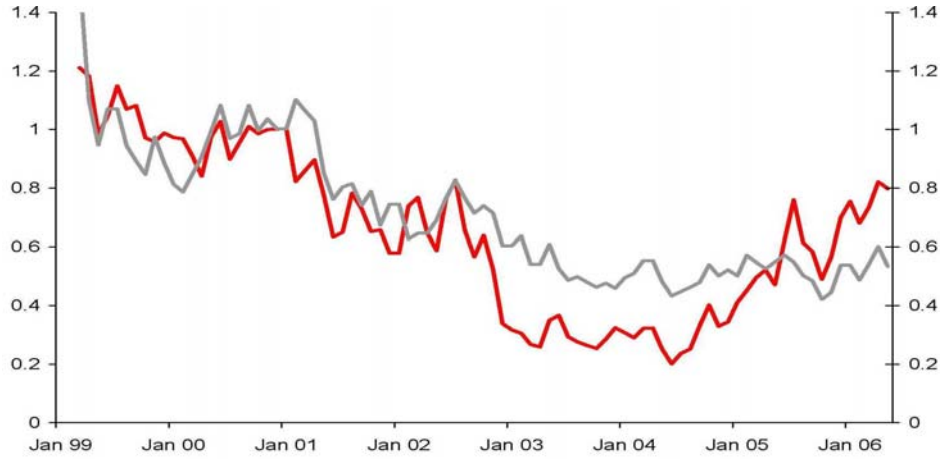
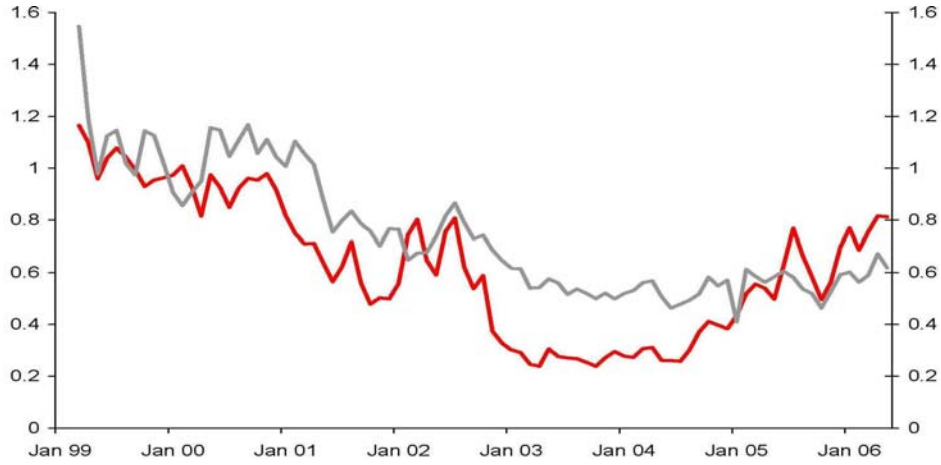(a) Official Interest Rates and the Original Taylor Rates
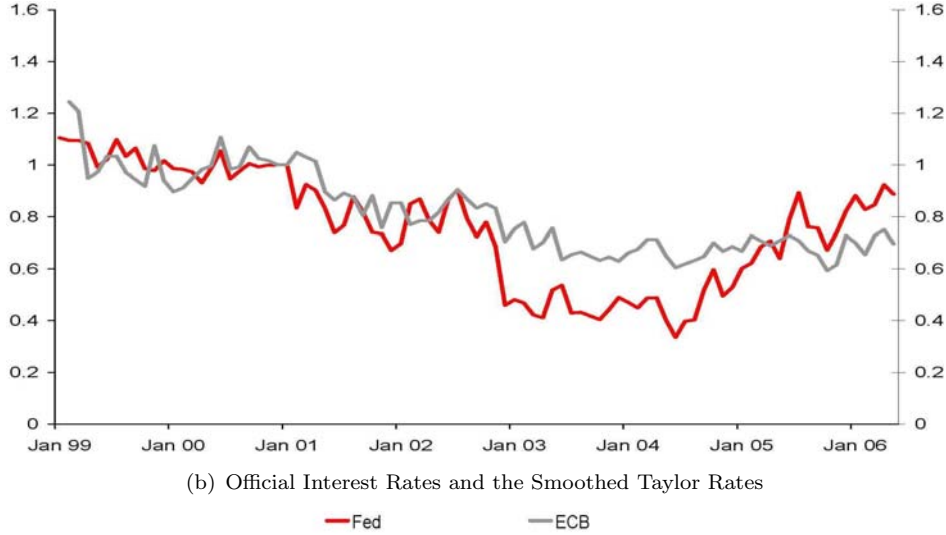
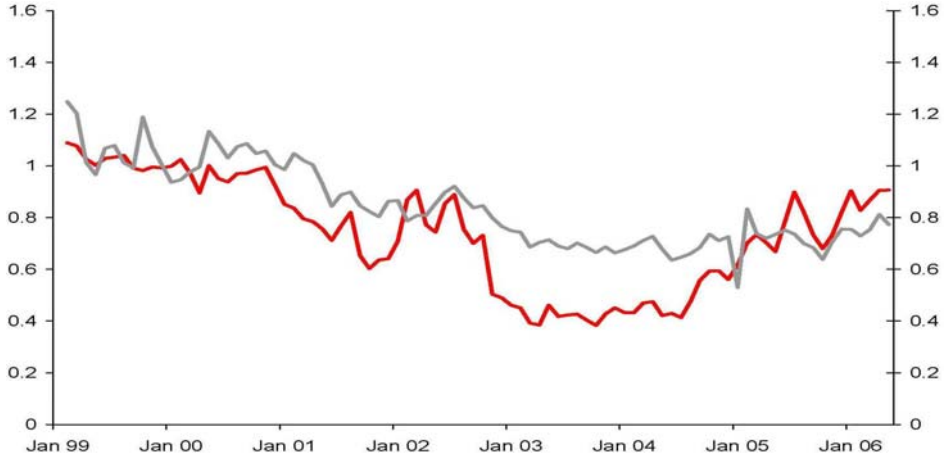(b) Official Interest Rates and the Smoothed Taylor Rates

— Fed   — ECB

Figure 1: Relative Deviation of the Official Interest Rates from the Neutral Policy Rates

The figure presents the ratio of the official interest rate to the original (subfigure (a)) and the smoothed (subfigure (b)) Taylor rates for the Fed (dark red line) and the ECB (light grey line). The original Taylor rates i_t^* are computed as $i_t^* = r + \pi_{t-1} + \alpha(\pi_{t-1} - \pi^*) + \beta(x_{t-1} - x_{t-1}^p)$. The smoothed Taylor rates i_t are computed as $i_t = \delta i_{t-1} + (1 - \delta)i_t^*$. The values α and β are assumed to be 0.5. The data for the ECB (source: ECB Statistics): interest rate - the ECB main refinancing rate (monthly data); π - inflation rate year over year calculated from the seasonally adjusted monthly HICP index (monthly data); x - GDP deflated with the seasonally adjusted, not working day adjusted deflator (quarterly data, monthly values assumed constant at 1/3 of the GDP in the corresponding quarter, natural logarithm taken of monthly values); x^p - Hodrick-Prescott filter ($\lambda = 1600$) applied to the quarterly x series (monthly values assumed constant at 1/3 of the potential GDP in the corresponding quarter, natural logarithm taken of monthly values). The data for the Fed (source: Federal Reserve Economic Data, Federal Reserve Bank of St. Louis): the federal funds rate (monthly), seasonally adjusted monthly CPI index, real GDP (quarterly) and real potential GDP (quarterly). The sample period: Jan 1999 - Apr 2006.

