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Monetary Policy Stance and Future Inflation: The Case of Czech Republic

Měnová politika a budoucí inflace: Evidence pro Českou republiku

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1 Introduction

Inflation targeting regimes are increasingly popular around the world. For example, regarding the Central and Eastern Europe while the first two countries adopted explicit inflation targeting regime in 1998, there are already seven countries conducting inflation targeting in 2006 and others are contemplating to do so (International Monetary Fund, 2006).[1] A characteristic feature of inflation targeting is that central banks set short-term nominal interest rate in the way to get inflation and output at their targeted levels. The level of interest rates that is associated with this objective is often labeled as policy neutral rate.

In this regard, Woodford (2003) notes that central banks should on average track policy neutral rate to stabilize the economy. In a similar fashion, Taylor (1999) emphasizes that the measurement of policy neutral rate is one of key issues for countries targeting inflation. In this respect, it is of great importance for central banks to identify as precisely as possible the policy neutral rate. This is quite intricate exercise, as the policy neutral rate is unobservable; however its mis-measurement is high-priced, as it likely results in over- or undershooting the inflation target.

In this light, it is quite striking that remarkably little evidence is available for Central and Eastern European Countries (CEECs) on the estimation of policy neutral rate. While there are dozens of studies on *equilibrium exchange rates* in the EU new members, there is surprisingly very little evidence on *equilibrium interest rates* (Brzoza-Brzezina, 2006, seem to the only exception with evidence on Poland). This imbalance is rather paradoxical, as half of EU new members target inflation (Czech Republic, Hungary, Poland, Romania and Slovakia), for which the concept as well as measurement of policy neutral rate is of primary importance for the conduct of monetary policy.[2] Consequently, this paper tries to bridge this gap.

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1 *Czech Republic and Poland adopted inflation targeting in 1998, followed by Hungary in 2001, Romania and Slovakia in 2005 and Armenia and Serbia in 2006 (note this is an updated list of Table 1 in IMF, 2006). Ukraine is likely to adopt inflation targeting in near future (IMF, 2006).*

2 *See Coats et al. (2003) and Kotlan and Navratil (2003) on Czech monetary policy.*

This paper addresses the issue of policy neutral rate estimation in one of EU new member states, the Czech Republic, based on various specifications of simple Taylor-type monetary policy rules. Former transition country provides an interesting case to evaluate policy neutral interest rate, as one can expect certain pattern in the path of nominal and real equilibrium interest rates over longer time horizon (note that policy neutral rate is in fact short-term nominal equilibrium interest rate, more on definitions below).

Lipschitz et al. (2006) points out that at the outset of transition the capital/labor ratios were much lower than those in Western Europe and therefore the marginal product of capital and for that reason real equilibrium interest rate was rather high. Given the capital accumulation over the course of transition, there should be tendency for the real equilibrium interest rate to decrease. From open economy perspective, EU new members exhibited a fall of exchange rate risk premium during their transition process to market economy (Beneš and N'Diaye, 2004), which also puts a downward pressure on real equilibrium interest rates (Archibald and Hunter, 2001). Analogously, it is a well-documented empirical regularity that these countries exhibit real equilibrium exchange rate appreciation (see Égert et al., 2006 for a comprehensive survey of the sources of appreciation). A decrease in foreign equilibrium interest rate, which is reported by several authors for the euro area (e.g. Wintr et al., 2005), may, especially in small open economy, reduce the level of domestic equilibrium interest rate as well. Additionally, the path of nominal equilibrium interest rates should reflect not only the decrease of real equilibrium rates, but also successful disinflation in transition countries (see Korhonen and Wachtel, 2006). All in all, aforementioned arguments provide rationale to model policy neutral rate as time-varying.

In this paper we provide first the estimation of monetary policy rules with time-varying intercept to assess the fluctuations of policy neutral interest rate over time. The novelty of our approach lies in estimation of policy neutral rate by the time-varying parameter model with endogenous regressors (Kim, 2006).[3] Unlike 'conventional' time-varying parameter model, this approach is robust to endogeneity of explanatory variables, which is indeed relevant when estimating the monetary policy rules. Additional feature of this paper is that we utilize ex-post as well as real-time based data (see e.g. Orphanides, 2001, on real-time data analysis within monetary policy rules framework), specifically the real-time output gap and real-time inflation forecast of Czech National Bank's (CNB) to estimate the monetary policy rules.

One of our primary policy applications, except for measuring policy neutral rate by the novel technique, is also proposing a measure of monetary policy stance based on a deviation of actual interest rate from policy neutral rate. Anticipating our results, we find this measure of monetary policy stance quite useful in predicting both the level as well as change of future inflation rate.

The paper is organized as follows. Section 2 discusses the related literature. Section 3 describes our data and empirical methodology. Section 4 gives the results on the estimation of time-varying estimates of policy neutral rate as well as analysis of ability of monetary

3 Note that in working paper version of Kim (2006), this procedure is also labeled as augmented Kalman filter.

policy stance to predict future inflation developments. Section 5 concludes. Appendix with additional results follows.

2 Related Literature

2.1 Methodological Background

It has been acknowledged in monetary economics for a long time that there exists some unobservable real interest rate that equilibrates aggregate demand and aggregate supply (Woodford, 2003). When actual real interest rate is equal to the unobservable, price stability is achieved. This unobservable rate is often labeled as natural rate of interest or equilibrium interest rate. Equivalently, it has been noted that equilibrium interest rate is the real interest rate that prevails, when prices are fully flexible in all markets (Neiss and Nelson, 2003; Woodford, 2003).

Consequently, equilibrium interest rate or natural rate of interest is fairly general concept and in principle, it may be well associated both with short-term, medium-term or long-term interest rates. In this context, it is worth pointing out that the determinants of equilibrium interest rate are likely to differ according to time horizon (different frequency movements). In the long-term, the level of equilibrium interest rate is influenced by supply-side structural characteristics of economy such as long-run growth potential, which in turn depends on technological progress, population growth and inter-temporal substitution of consumption (Crespo-Cuaresma et al., 2005). In the medium-term, equilibrium interest rate is associated with business cycle. In the short-term, equilibrium interest rate is linked merely to demand factors related to monetary policy and its targeting horizon (Archibald and Hunter, 2001). Here monetary policy may systematically effect inflation expectations and in turn the level of short-term nominal equilibrium rate.

For the purposes of monetary policy conduct, it is vital to know which level of interest rate monetary authority should set in order to achieve price stability (i.e. neutral policy stance). As the primary monetary policy instrument is the level of short-term interest rate, equilibrium interest rate in this context is rather short-term concept and is often labeled as policy neutral rate (Coats et al., 2003; Lam and Tkacz, 2004; Beneš et al., 2005). Policy neutral rate thus represents nominal equilibrium interest rate and is defined as real equilibrium interest rate plus expected inflation (Coats et al., 2003). In other words, policy neutral rate is linked to short-term nominal interest rate over which central bank has substantial control and thus, policy neutral rate may be understood as a bit narrower concept in comparison to equilibrium interest rate and natural rate of interest.[4]

Shall interest rate policy of monetary authority strictly follow the neutral rate, when targeting inflation? Not necessarily. First point is that obviously there is uncertainty in policy neutral rate measurement. Second, more importantly, there are shocks to which is suboptimal for the authority to react. More specifically, central banks deliberately do not react

4 *For convenience, we use policy neutral rate, natural rate of interest and equilibrium interest rate in the following text interchangeably to a certain extent. However, when we want to emphasize the short-run concept of it, we always use the term policy neutral rate.*

to the first-round effects of cost-push shocks, as this can be destabilizing the economy in the short run. This may however alter inflation expectation of economic agents, if some fraction of them is myopic, and as a result, induce a change in policy neutral rate. In such case, central bank interest rate policy may temporarily deviate from policy neutral rate.

