Evaluating Inflation Determinants with a Money Supply Rule in Four Central and Eastern European EU Member States

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We evaluate the monetary determinants of inflation in the Czech Republic, Hungary, Poland and Slovakia by using the McCallum rule for money supply. The deviation of actual money growth from the rule is included in the estimation of Phillips curves for the four economies by Bayesian model averaging. We find that money provides information about price developments over a horizon of ten quarters ahead, albeit the estimates are in most cases rather imprecise. Moreover, the effect of excessive monetary growth on inflation is mixed: It is positive for Poland and Slovakia, but negative for the Czech Republic and Hungary. Nevertheless, these results suggest that money does provide information about future inflation and that a McCallum rule could potentially be used in the future as an additional indicator of the monetary policy stance once the precision of the estimation improves with more data available.

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1 Introduction

The analysis of the monetary determinants of inflation is of obvious interest for countries that pursue a policy of inflation targeting. In our study, we focus on four Central and Eastern European (CEE) economies that are currently following an inflation targeting approach or did so in the recent past. These countries are the Czech Republic, Hungary and Poland, which aim to join a monetary union – the euro area – in the future but for the time being maintain monetary independence and conduct policy in an environment of flexible exchange rates, as well as Slovakia, which joined the euro area in January 2009. Slovakia's entry into Monetary Union was preceded by inflation targeting cum ERM II participation and prior to that by a managed float of the exchange rate with implicit inflation targeting.

The novelty of this study is that we employ a monetary indicator based on a prespecified monetary policy reaction function to assess the monetary determinants of inflation. While numerous studies have modeled monetary policy by Taylor-type interest rate feedback rules, less attention has been paid to a McCallum rule that grants a prominent role to the money stock (see e.g. McCallum, 1988 and 2000, and Taylor, 1993). In the rule specified by McCallum, the monetary base serves as the central bank's operating target. For the evaluation of policy both operating targets – short-term interest rates and base money – could potentially be of interest. McCallum (1999) notes that over long periods his rule has agreed with the Taylor rule concerning the correct stance of policy.

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Using the McCallum rule for money supply, we evaluate the monetary determinants of inflation in the Czech Republic, Hungary, Poland and Slovakia. We compute the deviation of actual monetary base growth from that suggested by the rule. Assuming that money matters in the medium and long run, we then include past values of this deviation in the estimation of standard backward-looking Phillips curves for these economies. These Phillips curves are estimated by employing a Bayesian model averaging technique, and the results are compared to estimates on the basis of standard general-to-specific and iterative model selection techniques. In this way, it is possible to evaluate whether money provides information on price level developments in addition to the variables that are typically included in a conventional backward-looking Phillips curve.

Our focus on four CEE economies is justifiable for various reasons. The Czech Republic, Hungary and Poland are all inflation targeters, i.e. price stability plays an important role for the monetary authorities in these economies.[3] All three countries aim to join the euro area, which gives a prominent role to money in the second pillar of the ECB's monetary policy strategy (see ECB, 2003). However, money is not – at least explicitly – currently emphasized in the monetary policy strategy of the three countries' central banks. In particular, money is not reported to be part of the forecasting tools of the monetary authorities. For the Czech Republic, monetary indicators are stated not to have significant information content for inflation forecasting over the monetary policy horizon (Czech National Bank, 2006). The fourth economy under study, Slovakia, has already entered the euro area, and its current monetary conditions cannot be analyzed separately from those of the other euro area countries. Nevertheless, the importance of money in the Phillips curve during the periods of implicit and explicit inflation targeting is of interest for those economies currently pursuing such a policy.

The policy rule specified by McCallum or other similar methods to derive an indicator of excess money supply have empirically shown that they provide useful information for policy. Masuch et al. (2003) note that while a Taylor rule indicated an appropriate policy stance with regard to developments in the output gap and inflation during the asset price boom of the late 1980s in Japan, an indicator for excess money growth suggested that monetary growth was very fast at the time. Christiano et al. (2003) argue that a monetary base rule – responding only to money demand shocks – would have made the Great Depression of the 1930s milder. But perhaps the most timely use for such a rule comes during a time when interest rates are very close to or at the zero bound. McCallum (2003) finds that according to his policy rule, the Bank of Japan's policy was too tight most of the time during 1990–1998, when Japan entered a period of deflation. While at the time of writing policy interest rates are still on positive territory in all the CEE economies under study, the financial crisis and the moderation in inflation pressures have led to significant declines in interest rates even in emerging economies.[4]

[3] *Romania also targets inflation, but it was not included in the analysis due to limited data availability in terms of sample length.*

[4] *As at April 2009, Slovakia recorded the lowest policy rate of the four economies, as the ECB had lowered its main refinancing rate to 1.25%; the Czech National Bank lowered its policy rate to 1.75% in February; Poland cut its reference rate to 3.75% in March 2009; Hungary's base rate was 9.5%.*

Most prominently, among the advanced economies, the U.S.A. has shifted to a policy of quantitative easing with interest rates effectively at the zero lower bound.

Applying the comprehensive Bayesian model averaging technique, which aggregates available information on the entire model space, we find that the growth of money stock above the McCallum rule-specified values enters Phillips curves robustly for all four countries over a horizon of ten quarters. However, the effect of excessive monetary growth is mixed: It is positive for Poland and Slovakia and negative for the Czech Republic and Hungary. The negative impact likely results from the short sample, which leads to somewhat unstable models and thus a negative sign for money. Nevertheless, regardless of the sign, the robustness of the monetary variable in the Bayesian procedure suggests that it significantly enters the inflation equation and therefore should be taken into account in the evaluation of price pressures. The benchmark results are complemented by the evaluation of the importance of ordinary monetary base growth and trend money growth, in the latter case abstracting from short-run fluctuations. However, the measure of excess money based on the McCallum rule appears to be the most informative indicator for price developments.

