Central Bank Misperceptions and the Role of Money in Interest Rate Rules[†]

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1 Introduction

John B. Taylor's interest in developing effective rules for government policy has been a driving force for his research from the 1970s till today. Taylor (2006) writes about his early research[1]:

> *Taylor (1979) showed that a fixed money growth rule - a Friedman rule - would have led to better performance than actual policy in the post World War II period ... (but) a money growth rule which responded to economic developments could do even better. Since then I have found that policy rules in terms of interest rates have worked better as practical guidelines for central banks.*

The tremendous influence of Taylor's contribution to the science of monetary policy is perhaps best illustrated by the fact that the last published writing of the late Milton Friedman focused on the Taylor rule. Friedman (2006) notes at first that he always preferred a nominal aggregate for an instrument (i.e. to be placed on the left-hand-side of a policy rule) but then he proceeds taking the perspective of Taylor's rule with the federal funds rate as instrument. From this perspective he justifies the inclusion of output and money growth as additional right-hand-side variables:

> *"The Taylor rule is an attempt to specify the federal funds rate that will come closest to achieving the theoretically appropriate rate of monetary growth to achieve a constant price level or a constant rate of inflation.*
>
> *Suppose the federal funds target rate is equal to a Taylor rule that gives 100 percent weight to inflation deviations. That may not be the right rate to achieve the desired inflation target because other variables such as output or monetary growth are not at their equilibrium levels. On this view, additional terms in the Taylor rule would reflect variables relevant to choosing the right target funds rate to achieve the desired inflation target."*

Not surprisingly, researchers steeped in Keynesian-style macroeconomics do not concur with Friedman's recommendation regarding interest-rate rules and money growth. Rather, recent theoretical advances in New-Keynesian macroeconomics building on microeconomic foundations with monopolistic competition and price rigidity[2] have tended

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[1] The famous paper introducing a variance tradeoff between output and inflation under rational expectations - the so-called Taylor curve.

[2] This model as laid out by Rotemberg and Woodford (1997) and Goodfriend and King (1997) and developed in detail in Woodford (2003) has quickly become the principal workhorse model in monetary economics. It has proved very useful in deriving several important principles for the conduct of monetary policy (see for example Clarida et al. (1999) and King (2000)). The model is shortly summarized in Section 4 in parallel to a more traditional, backward-looking model. Both models are used in the analysis of interest rate rules in the following sections.

to emphasize the irrelevance of money growth and instead the importance of (properly derived) output gaps for a policy aimed at controlling inflation. For example, Woodford (2006) states:

> *” I believe that a serious examination of the reasons given thus far for assigning a prominent role to monetary aggregates in (policy) deliberations provides little support for a continued emphasis on those aggregates ... There is at present little reason ... to devote much attention to questions such as the construction of improved measures of the money supply or improved econometric models of money demand. For there is little intelligible connection between those questions and the kinds of uncertainty about the effects of monetary policy that are the actual obstacles to the development of more effective, more reliable and more transparent ways of conducting policy.*”

As shown by Svensson (1997), Clarida et al. (1999) and King (2000) optimal policy in models with price rigidities may be easily implemented by means of Taylor-style interest rate rules that respond to inflation, or inflation forecasts and output gaps. Nevertheless, some macroeconomists remain reluctant to give up on money. For example, Lucas (2007), expressing his concern regarding the increasing reliance of central bank research on New-Keynesian models, writes:

> *”New-Keynesian models define monetary policy in terms of a choice of money market rate and so make direct contact with central banking practice. Money supply measures play no role in the estimation, testing or policy simulation of these models. A role for money in the long run is sometimes verbally acknowledged, but the models themselves are formulated in terms of deviations from trends that are themselves determined somewhere off stage.*
>
> *It seems likely that these models could be reformulated to give a unified account of trends, including trends in monetary aggregates, and deviations about trend but so far they have not been. This remains an unresolved issue on the frontier of macroeconomic theory. Until it is resolved, monetary information should continue to be used as a kind of add-on or cross-check.*”

In this paper, we take up the suggestions of Friedman and Lucas and try to incorporate them in Taylor-style interest rate rules. In particular, we aim to show that monetary information remains useful for monetary policy due to the possibility of repeated policy errors such as those due to biased output gap estimates in the 1970s.

Specifically, we use data on historical output gap misperceptions in the United States and Germany to show that such misperceptions may trigger persistent errors in monetary policy. We find that the resulting deviations in money supply will generate trend movements of similar extent and direction in money growth and inflation. In this manner we show that Keynesian-style models can provide a unified account of monetary and inflationary trends as requested by Lucas (2007).

This explanation of trends, however, does not absolve the central bank from considering monetary aggregates. Rather, we present an approach for combining interest rate prescriptions derived from a Taylor-style interest rate rule or from central bank loss minimization approaches (inflation targeting) with monetary cross-checking. Thus, we try to include monetary information as an add-on or cross-check as requested by Lucas (2007). We first presented our proposal for monetary cross-checking in Beck and Wieland (2007a).[3] In this paper, we proceed much beyond the simple exposition of our proposed strategy and conduct a systematic evaluation of the proposal using actual data on policy misperceptions within two simple benchmark models of the macro economy. Thus, we show that monetary cross-checking can substantially improve inflation control[4] in the event of persistent policy mistakes such as those triggered by output gap misperceptions.

We obtain these results in two different models of the macroeconomy. The first model is a Keynesian-style model with endogenous, but backward-looking dynamics as in Svensson (1997), Rudebusch and Svensson (1999), Orphanides and Wieland (2000) and Orphanides (2003). The advantage of this model is that it has been shown to fit the historical persistence in output and inflation quite well and given that it arguably embodies central banker's view on policy tradeoffs and monetary policy transmission. Thus, it seems the better candidate for modeling central bank perceptions and describing historical policy outcomes.

The second model considered is the benchmark New-Keynesian model from Clarida et al. (1999). Dynamics in this model derive from forward-looking market expectations and serial correlation in exogenous shocks. While this model cannot describe central bank perceptions prior to its existence it has the advantage of some microeconomic foundations in optimal decision-making of households and firms, and thereby addresses to some extent the original Lucas critique regarding alternative policy evaluation.

Finally, we also explore the potential of monetary cross-checking for improved inflation control in the presence of velocity shifts, which could trigger cross-checks that reduce inflation control. As we lack data on historical central bank perceptions of money demand parameters we consider the performance of monetary cross-checking with recursive estimation of the velocity shift parameter.

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[3] In that paper, we point out that this approach mirrors key elements of the ECB's description of its two-pillar policy strategy. However, the mathematical formulation of monetary cross-checking is solely due to the authors as the ECB has never published a formal, mathematical exposition of its strategy.

[4] We note also that our definition of monetary cross-checking is different from but complementary to another very interesting approach advanced by Christiano and Rostagno (2001) and Christiano et al. (2006) in order to identify benefits from monetary targeting in conjunction with Taylor-style interest rate rules.

The remainder of this paper is structured as follows. In section 2 we present an interest rate rule with monetary cross-checking. Section 3 discusses the data on output gap misperceptions in the U.S. and Germany. Section 4 shortly summarizes the two models including money and central bank misperceptions and presents the respectively optimal interest rate policies. Section 5 reports our finding on money and inflation trends due to output gap misperceptions. Section 6 confirms the potential of monetary cross-checking to improve inflation control. Section 7 reconsiders the effectiveness of monetary cross-checking in the presence of velocity shifts and section 8 concludes.

2 An interest rate rule with monetary cross-checking

In this section, we present our proposal for combining interest rate prescriptions derived from a Taylor-style rule or from central bank loss minimization with monetary cross-checking in one single rule. In other words, we try to include monetary information as an add-on or cross-check as requested by Lucas (2007). Necessarily, such a rule for setting the short-term nominal interest rate, denoted by i_t, consists of two components:

$$i_t = i_t^T + i_t^M \tag{1}$$

Here, the superscript ^{T} denotes Taylor-style interest-rate rules and the superscript ^{M} the (occasional) adjustment in interest rate levels based on monetary information.

The interest rate prescription in response to inflation dynamics and economic activity

A natural example for i^T is the specific rule shown by Taylor (1993) to match federal funds rate choices by the FOMC from 1988 to 1993.

$$i_t^T = r^{*,e} + \pi_t + 0.5(\pi_t - \pi^*) + 0.5x_t^e. \tag{2}$$

where π_t refers to inflation and x_t to the output gap. π^* refers to the central bank's inflation target and r^* to the equilibrium real interest rate. These long-run equilibrium determinants re set equal to 2.0 by Taylor (1993), who also sets policy responsiveness to deviations of period t inflation from target and to the output gap to 0.5. We have added a superscript e on $r^{*,e}$ and the output gap x^e in order to emphasize that the central bank always needs to obtain estimates of unobservable variables such as the equilibrium real rate and potential output.[5] In the remainder of this paper we normalize the inflation

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[5] In this paper, we emphasize the need for estimating unobservables such as potential output, because they represent a recognized source of very persistent errors. We disregard the fact that variables such as inflation, money growth and actual output are also observed with error, because data revisions occur relatively quickly and the persistence of resulting errors is much smaller. A more complete analysis of policy uncertainty should of course recognize the many sources of measurement error as done for example in Coenen et al. (2005).

target and the real equilibrium interest rate at zero, i.e. $(\pi^* = 0, r^* = 0)$ and focus on possible misperception regarding the output

Rather than simply adopting Taylor (1993)'s specification, the specific variables in the rule as well as the magnitude of the policy response coefficients, the (α's), may instead be chosen optimally given a particular model of the economy and a central bank objective function. We will consider such optimal Taylor-style rules for an inflation targeting central bank in two alternative models of the economy. Both models are described in more detail in section 4. The first model, (also used in Beck and Wieland (2007a), is a Keynesian-style model with backward-looking inflation and output dynamics and will be denoted by superscript ^{K}. The second model, is the base-line New-Keynesian model and denoted by superscript ^{NK}. The optimal Taylor-style interest rate rules that define $i_t^{T,K}$ and $i_t^{T,NK}$ are presented in section 4. In both, cases the optimal interest rule does not incorporate a measure of money growth, thus reinforcing the case made by Woodford (2006) and others against the inclusion of money growth in the interest rate rule of the central bank.