2.2 Methods for Natural Rate of Interest Estimation

Generally, there are several main methods to estimate the natural rate of interest (see e.g. Giammarioli and Valla, 2004, for survey).[5] The simplest is to assume that the equilibrium is captured reasonably well by some univariate trend such as HP filter. Nevertheless, a number of papers document that the estimates based on these filters is often misleading (Clark and Kozicki, 2005). In general, the limitations of the univariate methods have been pointed out by many authors (e.g. Canova, 1998).

Another method to derive equilibrium interest rates is based on the estimation of simple monetary policy rule of central bank (Taylor, 1993). The reaction function typically associates short-term interest rates to its lagged value, a difference between inflation (forecast) and its target, and output gap. The intercept of the estimated reaction function can be interpreted as the nominal equilibrium interest rate (this is, the interest rate that would prevail when inflation and output are at their targeted values). This method has been applied to estimate the equilibrium interest rates by e.g. Clarida et al. (1998, 2000) and Orphanides (2001) for the United States and Germany, Adam et al. (2005) for the United Kingdom and Gerdesmeier and Roffia (2004, 2005) for the euro area. Nevertheless, the assumption of constant equilibrium interest rates is often found too restrictive over the longer-term horizon (for example, when there is a change in monetary policy strategy). Consequently, it is possible to model the equilibrium interest rate, or more generally monetary policy rule as time-varying (see Plantier and Scrimgeour, 2002, Elkhoury, 2006 and Kim and Nelson, 2006). Typically, these studies find rationale to model the rule as time-varying, given that the equilibrium interest rate sometimes fluctuates considerably over longer time horizons (as well as other parameters in policy rule). Generally, the monetary policy rules approach measures the behavior of central bank and assumes that central bank estimates equilibrium interest rates correctly. In case of central bank's systematic mis-measurement of equilibrium rates, it is likely that equilibrium rates retrieved from the estimation of reaction function are mis-measured as well.

Structural time series models represent another common method to measure equilibrium interest rates as well. The primary contribution in this area is Laubach and Williams (2003), who formulate a simple empirical model containing IS curve, Phillips curve and an equation linking equilibrium interest rate to trend growth, and model equilibrium interest rates and potential output as unobserved components. Their method has gained popularity recently and has been applied by Manrique and Marques (2004) for the U.S. and Germany, Mesonnier

5 *Note that we do not present the exhaustive list of methods for equilibrium interest rate estimation, e.g. Brzoza-Brzezina (2006) proposes structural vector autoregression model in this regard. In general, the role of equilibrium interest rate for monetary policy conduct is discussed extensively by Taylor (1993), Woodford (2003) or Amato (2005).*

and Renne (2007) for the euro area and Wintr, Guarda and Rouabah (2005) for the euro area[6] and Luxembourg as well. In principle, the joint estimation of equilibrium interest rates and output gap is an advantage of this approach; however it also reduces the degrees of freedom, which may be an issue for transition countries with rather short time series.

Equilibrium interest rates can also be estimated within stochastic dynamic general equilibrium models. The advantage of this type of literature is that it specifies the structure of economy and thus in principle allows an identification of variety of shocks hitting the economy. On the other hand, Levin et al. (1999) find that more complex models seem to be less robust to model uncertainty (see also Giammarioli and Valla, 2004). Consequently, these model outcomes may be quite sensitive to model assumptions. The recent examples of this approach to estimate equilibrium interest rates include Giammarioli and Valla (2003), Neiss and Nelson (2003) and Smets and Wouters (2003).

The last major stream of literature estimates equilibrium interest rates from the yield curve and asset pricing models. Bomfim (2001) uses inflation linked bonds in order to eliminate the distortions from inflation expectations and retrieves equilibrium interest rates from the realized yields on U.S. Treasury inflation-indexed securities. In this regard, Giammarioli and Valla (2004) discuss equilibrium interest rate estimates in relation to consumption capital asset pricing models. In general, this stream of literature hinges on a notion of liquid financial markets and thus this approach is viable especially for countries with developed financial markets.

3 Data and Empirical Methodology

In this part, we discuss the methodology and dataset we employ to evaluate the policy neutral rate fluctuations in the Czech Republic. Concretely, we estimate a variety of backward or forward looking monetary policy rules with time-varying policy neutral rate.

3.1 Monetary Policy Rules

A starting point for a formal derivation of monetary policy rule is a reasonable assumption that central bank targets to set nominal interest rate in line with the state of economy (see Clarida et al., 1998, 2000), as postulated in Eq. (1):

$$r_t^* = \bar{r} + \alpha\left(E\{\pi_{t+i}|\Omega_t\} - \pi_{t+i}^*\right) + \beta E\{x_t|\Omega_t\} \quad (1)$$

r_t^* denotes the targeted interest rate, $\bar{r}$ is the policy neutral rate, π_{t+i} stands for the central bank forecast of yearly inflation rate i periods ahead, π_{t+i}^* is the central bank's inflation target. x_t represents a measure of output gap. $E(.)$ is the expectation operator and Ω_t is the information set available at the time when interest rates are set. Hereinafter, we set i either equal to 12 months to reflect the CNB's actual targeting horizon[7] or alternatively

6 See Crespo-Cuaresma et al. (2004) on related estimates on Euro area using somewhat different methodology.

7 This in line with the CNB main forecasting model – Quarterly Prediction Model; see Coats et al., 2003. The actual targeting horizon is 12-18 months, but due to data limitations we prefer to work with 12 months. In general, see Batini and Nelson, 1999, for contributions on optimal targeting horizon. Note also that policy to 0, i.e. using the current inflation for sensitivity analysis. Therefore, Eq. (1) links targeted nominal interest rates to a constant (i.e. interest rate – policy neutral rate – that would prevail, when expected inflation is at the target and output gap is null), the deviation of expected inflation from the target and output gap.

Nevertheless, Eq. (1) is often argued to be too restrictive, as it does not account for interest rate smoothing of central banks. Clarida *et al.* (1998) assume that central bank adjusts the interest rate sluggishly to the targeted value. This is so for a number of reasons. For example, Goodfriend (1991) puts forward the concerns over the stability of financial markets. Sack (1997) highlights uncertainty about the effects of interest rate changes on the economy.[8] Instead of explicit listing of various factors behind the interest rate smoothing, Clarida *et al.* (1998) assume for simplicity that actual policy interest rate is a combination of its lagged value and the targeted policy rate as in Eq. (2).

$$r_t = \rho r_{t-1} + (1-\rho) r_t^* + \nu_t \quad (2),^9$$

where $\rho \in [0,1]$. In line with Clarida *et al.* (1998), substituting Eq. (2) into Eq. (1) and eliminating unobserved forecast variables results in Eq. (3):

$$r_t = (1-\rho)\left[\bar{r} + \alpha\left(\pi_{t+i} - \pi_{t+i}^*\right) + \beta x_t\right] + \rho r_{t-1} + \varepsilon_t \quad (3)$$

Note that disturbance term ε_t is a combination of forecast errors and is thus orthogonal to all information available in time t (Ω_t).