This paper is structured as follows: The next section discusses the policy environment in the four economies under study, in particular the role of money and the specified inflation targets. We also mention some of the previous research about the determinants of inflation in these economies. Section 3 specifies and simulates the McCallum rule, and section 4 applies the results of the simulations in the estimation of Phillips curves in the four economies. The final section concludes with policy implications.

2 Policy Environment in the Czech Republic, Hungary, Poland and Slovakia and Previous Literature

All four economies under study are explicitly pursuing or have until recently pursued a policy of inflation targeting. The Czech Republic switched to the current policy regime in December 1997. The central bank set the first target, to be met by December 1998, at 5.5% to 6.5%. At that time, targets were defined in terms of net inflation. The current target is 3%, measured in terms of CPI inflation, and it has been in place since January 2006. An inflation target of 2% was announced to be in effect from January 2010 onwards until the Czech Republic joins the euro area. The Czech National Bank aims to keep inflation within a range of 1 percentage point in either direction of the target.

Hungary adopted an inflation targeting regime in June 2001. At the time, targets were set for December 2001 (7%) and December 2002 (4.5%). In August 2005, an explicit medium-term inflation target was announced for the period starting in 2007, defined as a 3% rate of increase in the consumer price index. A deviation of 1 percentage point is allowed on both sides of the target.

Poland has followed an inflation targeting strategy since 1999. The first inflation target of 8% to 8.5% was to be met by December 1999.[5] Since the start of

[5] *The target was reviewed in 1999, when the Monetary Policy Council, one of the National Bank of Poland's directing bodies, decided to change the end-year target for CPI from 8.0%–8.5% to 6.6%–7.8%. The inflation target was also reviewed in 2002 (from 5% +/- 1 percentage point to 3% +/- 1 percentage point).*

2004, a continuous inflation target of 2.5% has been in place, with a fluctuation band of 1 percentage point on both sides of the target.

Despite the focus on inflation as the current monetary policy target, money is largely absent, e.g. in the forecasting models used by the central banks of the three previously mentioned countries. In the Czech Republic, monetary aggregates do not enter the central bank's forecast directly. They are used as an "auxiliary indicator for verifying the forecast if they contain information on the present or future development of the economy" (Czech National Bank, 2006). The central bank's official publications also suggest that the indicators of the monetary overhang or the money gap do not have significant information content for forecasting inflation over the monetary policy horizon.[6] These indicators of excess liquidity are nevertheless followed on a regular basis for their information content regarding medium-term inflation developments.

Like in the Czech Republic, money supply does not enter the structural model of the Polish central bank to forecast GDP and inflation. Similarly, for Hungary, money supply is not part of the central bank's forecasting tools, nor does its inflation report discuss the development of monetary aggregates.

The central bank of Slovakia adopted inflation targeting in the beginning of 2005 and – in view of its prospective euro area entry – joined ERM II later that year. Explicit inflation targeting was preceded by a managed float of the exchange rate, coupled with implicit inflation targeting between 2000 and 2005.[7] A target of 3.5% with a fluctuation band of 0.5 percentage points on both sides was set for December 2005. The inflation target was set below 2.5% for December 2006 and below 2% for December 2007 and 2008. Slovakia became the 16th country to join the euro area on January 1, 2009; the responsibility for monetary policy was thereby transferred to the ECB, which assigns a prominent role to money under the "second pillar" of its monetary policy strategy.

Previous research about the inflation dynamics in the four economies under study include studies by Lendvai (2005), Allard (2007), Menyhért (2008) and Kokoszczyński et al. (2007). Lendvai (2005) estimates traditional backward-looking and hybrid Phillips curves for the Hungarian economy. She finds support for the hybrid specification and its open economy variant that includes imported goods as intermediate production goods. Menyhért (2008) proposes a simultaneous equations method with a maximum likelihood estimator and finds evidence in favor of a hybrid New Keynesian Phillips curve for Hungary. Kokoszczyński et al. (2007) focus on survey-based measures of inflation expectations and estimate New Keynesian Phillips curves using survey data for the Czech Republic and Poland. Allard (2007) estimates an augmented Phillips curve in a panel framework for eight CEE EU Member States in order to assess how trade openness affects the relationship between output and inflation. The study by Melecky and Najdov (2008) emphasizes the link between structural policies and the feasibility

[6] *The monetary overhang is defined as the deviation of actual money supply from the level corresponding to the current economic cycle or other fundamentals. The money gap is defined as the deviation of money stock from the level reflecting potential economic growth and the inflation target.*

[7] *Nell (2004) discusses Slovakia's implicit inflation targeting framework, including the use of internal short-term inflation forecasts.*

of macroeconomic stabilization and estimates a hybrid New Keynesian Phillips curve as part of a structural model for Slovakia and FYR Macedonia.

To our knowledge, no evidence of the importance of money for price dynamics, especially in a Phillips curve framework, exists for the four countries under study. However, such evidence has been provided for other economies. Gerlach (2004) proposes a two-pillar Phillips curve for the euro area that incorporates trend money growth – abstracting from short-term fluctuations – and where money growth influences inflation expectations. Neumann and Greiber (2004) similarly provide evidence in a Phillips curve framework that low-frequency growth in money is linked to inflation in the euro area, while Gerlach-Kristen (2007) finds supporting evidence for Switzerland.