10

(a) Market Interest Rates and the Original Taylor Rates

(b) Market Interest Rates and the Smoothed Taylor Rates

Figure 2: Relative Deviation of the Market Interest Rates from the Neutral Policy Rates

The figure presents the ratio of the market interest rate to the original (subfigure (a)) and the smoothed (subfigure (b)) Taylor rates for the Fed (dark red line) and the ECB (light grey line). The original Taylor rates i_t^* are computed as $i_t^* = r + \pi_{t-1} + \alpha(\pi_{t-1} - \pi^*) + \beta(x_{t-1} - x_{t-1}^p)$. The smoothed Taylor rates i_t are computed as $i_t = \delta i_{t-1} + (1-\delta)i_t^*$. The values α and β are assumed to be 0.5. The data for the ECB (source: ECB Statistics): interest rate - 3-Month Euribor (monthly data); π - inflation rate year over year calculated from the seasonally adjusted monthly HICP index (monthly data); x - GDP deflated with the seasonally adjusted, not working day adjusted deflator (quarterly data, monthly values assumed constant at 1/3 of the GDP in the corresponding quarter, natural logarithm taken of monthly values); x^p - Hodrick-Prescott filter ($\lambda = 1600$) applied to the quarterly x series (monthly values assumed constant at 1/3 of the potential GDP in the corresponding quarter, natural logarithm taken of monthly values). The data for the Fed (source: Federal Reserve Economic Data, Federal Reserve Bank of St. Louis): 3-Month Treasury constant maturity rate (monthly), seasonally adjusted monthly CPI index, real GDP (quarterly) and real potential GDP (quarterly). The sample period: Jan 1999 - Apr 2006.

11

(a) Fed, Original Taylor Rule

(b) ECB, Original TR

(c) Fed, Smoothed TR

(d) ECB, Smoothed TR

Estimated — Actual — Residual

Figure 3: Official Interest Rates vs. Estimated Taylor Rates

NOTE: The figure presents the actual official interest rates (dark red line) in comparison to the estimated Taylor rates (light grey line) for the Fed (subfigures (a), (c)) and the ECB (subfigures (b), (d)). The difference between the actual and the estimated values is shown in each figure (bottom line labelled "residual"). Subfigures (a) and (b) regard the original and subfigures (c) and (d) the smoothed Taylor rules (labelled "Original TR" and "Smoothed TR", respectively). The sample period: Jan 1999 - Apr 2006. Estimation results are reported in Tables A.1 and A.2 in Appendix A.

12

(a) Fed, Original TR

(b) ECB, Original TR

(c) Fed, Smoothed TR

(d) ECB, Smoothed TR

——— Estimated   ——— Actual   ——— Residual

Figure 4: Market Interest Rates vs. Estimated Taylor Rates

NOTE: The figure presents the market interest rates (dark red line) in comparison to the estimated Taylor rates (light grey line) for the Fed (subfigures (a) and (c)) and the ECB (subfigures (b) and (d)). The difference between the actual and the estimated values is shown in each figure (bottom line labelled "residual"). Subfigures (a) and (b) regard the original and subfigures (c) and (d) the smoothed Taylor rules (labelled "Original TR" and "Smoothed TR", respectively). The sample period: Jan 1999 - Apr 2006. Estimation results are reported in Tables A.1 and A.2 in Appendix A.

13

(a) Fed, Original TR

(b) ECB, Original TR

(c) Fed, Smoothed TR

(d) ECB, Smoothed TR
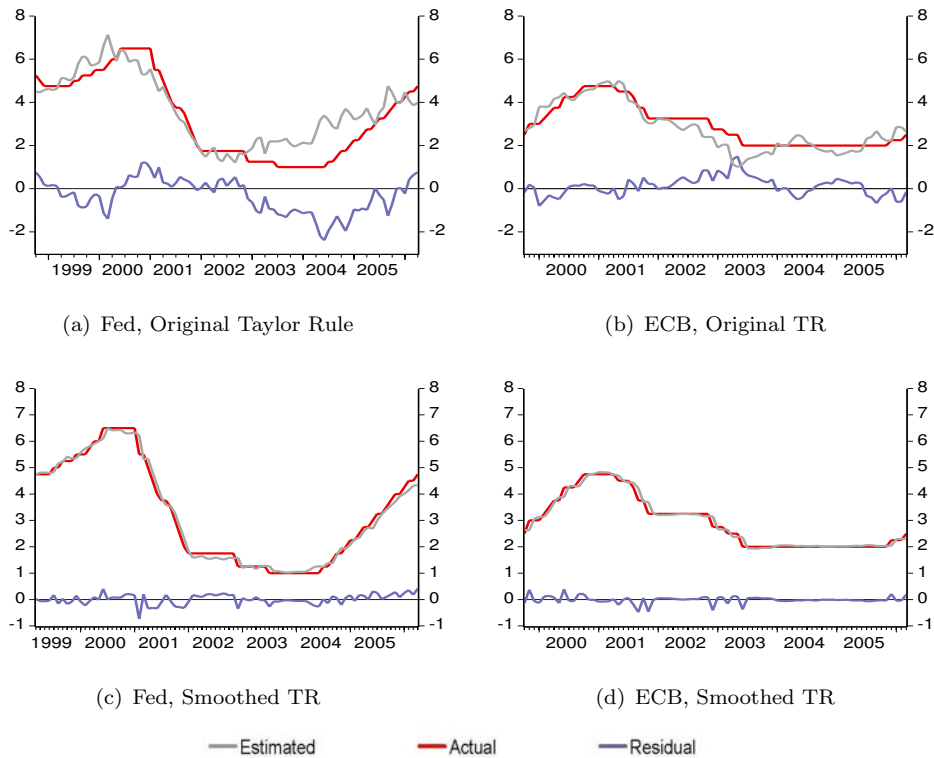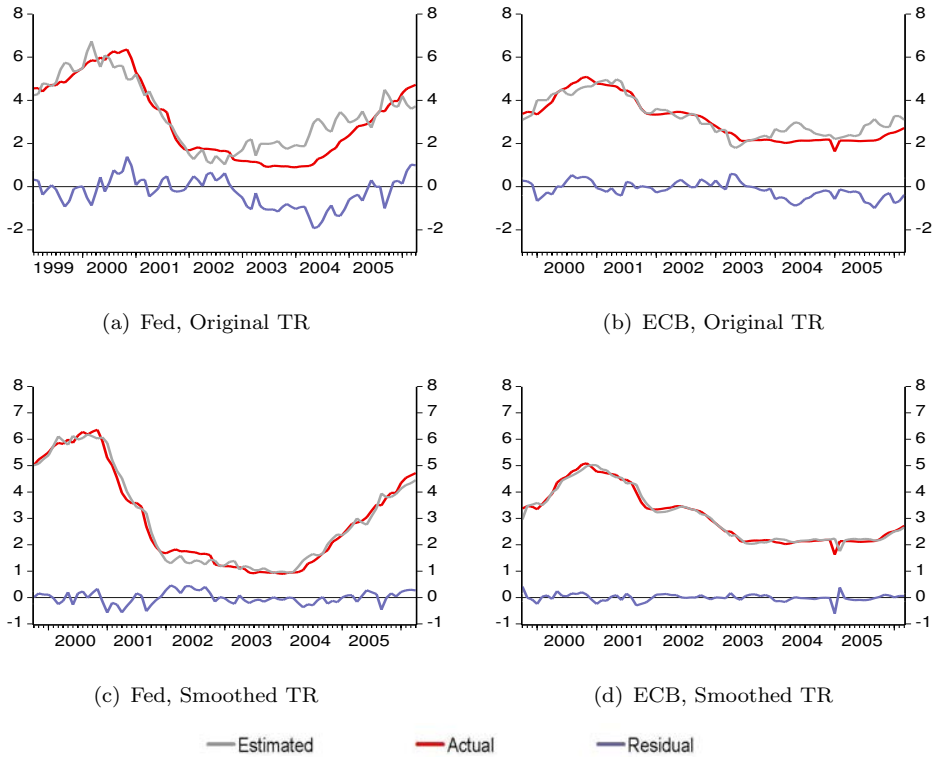
— Estimated   — Actual   — Residual

Figure 5: Official Interest Rates vs. Forecasted Taylor Rates

NOTE: The figure presents the actual official interest rates (dark red line) in comparison to the forecasted Taylor rates (light grey line) for the Fed (subfigures (a) and (c)) and the ECB (subfigures (b) and (d)). The difference between the actual and the estimated values is shown in each figure (bottom line labelled "residual"). Subfigures (a) and (b) regard the original and subfigures (c) and (d) the smoothed Taylor rules (labelled "Original TR" and "Smoothed TR", respectively). The forecasted interest rates denote the estimated interest rates for the period 1999-2002 and the out-of-sample forecasts for the period 2003-2006.