Cross-checking the interest rate prescription against monetary information

The second component of the rule, i_t^M, aims to capture the idea of cross-checking using the long-run relationship between money and inflation.[6] This component, which is additive and persistent, has first been proposed by Beck and Wieland (2007a). We suggest that the central bank regularly test whether a filtered and adjusted measure of money growth, to be denoted by μ_t^f, averages around the inflation target of the central bank. Thus, the central bank would regularly compute the test statistic,

$$\kappa = \frac{\mu_t^f - \pi^*}{\sigma_{\mu^f}}, \tag{3}$$

and check whether κ deviates from a critical value κ^{crit}. σ_{μ^f} denotes the standard deviation of the filtered monetary measure.[7]

If the central bank obtains successive signals of a sustained deviation from target, i.e. $(\kappa > \kappa^{crit}$ for N periods$)$ or $(\kappa < -\kappa^{crit}$ for N periods$)$, it responds by adjusting interest

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[6] This approach purposely disregards the potential usefuleness of monetary in the short-run. The novel aspect is the use of monetary information as a cross-check in the long-run. For a study of the benefits of monetary information in the short-run the reader is referred to Coenen et al. (2005) who focussed on revisions of GDP, industrial output, inflation and money growth in the first years of the Euro area. Interestingly, Coenen et al. found that monetary data was revised less and offered valuable information for short-run output and inflation dynamics. They showed that the optimal interest-rate policy would therefore assign some weight to monetary information but this weight was rather small. In the working paper version (ECB Working Paper 84) they also showed that including money in simple, Taylor-style rules would improve policy performance.

[7] Note that it is straightforward to compute this standard deviation for the following case: interest rates are set according to the model-dependent optimal interest rate rules i_t^K or i_t^{NK} and the model is correct. Then the mean of μ^f corresponds to π^*.

rates accordingly.

$$i_t^M = \begin{cases} i_{t-1}^M + (\alpha_{\mu^f})(\mu_t^f - \pi^*) & \text{if } \kappa > \kappa^{crit} \text{ or } \kappa < -\kappa^{crit} \text{ for } N \text{ periods} \\ \\ i_{t-1}^M + 0 & \text{else} \end{cases} \tag{4}$$

The response coefficient on deviations of μ_t^f from the target π^*, that is α_{μ^f}, corresponds to the response coefficient on inflation deviations (or expected inflation deviations) from target in the optimal interest rate rules, $i^{T,K}$ and $i^{T,NK}$ derived in section 4. The above definition of i_t^M implies that monetary cross-checking in form of such econometric tests is conducted regularly in every decision period. However, the parameters N and k^{crit} are chosen such that a central bank that implements the model-dependent optimal interest rate rule ($i^{T,K}$ or $i^{T,NK}$) and, on average, correctly estimates unobservables such as potential output, would never change policy due to monetary information.

Computing the long-run measure of monetary information for cross-checking purposes

It remains to derive the appropriately adjusted and filtered measure of money growth, μ_t^f, to be used in monetary cross-checking. Since monetarists in the tradition of Milton Friedman have long focused on the quantity theory and the implied long-run relationship between money growth and inflation, we make use this relationship for monetary cross-checking. It can easily be derived from a standard money demand equation[8] such as:

$$m_t - p_t = \gamma_y y_t - \gamma_i i_t + e_t. \tag{5}$$

This money demand specification forms part of the both models considered in this paper. Here, γ_y denotes the income elasticity and γ_i the semi-interest rate elasticity of money demand. Money demand shocks are assumed to be normally distributed with mean zero and variance σ_{md}^2. Taking first differences and re-arranging the money demand equation (5) we obtain a short-run relationship between money and inflation:

$$\Delta p_t = \Delta m_t - \gamma_y \Delta y_t + \gamma_i \Delta i_t - \Delta e_t. \tag{6}$$

Δ is the first-difference operator. From this equation, we can also determine the long-run equilibrium relation (superscript *). In the long run, money demand shocks will average to zero, and the nominal interest rate will converge to its steady-state level and consequently the first difference of the interest rate will converge to zero.[9] Furthermore,

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[8] Such a money demand equation can be derived from the optimization problem of a household, which values money holdings in its utility function that is separable in real balances and consumption goods, see Walsh (2003).

[9] According to Taylor's rule the steady state level of the nominal interest rate corresponds to the sum of the equilibrium real interest rate and the inflation target: $i^* = r^* + \pi^*$.

output growth will converge to the growth rate of potential, Δy_t^*, in the long-run. Thus, long-run inflation is proportional to long-run money growth adjusted for potential output growth and trend growth in velocity:

$$\Delta p_t^* = \Delta m_t^* - \gamma_y \Delta y_t^* = \Delta \mu_t^* . \tag{7}$$

In this case, trend velocity is equal to $(1-\gamma_y)\Delta y_t^*$.[10]

Recent studies obtained empirical support for this long-run relationship using various filters or frequency-specific estimation. These findings indicate that money growth may even lead inflation at this horizon. To give an example,[11] Gerlach (2004) uses the following filter

$$\Delta m_t^f = \Delta m_{t-1}^f + \omega \left(\Delta m_t - \Delta m_{t-1}^f \right) \tag{8}$$

to approximate long-run values of inflation and money growth. From equation (7) we obtain accordingly a filtered measure of adjusted money growth:

$$\mu_t^f = \Delta m_t^f - \gamma_y \Delta y_t^f . \tag{9}$$

In the long-run μ_t^f should converge to μ^* and consequently to the inflation target π^*.[12] Thus, μ_t^f defined in this manner forms the relevant monetary information variable for cross-checking interest rate rules based on inflation expectations and output gaps against the long-run relationship between money growth and inflation.

3 Central bank misperceptions: Perceived output gaps in the United States and Germany

Recent research exploiting data on historical revisions to real-time estimates of the output gap has identified very persistent policy misperceptions. For the United States Orphanides (2003) has collected and used real-time data on inflation, actual and potential output. Figure 1 taken from Orphanides (2003) reports the quarterly output gap as perceived at each point in time from 1966 to 1994, i.e. the real-time output gap (dashed line), as well as the the complete output gap series as perceived ex-post in 1994 (solid line). Treating the latter series as the final data, the difference between the two series represents the historical output gap misperceptions. Orphanides et al. (2000) quantify the degree of persistence in output gap misperceptions by estimating a stochastic process on this data that is found to exhibit a near unit root (0.96) and a standard deviation of

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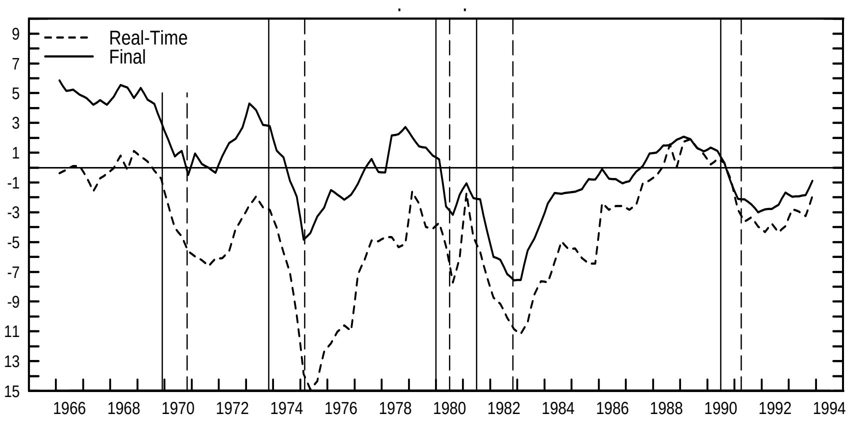
[10] Specifically, with velocity defined as $v_t \equiv -m_t + p_t + y_t$ and money demand determined by equation (5) the long-run trend in velocity corresponds to $\Delta v_t^* = (1-\gamma_y)\Delta y_t^*$.

[11] Other examples include Benati (2005), Pill and Rautananen (2006), Assenmacher-Wesche and Gerlach (2007).

[12] We will discuss the effect of velocity shifts in section 6.