Next, in order to estimate time-varying neutral policy rate we apply structural time-varying coefficient model with endogenous regressors. Kim (2006) shows that conventional time-varying parameter model delivers inconsistent estimates, when explanatory variables are correlated with the disturbance term, which is indeed relevant, when estimating policy rules. It is interesting to note that the correlation of π_{t+i} and x_t with ε_t in Eq. (3) is almost always taken into account in empirical work on time-invariant rules (as typically estimated by the GMM), while it is almost never considered in literature on time-varying monetary policy rules (Kim and Nelson, 2006, seem to be the exemption). So, Kim (2006) derives a consistent estimator of time-varying parameter model, when regressors are endogenous. In line with Kim (2006), we estimate the following empirical model:

neutral rate is defined as the real rate plus the expected inflation in period t+k, where k is given by the maturity of interbank rate (in our case k=3). k is thus different from forecasting horizon i. As argued by Clarida et al. (2000), this is not very relevant in practice, as the short-term interbank interest rates at various maturities are strongly linked together. Indeed, the correlation of 3M PRIBOR and 12M PRIBOR – to reflect that i=12 – stands at 0.991 in our sample.

8 *Nevertheless, Rudebusch (2006) recently questioned the extent of monetary policy inertia and argued that the inertia is rather low.*

9 *We have estimated the monetary policy rules including higher lags of interest rates, but failed to find it significant.*

$$r_t = (1-\rho)\left[\bar{r}_t + \alpha\left(\pi_{t+i} - \pi^*_{t+i}\right) + \beta x_t\right] + \rho r_{t-1} + \varepsilon_t \tag{4}$$

$$\bar{r}_t = \bar{r}_{t-1} + \vartheta_t,\ \vartheta_t \sim i.i.d.N\left(0, \sigma^2_\vartheta\right) \tag{5}$$

$$\pi_{t+i} = Z'_{t-j}\xi + \sigma_\varphi \varphi_t,\quad \varphi_t \sim i.i.d.N(0,1) \tag{6}$$

$$x_t = Z'_{t-j}\psi + \sigma_\nu \nu_t,\ \ \nu_t \sim i.i.d.N(0,1) \tag{7}$$

he measurement equation (4) is Taylor rule with policy neutral rate, $\bar{r}_t$, as outlined above. However, we relax here the assumption of constant policy neutral rate and let it vary over time, $\bar{r}_t$, as specified in the transition equation (5). We assume that $\bar{r}_t$ follows random walk without drift.[10] Given the data limitations and the fact that our sample is characterized by relatively stable institutional structure and actual conduct of monetary policy, we do not allow α, β and ρ being time-varying. The 'first-stage' equations (6) and (7) lay out the relationship between endogenous regressors (π_{t+i} and x_t) and its instruments, Z_t. The list of instruments, z_{t-j}, is as follows: π_{t-1}, π_{t-2}, x_{t-1}, x_{t-2}, r_{t-1} and r^+_t (foreign interest rate – 1YEURIBOR). We assume that the parameters in the Eqs. (6) and (7) are time-invariant. Next, the correlation between the standardized residuals φ_t and ν_t with ε_t is $\kappa_{\varphi,\varepsilon}$ and $\kappa_{\nu,\varepsilon}$, respectively (note that σ_φ and σ_ν are standard errors of φ_t and ν_t, respectively). The consistent estimates of coefficients in the equation (4) are then obtained in two steps. In the first step, we estimate the equations (6) and (7) and save the standardized residuals φ_t and ν_t. In the second step, we estimate Eq. (8) along with Eq. (5) using maximum likelihood via the Kalman filter. Note that (8) now includes bias correction terms, (standardized) residuals from Eqs. (6) and (7), to address the aforementioned endogeneity of regressors. Consequently, the estimated parameters in Eq. (8) are consistent, as ι_t is uncorrelated with the regressors.

$$r_t = (1-\rho)\left[\bar{r}_t + \alpha\left(\pi_{t+i} - \pi^*_{t+i}\right) + \beta x_t\right] + \rho r_{t-1} + \kappa_{\nu,\varepsilon}\sigma_{\varepsilon,t}\nu_t + \kappa_{\varphi,\varepsilon}\sigma_{\varepsilon,t}\varphi_t + \iota_t,$$

$$\iota_t \sim N\left(0, (1-\kappa^2_{\nu,\varepsilon} - \kappa^2_{\varphi,\varepsilon})\sigma^2_{\varepsilon,t}\right) \tag{8}$$

Several authors (see for example Gerdesmeier and Roffia, 2004) include additional economic variables such as (real) exchange rate or money growth in Eq. (3) trying to capture the state of economy in a fuller manner. Nevertheless, this is typically done in an *ad hoc* manner. On the other hand, when literature assumes that interest rates depend only on inflation and output, obviously it does not mean that there the other variables are completely neglected. As Taylor (2001, p. 266) puts it for exchange rate: *"Although the policy rule ... may not appear to involve interest rate reaction to exchange rate, it implies such a reaction. What might appear to be a closed economy policy rule is actually just as much as open*

10 *We also experimented with AR(1) structure in the equation (5), but it just marginally reduced the likelihood and the estimated AR parameter has been very close to one, anyway.*

economy rule as if the exchange rate appeared directly." In other words, additional variables that do not enter Taylor rule directly, may influence inflation and output and therefore the interest rate setting *indirectly*. It is also important to emphasize that CPI inflation targeting, as opposed to domestic inflation targeting, has an implicit concern for foreign shocks given the composition of consumer basket (Svensson, 2000). Therefore, in our paper we do not introduce foreign disturbances explicitly in the monetary policy rule, but we will employ them as the instruments in our empirical specification.

Additionally, in a book describing the current forecasting and policy analysis process in the CNB, Coats *et al.* (2003) report that no other variables than inflation and output gap enter into the monetary policy rule in the CNB Quarterly Projection Model (QPM hereinafter). In particular as regards exchange rate fluctuations the CNB has stated several times that it does not directly react to them. It acknowledged that exchange rate plays important role for inflation developments in small open economies and that it might react indirectly to exchange rate fluctuations, if they jeopardize the inflation developments (Kotlán and Navrátil, 2005). Regarding money aggregates, one can expect that inflation targeting central bank in general views it as only supplementary information about the degree of economic activity and/or inflationary pressures, and also does not directly react to it.

Originally, the design of Taylor rule lacked forward-looking element characteristic for the modern monetary policy conduct. Additional way to assess the sensitivity of our results is estimation of both backward- and forward-looking Taylor-type rules. Therefore, we formulate the monetary policy rule in the Eq. (3) in case of backward-looking policy rule such that we set $i = 0$, i.e. we use current inflation rate instead of its forecasted value (which is utilized for the forward-looking policy rule). Another important point has been raised about timeliness of information in the monetary policy conduct (Orphanides, 2001). Output data are typically revised at later stage, but monetary policy is conducted based on information available at the time. Therefore, we collect real-time based CNB output gap estimates (note that inflation is not revised at later stage by the Czech Statistical Office) and re-estimate the monetary policy rule with real-time output gap. Analogously, we use one year ahead CNB's real-time inflation forecast in estimating monetary policy rule.

There are further modeling issues stemming from the fact that policy interest rate is not changed in a continuous fashion. For instance, the CNB Bank Board meets on a monthly basis to discuss the policy interest rate settings. Besides, the policy rate change itself is not continuous. Typically, if the rates are changed, the respective magnitude is 0.25 percentage points (or eventually multiple of 0.25), despite the change maximizing economic stability according to model-based forecast might be of (slightly) different magnitude. In consequence, policy rate is not only discrete, but also censored. Given the inherent censoring of policy interest rates, majority of authors such as Clarida *et al.* (1998, 2000) or Adam *et al.* (2005) rely on using 3 months interbank rate as the approximation of the censored policy rate.