14

(a) Fed, Original TR

(b) ECB, Original TR

(c) Fed, Smoothed TR

(d) ECB, Smoothed TR

—— Estimated   —— Actual   —— Residual
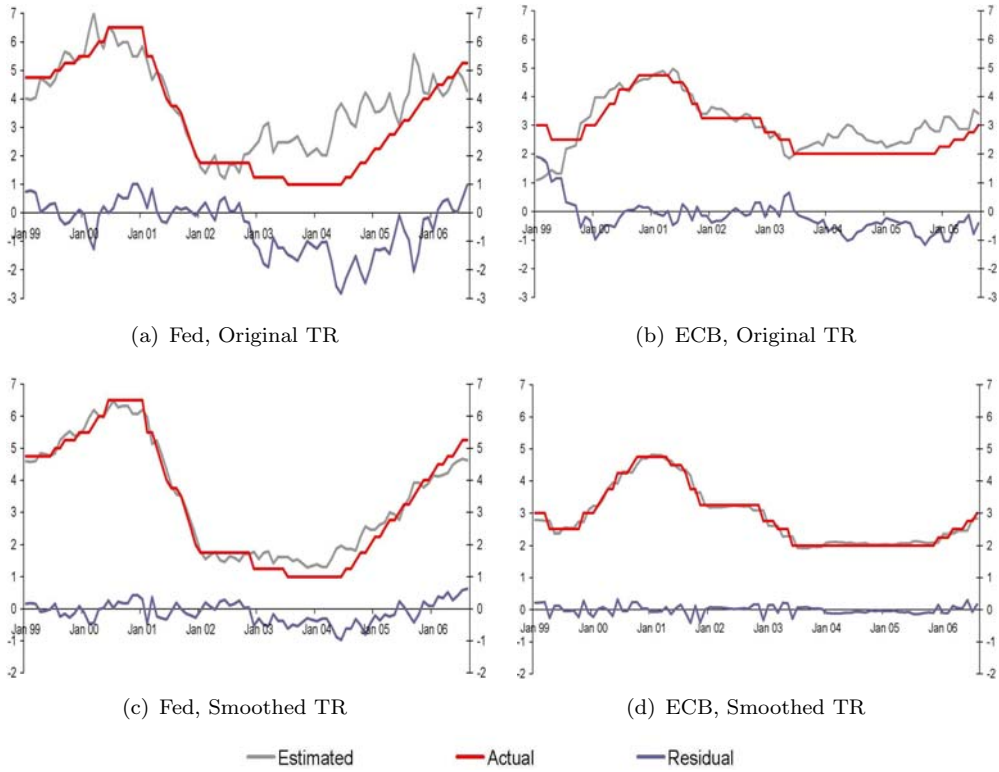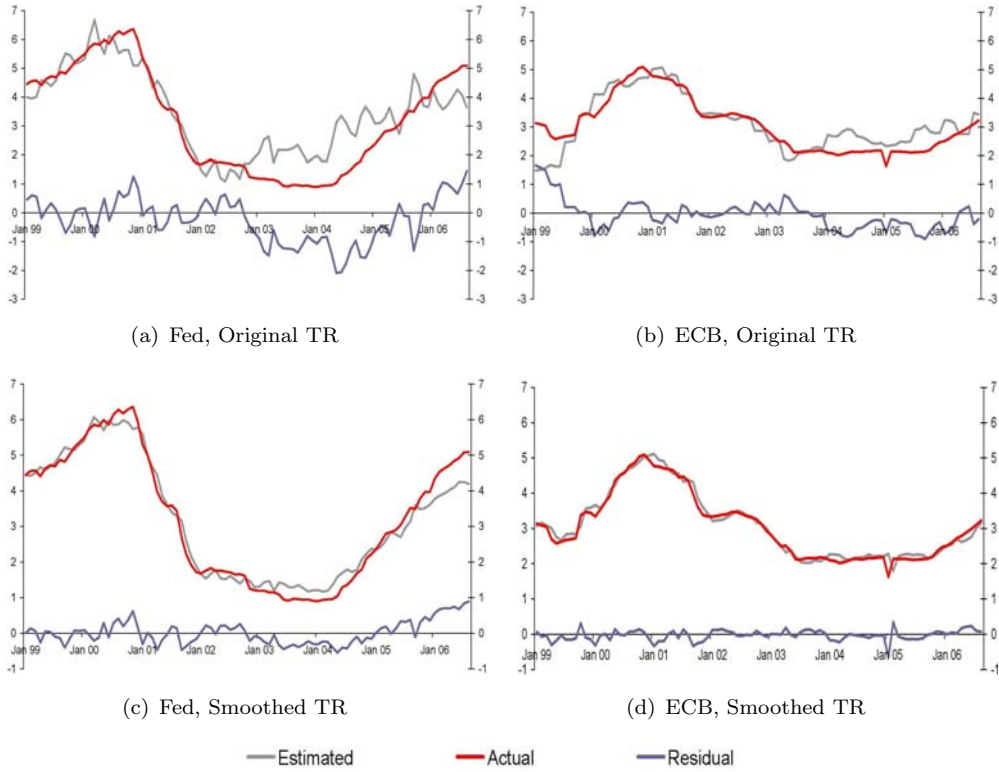
Figure 6: Market Interest Rates vs. Forecasted Taylor Rates

NOTE: The figure presents the market interest rates (dark red line) in comparison to the forecasted Taylor rates (light grey line) for the Fed (subfigures (a), (c), (e) and (g)) and the ECB (subfigures (b), (d), (f) and (h)). The difference between the actual and the estimated values is shown in each figure (bottom line labelled "residual"). Subfigures (a) and (b) regard the original and subfigures (c) and (d) the smoothed Taylor rules (labelled "Original TR" and "Smoothed TR", respectively). The forecasted interest rates denote the estimated interest rates for the period 1999-2002 and the out-of-sample forecasts for the period 2003-2006.

15

The third exercise considers investors who want to forecast future monetary policy decisions. Assume that investors can observe values of the interest rate and the fundamentals for the first part of the sample, i.e. years between 1999 and 2002. They estimate the parameters of the original and smoothed Taylor rules and forecast interest rate decisions for the period 2003-2006. Figures 5 and 6 present the results for both central banks (labels as in Figures 3 and 4). Note that the forecasted interest rates denote the estimated interest rates for the period 1999-2002 and the out-of-sample forecasts for the period 2003-2006. A negative forecast error means that the implemented policy was more expansive than the ex-ante forecast based on the Taylor rule estimated for the first part of the sample. The forecasts made for the Fed contain larger deviations from the actual values than the forecasts for the ECB. The results for the Fed depict a large negative forecast error in the period when the deflation scanario tried to be prevented and expansive policy was conducted. The forecasted interest rate decisions are up to 3 percentage points higher than the implemented decisions. Similar to the case of the estimated Taylor rules, forecast errors for the smoothed rules are lower than for the original ones. However, even for these rules there is a systematic negative error for the Fed in the period 2003-2004, when this bank applied the risk management approach.