Figure 1: U.S. real-time and final (1994) output gap from Orphanides (2003)

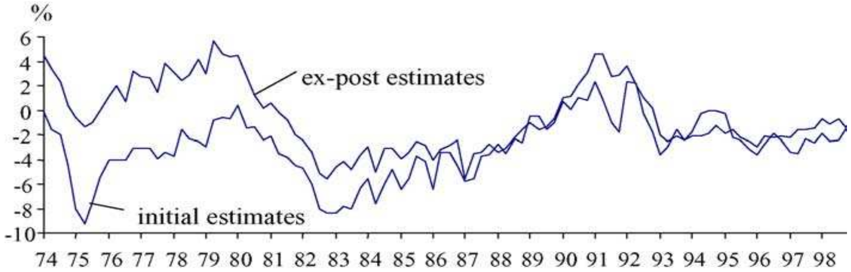


3.77%. This persistence is shown to arise primarily from biased estimates of unobservable potential output, since revisions to actual output decline more rapidly than those to the output gap. Also, revisions to potential and actual output growth turn out much less persistent than regarding output gaps. Consequently, if a central bank relies on potential output measures in policy design, there is a danger that its policy stance may be biased for a sustained period of time.

The output gap data for the 1980s and 1990s in Figure 1 was constructed based on information from the Greenbook, the Federal Reserve document summarizing the Board staff's analysis of economic developments distributed to the FOMC members a few days before each meeting. For the 1960s and 1970s, however, Orphanides could not recover a complete time series for potential output estimates from Federal Reserve sources although he notes that discussion of output gap measures appeared in the FOCM Memorandum of Discussion throughout this period. He instead uses real-time estimates of potential output produced by the Council of Economic Advisers in those years and apparently discussed at FOMC meetings. Critics have argued, however, that the construction of potential GDP measures at the CEA was politicized throughout this period and a maximum measure not taken seriously by Federal Reserve decision makers.

We contrast the U.S. CEA-FRB real-time output gap from Orphanides (2003) with a real-time output gap series for Germany from 1974 to 1999 constructed by Gerberding et al. (2005) based on available Bundesbank sources. Figure 2 taken from Gerberding et al. (2005) compares the German real-time output gap (line denoted initial estimates) to the complete output gap series as of 1999 (the line denoted ex-post estimates). In this case, the underlying production potential are the Bundesbank staff's estimates of the aggregate production potential. The data were reconstructed from official Bundesbank publications and from internal documents such as the briefing material for the Council's discussions on the monetary target for the year to come. The Bundesbank started to produce its own

Figure 2: German real-time and final (1999) output gap from Gerberding et al. (2005)



estimates of potential output in the early seventies. The methods used are described in detail in Bundesbank (1973). The Bundesbank then also made clear that it intended to construct a measure consistent with price stability — not a maximum measure.

Figure 3: Output Gap Misperceptions: United States and Germany

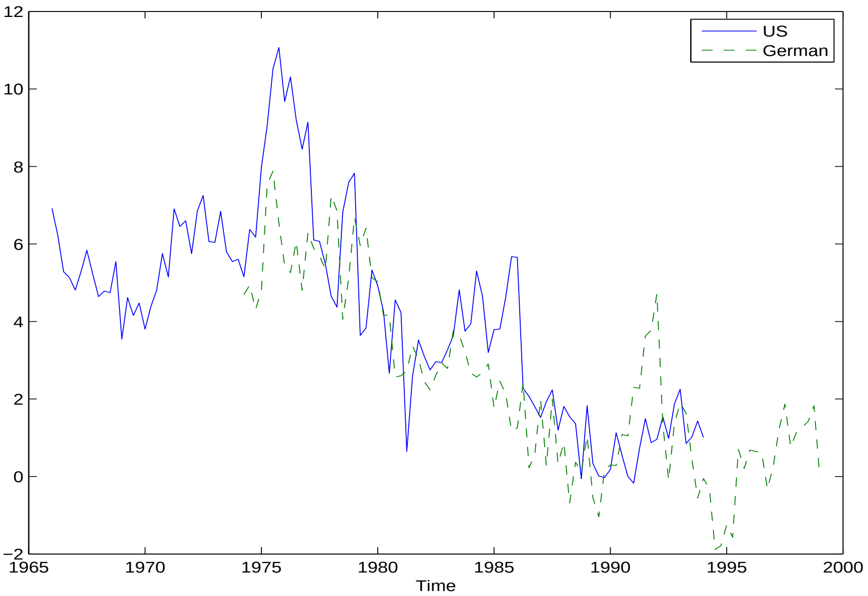


Figure 3 compares the differences between real-time and ex-post estimates of output gaps for the United States (solid line) and Germany (dashed line). Both series indicate that the production potential of these economies was over-estimated through the 1970s and well into the 1980s. U.S. and German policy makers taken into account these estimates were lead to believe that their respective economies suffered a very deep recession in 1974 to 1976. In retrospect, however, these period appears as a mild recession in the United States or decline from excessive levels to wards potential in Germany. This misperception proved extremely persistent. To the extent the Federal Reserve or the Bundesbank based their inflation forecasts on the output gap estimates available at the time, they must have concluded that inflation would soon decline as a consequence. In retrospect, such a forecast would have been wrong. In real-time, however, the resulting downward bias in interest rate setting would have contributed to inflation and money growth.

In section 5 we will try to quantify the possible consequences of the two alternative historical series of output gap mispercpetions from money growth and inflation using simulations of two different macroeconomic models which are introduced in the next section.

4 Two Keynesian models incorporating money and central bank misperceptions

In this paper, we make use of two Keynesian-type models for analyzing the implications of output gap misperceptions and monetary cross-checking. The first model exhibits exclusively backward-looking inflation and output dynamics just like the small models in Svensson (1997), Rudebusch and Svensson (1999) and Orphanides and Wieland (2000). As a short-hand we will use the term K-Model. The second model is the simple benchmark New-Keynesian model originally laid out by Rotemberg and Woodford (1997) and Goodfriend and King (1997). We use the specification of Clarida et al. (1999) and refer to it as the NK-Model. We have incorporated money and central bank misperceptions in these two models and have used them for illustrative examples of the effects of cross-checking in Beck and Wieland (2007a) and Beck and Wieland (2007b). For a detailed presentation and derivation of the optimal Taylor-style interest rate rules under uncertainty in these models the reader is referred to the earlier papers. In this paper we simply present the model equations in summary format in Tables 1 and 2 and review the optimal rules.

In both models the monetary transmission mechanism from the nominal interest rate to inflation works in the following manner. The nominal interest rate i is the policy instrument controlled by the central bank. Due to price rigidities changes in the nominal interest rate affect the real interest rate, which in turn impacts on the output gap x. The output gap then influences inflation π via a Phillips curve-type relationship. Thus, money m does not play a causal role in the transmission mechanism, and therefore need not appear in the model-dependent optimal policy. Of course, open-market operations by the central bank that are aimed at controlling interest rates do affect the money supply. The equilibrium level of money balances, however, is determined recursively from the money demand equation 5 in section 2 s.t. the desired nominal interest rate is achieved given the current levels of the price level and real income. The money demand equation is repeated for convenience in Table 1 and forms part of both models.[13]

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[13] For example, in the New-Keynesian model such a money demand equation can be derived from the

Table 1: Model Equations

Description	Model Equation
Common equations	
Money demand	$m_t - p_t = \gamma_y y_t - \gamma_i i_t + e_t$, $e_t \sim$ i.i.d. $\mathrm{N}(0, \sigma_e)$
Output gap	$x_t = y_t - z_t$
Perceived potential	$z_t^e = z_t + bias_t$
Loss function	$-\frac{1}{2} E_t \left\{ \sum\limits_{i=0}^{\infty} \beta^i \left[\pi_{t+i}^2 + \alpha x_{t+i}^2 \right] \right\}$
K-Model	
IS Curve	$x_t = x_{t-1} - \varphi(i_t - \pi_{t-1}) + g_t$
Phillips curve	$\pi_t = \pi_{t-1} + \lambda x_t + u_t$
NK-Model	
IS Curve	$x_t = -\varphi\left(i_t - \pi_{t+1}^e\right) + x_{t+1}^e + g_t$
Phillips curve	$\pi_t = \beta \pi_{t+1}^e + \lambda x_t + u_t$
Demand shocks	$g_t = \rho_g g_{t-1} + \varepsilon_t^g$, $\varepsilon_t \sim$ i.i.d. $\mathrm{N}(0, \sigma_g)$
Cost-push shocks	$u_t = \rho_u u_{t-1} + \varepsilon_t^u$, $\varepsilon_t \sim$ i.i.d. $\mathrm{N}(0, \sigma_u)$
Demand noise	$g_t = g_t^e + \nu_t^g$, $\nu_t^g \sim$ i.i.d. $\mathrm{N}\left(0, \sigma_{\nu_g}\right)$
Cost-push noise	$g_t = u_t^e + \nu_t^u$, $\nu_t^u \sim$ i.i.d. $\mathrm{N}(0, \sigma_{\nu_u})$
Money-demand noise	$e_t = e_t^e + \nu_t^e$, $\nu_t^e \sim$ i.i.d. $\mathrm{N}(0, \sigma_{\nu_e})$

The output gap and central bank misperceptions (defined by $bias_t$) regarding potential output (and thus the output gap) are defined in the same manner in both models.[14] Note, that the superscript e is used to refer to perceptions of unobservable variables such as potential or economic shocks and rational expectations of observables such as inflation and output. Thus, the perceived output gap corresponds to:

$$x_t^e = x_t - bias_t \tag{10}$$

Both models contain an aggregate demand (or IS) curve and a Phillips curve. In the K-Model these equations exhibit endogenous dynamics while the exogenous shocks are assumed to be unobserved and white noise. In the NK-Model expectations of future output and inflation matter for the determination of current output and inflation while lagged output and inflation play no role. Contrary to the model with backward-looking dynamics, in the NK-Model the market participants and central bank are assumed to have partial information on the exogenous cost-push, aggregate demand and money demand shocks, denoted by u^e,g^e and e^e respectively. The measurement error regarding the shocks is assumed to be white noise. All three shocks are assumed to display serial correlation that is known to market participants and the central bank. We solve the NK-

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optimization problem of a household, which values money holdings in its utility function that is separable in real balances and consumption goods, see Walsh (2003).