On the other hand, Choi (1999) and Carstensen (2006) put forward modeling censoring in policy rate directly by employing e.g. modified Tobit model and an ordered probit model, respectively. The advantage of this approach is that it models interest rate setting more realistically and does not have to make a rather simplifying assumption by utilizing the short-term interbank rate. On the other hand, this stream of literature so far models only censoring in the policy rate, but there it has been stressed that there is also censoring in the policy rate change (Podpiera, 2006). In addition, censored models are known to be less efficient and the results based on them do not seem to stand in sharp contrast to those using short-term interbank rate (for example, consider the extent of interest rate smoothing). Additional drawback of this approach in our case is that our main estimation technique is time-varying parameter model with endogenous regressors (Kim, 2006) and to our knowledge; this technique is simply not available with censored dependent variable. Besides, the CNB's QPM also uses 3 months interbank rate instead of 2 weeks policy rate. Having all pros and cons of these two approaches –short-term interbank rate vs. policy interest rate – in mind, we opt for using short-term interbank rate in estimation of the monetary policy rules.

3.2 Data

Our sample contains monthly data over the period 2001:1-2006:09 on yearly CPI inflation ($\pi_t = p_t - p_{t-12}$, where p_t is the log of price level at time t), yearly net inflation (price indexes of regulated goods excluded from the price index; thus $\pi_t^{net} = p_t^{net} - p_{t-12}^{net}$, where p_t^{net} is the log of net price level at time t), output gap (x_t, a difference between actual and potential GDP growth, defined as below), r_t, short-term interbank rate (3M PRIBOR), real effective exchange rate, $(reer_t)$, and r_t^+ - foreign interest rate – 1YEURIBOR. We also use the real-time CNB internal forecasts of CPI (π_{t+12}^f) and net inflation $(\pi_{t+12}^{net,f})$ and output gap. Three different estimates of output gap are employed: a) estimate using HP filter[11], b) ex-post revised output gap from CNB's QPM as of their October 2006 forecast round and c) real-time based output gap collected from CNB's QPM. The source of our data is the CNB public database system ARAD (except inflation forecasts and two aforementioned output gap measures – b) and c), which are not available publicly).

All our variables are available on the monthly basis, except the output gap. Following Adam et al. (2005), we linearly interpolate quarterly estimates of output gap to monthly values.[12] We use the mid-points of CNB inflation target. The choice of 2001-2006 period is motivated to have as long sample period as possible, while not rejecting stationarity of all variables at 5% significance level (using KPSS test). More importantly, real-time output gap and inflation forecast are not available before 2001. As a robustness check, we also estimate the monetary policy rules with net inflation (based on price indexes excluding regulated goods from the consumer basket) instead of CPI inflation.

11 *Standard smoothing parameter of 14440 has been used. Different smoothing parameter, as the one suggested by Ravn and Uhlig (2002), had very little impact on the resulting estimates of policy neutral rate. Output gap derived from HP filter estimates of potential output differs considerably from those used by the CNB – see Chart B.2 in the Appendix. Note that output gap from CNB's QPM is constructed using multivariate Kalman filter. Generally, output gap estimates based on HP filter can be viewed as less reliable, but we keep them in our empirical work, as this gap is replicable based on publicly available data, which is not the case of two other output gap measures derived from CNB's QPM. Note also that HP filter is known to suffer from end-point bias, making it difficult for real-time analysis.*

12 *We also used quadratic match procedure for interpolation. This yields only little differences on resulting output gap estimates.*

4 Results

4.1 Time-varying equilibrium interest rates

Generally, we find that the policy neutral rate decreases over time, as depicted in Chart 1. This is in line with our conjecture laid out in the introduction. We report all specifications, from backward-looking policy rule with the output gap estimated by HP filter to the forward looking rule with the real-time output gap.

The results in Chart 1 unambiguously indicate that policy neutral rate gradually decreased from some 5% to the values around 2% at the end of 2005 and subsequently slightly increased to some 2.5% over the course of 2006.[13] This confirms substantial interest rate convergence to the levels comparable to the euro area countries. For example, Messonier and Renne (2007) estimate euro area real equilibrium interest rate around 1% at the end of their sample (i.e. year 2002) and Wintr et al. (2005) find it a bit below 1% in 2004. If we add to these estimates 2% for the expected inflation – to reflect the European Central Bank definition of price stability –, we receive the estimate of policy neutral rate of about 3% for the euro area. The results actually suggest that the estimated policy neutral rate seem to be a bit below the euro area level. This should not come as surprise, as also actual short-term interest rates were often below those in the euro area (except several months in 2004, Czech rates appear to be below the euro area rates from some mid-2002 onwards).

Detailed parameter estimates of monetary policy rules are presented in the Appendix – Table A.2. It is interesting to note that the degree of interest rate smoothing falls considerably, when allowing for time-varying parameter specification. Compared to the case of constant policy neutral assumption, which is estimated by the GMM[14], the value of interest rate smoothing parameter falls from some 0.9 to 0.4. Time-invariant rules thus overestimate substantially the degree of interest rate smoothing in our case. Other studies in this stream of literature often employ quarterly data; to compare our monthly estimates, taking the cube of 0.4 (this is 0.06) one can get approximately the smoothing term on the quarterly frequency. This complies with the results of Rudebusch (2006), who stresses that once accounting for expectations about future monetary policy the actual policy rate inertia is in fact quite low. The standard errors of the estimates are in some cases large probably reflecting smaller sample size. The coefficient on inflation is around 0.3 in case of backward-looking specifications (interestingly, it is significant only when we introduce bias correction terms, φ_t and ν_t, and insignificant for the forward-looking specifications. The coefficient on output gap ranges from 0.2 to 0.7 according to specification.

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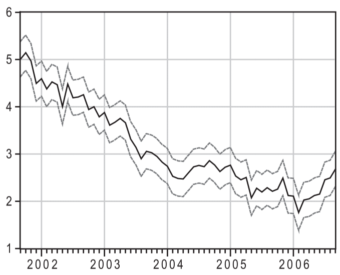
13 *The increase at the end of sample period is likely to reflect higher inflation expectations of economic agents. The CNB conducts regularly a survey on inflation expectations of financial markets, households and non-financial firms (actual numbers are easily available from CNB website within their public database ARAD). Inflation expectations of financial markets for the 1 year horizon have risen from some 2.5% in mid 2005 to 3% over the course of 2006. Similar pattern is visible also for household's and firm's expectations.*

14 *The GMM results are available upon request.*

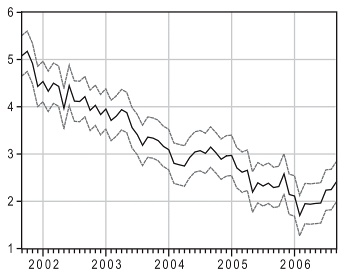
Chart 1 – Policy Neutral Rate Estimates

Time-varying parameter model with endogenous regressors

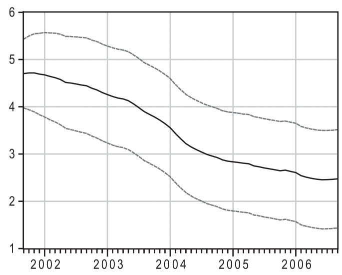
Backward-looking policy rule



Current inflation, output gap – HP filter

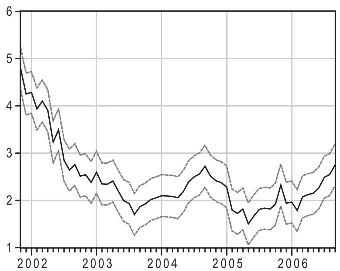


Current inflation, output gap – ex-post

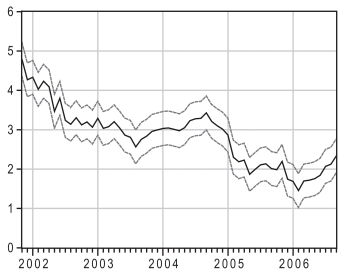


Current inflation, output gap – real-time

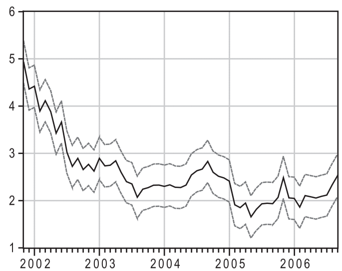
Forward-looking policy rule



Inflation forecast – real-time, output gap – HP filter



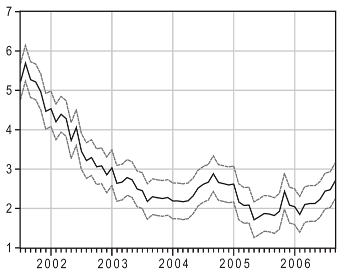
Inflation forecast – real-time, output gap – ex-post