All three exercises show that the period when the U.S. central bank accounted for uncertainty and tried to exclude the possibility of a deflation scenario involved an unusually expansive policy. This finding is in line with the theoretical excercise conducted in Svensson and Williams (2005). Consequently, the policy maker discussing the implementation of the risk management approach has to take into account that this policy may involve aggressive interest rate decisions in certain states.

3 Hypotheses

The objective of this study is to find the conditions, under which the risk management approach proposed by Alan Greenspan is successful and to test whether the Fed and the

ECB meet these conditions. Theoretical literature and empirical results presented in the previous section show that the implementation of the risk management approach may involve expansive monetary policy. Such policy usually implies the risk of large values of the central bank's loss function. This section discusses, under which conditions the policy maker realizes gains from expansive monetary policy. Derived hypotheses enable to test whether the Fed and the ECB meet these conditions and, consequently, whether these banks may account for uncertainty in a way proposed by Alan Greenspan without any increased risk of losses.

The consequences of expansive monetary policy are usually analyzed in the models of interaction between the central bank and private subjects. The first model of monetary policy as a dynamic game was introduced in Barro and Gordon (1983). They show that it is optimal for a policy maker minimizing the value of its loss function to commit to the low-inflation policy. Expansive monetary policy results in high losses for the central bank and thus should be avoided. The key assumption behind this finding is that inflation expectations of private subjects react to the observed policy. However, if they are constant, the central bank can realize either high gains or high losses.[7] For example, if private subjects expect high inflation in every period, meaning that they have no trust in the central bank's commitment, the policy maker suffers high losses.[8] In another extreme case, if private subjects trust fully in the commitment of the policy maker and expect low inflation in every period, the central bank can maximize its utility by conducting expansive policy.

Aa a consequence of the model of Barro and Gordon (1983), expansive monetary policy is successful only if private subjects do not have permanently high inflation expectations. Further analysis focuses thus on the changes of inflation expectations. High probability that private subjects increase them permanently makes expansive policy very dangerous for the central bank. In this case, it is not able to take certain aggressive policy decisions that

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[7]The case with constant inflation expectations is discussed in Appendix B where the model of Barro and Gordon (1983) is calculated.

[8]The losses are particularly high if the central bank conducts a low-inflation policy. Such a scenario is very plausible after the central bank lost trust of private subjects and tries to reestablish its reputation.

may result from the risk management approach. The remainder of this section derives two conditions that help to assess the probability of the permanent reputation loss, reflected in a permanent increase of inflation expectations, as reduced.

The first hypothesis focuses on the idea of price level targeting which is a monetary policy regime having the goal of a stable price level, meaning a stationary price level with low variance. A central bank with the price level target is committed to reverse policy errors which cause deviations from the desired price level path.[9] For example, high inflation in one period has to be compensated in the following periods. The rule has the following form:

$$i_t = f_p \tilde{p}_t + f_\pi \pi_t + f_y y_t + f_i i_{t-1} \tag{4}$$

where i_t is the interest rate, y_t the output gap, π_t the inflation and $\tilde{p}_t$ the price level gap defined as $\tilde{p}_t = p_t - p_t^*$ with p_t being the log price level and p_t^* the desired log price level. Fischer (1994) argues that price level targeting induces the short-run inflation variability relative to inflation targeting. However, Clarida, Gali, and Gertler (1999), Svensson (1999), Woodford (1999), and Vestin (2000, 2006) demonstrate that price level targeting is welfare-improving.[10] "The intuition is that with price level targeting, the private sector expects the central bank to counter an above average inflation with a below average inflation in the future. This interacts with the price-setting behaviour of the forward-looking agents in a way that automatically stabilizes (part of the) shocks to inflation" (Vestin (2006, p. 1374)).

Price level targeting is also recommended for particularly difficult periods in monetary policy. For example, Eggertsson and Woodford (2004) show that this policy can be successful in a liquidity trap.[11] Gorodnichenko and Shapiro (2007) use this idea to explain why periods

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[9]For this reason, price level targeting is an error-correction model.

[10]Among others because it reduces, according e.g. to Svensson (1999), the long-term price variability. Other authors, e.g. Friedman and Kuttner (1996) and Friedman (1999), argue that the central bank may need very tough decisions to pull down the price level after adverse economic shocks which can generate a deflation. However, according e.g. to Gorodnichenko and Shapiro (2007), as long as the desired price level has a trend there is room for the price level to revert to its target through a period of the lower-than-average inflation without having prices actually fall. Hence, the central bank can simultaneously pursue price level targeting and the goal of avoiding deflation.

[11]In this situation, the target is a commitment regarding the conditions, under which low-intrest-rate policy

of expansive policy were not followed by a permanent increase of inflation expectations. According to them, having a price level target explains the success of the Fed's policy in accomodating growth with stable inflation in the late 1990s. Crucial for the further argument developed in this study is that price level targeting anchors inflation expectations at a low and stable level. Therefore, the fact that the central bank has a price level target reduces the probability of large and permanent increases in inflation expectations. This, in turn, enables the policy maker to conduct expansive policy if it wishes to exclude dangerous scenarios as suggested by the risk management approach. Consequently, the first hypothesis tests whether the policy maker has a price level target:

H1: The price gap coefficient in the reaction function of the Fed (ECB) is positive and significant.

The second hypothesis is based on the idea that past observations of inflation expectations after certain policy decisions are informative for anticipating future reaction of private subjects to similar policy steps. For example, if a central bank experienced a long and persistent increase in inflation expectations after a period of expansive monetary policy, it is quite probable that another period of expansive policy will have similar consequences. In other case, if private subjects kept their inflation expectations at a low level even though the policy maker conducted expansive policy, similar reaction can be expected in the future. Consequently, it is less risky for such a central bank to apply the risk management approach because it can conduct aggressive policy more easily. Hypothesis H2 is thus as follows:

H2: The increases of inflation expectations for the Fed (ECB) were transitory.

Results supporting both hypotheses would indicate that inflation expectations for the monetary policy area are unlikely to increase permanently after observing a period of expansive policy. Therefore, a central bank that meets the conditions presented in H1 and H2 can ac-

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will be abandoned (e.g., interest rates remain very low for several months after natural interest rates increase). The central bank applying this strategy suffers no credibility loss even if it fails to hit the desired price level.

count for uncertainty as proposed by Alan Greenspan with relatively low risk. The results that do not support any hypothesis suggest that the implementation of the risk management approach by such a bank can be connected with high risk.

4 Results

This section includes hypothesis tests for the Fed and the ECB. First, the Taylor-like reaction function with the price gap is estimated. The test of hypothesis H1 involves investigating whether the price gap coefficient is positive and significant. Hypothesis H2 is considered in the further part of the section. Past inflation expectations are analyzed and compared with the actual inflation which enables to identify unusually negative or positive assessments of monetary policy made by private subjects. The results enable to compare the risk that both central banks would face if they wished to conduct expansive policy. Consequently, one can compare how hazardous it is for the policy maker to implement the risk management approach.

In the test of hypothesis H1, the following Taylor-like reaction function whith the price level target is estimated:

$$i_t = c + f_p \tilde{p}_t + f_\pi \pi_t + f_y y_t + f_i i_{t-1} + \epsilon_t \tag{5}$$

where i_t is the interest rate, y_t the output gap, π_t the inflation and $\tilde{p}_t$ the price level gap defined as $\tilde{p}_t = p_t - p_t^*$ with p_t being the log price level and p_t^* the desired log price level.[12] I use monthly data for the period from Jan 1999 to Apr 2006 obtained from the ECB Statistics and the Federal Reserve Economic Data (Federal Reserve Bank of St. Louis).[13] Most studies in the literature use quarterly data. The reason is that the GDP data is not available for a higher

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[12]The specifications of the Taylor rule with and without an intercept can be found in the literature. The intercept is included in the above equation in order to account for the target inflation value as well as the long-run interest rate. All results reported here are robust to the specification without an intercept.