[14] For the NK model we do not take into account that so-called flexible-price equilibrium output may also respond to other disturbances.

Model assuming rational expectations and symmetric information by market participants and the central bank. The parameter values used for the two models are taken from Beck and Wieland (2007a,b) and are summarized in Table 2.

Table 2: Parameter Values

Parameter	Value	Economic interpretation
β	0.99	Discount factor of the policy maker.
$-\varphi$	-1	Real interest rate elasticity of aggregate demand (in line with Andres et al. (2006) and Ireland (2004)).
λ	0.5	Elasticity of Phillips curve w.r.t. output gap (broadly in line with Gerlach (2004)).[15]
γ_y	0.1	Income elasticity of money demand (in line with Andres et al. (2006) and Ireland (2004)).
$-\gamma_i$	-0.4	Interest rate elasticity of money demand (in line with Andres et al. (2006) and Ireland (2004)).
ω	0.2	Weighting parameter of filter (broadly in line in Gerlach (2004))
$\Delta y_t^*, \pi^\star$	2	Equilibrium real interest rate, potential output growth and inflation target
$\sigma_g, \sigma_u, \sigma_e$	0.8	Standard deviation of cost-push, demand and money demand shocks
ρ_g, ρ_u	0	Persistence of aggregate demand and cost-push shocks
$\sigma_{\nu_g}, \sigma_{\nu_u}$	0.4	Standard deviation of noise of aggregate demand and cost-push shocks
σ_{ν_e}	0.1	Standard deviation of money demand shocks
σ_{μ^f}	depends on model	Standard deviation of μ^f
κ^{crit}	5%	Critical value for the cross-checking rule.
N	4	Number of periods required for a sustained deviation in the cross-checking rule.

Why do we use the two models in parallel in this paper? The advantage of the Keynesian model with backward-looking dynamics is that it fits the historical persistence in output and inflation and arguably embodies central banker's view on policy tradeoffs and monetary policy transmission quite well. Thus, it seems the better candidate for modeling central bank perceptions and describing historical policy outcomes. The model used by Orphanides (2003) in his study also falls into this class of models. While the New-Keynesian model cannot describe central bank perceptions prior to its existence it has the advantage of some microeconomic foundations in optimal decision-making of households and firms. Thus, it addresses to some extent the original Lucas critique regarding alternative policy evaluation and constitutes an important testing ground for policy strategies currently recommended to central banks.

It remains to specify the objective function of the central bank. The following is a standard objective function consistent with the stated ultimate goals of many central banks, and is referred to by some as flexible inflation targeting. It has some welfaretheoretic foundations in the NK-Model.

$$\min \frac{1}{2} E_t \left\{ \sum_{i=0}^{\infty} \beta^i \left[\pi_{t+i}^2 + \alpha x_{t+i}^2 \right] \right\} \tag{11}$$

The central bank's optimization problem consists of choosing current and future interest rates such that the loss function is minimized conditional on the other equations for the respective model as summarized in Table 1.

Given the above loss function, the first-order condition characterizing optimal policy under uncertainty would take the following form in both models:

$$x_t^e = -\Lambda^{(K,NK)} \pi_t^e \tag{12}$$

The superscripts ^{K} and ^{NK} indicate that the coefficient Λ will take different values in the two models[16] The first-order condition incorporates the trade-off between the expected (current) output gap and expected (current) inflation implicit in the Phillips curve and the central bank loss function. In the NK model the question arises whether to consider the optimal policy under discretion or commitment. The above first-order condition corresponds to the optimal policy under discretion. Note, however, for the special case of strict inflation targeting ($\alpha = 0$) the optimal policies under discretion and commitment would be identical.

The optimal Taylor-style interest rate rule then defines the interest rate level that achieves a combination of expected output gap and inflation that satisfies the above first-order condition. This rule is not identical in the two models due to subtle differences in the timing of information and policy decisions. First, in the Keynesian model with backward-looking dynamics (K-Model), the central bank sets the nominal interest rate i_t in period t based on $t-1$ information regarding the rate of inflation and the output gap (π_{t-1}, ξ_{t-1}^e) because it has no information on the period t shocks, that represent the other possible sources of inflation. Thus, the Taylor-style interest rate with optimal response coefficients corresponds to:

$$i_t^{T,K} = r_t^{*,e} + \pi_{t-1} + \alpha_\pi^K \pi_{t-1} + \alpha_x^K x_{t-1}^e. \tag{13}$$

The timing of information and policy action in the New-Keynesian models is slightly different. Lagged inflation and output gaps do not influence current inflation and therefore do not appear in the rule. However, the central bank has partial information on the contemperaneous demand and cost-push shocks which will affect current inflation. The optimal Taylor-style rule that implements the optimal policy under discretion in the

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[16] For further details see the discussion in Beck and Wieland (2007a,b).

New-Keynesian model is then given by:

$$i_t^{T,NK} = r_t^{*,e} + \pi_{t+1}^e + \alpha_\pi^{NK} \pi_{t+1}^e + \alpha_g^{NK} g_t^e \tag{14}$$

The policy response coefficients for the two rules, $(\alpha_\pi^K, \alpha_x^K, \alpha_\pi^{NK}, \alpha_g^{NK})$, have been derived in Beck and Wieland (2007a,b). Interest rates are set in response to changes in expected inflation, which is a function of the perceived output gap, as well as the estimate of the aggregate demand disturbance.

To sharpen the exposition of our analysis in the following sections we focus on the extreme case of a strict inflation-targeting central bank that assigns no weight to stabilizing output gaps, i.e. $\alpha = 0$. The interest rate rule of the central bank will consequently only respond to the output gap to the extent the output gap is useful in inflation forecasting. As a result, we are more likely to understate than overstate the potential negative implications of output gap misperceptions. Furthermore, we normalize the inflation target as well as the equilibrium real interest rate at zero, $\pi^* = 0$ and $r_t^* = r_t^{*,e} = 0$.

5 Monetary and inflation trends due to historical output gap misperceptions

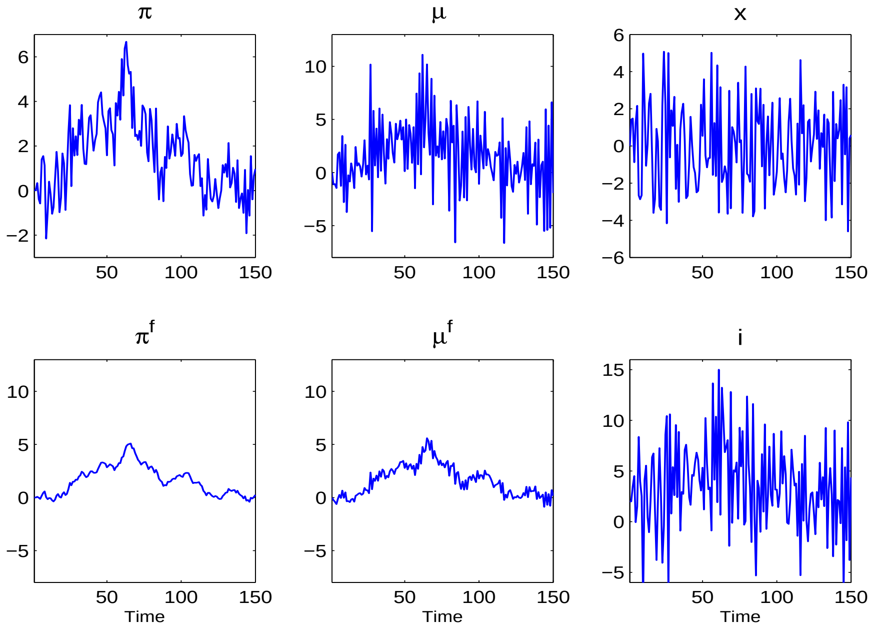
In this section we use the historical output gap misperceptions based on the data collected by Orphanides (2003) for the United States and Gerberding et al (2005) for Germany in order to simulate the two models provided in the preceding section. We show that in both models such persistent output gap misperceptions lead to excessively easy monetary policies, excessive growth in the money supply and as a result sustained trends in money growth and inflation even though the central bank's target for inflation remains constant and equal to zero through the whole simulation period.

To conduct such simulations we need to obtain draws for the normally-distributed demand, cost-push and money demand shocks and noise terms that have been discussed in the preceding section. Figure 4 reports simulations with U.S. and German output gap misperceptions in the Keynesian model with backward-looking dynamics (K-Model) given the same draw of exogenous shocks. The sequence of shocks is arbitrary but we obtain similar results for many alternative draws and will discuss averages later on in this section.