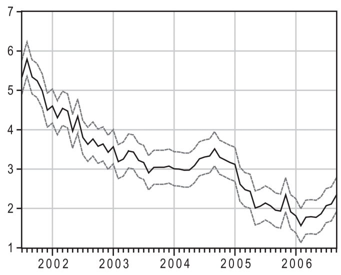
Inflation forecast – real-time, output gap – real-time

Conventional time-varying parameter model

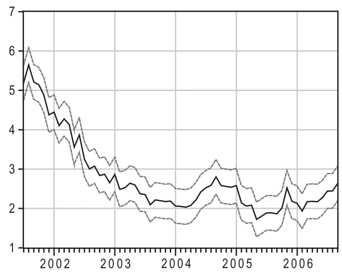
Backward-looking policy rule



Current inflation, output gap – HP filter

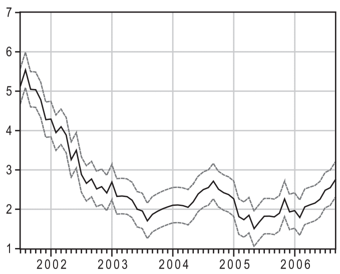


Current inflation, output gap – ex-post

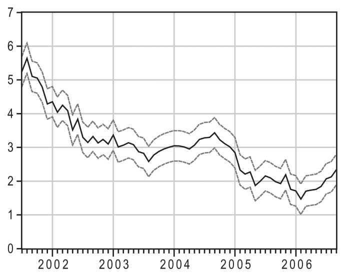


Current inflation, output gap – real-time

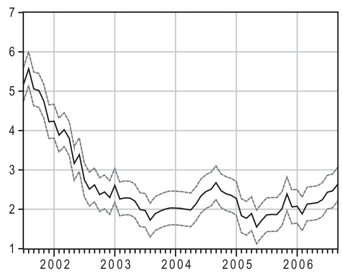
Forward-looking policy rule



Inflation forecast – real-time, output gap – HP filter



Inflation forecast – real-time, output gap – ex-post



Inflation forecast – real-time, output gap – real-time

Note: Policy neutral rate ±2 standard errors reported. The measure of output gap and inflation is used for estimation of policy neutral rate is reported below each chart.

Additionally, the results support the usefulness of applying time-varying parameter model with endogenous regressors. The bias correction terms, φ_t and ν_t, in Eq. (8), are typically significant and the log likelihood improves after their inclusion. Comparing the estimated policy neutral rate with those implied by conventional time-varying parameter model (not accounting for endogeneity of regressors), we find that the resulting difference between these two varies according to the specification of policy rule as well as over time. While the median difference is only 0.05 p.p. in the absolute terms, the maximum difference, that the inclusion of bias correction terms amounts to, is 1.8 p.p.

Chart 3 in the Appendix presents a comparison of policy neutral rate based on identical specification of policy rule, but estimated either by the time-varying parameter model with endogenous regressors or by the conventional time-varying parameter model (i.e. not accounting for endogenous regressors). Denoting the policy neutral rate estimated by the former method, $\bar{r}_{t,e}$, and, $\bar{r}_{t,c}$, by the latter, the Chart A.3 report a difference between these two. Obviously, if $\bar{r}_{t,e} - \bar{r}_{t,c} = 0$, the bias correction terms do not matter at all.[15] However, we can see from the results that albeit the two methods yield in general rather similar estimates of policy neutral rate path, there are periods, when the bias correction terms matter considerably, i.e. when the policy neutral rate estimates by the conventional time-varying parameter model do not even lie inside the confidence interval of the policy neutral rate estimated by the time-varying parameter model with endogenous regressors.

4.2 Monetary policy stance and inflation developments

There is a discussion in literature to what extent the monetary policy rules provide a useful framework to evaluate the monetary policy tightness and its impact on subsequent inflation. This is typically done by comparing actual interest rate setting with the one implied by the rule and inflation outcomes. For example, Taylor (1999, p. 340) labels the difference as the policy mistakes (i.e. a residual from the policy rule) and shows that they are well associated with high inflation or low capacity utilization with the U.S. data. On the other hand, Reynard (2007) analyzing the U.S. and Swiss data questions the reliability of the so-called policy mistakes, as he observes rather weak link between the so-called policy mistakes and inflation relative to inflation target. Here we propose a little bit different framework to evaluate the policy rule. Instead of focusing on the residual from the policy rule, we analyze the deviation of actual interest rates from policy neutral rate ("equilibrium rate") and its impact on subsequent inflation. We leave examination of the link between policy mistakes and inflation outcomes for further research, as we do not concentrate in this paper, whether the estimated monetary policy rule provides accurate description of CNB policy, but rather on the estimation and evolution of policy neutral rate.

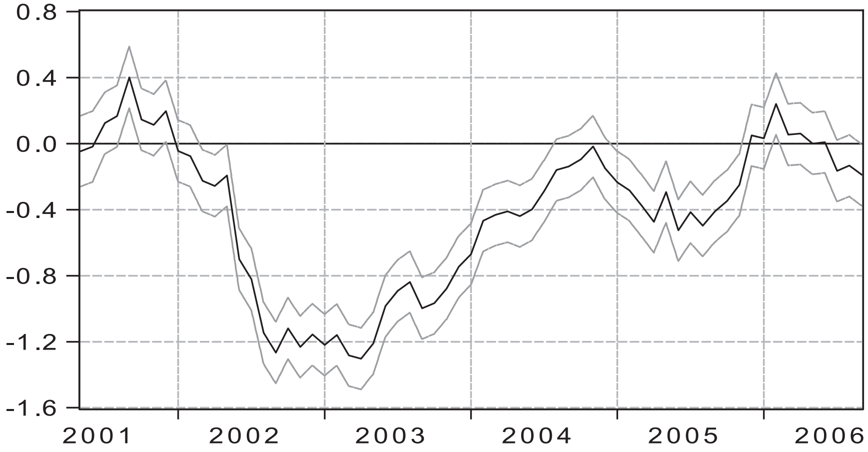
So our simple test here is to examine, whether our estimated policy neutral rate is helpful in predicting future inflation developments. If policy neutral rate is too uncertain measure, then it is likely it does not provide information for subsequent inflation. Our supposition is thus that when actual interest rate is above policy neutral rate, future inflation rate is then likely

15 *Obviously, it might be the case that both bias correction terms are statistically significant, but they just „cancel out" their impact on estimated policy neutral rate. The probability of „canceling out" for each month is virtually zero.*

to fall, as monetary policy can be considered restrictive and *vice versa*. We label a difference between actual interest rate and policy neutral rate as monetary policy stance hereinafter.

