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Are Eastern European Taylor Reaction Functions Asymmetric in Inflation or Output: Empirical Evidence for four Countries

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Are Eastern European Taylor Reaction Functions Asymmetric in Inflation or Output: Empirical Evidence for four Countries

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Abstract

Do central banks in Eastern European countries react asymmetrically and in a non-linear fashion to changes in inflation and output? We tackle this question by expanding the standard Taylor reaction function for the four inflation targeting countries Czech Republic, Hungary, Poland and Romania. We do so taking explicitly inflation rates below or above target and output below or above potential, the so-called state of the economy, into account. The results reveal that there are indeed substantial asymmetries in the reaction function of the Czech, Polish and Romanian central bank, which are only evident when the combination of inflation and output thresholds is explicitly modelled in one estimation equation. For these three central banks also non-linearities in the inflation and output response could be verified.

Keywords: Taylor reaction function, Asymmetries, Eastern European countries

JEL-codes: E52, E58

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1 Introduction

Central banks all over the world tend to set their policy instruments ex- or implicitly according to certain rules. The surely most famous of these rules is the Taylor rule, linking the central bank policy rate to the inflation rate and the output-gap (Taylor, 1993). While Taylor (1993) simply set the reaction coefficients of inflation and the output-gap equal to 0.5, several studies have estimated so-called Taylor reaction functions for various central banks in order to find the reaction coefficients towards these two variables.[1] Also for Eastern European countries these types of reaction functions have been estimated (see e.g. Maria-Dolores, 2005; Frömmel and Schobert, 2006 or Angeloni et al., 2007).

According to the Taylor rule the central bank interest rate is set in response to the evolution in two different variables: Inflation and output. Thus the reaction may be asymmetric with respect to both variables, i.e. the reaction may be different when inflation rates are higher than the target of the central bank or below this value. The same holds with respect to output and its potential. Estimating these kinds of asymmetric Taylor reaction functions was performed for various central banks mainly for industrialized countries (Dolado et al., 2000 and 2005; Bec et al., 2002; Altavilla and Landolfo, 2005; Surico 2003, 2007 and 2007a; Ruge-Murcia, 2005; Cukierman and Muscatelli, 2008 or Bunzel and Enders, 2010). Klose (2011) even more took also the combination of inflation above or below target and output above or below potential into account and estimated thus an asymmetric Taylor reaction functions in four different states of the economy for the Euro-area. We follow this approach and estimate these kind of asymmetric Taylor reaction func-

[1] See e.g. Kahn (2012) for the US, Sauer and Sturm (2007) or Belke and Klose (2011) for the Euro-Area, Miyazawa (2011) for Japan or Taylor and Davradakis (2006) for the United Kingdom.

tions for four inflation targeting Eastern European countries, the Czech Republic, Hungary, Poland and Romania. To the best of our knowledge we are thus the first to estimate asymmetric Taylor reaction functions of this type for these set of countries.

The article proceeds as follows: In section 2 a literature overview is given. Section 3 develops the empirical specification of the asymmetric and nn-linear Taylor reaction functions out of the standard Taylor reaction function, while section 4 discusses which data are used. In section 5 the results of our estimations are presented. Section 6 finally concludes.

2 Literature Review

Several studies have estimated Taylor reaction functions for different Eastern European countries so far. Most of the studies find that the so-called Taylor-principle of an response coefficient to inflation exceeding unity does not hold. The studies can broadly be categorized into three groups: First, estimations of standard Taylor reaction functions, second, estimations of augmented Taylor reaction functions by adding the exchange rate as an additional explanatory variable and third, asymmetric and non-linear Taylor reaction functions.

Among the first group are Maria-Dolores (2005) and Angeloni et al. (2007). Maria-Dolores (2005) estimates various forms of standard Taylor reaction functions for the Czech Republic, Poland, Hungary and Slovakia finding that the estimated coefficients are rather high for the prior three which will also be part of our study. However, the Taylor principle is not always fulfilled. Angeloni et al. (2007) estimate standard Taylor reaction functions for the Czech Republic, Hungary and

Poland, finding that the Taylor principle is violated for all countries.

The second strand of literature on Taylor reaction functions adds some kind of exchange rate to the standard approach. This is done because Eastern European countries are considered to be open-economies and some even are exchange rate targeters since they e.g. want to become member of the European Economic and Monetary Union. While it is generally found that the exchange rate plays a significant role in the interest rate setting of some Eastern European countries, we do not follow this approach inthis paper. This is motivated by the fact that we carry out our analysis for the four Eastern European countries Czech Republic, Hungary, Poland and Romania after those have introduced an explicit inflation target and thus do no longer tackle the exchange rate actively.

The first paper adding the exchange rate to Taylor reaction functions for Eastern European countries is Frömmel and Schobert (2006). They estimate these type of augmented Taylor reaction functions for six countries (Czech Republic, Hungary, Poland, Romania, Slovenia and Slovakia). Generally, the response coefficients are found to be quite low or even negative. The Taylor-principle is thus violated in almost all specifications.

Vasicek (2009) adds the exchange but also other variables like asset prices, money growth or long-term interest rates to the standard Taylor reaction function. Doing so he estimates for twelve at that time new member countries of the European Union, among them mostly Eastern European countries, low or even negative response coefficients towards inflation and output.

The same holds for Orlowski (2010) who estimates augmented Taylor reaction functions for the Czech Republic, Poland and Hungary. While the prior two do mainly react to changes in the inflation rate, Hungary is found to be more exchange rate focused.