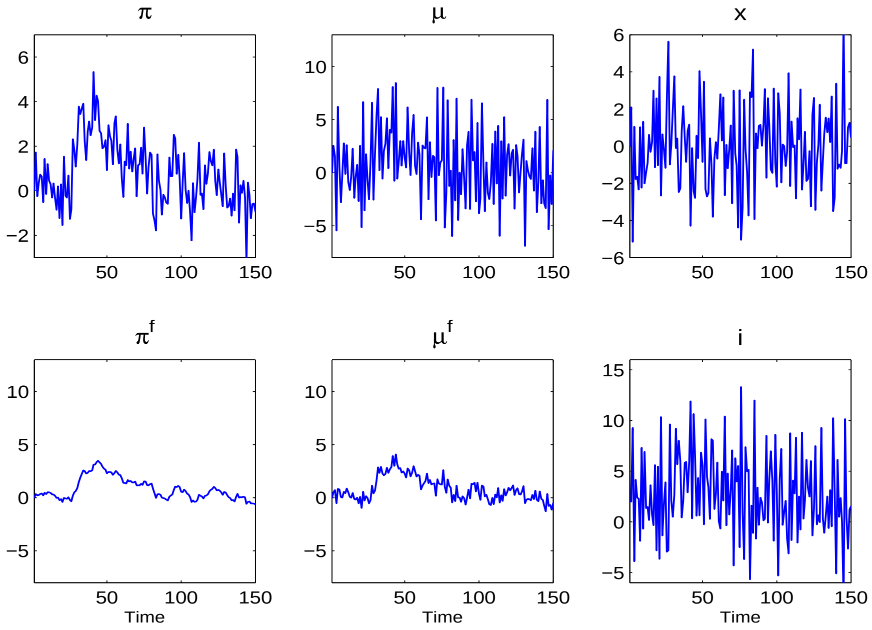
Turning to the top six panels in Figure 4, the first row shows the performance of inflation, π, adjusted money growth, $\mu = \Delta m - \gamma_y \Delta y$, and the true output gap x given that from period 15 onwards the difference between the true and the perceived output gap, $x_t - x_t^e = bias_t$, corresponds to the U.S. misperceptions from Figure 1 till period 135. The persistent over-estimate of potential output embodied in these misperceptions leads

Figure 4: Keynesian Model with Backward-Looking Dynamics (K-Model)

U.S. Output Gap Misperceptions



German Output Gap Misperceptions



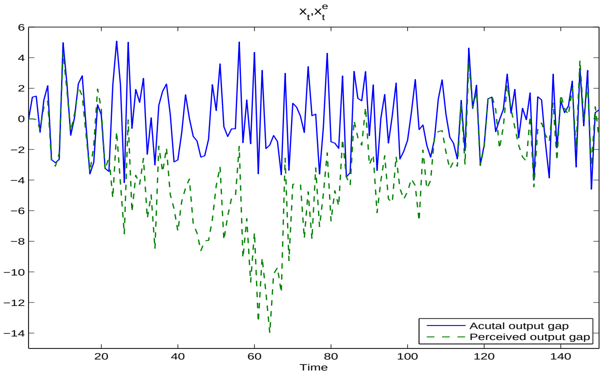
the central bank to set interest rates too low to maintain price stability.

$$i_t^{T,K} = r_t^{*,e} + \pi_{t-1} + \alpha_\pi^K \pi_{t-1} + \alpha_x^K (x_{t-1} - bias_{t-1}). \tag{15}$$

Due to an interest rate policy that is more accommodative than the central bank believes to be the case, money growth and inflation rise. This increase inherits the persistence properties of the central bank's misperceptions regarding potential output. Over time, also the filtered measures of inflation, π^f, and adjusted money growth, $\Delta\mu^f$, increase, thus depicting a trend change in nominal variables. These trends in the filtered measures are depicted in the first two panels of the second row of Figure 4. In turn, this trend change in money and inflation is mirrored by a sustained increase in nominal interest rates - a consequence of the Fisher effect.

The lower six panel of Figure 4 report the same simulation but now using the data on Bundesbank misperceptions regarding the German output gap from Figure 2 due to Gerberding et al (2005). The misperceptions start in period 15. From then on policy is too accommodative and (adjusted) money growth and inflation increase up to a peak of around 5 percent. This peak is somewhat smaller than in the case of the U.S. perceptions which trigger an increase up to an inflation rate of 6 percent. Otherwise, the simulation delivers similar trends in money growth, inflation and interest rates in spite of the constant inflation target of the central bank.

Figure 5: K-Model: Perceived and Actual U.S. Output Gap



One may certainly ask why the central bank does not realize that its perceptions are biased, raises interest rates to an even higher level and thereby ensures that inflation returns to target relatively quickly. The reason is simple. Optimal monetary policy takes account of the best available forecast for inflation, which is based on the available estimate of the output gap, x_t^e. Figure 5 compares the perceived output gap to the actual output gap for the case of the U.S. misperceptions. As is directly apparently, the central bank perceives the economy to be in a recession most of the time, while in truth it is fluctuating fairly symmetrically around potential. Thus, on average, the forecast for inflation which will be based on the incorrect output gap, indicates that inflation will return to target due to a sustained weakness of aggregate demand. If the central bank were to raise interest rates further its own forecast would signal a worsening of the recession and undershooting of its inflation target. The persistent bias in the forecast implies that the central bank is attributing successive periods of high inflation to a sequence of unfavorable shocks rather than a mistaken output gap estimate. This example is not without historical parallel considering many accounts of the 1970s attribution the stagflation in the United States and Germany primarily to inflationary and recessionary consequences of oil price shocks.

We now turn to the New-Keynesian model and simulate the consequences of U.S. and German historical output gap misperceptions. The basic approach remains the same. We draw the sequences of exogenous shocks from their respective distributions and feed the historical values for $bias_t$ in the model. The findings for one representative simulation are shown in Figure 6. Again, the top 6 panels report the simulation results with U.S. misperceptions and the bottom 6 panels those for Bundesbank misperceptions.

Albeit the New-Keynesian model implies a different, expectations-driven transmission mechanism and quite different dynamics than the more traditional backward-looking model, the basic implications of output gap misperceptions and persistent policy mistakes carry over to this micro-founded model. The over-estimate of potential output generates excessively easy monetary policy. Of course, the output gap in the NK model is, in principle, not the same concept as in the traditional model.[17] The flexible-price equilibrium output that defines the benchmark for the gap in this model may respond to a variety of shocks in the economy. However, misperceptions regarding the long-run potential of the economy would similarly affect the flexible-price equilibrium output in this model. With interest rates persistently too low, money growth and inflation rise for a sustained period.

So far, we have only reported results for a single draw of exogenous cost-push, money demand and aggregate demand shocks. Figure 7 summarizes the trend movements exhibited by the filtered measures of adjusted money growth, μ^f, and inflation π^f. It reports averages over 1000 simulations of equal length. The eight panels display the results generated for the U.S. output gap misperceptions data (US) as well as the data from Germany (DE) using the two differen models (K) and (NK). These findings confirm that on average the central bank's policy mistakes due to mistaken beliefs about the output gap can be expected to lead to similar trend movements in money growth and inflation.

These simulations suggest that the introduction of imperfect knowledge and persistent central bank misperceptions is sufficient to provide a unified account of monetary

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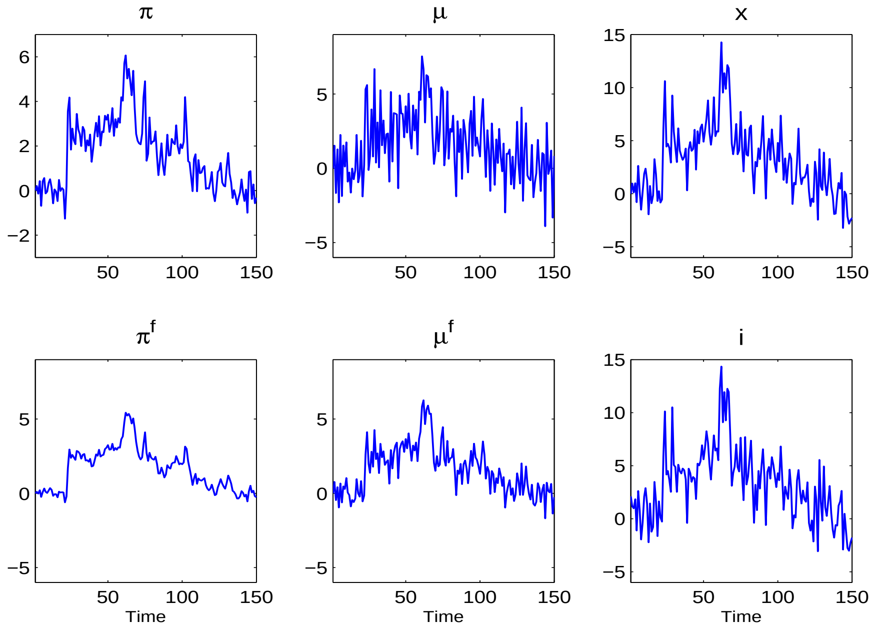
[17] See for example Woodford (2003) and Walsh (2003).