The generic monetary policy stance is plotted in Chart 2.[16] As we also have confidence intervals for the policy neutral rate, it is possible to evaluate if the stance was statistically different from zero. The results indicate that monetary policy during the sample period can be regarded as relatively easy, especially around the years 2002-2003. This should not come as surprise since the inflation was well below the target and even got into the negative numbers for several months in 2003 and the output gap was negative, with the bottom in mid 2003 according to the CNB output gap estimates (see Chart B.1).

Chart 2 – Monetary Policy Stance



Note: Positive values refer to monetary policy tightening, while negative values point to policy easing.

As there are transmission lags between monetary policy action and the response in the economy, we assume that current monetary policy stance affects inflation after from 12 to 24 months. This coincides well with the CNB monetary policy horizon, as the bank acknowledges that *"…interest rate changes have their greatest impact on inflation some 12 to 18 months…"* (CNB). It is also supported by the empirical findings of Borys-Morgese and Horvath (2007). Within their factor augmented VAR framework, they find that the peak response of inflation to interest rate shocks is around year or so (note the maximum reaction of non-tradable inflation is close to two years). Based on this evidence, it seems to be fruitful to analyze the horizon between about one and two years. Here we broadly follow the empirical specification by Moser *et al.* (2007), which is a variant of Stock and Watson (1999). While these two studies examine the role of factor models for inflation forecasting, we analyze

16 Monetary policy stance presented in Chart 2 is based on monetary policy rule specification with inflation forecast and ex-post GDP gap. Different specification play rather minor role in overall assessment of monetary policy stance. In addition, it is interesting to note that the significance of monetary policy stance has not been affected by the fact, whether we employed backward or forward looking policy rule.

our monetary policy stance instead. More specifically, we test the significance of monetary policy stance including it in autoregressive-type model for the inflation process.

Our estimation framework begins with the following regression:

$$\pi_{t+i} = \phi_0 + \phi_1\left(\left(r_t - \bar{r}_t\right)\Big/\bar{r}_t\right) + \upsilon_{t+i} \quad (9)$$

where π_{t+i} is yearly inflation i months ahead, where i=12,….,24.

Next, we control for the lagged inflation terms:

$$\pi_{t+i} = \phi_0 + \phi_1\left(\left(r_t - \bar{r}_t\right)\Big/\bar{r}_t\right) + \sum_{h=1}^{n} \phi_{h+1}\pi_{t-h} + \upsilon_{t+i} \quad (10)$$

where for simplicity we set n=4.[17]

Using Eqs. (9) and (10), we investigate the information content of monetary policy stance on the future level of inflation. We also re-specify the above equations to address the future change in the inflation rate as follows:

$$\pi_{t+i} - \pi_t = \phi_0 + \phi_1\left(\left(r_t - \bar{r}_t\right)\Big/\bar{r}_t\right) + \upsilon_{t+i} \quad (11)$$

$$\pi_{t+i} - \pi_t = \phi_0 + \phi_1\left(\left(r_t - \bar{r}_t\right)\Big/\bar{r}_t\right) + \sum_{h=1}^{n} \phi_{h+1}\pi_{t-h} + \upsilon_{t+i} \quad (12)$$

The results from Eq. (9) are given in Table A.3 in the Appendix. Our definition of monetary policy stance seems to be informative for future inflation, explaining typically about 1/3 of its variance. These results are largely confirmed, when controlling for the lagged inflation terms, as suggested the estimation of Eq. (10) presented in Table A.4. The results suggest that when actual interest rate is 10% above the policy neutral rate, inflation is likely to fall by about 1 p.p. at the monetary policy horizon. Similarly, policy neutral rate seems to be relatively good predictor of the future change of inflation rate, as presented in Table A.5. This result is largely robust to inclusion of lagged inflation as well (see Table A.6). All in all, the results suggest usefulness of policy neutral rate in understanding future behavior of inflation.[18]

5 Conclusions

This paper analyzes the policy neutral rate in the Czech Republic. In order to do so, we estimate various specifications of simple Taylor-type monetary policy rules at the monthly

17 *We also included higher lags, but with little impact on the results.*

18 *We also tested the robustness of our results by including other macroeconomic variables to Eqs. (10) and (12) such as real effective exchange rate, credit and monetary aggregates. The results remain largely unchanged and are available upon request.*

frequency from 2001:1 to 2006:9. To address the sensitivity of results, the specifications differ based on whether we include real-time or ex-post revised data, employ backward or forward-looking monetary policy rules or vary the measure of output gap.

To estimate time-varying policy neutral rate, we use time-varying parameter model with endogenous regressors (Kim, 2006). This approach is especially appealing, when estimating monetary policy rules, as it addresses the endogeneity of inflation (forecast) and output gap. Indeed, the results support the usefulness of applying time-varying parameter model with endogenous regressors. The bias correction terms, accounting for the endogeneity of regressors, are typically significant, the log likelihood improves after their inclusion and the estimated path of policy neutral rate is for certain periods considerably different.

The results indicate that policy neutral rate decreases gradually over the course of sample period from some 5% in 2001 to about 2.5% in 2006 showing a substantial interest rate convergence to the levels comparable to the euro area. Over the longer time horizon, the decrease may be supported a number of factors such as capital accumulation, the decrease in risk premium, real equilibrium exchange rate appreciation as well as successful disinflation of Czech economy and well-anchored inflation expectations.

One of our primary policy applications, except for measuring policy neutral rate by the novel technique, is also proposing a measure of monetary policy stance based on a deviation of actual interest rate from policy neutral rate. Our results indicate that this measure is quite useful in predicting future inflation developments. More specifically, monetary policy stance affects both the level as well as change of future inflation rate. In terms of future research, it would be interesting to see more evidence on other inflation targeting countries to uncover, whether our proposed monetary policy stance measure remains useful predictor of future inflation developments, as we find in the case of Czech Republic.

Abstract
This paper examines time-varying policy neutral interest rate in real time for the Czech Republic in 2001:1-2006:09 estimating various specifications of simple Taylor-type monetary policy rules. For this reason, we apply a structural time-varying parameter model with endogenous regressors. The results indicate that policy neutral rate gradually decreased over sample period to the levels comparable to those of in the euro area. Next, we propose a measure of monetary policy stance based on a difference between the actual interest rate and estimated policy neutral rate and find it a useful predictor of the level as well as change of future inflation rate.

Keywords
policy neutral rate, Taylor rule, time-varying parameter model with endogenous regressors

JEL classification / JEL klasifikace
E43, E52, E58

Souhrn

Tento článek analyzuje politicky neutrální („rovnovážnou“) úrokovou míru s tzv. daty v reálném čase v České republice od 2001:1 do 2006:09 na základě odhadů různých specifikací Taylorova pravidla. Aplikujeme strukturální model s časově proměnlivými parametry a s endogenními regresory, abychom vyhodnotili fluktuace politicky neutrální sazby v čase. Nalézáme, že politicky neutrální sazba v čase klesá na úroveň srovnatelnou se zeměmi eurozóny. Dále navrhujeme způsob měření nastavení měnové politiky založeném na rozdílu mezi skutečnou úrokovou mírou a námi odhadnutou politicky neutrální sazbou a nalézáme, že tímto způsobem jsme schopni dobře predikovat budoucí inflaci i budoucí změnu inflace.

Klíčová slova

politicky neutrální úroková míra, Taylorovo pravidlo, model s časově proměnlivými parametry a endogenními regresory

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Je editorem AUCO Czech Economic Review a členem redakční rady Finance a úvěr – Czech Journal of Economics and Finance. Je členem Ekonometrické společnosti a Evropské ekonomické asociace.