3 Simulating the McCallum Rule for the Czech Republic, Hungary, Poland and Slovakia

Following McCallum (2000), the policy rule is defined as:

$$\Delta b_t = \Delta x^* - \Delta v_t^a + 0.5(\Delta x^* - \Delta x_{t-1}) \quad (1)$$

Here, Δb_t denotes monetary base growth, Δx^* is the target growth rate of nominal GDP, Δv^a_t denotes the average change in base money velocity over the previous 16 quarters, and Δx_{t-1} is the nominal GDP growth of the previous period. According to the rule, the central bank must increase monetary base growth when nominal GDP growth falls below its target. The coefficient before the last term $(\Delta x^* - \Delta x_{t-1})$ determines the extent of counter cyclicality of the policy response – it should be high enough so that monetary policy is responsive to misses in the nominal GDP target. However, it should not be so high that the policy rule leads to a destabilizing movement in nominal GDP in the other direction; the value 0.5 is suggested by McCallum (2000).[8] The average velocity change over four years captures long-term changes in the demand for base money that are due to financial innovations or regulatory changes. Four years is the value suggested by McCallum and is arguably sufficient to avoid cyclical factors influencing base money demand. This measure should also capture changes in the financial system such as remonetization, which may be relevant for transition economies.[9] The rule has been much less prominent in the literature than Taylor-type interest rate feedback rules due to the obvious fact that central banks in advanced economies use interest rates mainly as operating target, with money adjusting endogenously. In addition to the environment of the zero lower bound and the possible close connection of money with asset prices discussed in the introduction, an additional benefit from a rule such as (1) is that it is fully operational, as mentioned by McCallum (2000). The time-variant terms on the right-hand side of (1) are all known to the policymaker at period t.

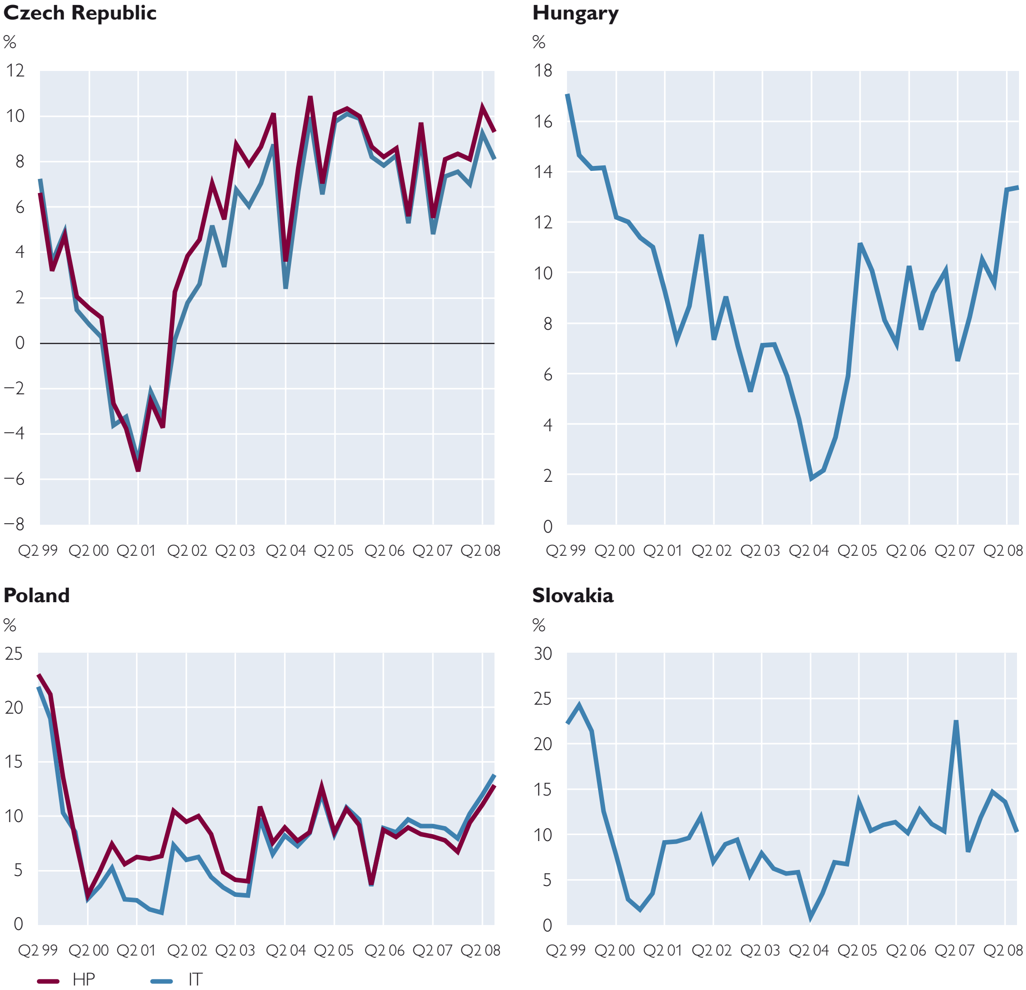
An important issue is the determination of the nominal GDP target growth in (1). For Japan, McCallum (2003) assumes a constant value of 5 over 1972–1998,

[8] *McCallum has also used other values for this coefficient, notably 0.25 (e.g. McCallum, 1988). The results from our estimations in section 4 are identical for both coefficient values.*

[9] *Admittedly, some phenomena that may affect money supply are outside the scope of this modelling approach, such as changes in international investor risk aversion and the corresponding capital flows to or from emerging Europe.*

Chart 1

Monetary Base Growth as Suggested by the McCallum Rule



Source: Authors' calculations based on data obtained from national central banks and the European Commission's AMECO database.