Figure 6: New-Keynesian Model with Forward-Looking Dynamics (NK-Model)

U.S. Output Gap Misperceptions



German Output Gap Misperceptions

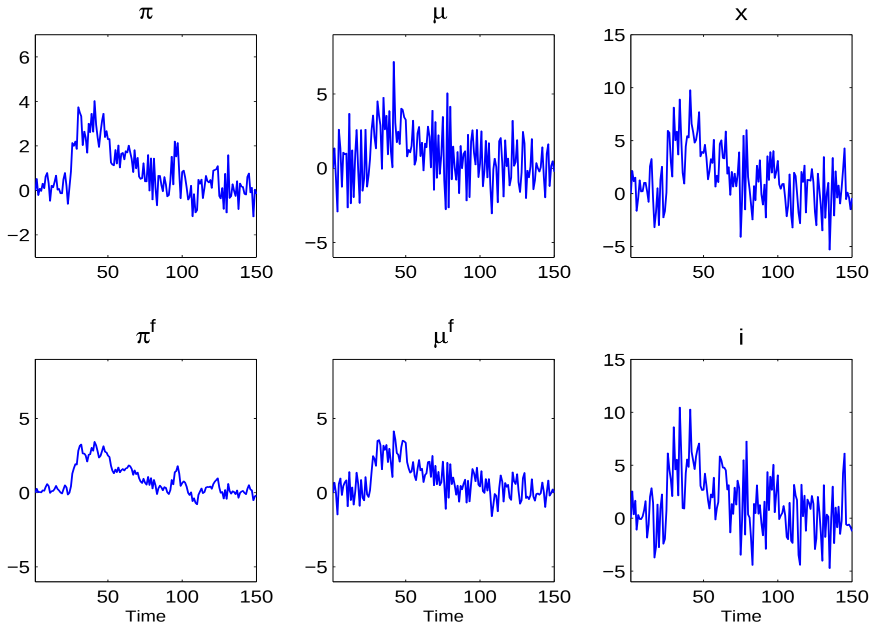
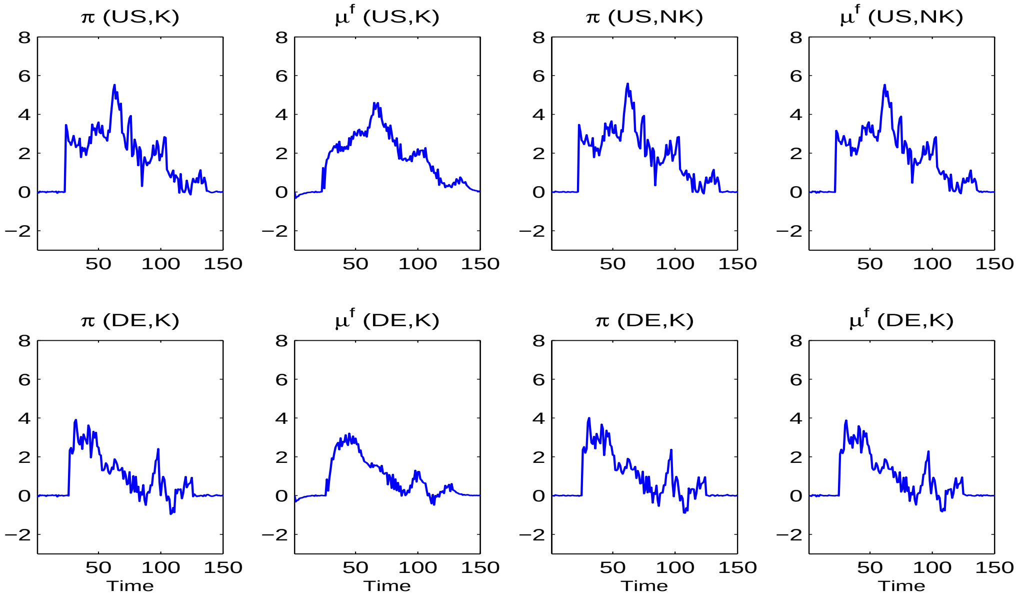


Figure 7: Filtered Money Growth and Inflation Averages over 1000 Simulations



and inflation trends – the unresolved issue on the frontier of macroeconomic theory noted by Robert E. Lucas in the quote cited in the introduction of this paper. An alternative explanation of these trends that has typically been used in the estimation of New-Keynesian models over episodes with trending inflation is to assume that the central bank's inflation target follows a random walk. Our explanation with a constant inflation target but persistent policy mistakes due to persistence misperceptions regarding unobservables offers an alternative that can be grounded in empirical observation (i.e. historical output gap revisions data) and does not require unobserved random changes in the central bank's price objective.

Finally, we point out that the trends displayed by money growth and inflation on average in our simulations appear not unlike the parallel movements in low-frequency money growth and inflation discovered, for example, by Gerlach (2004), Benati (2005), Pill and Rautanen (2006)and Assenmacher-Wesche and Gerlach (2007). In this sense, we would argue that, both the Keynesian model with backward-looking dynamics and the New-Keynesian model, could be consistent with these empirical findings. Thus, they do not necessarily require allowing for direct effects of money growth on inflation in the aggregate demand specification or the Phillips curve. The empirical findings of these authors essentially replicate the quantity-theory relationship that is also embodied in the Keynesian-style models considered here.

An open question however remains. The above authors find that typically the movements in low-frequency, adjusted money growth tend to lead the movements in low-frequency inflation by several quarters. This feature of the data is not replicated in the simulations based on the above models.

6 The potential of monetary cross-checking

Having shown that sustained output gap misperceptions may bias policy and lead inflation far away from the central bank's intended target in spite of an interest rate policy that is optimal given the central bank's beliefs, we now turn to explore the performance of the interest rate rule with monetary cross-checking as defined by equations (1)and (4) in section 2.

The interest rate is set based on two components of the rule, the model-based optimum and the cross-check, $i_t = i_t^{T,K/NK} + i_t^M$. Cross-checking incorporates an additive and persistent adjustment in the event of sustained deviations of filtered (adjusted) money growth, μ_t^f, from target. The policy response depends on a simple econometric test for a mean shift.

$$i_t^M = \begin{cases} i_{t-1}^M + (\alpha_{\mu^f})(\mu_t^f - \pi^*) & \text{if } \kappa > \kappa^{crit} \text{ or } \kappa < -\kappa^{crit} \text{ for } N \text{ periods} \\ \\ i_{t-1}^M + 0 & \text{else} \end{cases} \tag{16}$$

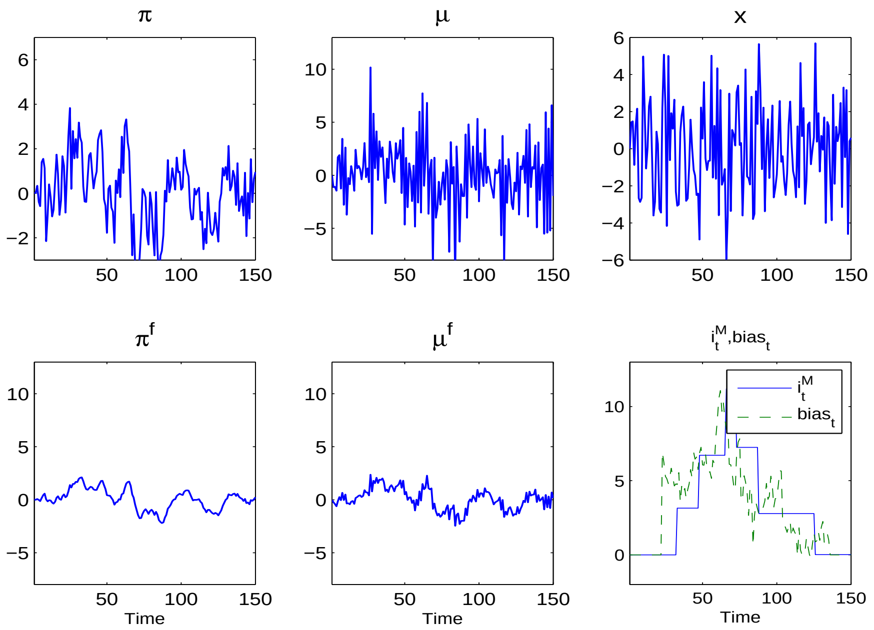
The test parameters, i.e. N and κ^{crit}, are calibrated such that if the beliefs of the central bank regarding the appropriate economic model, its parameter values and the unobserved output gap, are correct, the test would almost never trigger an adjustment in interest rate setting. Thus, the ex-ante rational expectation would be that monetary cross-checking does not come into play.

Figures 8 and 9 report stochastic simulations of monetary cross-checking in the K- and NK-models using the U.S. and German output gap misperceptions for the beliefs of the central bank. The sequence of exogenous shocks corresponds to the same draw used in the preceding section for simulations without cross-checking displayed in Figures 4 and 6. The resulting inflation performance, however, is quite different. Considering first the top six panels in Figure 8, the simulation of cross-checking with U.S. output gap misperceptions in the model with backward-looking dynamics, we note that the sustained upward trend inflation observed previously in Figure 4 has disappeared. The policy with cross-checking responds to the increase in filtered money growth, μ_t^f, fairly quickly after the policy bias has arisen.