[13]Orphanides (2001) shows that the reliance on the information that is actually available to policy makers in real time is essential for the analysis of monetary policy rules. However, due to the lack of the central bank's forecasts, all data used here is revised.

frequency. However, such an approach leads to eliminating a lot of monthly observations of interest rate decisions and the inflation rate. In order to have as many observations as possible (it is very important in the case of the ECB, which operates since 1999), monthly data is used here. I assume that the monthly GDP is constant within each quarter and equal to 1/3 of the value for the corresponding quarter.

The data for the ECB includes the ECB main refinancing rate (i for the official interest rate), 3-Month Euribor (i for the market interest rate), the inflation rate year over year calculated from the seasonally adjusted monthly HICP index (π) and the GDP deflated with the seasonally adjusted, not working day adjusted deflator. Hodrick-Prescott filter ($\lambda = 1600$) is applied to the GDP series in order to compute the potential GDP. The data for the Fed includes the federal funds rate, 3-Month Treasury constant maturity rate, the seasonally adjusted CPI index, the real GDP and the real potential GDP.[14] To calculate the price level target in every month t, I set the average price level of the CPI (U.S.) and HICP (EU) indices in 1998 as a reference and assume that the desired inflation is 2%. The results are robust to setting the values of the CPI (U.S.) and HICP (EU) indices in each month of 1998 as a reference (see Table C.1 in Appendix C).[15] Following Clarida, Gali, and Gertler (2000), Gerdesmeier, Mongelli, and Roffia (2007) and Gorodnichenko and Shapiro (2007), the rule is estimated by GMM using the lagged interest rate, the inflation and the output gap as instruments. The results are reported in Panel A of Table 1 for the official interest rates and in Panel B for the market interest rates.

The results show that only the U.S. central bank puts weight on the price level target. This finding complements the results of Gorodnichenko and Shapiro (2007) who show the importance of the price level target for the Fed in the period 1982-2003. Hypothesis H1 cannot be confirmed for the ECB as the price gap is not significant in the reaction function

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[14]Since the actual GDP and the potential GDP are measured on the quarterly basis, monthly values are assumed constant at 1/3 of the corresponding quarter values.

[15]This approach is different from the one in Gorodnichenko and Shapiro (2007). They have to introduce additional restrictions to the model which allow them to estimate it without having data for the price gap.

Table 1: Reaction Functions with a Price Level Target: the Fed and the ECB

Variable	Fed		ECB	
A: Official Interest Rates				
c	−0.1425	*0.1965*	0.6049**	*0.1658*
Price gap (f_p)	8.7999**	*3.6084*	−16.8934	*11.552*
Inflation (f_π)	0.2226**	*0.0985*	−0.1181	*0.1202*
Output gap (f_y)	0.3625***	*0.0971*	0.3459**	*0.1679*
Interest rate (f_i)	0.8357***	*0.0422*	0.8679***	*0.0595*
Adjusted R^2	0.9857		0.9773	
SE	0.2250		0.1511	
J-statistic	0.0371		0.0103	
B: 3-Month Interest Rates				
c	−0.1497	*0.1632*	0.6192**	*0.2812*
Price gap (f_p)	11.4472***	*3.6245*	−21.9128	*25.519*
Inflation (f_π)	0.2146**	*0.0898*	0.2552*	*0.1288*
Output gap (f_y)	0.4333***	*0.1119*	0.9385**	*0.4657*
Interest rate (f_i)	0.7922***	*0.0529*	0.6468***	*0.1001*
Adjusted R^2	0.9834		0.9816	
SE	0.2265		0.1392	
J-statistic	0.0395		0.0013	

NOTE: The dependent variable is the federal funds rate for the Fed and the minimum bid rate for the ECB (Panel A) as well as 3-Month Treasury constant maturity rate for the Fed and 3-Month Euribor for the ECB (Panel B). The equation $i_t = c + f_p \tilde{p}_t + f_\pi \pi_t + f_y y_t + f_i i_{t-1} + \epsilon_t$ is estimated by GMM with instruments that include the lags of the output gap and the inflation. *, **, *** denote significance at 90 percent, 95 percent and 99 percent, respectively. Italic numbers are standard errors.

of this central bank. This result is compatible with the officially announced objective and the strategy of the European policy maker. For the question investigated in this study, it means that there is no reason for private subjects to believe that the ECB would reverse policy errors if they happened. In result, expansive policy in Europe may imply faster and longer increases in inflation expectations than in the case of the Fed. Consequently, the risk management approach is more risky for the European than for the U.S. policy maker.

The test of hypothesis H2 involves investigating historical inflation expectations. Following the approach of Krane (2003) and Gorodnichenko and Shapiro (2007), I calculate the forecast error as the difference between the actual inflation in each period and the value of the inflation forecast for that period. Such measure does not depend on the level of inflation but rather shows whether private subjects had particularly pessimistic or optimistic projections about the price development. A negative forecast error indicates that the expected inflation was higher than the actual one and thus that private subjects were pessimistic about monetary policy decisions. Particularly long periods with negative forecast errors indicate that private subjects were generally sensitive to the observed monetary policy and were ready to increase their inflation expectations permanently. However, if periods of negative errors are followed by a quick return to normal expectations, the central bank can assume that private subjects have rather stable inflation expectations and the probability of permanent upward expectation shifts is rather low. Consequently, such a policy maker can implement the risk management approach with a lower risk than a central bank that observed permanent (or very long) increases of inflation expectations in the past.

Two types of data on inflation expectations are used to conduct the test of hypothesis H2. First, forecasts of the yearly inflation rate made by the Survey of Professional Forecasters in the first quarter of each year are considered.[16] The results regarding the inflation and the

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[16]This approach follows Gorodnichenko and Shapiro (2007). Data for the forecasts (Survey of Professional Forecasters) is provided by the ECB and the Federal Reserve Bank of Philadelphia. Data for the actual inflation and the output values is provided by the Eurostat and the Bureau of Labor Statistics.

output growth forecasts for both monetary policy areas are reported in Table 2. Furthermore, three other measures of inflation expectations are used: the University of Michigan Inflation Expectation Index as well as the difference between the 5-Year (7-Year) Treasury constant maturity rate and the 5-Year (7-Year) Treasury Inflation-Indexed Security (data source: Federal Reserve Economic Data, Federal Reserve Bank of St. Louis). Unfortunatelly, they are available only for the U.S. Figure 7 presents the difference between the actual monthly CPI and inflation expectations for all three measures.

Table 2: Inflation and Real GDP Growth: Actual vs. Forecasted Values

	1998	1999	2000	2001	2002	2003	2004	2005	2006
Fed									
Inflation	-0.5	0.2	0.9	0.4	-0.4	0.1	1.1	1.1	0.8
GDP growth	1.4	1.2	-0.1	-1.4	0.2	0.0	-0.7	-0.4	0.1
ECB									
Inflation	-	0.2	0.2	0.2	0.4	0.2	0.2	0.3	0.2
GDP growth	-	0.9	0.8	-0.7	-0.1	-0.1	0.6	-0.1	0.9

NOTE: The table shows the difference between the actual value of the average inflation (the real GDP growth rate) in a given year and the median forecast made in the first quarter of that year. Data for the forecasts (Survey of Professional Forecasters) is provided by the ECB and the Federal Reserve Bank of Philadelphia. Data for the actual values is provided by the Eurostat and the Bureau of Labor Statistics.