Note: For the Czech Republic and Poland we show not only the proposed growth in money supply based on the HP filter but also the alternative measure that relies on an actual announcement of an inflation target (IT) by a central bank. The latter is then added to an estimate of the potential real GDP growth rate of the economy for each year.

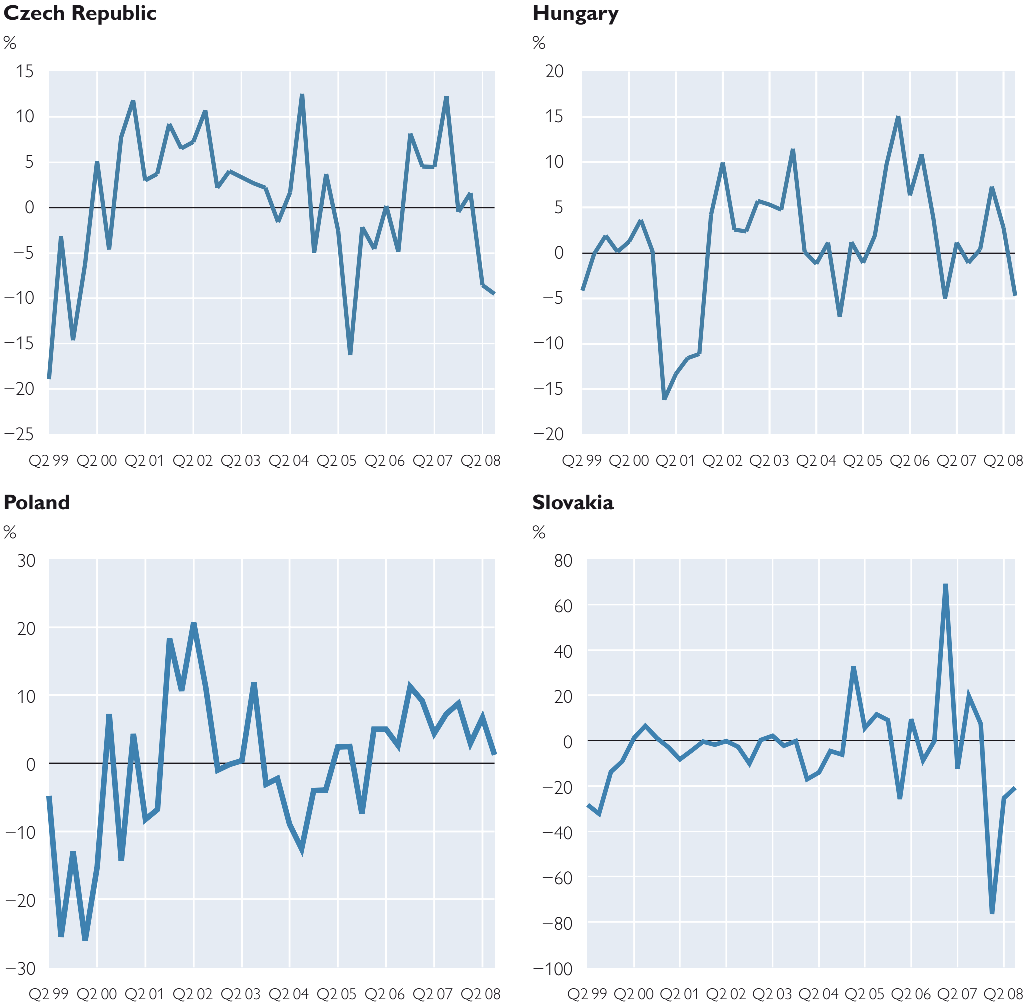
given a long-term potential real GDP growth rate of 3%, combined with an inflation target of 2%.[10] We follow two different approaches. Under the first approach, we apply a filtering technique, extracting the trend from actual nominal GDP series in levels with a Hodrick-Prescott (HP) filter and calculate the growth rate from the resulting smooth trend series.[11] The alternative approach relies on an

[10] *In McCallum and Hargraves (1994), the authors specify real GDP targets as the long-run averages of realized values for G-7 countries. Moreover, 2% is taken as a common inflation target. As these data span several decades for advanced economies, we do not consider this a relevant approach for our study, as the relevant economies underwent structural change and a disinflation process.*

[11] *In order to mitigate the end-of-sample problem with the HP filter, we calculate 1-quarter-ahead forecasts for the first differences in nominal GDP with an AR(1) model for Q4 2008–Q4 2009, at each step re-estimating the model. The HP filter is then applied to the resulting extended nominal GDP series in levels, with the conventional smoothing parameter of 1,600.*

Chart 2

Deviation of Actual Base Money Growth from the McCallum Rule



Source: Authors' calculations based on data obtained from national central banksand the European Commission's AMECO database.