To illustrate the interest rate adjustment from cross-checking more clearly, we have replaced the panel reporting the nominal interest rate (second row, third panel) with a panel that reports the interest rate bias arising from the policy misperception series $(i - bias_t)$ and the adjustment based on monetary information, i^M. Once sufficient information regarding a mean-shift in filtered, adjusted money growth has been accumulated

Figure 8: Monetary Cross-Checking in the K-Model

U.S. Output Gap Misperceptions



German Output Gap Misperceptions

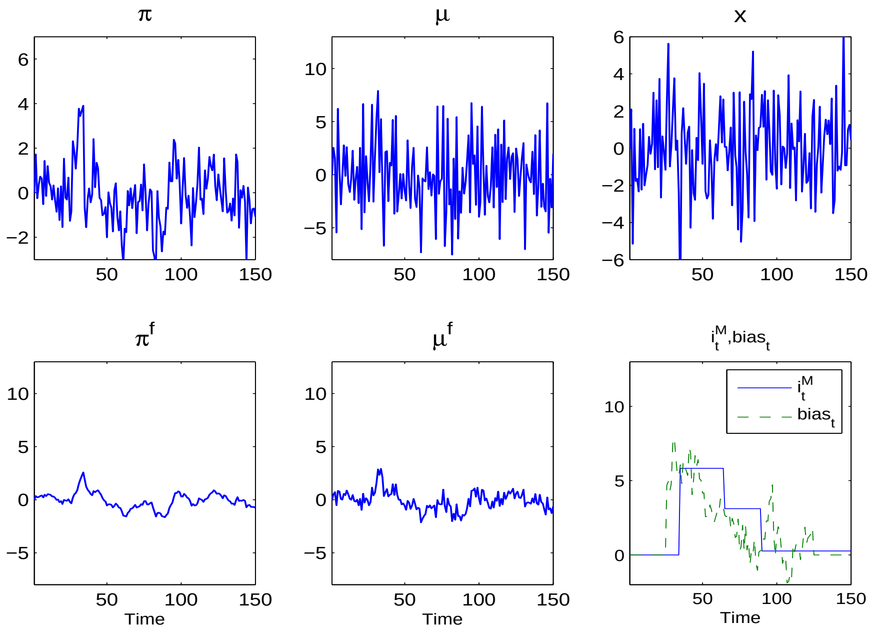
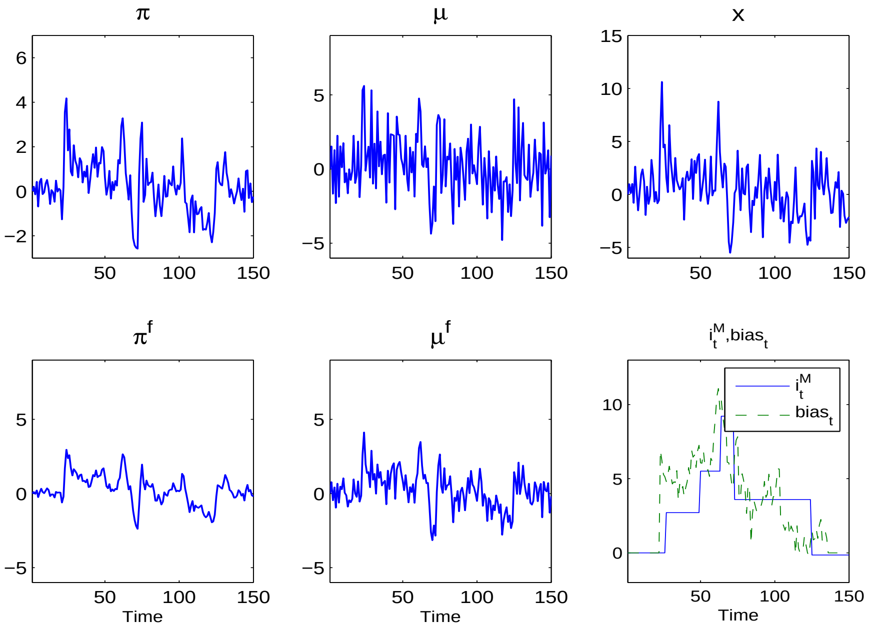
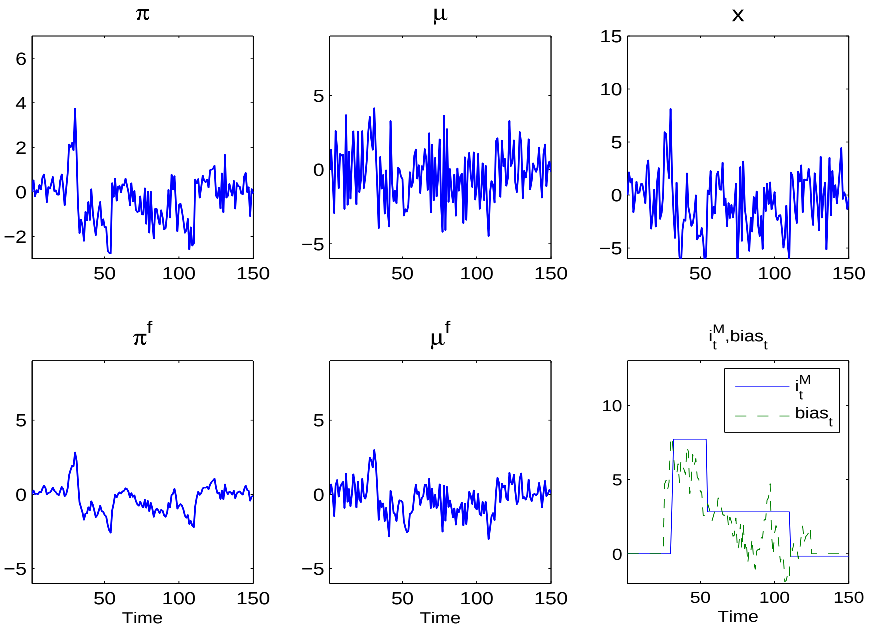


Figure 9: Monetary Cross-Checking in the NK-Model

U.S. Output Gap Misperceptions



German Output Gap Misperceptions

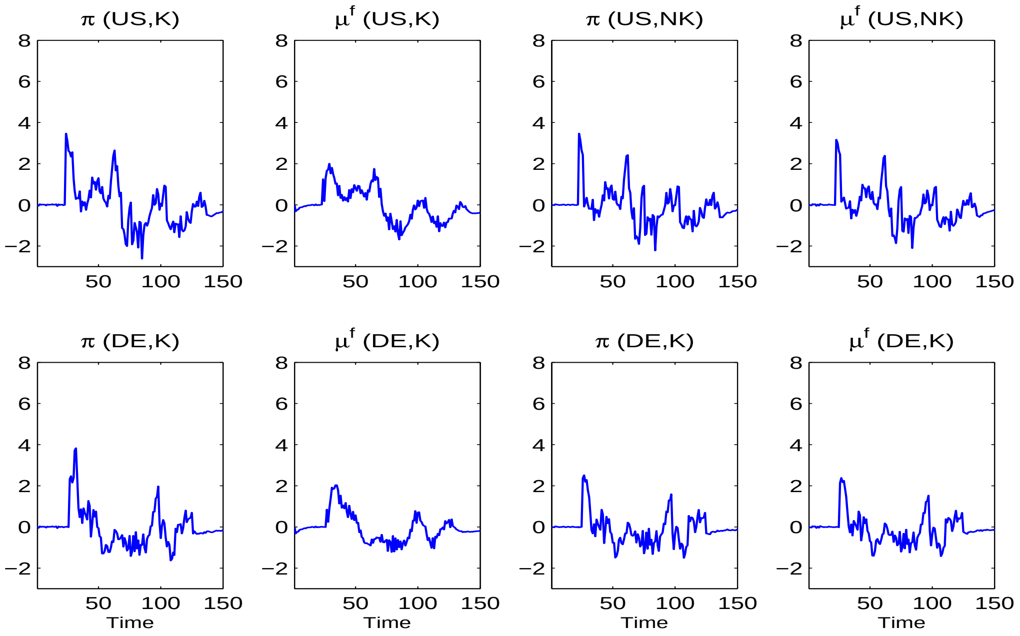


the cross-checking triggers an adjustment in the overall level of interest rates. This new level is maintained for a while. Since further increases in output gap misperceptions lead to a continued increase in money growth and inflation the test triggers another two adjustments in the level of interest rates based on monetary information. This causes a ”Volcker”-like recession but reigns-in inflationary tendencies.

Cross-checking also works ”on the way down” as output gap misperceptions subside and inflation and adjusted money growth decline below target for some time. As a result, monetary cross-checking triggers two downward adjustments in the level of nominal interest rates. In sum, the interest rate adjustment of $(\alpha_{\mu^f})(\mu_t^f - \pi^*)$, on average, offsets the policy bias arising from potential output misperceptions quite well. Note, the response parameter in i^M, that is, (α_{μ^f}), simply corresponds to the response coefficients in inflation rule.

The lower set of six panels in Figure 8 concerns the simulation with German output gap misperceptions. Here, monetary cross-checking also serves to offset the inflationary trends arising from mistaken beliefs and policies. However, one large upward shift and two smaller downward shifts due to monetary information turn out to broadly match the outline of the policy bias. Figure 9 confirms that the same policy recommendation works, in principle, in the New-Keynesian model. The simulations are conducted under the assumption of symmetric information.