The results for all measures of inflation expectations for the U.S. monetary area support hypothesis H2. Periods with negative forecast errors can be observed in year 2002 as well as in late 2003 and early 2004. However, they last no longer than 1 year in each case. It is interesting to see the reaction of private subjects following the implementation of the risk management approach by the Fed in 2003 and 2004. According to the calculations based, for example, on the University of Michigan Inflation Expectation Index, around early 2004 investors expected inflation higher by 1 percentage point than the actual value but became optimistic already before the end of that year. This and the other examples of temporarily increased inflation expectations in the U.S. suggest that the probability that private subjects increase their expectations permanently is rather low. In contrast, the results provide no
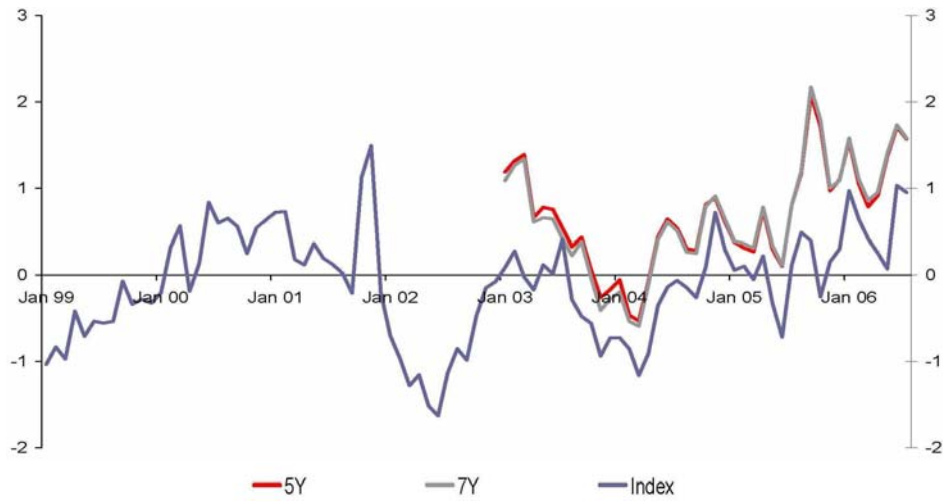
Figure 7: Shifts in Inflation Expectations - U.S.
The figure presents the difference between the actual monthly CPI and inflation expectations for three measures of inflation expectations (data source: Federal Reserve Economic Data, Federal Reserve Bank of St. Louis). Blue line labelled "Index" and starting in 1999 denotes the University of Michigan Inflation Expectation Index, dark red (light grey) line denotes inflation expectations computed as a difference between the 5-Year (7-Year) Treasury constant maturity rate and the 5-Year (7-Year) Treasury Inflation-Indexed Security, Constant Maturity. Negative values mean that the expected inflation was higher than the actual inflation rates and thus private subjects were pessimistic about the policy of the U.S. central bank.

support for hypothesis H2 in case of the ECB. The calculations for the only dataset that is available, Survey of Professional Forecasters, show that no increased inflation expectations can be observed for the whole period of the ECB operation. It does not mean that private subjects had an overall good outlook regarding the business cycle. The forecasts of the output growth were often pessimistic (high positive forecast errors for the GDP growth). However, private subjects were never particularly pessimistic about the monetary policy of the ECB. Due to the lack of observations, it cannot be predicted how long periods of pessimistic inflation outlook would last if they occured. Consequently, the risk of conducting expansive monetary policy cannot be assessed on this basis.

The results presented in this section provide support for both hypotheses in the case of the Fed. The U.S. central bank is shown to put weight on the price level target which anchors inflation expectations and keeps them on a low and stable level. Moreover, all past periods of increased inflation expectations in the sample were temporary and last no longer than a

couple of months. Both of these findings suggest that periods of expansive monetary policy are not likely to be followed by permanent upward shifts of inflation expectations. In result, the Fed can implement expansive policy for a couple of periods, when needed, with a relatively low risk. Consequently, this policy maker can account for uncertainty as proposed by Alan Greenspan and is able to implement the consequences of this strategy without an increased risk of the reputation loss.

In the case of the ECB, no support for any of the investigated hypotheses can be found. The probability of large and permanent increases in inflation expectations cannot be assessed as reduced because this central bank has no price level target. Moreover, inflation expectations observed in the past do not include any periods of upward shifts. Therefore, it is much more difficult to assess the reaction of private subjects after observing expansive monetary policy than in the case of the Fed. Consequently, implementing Greenspan's approach is connected with higher risk for the European than for the U.S. policy maker.

5   Conclusion

This paper investigates whether accounting for uncertainty in monetary policy as proposed by Alan Greenspan and conducted by the Federal Reserve System in years 2003 and 2004 can be used as a model for the European Central Bank. In contrast to the standard approach where the central bank considers the expected value of the loss function, the main objective of the policy applying the risk management approach is to avoid scenarios defined as particularly dangerous for the economy. For example, an unusually expansive policy of the Fed in 2003 and 2004 was aimed at preventing a deflation scenario. This first implementation of Greenspan's strategy can be described as successful since it was not followed by high inflation and the loss of trust. However, the question remains under which conditions this approach is likely to be successful and whether the ECB meets these conditions.

The results for the Fed suggest that periods of expansive monetary policy are not likely to be

followed by a permanent upward shift of inflation expectations. Firstly, the reaction function of the U.S. central bank includes a price level target which, according to the literature on price level targeting, anchors inflation expectations and keeps them on a low and stable level. Moreover, inflation expectations increased only temporarily in the recent years of the Fed's operation. Consequently, the U.S. policy maker can account for uncertainty as proposed by Alan Greenspan and is able to implement aggressive policy when needed. In contrast, the results for the ECB show that it is much more difficult to assess the reaction of private subjects to expansive monetary policy. Firstly, this central bank does not implement price level targeting. Secondly, inflation expectations observed in the past do not include any periods of upward shifts which could help to assess how private subjects react to expansive monetary policy of the ECB. Consequently, implementing Greenspan's approach is connected with higher risk for the European than for the U.S. policy maker.

The central bank is one of the most important institutions in the financial system because it regulates the money supply. In case of severe liquidity crises, it intervenes by providing additional liquidity to the banks or sometimes even by organizing bailouts of failed credit institutions. Whether liquidity shortages originate in capital markets or in the banking sector, such interventions are aimed at preventing the problems from spreading to other parts of financial system and to other countries. However, the results of this study show that the risk of implementing an aggressive policy differs among central banks. Consequently, we can observe different reactions in some crisis situations in the U.S. and in Europe. For example, in the latest liquidity crisis both central banks tried to eliminate liquidity shortages in capital markets using different strategies. While both banks provided large injections of liquidity in the form of short-term loans to the banks, only the Fed decided to cut interest rates drastically.

References

AL-NOWAIHI, A., AND P. LEVINE (1994): "Can Reputation Resolve the Monetary Policy Credibility Problem?," *Journal of Monetary Economics*, 33(2), 355–380.

BARRO, R. J., AND D. B. GORDON (1983): "Rules, Discretion and Reputation in a Model of Monetary Policy," *Journal of Monetary Economics*, 12(1), 101–121.

BERNANKE, B. S. (2004): "The Logic of Monetary Policy," Speech before the National Economists Club, Washington D.C., Dec 2., 2004. Available at: http://www.federalreserve.gov/boarddocs/Speeches/2004/20041202/.

BLINDER, A. S., AND R. REIS (2005): "Understanding the Greenspan Standard," in *The Greenspan Era: Lessons for the Future*, ed. by Federal Reserve Bank of Kansas City, chap. 4, pp. 11–96. Jackson Hole.

CLARIDA, R., J. GALI, AND M. GERTLER (1998): "Monetary Policy Rules in Practice: Some International Evidence," *European Economic Review*, 42, 1033–1067.

———— (1999): "The Science of Monetary Policy: A New Keynesian Perspective," *Journal of Economic Literature*, 37, 16611707.

———— (2000): "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory," *Quarterly Journal of Economics*, 115, 147180.