Note: The McCallum rule is calculated by means of the nominal GDP target obtained by a Hodrick-Prescott filter.

actual announcement of an inflation target by a central bank, which is then added to an estimate of the potential real GDP growth rate of the economy for each year, obtained from the European Commission's AMECO database. For Hungary and Slovakia, the latter method is not possible as inflation targets have been specified only from 2001 and 2005 onwards, respectively. Due to the need to include four years of data in the specification of the velocity variable, the McCallum rules are simulated for the period Q2 1999 to Q3 2008 for all four economies (raw data for quarterly GDP are typically available from 1995 onwards).[12]

[12] *Data for GDP are from the CEIC database (Hungary, Poland, nominal GDP for the Czech Republic). Real GDP series for Poland 1995–1996 and the Czech Republic are from the Eurostat Newcronos database. For Slovakia, both real and nominal GDP are from Eurostat. Base money data come from the CEIC database, combined with data from the websites of the Hungarian and Polish central banks and the BIS for Slovakia. Consumer price data are from the Vienna Institute for International Economic Studies (wiiw) database. The data for nominal effective exchange rates are from the BIS (Eurostat database for Slovakia).*

Chart 1 displays the proposed growth in money supply by the McCallum rule employing the two different approaches to calculate the nominal GDP target. Here, as in other parts of the paper, we use year-on-year growth rates since the quarter-on-quarter changes in the monetary base are very volatile in the countries under study.[13] For the Czech Republic and Poland, where both measures of the nominal GDP target are available, these provide strikingly similar McCallum rule-based prescriptions for monetary base growth.[14]

The measure of deviation of actual money growth from the policy rule, for which we used the nominal GDP target obtained by a HP filter, is displayed in chart 2. Due to the volatility in actual base money growth, the measure of deviation is quite volatile for all economies.[15] However, over time, the average deviation is effectively zero in three countries in our sample. It amounts to only 1.02 percentage points in Hungary and is even smaller in the Czech Republic and Poland (0.67 and –0.09 percentage points, respectively). In Slovakia, the deviation is somewhat higher at –4.02 percentage points.

4 Estimation of Phillips Curves with a Monetary Indicator

4.1 Econometric Model and Estimation Technique

After having computed our monetary indicator, we now evaluate its information properties as regards inflation developments. We base our model specification on the standard Phillips curve similar to the one used by Gerlach-Kristen (2007) in her analysis of a two-pillar Phillips curve for Switzerland. While some studies mentioned in section 2 have analyzed inflation dynamics by means of hybrid Phillips curves for the economies under study, the inclusion of money does bring a forward-looking element to the model. Money growth may affect both current and future inflation by increasing inflation expectations. We augment the Phillips curve by including the deviation of actual money growth from the value specified by the McCallum rule. This results in the estimation of the following equation:

$$\pi_t = \alpha + \sum_{i=1}^{p} \beta_{1,i}\pi_{t-i} + \sum_{j=1}^{\gamma} \beta_{2,j} y_{t-j} + \sum_{k=1}^{\varepsilon} \beta_{3,k} \Delta e_{t-k} + \sum_{l=1}^{\mu} \beta_{4,l} m_{t-l} + d_H + u_t \qquad (2)$$

Apart from the monetary indicator m_t, inflation π_t in (2) depends on its past values, past values of the output gap y_t and cost-push shocks, Δe_t, represented by changes in the nominal effective exchange rate. In the case of Hungary, we include a dummy variable d_H that takes the value of 1 in all four quarters of 2001 and 0 otherwise. It captures the level shift in base money resulting from a decrease in the compulsory reserve deposit ratio by 4 percentage points on February 1, 2001.

[13] *The volatility associated with quarter-on-quarter changes in prices also led to the choice of year-on-year changes in consumer prices as the measure of inflation in the estimation of Phillips curves. The Bayesian model averaging method produces more significant coefficients in this case. The calculation of the four-year average change in base money velocity is based on quarter-on-quarter changes in velocity in order to preserve sufficient observations in our short samples.*

[14] *As the two measures provide very similar nominal GDP targets and estimation results for the Czech Republic and Poland, we did not consider additional methods of constructing the nominal GDP target, for example different filtering methods.*

[15] *For Hungary, the monetary base growth rate is affected by a change in the compulsory reserve deposit ratio, as explained in section 4 of the paper.*

Due to the limited length of the sample (Q2 1999 to Q3 2008), the lag structure of (2) is restricted a priori to include lags 1 and 3 of inflation, output gap and the nominal effective exchange rate (hence, $p = \gamma = \varepsilon \in \{1,3\}$) as these variables are expected to impact inflation particularly in the short run (see Slačík, 2008). In contrast, for the monetary indicator the 4th, 6th and 10th lags are included ($\mu \in \{4,6,10\}$) on the grounds that excessive monetary growth has been shown in the literature to matter for inflation rather in the medium to long run, as in the second pillar of the ECB's monetary policy strategy (ECB, 2003).[16]

Since our model is technically an autoregressive distributed lag model (ARDL) of the general form

$$\pi_t = \mu + \sum_{i=1}^{p} \gamma_i \pi_{t-i} + \sum_{j=1}^{r} \beta_j x_{t-j} + u_t \qquad (3)$$

the long-term effect of the variable x can be computed simply by

$$\frac{\sum_{j=1}^{r} \beta_j}{1 - \sum_{i=1}^{p} \gamma_i}, \qquad (4)$$

see Greene (2003). The estimations are carried out by using ordinary least squares (OLS).[17] However, due to possible autocorrelation in the error terms we employ the Newey-West heteroscedasticity and autocorrelation consistent (HAC) covariance estimator. In order to determine the relevant inflation determinants, including their lags, three alternative techniques are employed. The first one is a general-to-specific strategy based on hypothesis testing. The starting point is the most general model including all variables and lags from the prespecified set. We then proceed iteratively, at each step eliminating the least significant regressor, i.e. variable-lag combination, based on the *p*-value. We continue with this procedure until we are left with a parsimonious model containing only those regressors that are significant at the 10% level. The second strategy involves an iterative selection from all possible models (a total of 2k models, where k stands for the number of initial regressors).[18] Here, the model corresponding to the lowest value for the Schwarz information criterion (SIC) is chosen.