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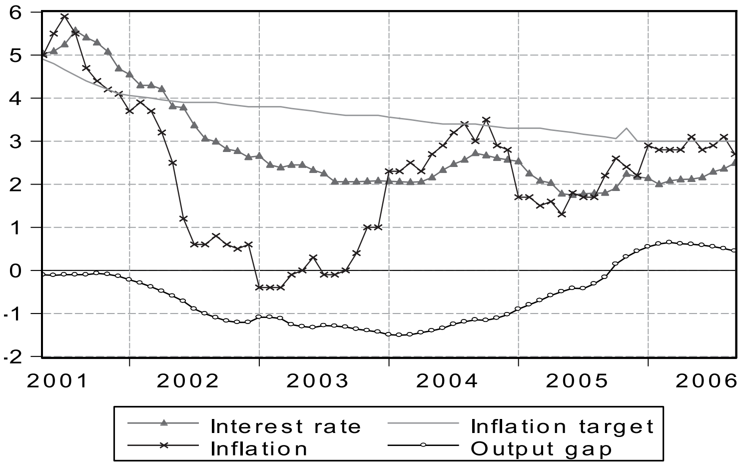
APPENDIX

Table A.1 – KPSS Test

Series	**Test statistic**
PRIBOR 3M	0.355*
CPI Inflation	0.165
CPI Inflation forecast (t+12)	0.163
Net Inflation	0.147
Output gap – HP filtered	0.106
Output gap – Real-time	0.293
Output gap – Ex-post	0.214
M2 growth	0.168
Real effective exchange rate	0.447*

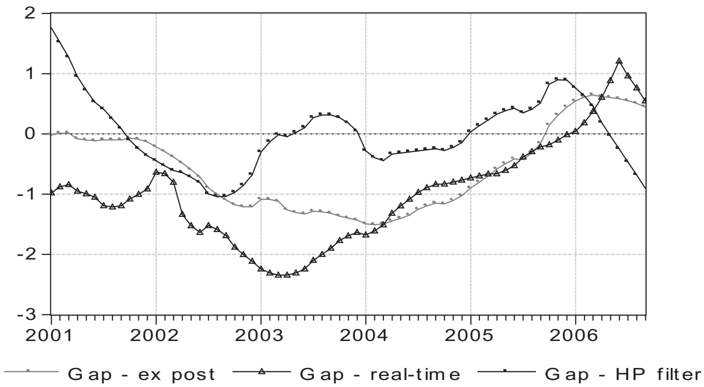
*The null hypothesis is that the series is level stationary. Critical values for the null hypothesis: 10% - 0.347, 5% - 0.463, 1% - 0.739. Sample period: 2001:1-2006:09. *, **, *** denotes significance at the 10, 5 and 1 percent level, respectively.*

Chart A.1 – Interest Rate, Output Gap and Inflation



Note: This chart presents current inflation, short-term interbank interest rate (3M PRIBOR) and CNB output gap as of October 2006 forecast round.

Chart A.2 – Comparison of Output Gap Estimates



Note: This chart presents three measures of output gap used in the paper: Output gap estimated by the CNB as of their October 2006 forecast round (Gap - ex post), Real-time based output gap estimated by the CNB (Gap - real-time) and the output gap calculated using HP filter (Gap – HP filter) as the estimate of potential output.

Table A.2 – Monetary Policy Rules Estimation

$$r_t = (1-\rho)\left[\bar{r}_t + \alpha\left(\pi_{t+i} - \pi^*_{t+i}\right) + \beta x_t\right] + \rho r_{t-1} + \varepsilon_t$$

$$\bar{r}_t = \bar{r}_{t-1} + \vartheta_t,\ \vartheta_t \sim i.i.d.N\left(0, \sigma^2_\vartheta\right)$$

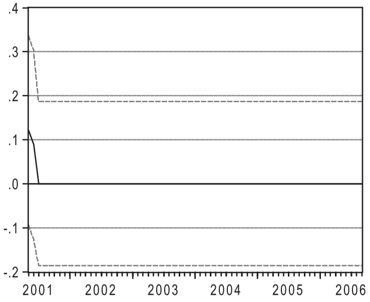
$$\varepsilon_t = \kappa_{\nu,\varepsilon}\sigma_{\varepsilon,t}\nu_t + \kappa_{\varphi,\varepsilon}\sigma_{\varepsilon,t}\varphi_t + \iota_t,\ \ \iota_t \sim N\left(0, (1-\kappa^2_{\nu,\varepsilon} - \kappa^2_{\varphi,\varepsilon})\sigma^2_{\varepsilon,t}\right)$$

	Model											
Parameters	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
ρ	0.40***	0.40***	0.40***	0.41***	0.40***	0.40***	0.42***	0.40***	0.42***	0.42***	0.45***	0.40***
	(0.02)	(0.09)	(0.06)	(0.06)	(0.07)	(0.09)	(0.11)	(0.10)	(0.10)	(0.09)	(0.10)	(0.15)
α	0.27***	0.07	0.28***	0.06	0.28***	0.07	-0.15	-0.15	-0.18	-0.16	-0.17	-0.14
	(0.07)	(0.07)	(0.08)	(0.06)	(0.07)	(0.06)	(0.12)	(0.11)	(0.11)	(0.11)	(0.10)	(0.09)
β	0.21	0.11	-0.06	0.57**	-0.06	-0.06	0.12	0.14	0.66**	0.66**	0.18	-0.02
	(0.24)	(0.24)	(0.28)	(0.29)	(0.22)	(0.23)	(0.27)	(0.25)	(0.28)	(0.31)	(0.23)	(0.19)
$\kappa_{\nu,\varepsilon}$	-0.06***		-0.07***		-0.06***		0.01		0.02		0.02	
	(0.01)		(0.02)		(0.02)		(0.01)		(0.01)		(0.01)	
$\kappa_{\varphi,\varepsilon}$	-0.02*		-0.02*		-0.02*		0.01		-0.01		-0.02***	
	(0.01)		(0.01)		(0.01)		(0.01)		(0.02)		(0.01)	
AIC	-1.10	-1.00	-1.07	-1.00	-0.95	-0.94	-0.91	-0.94	-0.94	-0.96	-0.91	-0.88

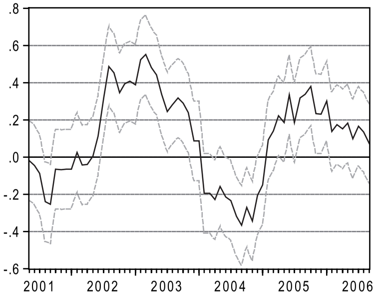
*Note: Robust standard errors in brackets. ***, ** and *indicates the significance at 1,5 and 10%, respectively. Models differ according to whether bias correction terms are included and the specification of π_{t+i} and x_t. π_{t+i} is either CNB inflation forecast one year ahead (abbreviated as IF below) or current inflation rate (IC). x_t is a measure of output gap: 1. as estimated by HP filtering (HP), 2. CNB ex-post output gap measure based on multivariate Kalman filter procedure (EX), 3. CNB real-time output gap measure based on multivariate Kalman filter procedure (REAL). Model 1 and 2 = IC, HP; Model 3 and 4 = IC, EX; Model 5 and 6 = IC, REAL; Model 7 and 8 = IF, HP; Model 9 and 10 = IF, EX and Model 11 and 12 = IF, REAL;*