EGGERTSSON, G. B., AND M. WOODFORD (2004): "Policy Options in a Liquidity Trap," *American Economic Review*, 94, 76–79.

FELDSTEIN, M. (2004): "Innovations and Issues in Monetary Policy: Panel Discussion," *American Economic Review*, 94, 41–43.

FISCHER, S. (1994): "Modern Central Banking," in *The Future of Central Banking: The Tercentenary Symposium of the Bank of England*, ed. by F. Capie, C. Goodhart, S. Fischer, and N. Schnadt, p. 262308. Cambridge: Cambridge University Press.

FRIEDMAN, B. M. (1999): "Comment," in *Monetary Policy Rules*, ed. by J. B. Taylor, p. 398402. Chicago: University of Chicago Press.

FRIEDMAN, B. M., AND K. N. KUTTNER (1996): "A Price Target for US Monetary Policy? Lessons from the Experience with Money Growth Targets," *Brookings Papers on Economic Activity*, 1, 77146.

GERDESMEIER, D., F. MONGELLI, AND B. ROFFIA (2007): "The Eurosystem, the US Federal Reserve and the Bank of Japan: Similarities and Differences," *Journal of Money, Credit, and Banking*, 39, 1785–1819.

GOODFRIEND, M. (1991): "Interest Rates and the Conduct of Monetary Policy," *Carnegie-Rochester Conference Series on Public Policy*, 34, 7–30.

GORODNICHENKO, Y., AND M. D. SHAPIRO (2007): "Monetary Policy When Potential Output is Uncertain: Understanding the Growth Gamble of the 1990s," *Journal of Monetary Economics*, 54, 1132–1162.

GREENSPAN, A. (2003): "Monetary Policy under Uncertainty," Remarks at a symposium sponsored by the Federal Reserve Bank of Kansas City, Jackson Hole, Wyoming, Aug 29, 2003. Available at: http://www.federalreserve.gov/ boarddocs/speeches/2003/20030829/default.htm.

——— (2004): "Risk and Uncertainty in Monetary Policy," *American Economic Review*, 94(2), 33–40.

KRANE, S. D. (2003): "An Evaluation of Real GDP Forecast: 1996-2001, Economic Perspectives," *Federal Reserve Bank of Chicago*, 1, 221.

ORPHANIDES, A. (2001): "Monetary Policy Rules Based on Real-Time Data," *American Economic Review*, 91, 964–985.

PEERSMAN, G., AND F. SMETS (1999): "The Taylor Rule: A Useful Monetary Policy Benchmark for the Euro Area?," *International Finance*, 2(1), 85–116.

RUDEBUSCH, G. D. (2006): "Monetary Policy Inertia: Fact or Fiction?," *International Journal of Central Banking*, 2(4).

SVENSSON, L. E. (1999): "Price Level Targeting vs. Inflation Targeting: A Free Lunch?," *Journal of Money, Credit and Banking*, 31, 277–295.

——— (2005): "Monetary Policy with Judgment: Forecast Targeting," *International Journal of Central Banking*, 1, 1–54.

SVENSSON, L. E., AND N. WILLIAMS (2005): "Monetary Policy with Model Uncertainty: Distribution Forecast Targeting," NBER Working Paper No. W11733.

——— (2006): "Bayesian and Adaptive Optimal Policy under Model Uncertainty," Working Paper.

TAYLOR, J. B. (1993): "Discretion versus Policy Rules in Practice," Carnegie-Rochester Conference Series on Public Policy 39.

——— (1999): "The Robustness and Efficiency of Monetary Policy Rules as Guidelines for Interest Rate Setting by the European Central Bank," *Journal of Monetary Economics*, 43(3), 655–679.

VESTIN, D. (2000): "Price-Level Targeting versus Inflation Targeting in a Forward-Looking Model," Sveriges Riksbank Working Paper Series No. 106.

——— (2006): "Price-level Versus Inflation Targeting," *Journal of Monetary Economics*, 53, 1361–1376.

WOODFORD, M. (1999): "Commentary: How Should Monetary Policy Be Conducted in an Era of Price Stability?," in *New Challenges for Monetary Policy*, ed. by Federal Reserve Bank of Kansas City, pp. 277–316. Kansas City.

Appendix A: Estimated Taylor Rules for the Fed and the ECB

Table A.1: Estimated Original Taylor Rules for the Fed and the ECB

Variable	Fed		ECB	
A: Official Interest Rates				
c	1.8705***	*0.3925*	0.9310**	*0.4440*
Inflation (π_t)	0.9053***	*0.1565*	0.6785***	*0.2100*
Output gap (y_t)	1.4725***	*0.1370*	3.6585***	*0.2400*
Adjusted R^2	0.7804		0.7757	
SE	0.8851		0.4607	
J-statistic	0.0993		0.0813	
B: 3-Month Interest Rates				
c	1.6238***	*0.3926*	1.6836***	*0.4414*
Inflation (π_t)	0.8872***	*0.1452*	0.5643***	*0.1990*
Output gap (y_t)	1.3996***	*0.1127*	2.8868***	*0.1893*
Adjusted R^2	0.8267		0.8371	
SE	0.7482		0.4017	
J-statistic	0.0968		0.1067	

NOTE: The dependent variable is the federal funds rate for the Fed and the minimum bid rate for the ECB (Panel A) as well as 3-Month Treasury constant maturity rate for the Fed and 3-Month Euribor for the ECB (Panel B). The equation $i_t = c + f_\pi \pi_t + f_y y_t + \epsilon_t$ is estimated by GMM with instruments including the lags of the interest rate, the inflation and the output gap. *, **, *** denote significance at 90 percent, 95 percent and 99 percent, respectively. Italic numbers are standard errors.

Table A.2: Estimated Innertial Taylor Rules for the Fed and the ECB

Variable	Fed		ECB	
A: Official Interest Rates				
c	0.2079	*0.1427*	0.3826***	*0.1399*
Rate $t-1$ ($\imath_{t-1}$)	0.8464***	*0.0386*	0.9030***	*0.0330*
Inflation (π_t)	0.1526***	*0.0492*	−0.0630	*0.0805*
Output gap (y_t)	0.2938***	*0.0726*	0.4100***	*0.0968*
Adjusted R^2	0.9890		0.9778	
SE	0.1993		0.1449	
J-statistic	0.0357		0.0219	
B: 3-Month Interest Rates				
c	−0.0041	*0.2521*	0.7496***	*0.2406*
Rate $t-1$ ($\imath_{t-1}$)	0.7546***	*0.0748*	0.8443***	*0.0593*
Inflation (π_t)	0.3497***	*0.1191*	−0.1555	*0.1320*
Output gap (y_t)	0.3765***	*0.1182*	0.5872***	*0.1872*
Adjusted R^2	0.9826		0.9789	
SE	0.2397		0.1446	
J-statistic	0.0042		0.0049	

NOTE: The dependent variable is the federal funds rate for the Fed and the minimum bid rate for the ECB (Panel A) as well as 3-Month Treasury constant maturity rate for the Fed and 3-Month Euribor for the ECB (Panel B). The equation $i_t = c + i_{t-1} + f_\pi \pi_t + f_y y_t + \epsilon_t$ is estimated by GMM with instruments that include the lags of interest rate, the inflation and the output gap. *, **, *** denote significance at 90 percent, 95 percent and 99 percent, respectively. Italic numbers are standard errors.

Appendix B: Inflation Expectations and Utility of the Central Bank

This section analyzes the conditions under which expansive monetary policy is successful for the central bank. Using a model of strategic interaction between the central bank and private subjects introduced by Barro and Gordon (1983), the importance of inflation expectations for the efficiency of monetary policy is shown.