Although the two previous techniques are rather standard, they entail some pitfalls. Under the general-to-specific strategy, the model space is strongly limited, as model reduction starts from the biggest model, whose size is then iteratively reduced. It does not take into account possible model alternatives with variables that have already been excluded. Implicitly, this procedure thus imposes a rather

[16] *Admittedly, there is some arbitrariness in the choice of lags, but due to the limited sample size not all lags can be included in the general model and the lags chosen should capture the short-, medium- and long-term impact.*

[17] *If money and prices were cointegrated, an error correction model would be a possible alternative to the approach employed in the paper. However, our measure of excess liquidity is clearly stationary according to a standard ADF test for all four economies (see also chart 2), which rules out cointegration in its usual sense for the two variables. If ordinary money growth is used instead, an ADF test rejects a unit root for this series as well, at least at the 10% level for all countries. The results for inflation are not clear-cut; for some economies a unit root cannot be rejected, depending on the exact specification of the test.*

[18] *As the prespecified set includes 9 regressors (3 variables with 2 lags each and 1 variable with 3 lags), there are in total 2^9=512 possible models.*

strong restriction, as it presumes to know a limited model space in which the true model has to be included. Given the lack of an unambiguous theoretical framework that would uniquely determine the variables and lags to be chosen, neither the true model nor the restricted subset of all possible models from which the true model must be selected are known. The strategy based on the SIC in principle takes into account this model uncertainty. Nevertheless, it often fails to converge to an unambiguous model owing to sensitivity with respect to the definition of variables and the initial specification (see e.g. Slačík, 2008, and the references therein). Yang (2007), who compares hypothesis testing and model selection strategies both theoretically and empirically, argues in favor of model combining for estimation and prediction. He suggests that the large variability of the estimator from model selection can be significantly reduced with a proper weighting.

One way to combine models with a proper weighting is the Bayesian model averaging (BMA) technique, which we employ as our third approach. The BMA algorithm proposes averaging the parameter values over all (relevant) alternative models using posterior model probabilities as respective weights.[19] Hence, the BMA algorithm aggregates disperse information from the entire model space and is thus the most comprehensive of our three methods. As such major attention should be paid to it while the other, often inconsistent, selection criteria should be taken with a grain of salt. The key measure capturing the relative importance of the different inflation determinants under BMA is the so-called inclusion probability. For each covariate, it is computed as the sum of the posterior probabilities of those visited models that include the respective variable. It can be interpreted as the probability that a given variable belongs to the true specification. Since we assign equal priors to all models, our prior on the inclusion probability of each variable is 0.5.[20]

4.2 Estimation Results

Tables 1 to 4 in the appendix display the results for each of the four countries under study. The monetary measure is the deviation of monetary base growth from the McCallum rule (based on year-on-year growth rates), with the nominal GDP target computed by applying the Hodrick-Prescott filter. This measure is available for all four economies. The three columns in the tables show the estimated parameter values and standard errors for the models based on the BMA, the *p*-value, and the SIC procedure, respectively. In the BMA column, we report the posterior inclusion probability for each variable and the posterior expected value of the corresponding parameter. Also, the tables show the ratio of the posterior expected value of the parameter to the root of the posterior variance of the parameter. This can be interpreted as a measure of estimate precision, analogous to the *t*-ratio in classical econometrics. It should be borne in mind that the two sub-columns under BMA – the inclusion probability and the Bayesian counterpart to the *t*-ratio – convey very different sorts of information. While the inclusion probabil-

[19] *For a detailed description of the BMA procedure, see e.g. Crespo Cuaresma and Slačík (2007). The Markov Chain Monte Carlo Model Composite (MC³) algorithm with 10,000 replications was used to reduce the model space (see Crespo Cuaresma and Slačík, 2008).*

[20] *It is also possible to combine the Bayesian and classical (frequentist) approaches and use the BMA as a model selection criterion. One would thus simply rerun the estimation with only those regressors whose model averaged parameters have an inclusion probability equal to or greater than the prior benchmark of 0.5.*

ity indicates whether a particular variable belongs to the true specification or not, the *t*-ratio provides information on the precision with which the effect of the regressor in question may be estimated. Hence, the inclusion probability does not necessarily have to be positively correlated with what would correspond to the concept of significance in classical econometrics.

Moving on to the interpretation of the results, for the Czech Republic all three approaches suggest that inflation is persistent in the short run (i.e. the first lag of the dependent variable). According to the *p*-value and SIC approach, inflation also rises with the output gap of the previous quarter but the BMA procedure does not suggest a sufficiently robust impact of this variable.[21] In contrast, higher lags of inflation and, surprisingly enough, also strong monetary growth (if going by the BMA results) decrease the pressure on prices at higher lags. However, the effect of the 10th lag of our McCallum indicator is not precisely estimated. Indeed, the negative impact is likely to result from the short sample, which leads to instability in the models. We emphasize that the robustness of the monetary variable in the Bayesian procedure (regardless of the sign) suggests that it significantly enters the inflation equation and therefore should be taken into account in the evaluation of price pressures. In addition to these findings, the *p*-value-based model selection also suggests some negative effect of the third lag of the nominal effective exchange rate, as appreciation puts downward pressure on inflation. This exchange rate pass-through, however, seems to be a matter of coincidence as the posterior inclusion probability for both lags of the nominal exchange rate is well below the 0.5 threshold (as determined by our prior on the inclusion probability of each variable).