Figure 10: Filtered Money Growth and Inflation Averages over 1000 Simulations



To assess whether these findings hold true on average we again draw 1000 series of shocks of 150 periods length from the respective normal distributions and use them to conduct a set of alternative simulations. The resulting averages of the sequence of filtered, adjusted money growth and inflation are reported in Figure 10. These plots confirm confirms that, on average, cross-checking leads to effective interest rate adjustments that reduce the duration of the policy bias arising from persistent output gap misperceptions. Of course, the simulations are still characterized by inflationary or disinflationary trends lasting for shorter periods. It is these sustained movements that signal the danger of a mean shift in nominal trends and thereby trigger the interest rate adjustment due to cross-checking. As a consequence, however, inflation control is improved relative to the persistent upward trends observed previously.

In sum, we find that monetary cross-checking provides a convenient and effective avenue for correcting the central bank's policy bias that lead to the sustained increase in filtered money growth and inflation in the preceding simulations.

7 Monetary cross-checking with velocity shifts

It is well-known that the most important challenge for monetary targeting as recommended by the early monetarists or as implemented by the Bundesbank concerns dealing with changes in the velocity of money. In the money-demand equation considered in this model,

$$m_t - p_t = \gamma_y y_t - \gamma_i i_t + e_t, \tag{17}$$

short-term fluctuations in money demand arise from three sources, the money demand shocks e, the effect of changes in interest rates on money demand $\gamma_i \Delta i_t$ and changes in real income $\gamma_y \Delta_t$. While such fluctuations render the implementation of monetary targets complex and undesirable, they do not inhibit monetary cross-checking. This point needs no further reinforcement as these three sources of fluctuations in velocity were present in the all the simulations with cross-checking in the preceding sections.

A more interesting question concerns the performance of monetary cross-checking in light of changes in equilibrium velocity due to financial innovations. Two interesting examples regarding money demand in the United States have been documented by Orphanides and Porter (2001), Orphanides and Porter (2000) and Reynard (2004). Reynard (2004) notes an apparent increase in the interest-rate elasticity of money demand, i.e. γ_i, in the early 1970s from the perspective of time-series analysis and emphasizes the usefulness of cross-section al analysis for obtaining improved estimates of the true structural parameters of money demand. Orphanides and Porter (2001) and Orphanides and Porter (2000) point out that M2 velocity increased substantially in the mid 1990s. They find that this change in equilibrium velocity is directly apparent as a sustained intercept shift in their estimated velocity equation occurring over a period of several years. However, they also show that this shift was understood quite well in real time by recursive estimation allowing for such a possibility.

A shifting intercept is easily included in the above money demand equation:

$$m_t - p_t = \gamma_{0,t} + \gamma_y y_t - \gamma_i i_t + e_t, \tag{18}$$

Of course, a simple one-period jump in $\gamma_{0,t}$ would not have a substantial effect on the usefulness of monetary cross-checking as proposed in this paper. However, if the intercept keeps changing over a longer period of time inducing a trend in velocity it would trigger monetary cross-checking that is detrimental to inflation control.

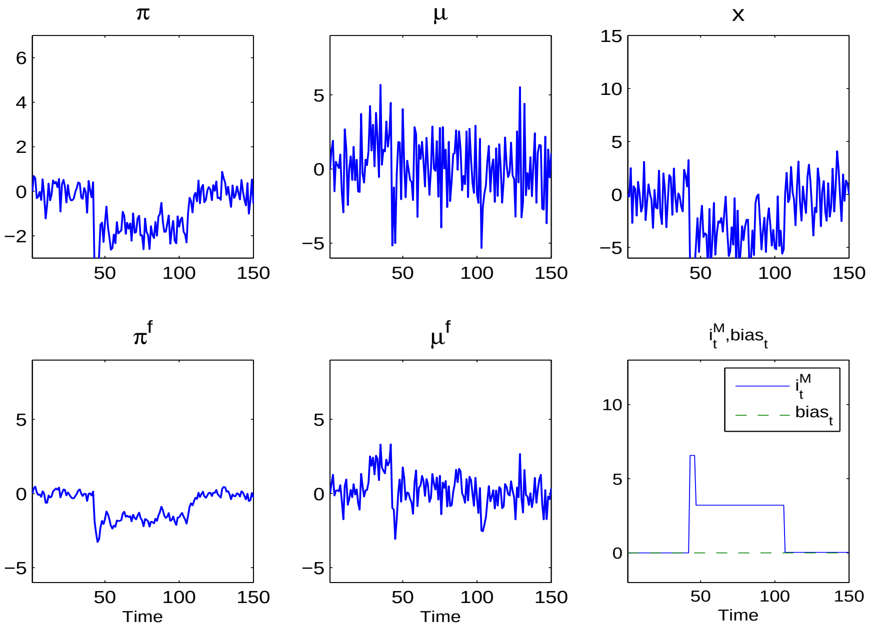
To illustrate this point, we use the NK model to simulate a fairly dramatic shift in the money demand intercept generating a trend of 2 percentage points, $\Delta\gamma_{0,t} = 2$, for 75 periods. The increase in the intercept, generates a decline in velocity and an increase in money growth.

We first assume that the central bank sticks to the original estimate of the intercept, never re-estimates and never considers the possibility of a structural shift. The resulting simulation is reported in the top 6 panels of Figure 11. The observed, sustained increase in money growth due to the ongoing velocity shift triggers monetary cross-checking and thus policy tightening. The increase in interest rates is apparent in the third panel in the second row. As a result of this tightening inflation declines below target by 2 percentage for the duration of this downward trend in velocity. Once the shift subsides, another cross-check brings inflation back to target.

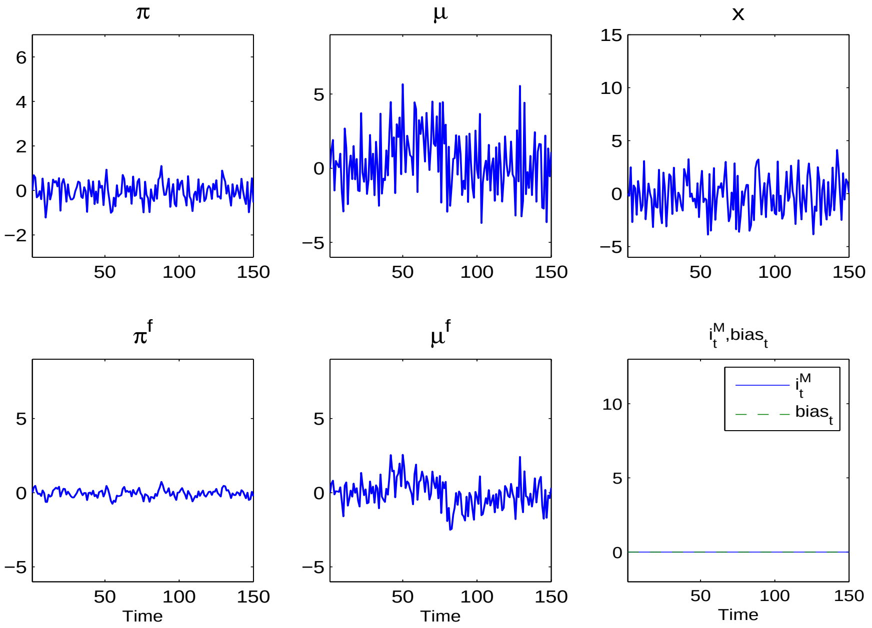
Secondly, we allow the central bank to recursively estimate money demand and consider the possibility of structural shifts. Orphanides and Porter (2001) propose regression tree methods as a new and very effective approach to identify such shifts in real time. For the purpose of our paper we stick to a more traditional tool of money demand analysis in the form of recursive least squares with time-varying parameters or recursive least-squares with forgetting (See Harvey (1993, Chapter 4). The resulting simulation is reported in the lower 6 panels in 11. We find that such a standard recursive estimation approach is sufficient to maintain the usefulness of monetary cross-checking and avoid unnecessary interest-rate adjustments when money growth rises as a consequence of sustained money demand shifts due to financial innovation. This finding also underscores the usefulness of money demand analysis.

Figure 11: Monetary Cross-Checking and Velocity Shifts in the NK-Model

Central Bank Never Considers the Possibility of Shifts



Central Bank Uses Recursive Least Squares with Possibility of Shifts



8 Conclusions

In this paper, we have shown that a traditional Keynesian models with backward-looking dynamics as well as New-Keynesian models are capable of providing a unified explanation of money growth and inflation trends of similar direction. Rather than relying on undocumented shifts in inflation targets we obtain this result by using data on historical central bank misperceptions regarding potential output in the United States and Germany. These misperceptions lead to easy interest rate policy with similar long-run effects on money growth and inflation.

Furthermore, we have shown that using monetary information for cross-checking the optimal interest rate policies implied by the central bank's baseline model can help improve inflation control in the presence of central bank misperceptions. Our specification provides a simple, formal approach for including a cross-checking component in otherwise standard interest rate rules.

We find that cross-checking with regard to monetary information based on the long-run quantity theory relation even remains effective in the presence of long-lasting velocity shifts if standard recursive estimation techniques allowing for such shifts are used in money demand analysis.

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