THE BASIC MODEL

Consider a dynamic game with complete information and two player groups: the central bank and homogenous private subjects. The basic game is composed of two stages. In the first one private subjects form inflation expectations π^e. In the second stage the central bank observes π^e and takes its monetary policy decision, determining the actual inflation rate π. Note that the bank itself decides about the inflation and that π is here an exogenous variable independent of π^e. The payoff functions of private subjects (U) and the central bank (W) are given in equations (B.1) and (B.2). Equation (B.3) defines the relation between the unemployment rate u and the natural unemployment rate u^n equivalent to the Lucas supply function.[17]

$$U(\pi, \pi^e) = -(\pi - \pi^e)^2 \tag{B.1}$$

$$W(\pi, u) = -u - c\pi^2 \tag{B.2}$$

$$u = u^n - b(\pi - \pi^e) \tag{B.3}$$

The Nash equilibrium of the basic game is found using backward induction. The central bank maximizes its payoff choosing the optimal inflation level $\pi^* = \frac{b}{2c}$. Since private subjects are assumed to be rational, they expect this reaction correctly with $\pi^e = \pi^* = \frac{b}{2c}$. In result, the central bank receives $W = -u^n - \frac{b^2}{4c}$. This is not the first-best solution as the central bank

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[17] The same analysis can be conducted using the Lucas supply function with the output y and the potential output y^P: $y = y^P + a(\pi - \pi^e)$ and the following loss function of the central bank: $L = \pi^2 + \gamma(y - y^P)^2$ with the weight of the output target γ.

could increase its utility by $\frac{b^2}{4c}$ if it conducted the zero-inflation policy and if private subjects expected it.[18]

INFINITE INTERACTION - SHIFTS IN INFLATION EXPECTATIONS

The long-run interaction is modeled with the infinite repetition of the basic game. Each payoff function is the sum of the discounted expected period payoffs. Consider the case when private subjects react to the decisions of the central bank. Their knowledge about the monetary policy strategy can be modeled using learning rules or assuming rational expectations, meaning that the strategy is perfectly anticipated. Assuming rational expectations, consider the following trigger strategy: Private subjects expect $\pi^e = 0$ in the first round. They expect $\pi^e = 0$ in the following rounds if the central bank played $\pi = 0$ in all past rounds; otherwise they expect $\pi^e = \pi^*$. The central bank chooses $\pi_1 = 0$ in the first round if private subjects expect $\pi_1^e = 0$. In the following rounds $\pi = 0$ is realized when neither of the players has deviated from the path ($\pi^e = 0$, $\pi = 0$) in any of the former rounds, otherwise $\pi = \pi^*$ is chosen.

The central bank has two possibilities in this setting: it conducts a zero-inflation policy consequently or deflects in round n with an inflationary policy. This problem can be interpreted as the choice between a credible commitment to the zero-inflation rule $\pi_t = 0$ for all t and a one-period benefit from positive inflation at the cost of the credibility loss. The decision to follow the rule depends on the discount factor δ. If $\delta \geq \frac{1}{2}$, the benefit from the commitment is greater than the one from the surprise inflation. A central bank that is concerned about the long-run development of the economy will always follow a zero-inflation policy in order not to loose its credibility.[19] The credibility loss leads to high inflation expectations causing the utility loss for the central bank. Any policy strategy is in this case inefficient.[20]

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[18]Utility of private subjects would remain at the same level.

[19]Imposing the credibility conditions on the equilibrium results in the positive inflation rate, which is far less than the discretionary outcome (e.g., al-Nowaihi and Levine (1994)).

[20]This finding is based on the assumption of rational private subjects having a trigger strategy where they loose trust for the central bank immediately after observing inflationary policy. The credibility loss is permanent. This model can be modified to account for the dependence of inflation on inflation expectations, incomplete information about the central bank's utility function, the lack of rational expectations or the time

Consider now two cases where private subjects have such firm beliefs about the central bank's policy that they do not react to monetary policy decisions at all (the value $\bar{\pi}^e$ is independent of observed monetary policy decisions). In the first case, the central bank has no credibility at all and the market expects positive inflation. In the second case, the market has thorough trust in the noninflationary policy of the central bank and expects zero inflation in all periods. Table B.1 compares central bank's payoffs for the two types of expectations and policies.

Table B.1: Naïve Expectations and Monetary Policy

Expectations	Inflation, $\bar{\pi}^e = \frac{b}{2c}$	Zero-Inflation, $\bar{\pi}^e = 0$
Inflationary Policy, $\pi = \frac{b}{2c}$	$-\frac{u^n}{1-\delta} - \frac{b^2}{4c(1-\delta)}$	$-\frac{u^n}{1-\delta} + \frac{b^2}{4c(1-\delta)}$
Zero-Inflation Policy, $\pi = 0$	$-\frac{u^n}{1-\delta} - \frac{3b^2}{4c(1-\delta)}$	$-\frac{u^n}{1-\delta}$

NOTE: The table reports the values of the central bank's payoff (W) for different strategies and expectations.

A central bank having the absolute trust of private subjects receives higher payoffs for any of the two strategies than a central bank that is not credible. If it conducts inflationary policy, it has no costs regarding the credibility loss. A central bank without credibility has to account for the permanent expectations of high inflation. Independent of the policy it chooses, it suffers large utility losses. In this sense, decisions of the policy maker with bad reputation are inefficient. The highest costs result if the bank conducts noninflationary policy in the difficult environment with $\bar{\pi}^e > 0$. Note that this is the case when the policy maker with the long-run objective that has lost credibility tries to restore its reputation by conducting a consequent

needed to rebuild credibility. The main result remains the same, implying that the reputation loss causes costs for the central bank having a long-term objective.

zero-inflation policy.

To summarize, the central bank's utility depends on how long private subjects penalize the deviation from the noninflationary policy. This means that if the market has deep trust in the noninflationary policy and keeps expectations at a constant low level, the central bank can afford to conduct expansive policy.

Appendix C: Robustness Tests: Reaction Functions

Table C.1 presents the results for the Taylor-like rule including a price level gap, where the values of the CPI (U.S.) and HICP (EU) indices in each month of 1998 are taken as the reference to calculate the desired price level p^* in the sample.

Table C.1: Robustness Test: Reaction Functions with the Price Level Target, the Fed and the ECB

Variable	Fed		ECB	
A: Official Interest Rates				
Price gap ($\tilde{p}_t$)	9.5886***	*2.9048*	-12.6511	*11.682*
Inflation (π_t)	0.1880***	*0.0539*	0.2726***	*0.0791*
Output gap (x_t)	0.4146***	*0.0812*	0.6641**	*0.2733*
Interest rate (i_{t-1})	0.8239***	*0.0403*	0.7777***	*0.0679*
Adjusted R^2	0.9881		0.9772	
SE	0.2093		0.1516	
J-statistic	0.0261		0.0571	
B: 3-Month Interest Rates				
Price gap ($\tilde{p}_t$)	8.6016***	*2.4896*	-20.0638	*16.586*
Inflation (π_t)	0.1417**	*0.0580*	0.4298***	*0.1219*
Output gap (x_t)	0.3210***	*0.0885*	0.7879**	*0.3230*
Interest rate (i_{t-1})	0.8610***	*0.0503*	0.6636***	*0.0942*
Adjusted R^2	0.9880		0.9716	
SE	0.1985		0.1727	
J-statistic	0.0520		0.0592	

NOTE: The dependent variable is the federal funds rate for the Fed and the minimum bid rate for the ECB (Panel A) as well as 3-Month Treasury constant maturity rate for the Fed and 3-Month Euribor for the ECB (Panel B). The equation $i_t = c + f_p \tilde{p}_t + f_\pi \pi_t + f_y y_t + f_i i_{t-1} + \epsilon_t$ is estimated by GMM with instruments that include the lags of the output gap and the inflation. *, **, *** denote significance at 90 percent, 95 percent and 99 percent, respectively. Italic numbers are standard errors.