In the case of Poland, inflation is also persistent in the short run and it rises with the past quarter's positive output gap, which, unlike in the Czech Republic, shows up robustly under BMA. A positive off-equilibrium growth of the monetary base increases inflationary pressure with a 2.5-year lag, although the estimate is somewhat imprecise. The *p*-value- and SIC-based approaches suggest that inflation accelerates also with shorter lags of excessive monetary growth. For example, the long-term effect of money on inflation in the *p*-value-based approach amounts to 0.24, so that a 1 percentage point monetary base growth in excess of the McCallum rule increases inflation by 0.24 percentage points. All three approaches indicate that there is no significant pass-through from nominal effective exchange rate movements into consumer prices.

The situation looks slightly different in the case of Slovakia. Except for the first and the third inflation lag no other variable surpassed the 10% significance level under the *p*-value procedure. As in the Czech case, the two lags of inflation have a positive and a negative sign, respectively. However, according to the SIC and, more importantly, the BMA approach, the monetary indicator shows up with a positive sign at the 10th lag. Although the precision of the estimate is rather low, it still suggests that money growth in excess of the McCallum rule increases inflation in the long run. Under the BMA the short-term exchange rate pass-through just misses the 0.5 threshold. None of the applied methodologies identifies the output gap as a robust inflation determinant for Slovakia.

[21] *The insignificance of the output gap for the Czech Republic is in line with Slačík (2008).*

Turning our attention to Hungary, it is striking that none of the three methodologies includes the dummy variable corresponding to the level shift in the base money series in the "true" model. While inflation is persistent in the short run, the output gap has no impact on inflation, as in the case of Slovakia and, judging by BMA, the Czech Republic.[22] Moreover, yet again none of the selection procedures detects any effect of the nominal effective exchange rate on inflation. The measure of excessive money growth does show up under the SIC and, most importantly, the BMA procedure. However, only the 10th lag of the indicator turns out robust and very precise with a negative sign, which may be interpreted similarly to the Czech case above.

4.3 Robustness Checks[23]

Given that monetary base growth as such may also be indicative of future inflation pressures, it is of interest to estimate the models by substituting the McCallum-motivated measure of excess liquidity by year-on-year monetary base growth. This also allows for a longer estimation sample, as the computation of the four-year average change in velocity is not necessary. We find that the estimation results are largely similar for all other variables except, interestingly, the monetary variable. Indeed, the Bayesian method does not identify ordinary growth in the monetary base as a robust regressor for any of the four economies. It should be noted that the speed of base money growth as such does not provide indication about whether monetary policy is contractionary or expansionary. In contrast, information about the policy stance is obtainable by comparing the actual growth in base money to the growth proposed by the McCallum rule. This provides further support for the selection of our rule-based measure as the benchmark monetary indicator.

As noted in section 2, some studies assess the inflationary impact of trend money growth, motivated by the assumption that what matters are long-term trends of money rather than short-term fluctuations. We have calculated a measure for trend money growth for the four economies using two different methodologies. In the first, a Hodrick-Prescott filter is applied to the monetary base (in logarithms), and the resulting trend is differenced once. As the second measure, we first take the differences of the monetary base variable and then apply the Hodrick-Prescott filter to the growth rates. Both measures provide similar results. For the Czech Republic and Poland, trend money growth is not identified as a robust determinant of inflation pressures, whereas other regressors remain robust. For Slovakia, trend money growth appears as a significant variable in the regression. Finally, for Hungary, the results from the Bayesian estimation are very unstable, possibly due to the inclusion of the dummy variable that further reduces the low number of degrees of freedom in the sample. In sum, trend money growth provides less information for inflation pressures than the McCallum rule-based indicator, which is the focus of the study.

[22] *The limited significance of the output gap is echoed in Égert (2007), where the author states that the business cycle is a less robust determinant of inflation in transition economies than in the euro area. Moreover, in small open economies external factors typically play a strong role in inflation developments, with a weaker influence of domestic output gaps.*

[23] *The detailed estimation output for all robustness checks is available from the authors upon request.*

Finally, we have assessed the possibility that excess liquidity calculated in terms of broader money aggregates would be conducive to inflation pressures. Unfortunately, time series long enough for the computation of excess liquidity with the McCallum measure exist only for the Czech Republic. Moreover, it should be noted that while the monetary base is fully controllable by the monetary authorities, making the McCallum rule operational, this cannot be said of broader monetary aggregates. We find that for both M1 and M2, the results practically do not differ from those obtained in the benchmark estimation (i.e. with base money), although the estimation precision is much higher under the M1-based indicator.

In sum, monetary base growth in excess of the McCallum rule provides robust information about future inflation over a ten-quarter horizon for all four analyzed countries. These results thus suggest that a McCallum rule could potentially be used as an additional indicator of the monetary policy stance in the future.

5 Conclusion

In this paper, we have examined the monetary determinants of inflation in four Central and Eastern European EU Member States. The novelty of the study is that we have used a monetary indicator based on a simulated McCallum money supply rule for the four economies. Then, in a backward-looking Phillips curve framework, we included the deviation of actual base money growth from the policy rule to investigate its impact on inflation in the medium to long run. The variables and their lags were selected by means of three various algorithms, of which our primary focus is on the Bayesian model averaging technique, due to its comprehensiveness and favorable robustness properties. We found that actual money growth in relation to the rule provides information about inflation developments over a horizon of ten quarters for all four investigated countries.

Our focus is on four economies that are pursuing or have until recently pursued inflation targeting, which makes the comparison of actual policy with that proposed by the McCallum rule interesting. Nevertheless, and pertaining to the estimation of the Phillips curves, there is no a priori reason to assume that the significance of a monetary variable in the estimation would depend on the actual policy regime of the central bank. As Galí (2003) points out, the relationship between money and prices simply follows from a long-term money demand relationship, when trend growth in output is determined by nonmonetary factors. This holds irrespectively of the monetary policy regime in place. Moreover, if we take the McCallum rule seriously, then any deviation of money from the rule would simply signal an expansionary or contractionary policy stance, with expected impacts on inflation with some time lag.