Chart A.3 – Importance of Bias Correction Terms in Estimating Policy Rules

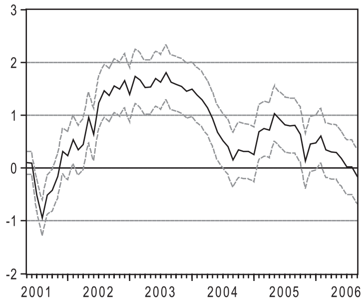
Backward-looking policy rule



Current inflation, output gap – HP filter

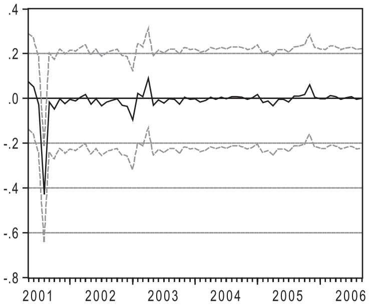


Current inflation, output gap – ex-post

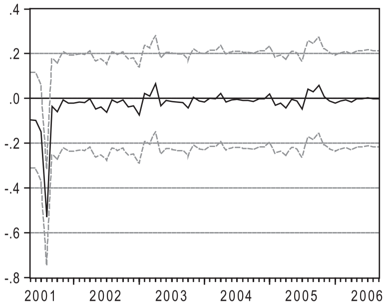


Current inflation, output gap – real-time

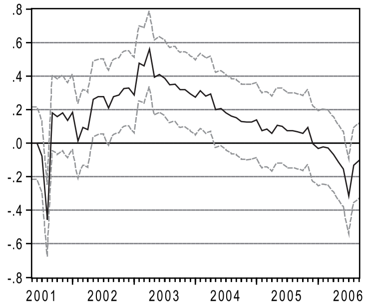
Forward-looking policy rule



Inflation forecast – real-time, output gap – HP filter



Inflation forecast – real-time, output gap – ex-post



Inflation forecast – real-time, output gap – real-time

Note chart A3: The difference between the policy neutral rates estimated from the time-varying parameter model with endogenous regressors, $\bar{r}_{t,e}$ with its confidence intervals, and from the conventional time-varying parameter model, $\bar{r}_{t,c}$. The measure of output gap and inflation is used for estimation of policy neutral rate is reported below each chart. Consequently, if the confidence intervals are different from zero, it means that $\bar{r}_{t,c}$ does not lie within the confidence intervals of $\bar{r}_{t,e}$.

Table A.3 – Monetary Stance and Future Level of Inflation

$$\pi_{t+i} = \phi_0 + \phi_1\left(\left(r_t - \bar{r}_t\right)\Big/\bar{r}_t\right) + \upsilon_{t+i}$$

i	ϕ_0	ϕ_1	Adj. R2
12	1.43***	-6.89	0.07
13	1.31***	-9.91*	0.15
14	1.26***	-11.30**	0.19
15	1.26***	-11.58**	0.20
16	1.22***	-13.23**	0.27
17	1.20***	-14.31***	0.32
18	1.23***	-13.93***	0.31
19	1.14***	-16.02***	0.39
20	1.18***	-15.81***	0.39
21	1.25***	-14.81***	0.36
22	1.31***	-13.82**	0.32
23	1.42***	-12.54**	0.30
24	1.57***	-10.16*	0.21

*Note: Robust standard errors. ***, ** and *indicates the significance at 1,5 and 10%, respectively.*

Table A.4 – Monetary Stance and Future Level of Inflation, Controlling for Lagged Inflation

$$\pi_{t+i} = \phi_0 + \phi_1\left(\left(r_t - \bar{r}_t\right)/\bar{r}_t\right) + \sum_{h=1}^{n}\phi_{h+1}\pi_{t-h} + \upsilon_{t+i}$$

i	ϕ_0	ϕ_1	ϕ_3	ϕ_3	ϕ_4	ϕ_5	Adj. R2
12	2.33***	-0.94	0.03	0.04	0.07	-0.48	0.33
13	1.95**	-2.49	-0.11	0.19	-0.06	-0.33	0.41
14	1.67*	-3.59	-0.14	0.04	0.19	-0.36	0.46
15	1.49	-4.26	-0.25	0.24	-0.07	-0.15	0.48
16	0.66	-6.86**	-0.09	-0.07	-0.22	0.30	0.52
17	0.02	-8.89***	-0.25	-0.16	0.14	0.31	0.57
18	-0.33	-9.98***	-0.55***	0.19	0.14	0.33	0.60
19	-1.05	-12.12***	-0.57***	0.20	0.27	0.36	0.63
20	-1.12	-12.27***	-0.62**	0.36	0.17	0.38	0.60
21	-0.78	-11.09**	-0.46	0.18	0.21	0.34	0.51
22	-0.57	-10.31**	-0.42**	0.25	-0.09	0.52	0.45
23	-0.48	-9.86**	-0.26	-0.06	0.01	0.61*	0.41
24	-0.53	-9.89**	-0.40	0.12	-0.12	0.73*	0.39

*Note: Robust standard errors. ***, ** and *indicates the significance at 1,5 and 10%, respectively.*

Table A.5 – Monetary Stance and Future Change of Inflation

$$\pi_{t+i} - \pi_t = \phi_0 + \phi_1\left(\left(r_t - \bar{r}_t\right)/\bar{r}_t\right) + \upsilon_{t+i}$$

i	ϕ_0	ϕ_1	Adj. R2
12	-3.04***	-15.39***	0.53
13	-3.29***	-16.55***	0.57
14	-3.48***	-17.47***	0.59
15	-3.54***	-17.77***	0.59
16	-3.58***	-18.01***	0.60
17	-3.60***	-18.09***	0.60
18	-3.56***	-17.93***	0.59
19	-3.60***	-18.05***	0.60
20	-3.54***	-17.81***	0.60
21	-3.42***	-17.24***	0.60
22	-3.28***	-16.62***	0.58
23	-3.10***	-15.88***	0.56
24	-2.89***	-15.11***	0.53

*Note: Robust standard errors. ***, ** and *indicates the significance at 1,5 and 10%, respectively.*

Table A.6 – Monetary Stance and Future Change of Inflation, Controlling for Lagged Inflation

$$\pi_{t+i} - \pi_t = \phi_0 + \phi_1\left(\left(r_t - \bar{r}_t\right)\Big/\bar{r}_t\right) + \sum_{h=1}^{n} \phi_{h+1}\pi_{t-h} + \upsilon_{t+i}$$

i	ϕ_0	ϕ_1	ϕ_2	ϕ_3	ϕ_4	ϕ_5	Adj. R2
12	2.12***	-1.26	-1.11***	-0.08	0.53*	-0.59	0.82
13	1.62*	-3.18	-1.26***	0.05	0.43	-0.42	0.84
14	1.41	-4.06	-1.28***	-0.11	0.67*	-0.46	0.85
15	1.44	-4.10	-1.41***	0.08	0.46	-0.33	0.86
16	0.56	-6.82*	-1.24***	-0.23	0.33	0.13	0.86
17	-0.08	-8.89**	-1.41***	-0.31	0.69**	0.14	0.89
18	-0.33	-9.70***	-1.72***	0.05	0.68*	0.14	0.89
19	-1.13	-12.05***	-1.74***	0.07	0.80**	0.19	0.88
20	-1.19	-12.20***	-1.79***	0.23	0.70*	0.20	0.87
21	-0.86	-11.03***	-1.63***	0.02	0.77*	0.16	0.86
22	-0.67	-10.31***	-1.61***	0.12	0.45	0.36	0.85
23	-0.49	-9.55***	-1.45***	-0.13	0.42	0.48*	0.85
24	-0.51	-9.49***	-1.57***	0.02	0.32	0.59**	0.86

*Note: Robust standard errors. ***, ** and *indicates the significance at 1,5 and 10%, respectively.*