Finally, our results point to an important indicator role of money as one of the variables that deserve to be analyzed by the central bank in maintaining price stability, particularly in the future once the precision of the estimation improves with more data available. This is especially the case as an inflation targeting regime – as currently in place in the Czech Republic, Hungary and Poland – is flexible and can quickly react to various shocks and signals of inflationary pressures in the economy.

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Appendix

Table 1

Czech Republic

	BMA-based		P-value-based	SIC-based
	PIP	$E(\beta\|Y)$ $\left(\frac{E(\beta\|Y)}{\sqrt{\text{var}(\beta\|Y)}}\right)$		
π_{t-1}	1.000	0.995	0.890***	0.997***
		−11.987	−12.445	−16.599
π_{t-3}	0.987	−0.500	−0.355***	−0.404***
		(−4.618)	(−4.800)	(−4.868)
y_{t-1}	0.238	40.478	59.141***	54.377**
		−1.829	−2.751	−2.550
y_{t-3}	0.048	29.314		
		−1.236		
Δe_{t-1}	0.007	−0.043		
		(−0.760)		
Δe_{t-3}	0.008	−0.018	−0.057*	
		(−0.528)	(−1.943)	
m_{t-4}	0.062	0.045	0.041*	0.029
		−1.535	−1.885	−1.614
m_{t-6}	0.181	−0.052		
		(−1.794)		
m_{t-10}	0.999	−0.042		
		(−0.995)		
α			1.431***	1.042***
			−3.981	−3.848
Adj. R-squared			0.873	0.864
Obs.	Varies with model length		34	34

Note: Estimation results are based on the Bayesian model averaging algorithm (second column), our primary approach, and, for the sake of completeness, on the p-value (third column) and on the Schwarz information criterion (fourth column). Numbers in parentheses display the t-statistic for the respective parameters or, in the case of BMA, the analogy to a t-statistic. PIP stands for the posterior inclusion probability, our major quality indicator as explained in the text.

****/**/* mark the 1%, 5% and 10% significance level respectively.*

Table 2

Slovakia

	BMA-based		P-value-based	SIC-based
	PIP	$E(\beta\|Y)$ $\left(\frac{E(\beta\|Y)}{\sqrt{\text{var}(\beta\|Y)}}\right)$		
π_{t-1}	1.000	1.000	1.000***	1.037***
		−9.509	−10.073	−13.925
π_{t-3}	0.703	−0.315	−0.221***	−0.305***
		(−10.041)	(−3.140)	(−6.434)
y_{t-1}	0.007	3.617		
		(0.390)		
y_{t-3}	0.011	−12.710		
		(−0.658)		
Δe_{t-1}	0.429	−0.025		
		(−0.493)		
Δe_{t-3}	0.005	−0.004		
		(−0.085)		
m_{t-4}	0.008	0.005		
		(0.535)		
m_{t-6}	0.006	0.001		
		(0.141)		
m_{t-10}	1.000	0.026		0.018
		−1.298		−1.276
α			1.365***	1.285**
			−2.647	−2.405
Adj. R-squared			0.749	0.791
Obs.	Varies with model length		41	41

Note: As in table 1.

Table 3

Poland

	BMA-based		P-value-based	SIC-based
	PIP	$E(\beta\|Y)$ $\left(\frac{E(\beta\|Y)}{\sqrt{var(\beta\|Y)}}\right)$		
π_{t-1}	1.000	0.636	0.725***	0.725***
		−7.818	−9.878	−9.314
π_{t-3}	0.006	−0.007		
		(−0.088)		
y_{t-1}	0.995	51.825	44.472***	45.517***
		−4.908	−4.399	−4.199
y_{t-3}	0.004	−0.874		
		(−0.061)		
Δe_{t-1}	0.045	−0.024		
		(−1.257)		
Δe_{t-3}	0.025	−0.016		
		(−1.081)		
m_{t-4}	0.118	0.027	0.026**	0.032**
		−1.635	−2.085	−2.553
m_{t-6}	0.048	0.017	0.018**	
		−1.417	−2.473	
m_{t-10}	1.000	0.018	0.022**	0.019*
		−1.432	−1.979	−1.681
α			0.801***	0.807***
			−3.697	−3.096
Adj. R-squared			0.833	0.820
Obs.	Varies with model length		27	27

Note: As in table 1.

Table 4

Hungary

	BMA-based		P-value-based	SIC-based
	PIP	$E(\beta\|Y)$ $\left(\frac{E(\beta\|Y)}{\sqrt{var(\beta\|Y)}}\right)$		
π_{t-1}	0.996	0.560	0.554***	0.729***
		−3.401	−3.392	−9.006
π_{t-3}	0.009	−0.037		
		(−0.312)		
y_{t-1}	0.076	50.340		
		−1.204		
y_{t-3}	0.006	3.269		
		(0.132)		
Δe_{t-1}	0.026	−0.040		
		(−0.718)		
Δe_{t-3}	0.015	−0.032		
		(−0.646)		
m_{t-4}	0.008	0.012		
		(0.475)		
m_{t-6}	0.005	0.002		
		(0.097)		
m_{t-10}	1.000	−0.073	−0.072***	−0.095**
		(−2.703)	(−2.722)	(−2.540)
2001-dummy	0.007	−0.104		
		(−0.291)		
α			2.442**	1.764**
			−2.495	−2.467
Adj. R-squared			0.456	0.851
Obs.	Varies with model length		27	27

Note: As in table 1.