Employing an cointegration approach Frömmel et al. (2011) estimate exchange rate augmented Taylor reaction functions for six Eastern European countries among them also the Czech Republic, Hungary, Poland and Romania which we will also investigate in this article. While the inflation response for these four countries is generally found to be significantly positive, only in the case of the Czech Republic it exceeds unity thus fulfilling the Taylor-principle.

For the same six Eastern European countries Popescu (2014) estimates Taylor reaction functions including the real effective exchange rate. He finds that the Taylor-principle is fulfilled the Czech Republic, Poland and Hungary, while for Romania it is slightly below unity. These comparably high estimates may be due to the comparably longer sample period in this study.

The last study of the exchange rate augmented Taylor reaction functions is delivered by Klose (2014). Using data for seven Eastern European countries including the four investigated in our study, he finds that the Taylor-principle is fulfilled for Poland and Romania. However, it is also shown that the response coefficients change in the wake of the financial crisis 2008/09.

Closest to the analysis conducted in this article are the third group covering asymmetric and non-linear Taylor reaction functions. The first one to estimate non-linear reaction functions is Paez-Farrell (2007). Besides other specifications[2] he accounts for non-linearities in the response coefficients by adding a quadratic term in inflation and output. He does so for the Czech Republic, Poland, Hungary and Slovakia and finds indeed evidence of non-linearities in both inflation and output. We will follow a similar approach in this article. However, we do also take

[2]E.g. also augmented Taylor reaction functions including the exchange rate are estimated.

asymmetries into account.

Following a very similar approach Vasicek (2012) estimates non-linear Taylor reaction functions for the Czech Republic, Hungary and Poland, he finds at least some non-linearity in Hungarian inflation reactions. Moreover, he estimates asymmetric Taylor reaction functions accounting for regime switches in the inflation rate, output and financial stress index. Since the thresholds are estimated rather than set according to announcements as commonly done by other studies, the results with respect to asymmetric inflation response remain inconclusive. The same holds for Hungary when it comes to output asymmetries. For the Czech Republic and Poland it is, however, found that they react asymmetrically, i.e. the response to the upward deviations from the threshold is larger.

Using a rather similar approach as Vasicek (2012) for the National Bank of Poland Sznajderska (2014) comes up with rather different results. Indeed the inflation response is now found to be asymmetric, i.e. that the Polish central bank reacts stronger to positive deviations from the threshold than to negative. The same holds with respect to the output reaction which is thus also found to be asymmetric. Moreover, Sznajderska (2014) estimates the thresholds for inflation and output to be close to zero, which is a justification for us to use politically set thresholds rather than economically estimated ones, since the prior assume that the thresholds for the inflation-gap (inflation minus the inflation target set by the central bank) or the output-gap are zero.

Finally, Su et al. (2016) estimate non-linear Taylor reaction functions for ten Eastern European countries among them the four countries also investigated in this study. Using a sequential panel selection method they find indeed non-linearities in seven of the ten investigated countries at least when it comes to the real effective exchange rate.

This article contributes to the existing literature by taken not only asymmetries in either the inflation rate or the output into account but also the combination of both. So we identify different states of the economy. We do so for the four Eastern European countries who are explicit inflation targeters the Czech Republic, Hungary, Poland and Romania since they introduced these targets.

3 Empirical specification

The starting point of our analysis is the standard Taylor reaction function introduced by Taylor (1993):

$$i_t^T = \overline{r}_t + \pi_t + a_\pi(\pi_t - \pi_t^*) + \alpha_Y(Y_t - Y_t^*) \tag{1}$$

Here i_t^T signals the Taylor interest rate, $\overline{r}_t$ is the equilibrium real interest rate, π_t and π_t^* are the inflation rate and the inflation target, Y_t and Y_t^* are the output and potential output, thus subtracting the latter from the former delivers the output-gap. a_π and α_Y are the reaction coefficients towards inflation and output, respectively. Taylor (1993) set those equal to 0.5 each. Moreover, he assumed the equilibrium real interest rate and the inflation target to be constant and equal to two percent each. With these assumptions he was able to mimic the interest rate setting of the US Federal Reserve rather well.

Please note, that we deviate from this simple rule in a few ways: First, we do not assume the response coefficients to be 0.5 each. We rather estimate what the empirical response of the central banks towards inflation and output is. Second, several studies have shown that the equilibrium real rate is not constant over time but seems to have declined in recent years.[3]. Therefore, the equilibrium real interest rate is modelled as time-varying and thus it is also indexed by t. The same holds, third, for the inflation target which the central banks under investigation changed frequently after becoming inflation targeters in the process of bringing inflation rates down to low levels. Simple rearranging of equation (1) leads to:

$$i_t^T = \overline{r}_t + (1 - \alpha_\pi)\pi_t^* + \alpha_\pi \pi_t + \alpha_Y (Y_t - Y_t^*) \tag{2}$$

Please note, that $\alpha_\pi = (1 - a_\pi)$. In equation (2) the Taylor-principle is evident, since only a response coefficient towards inflation (α_π) exceeding unity changes the nominal rate by more than the change in inflation thus influencing the real interest rate, being the decisive variable for investment and consumption decisions, in the desired direction.

However, it is observed empirically that central banks adjust their policy rate rather inertially. Therefore, the lagged interest rate should also have an effect on the current interest rate:

$$i_t = \rho i_{t-1} + (1 - \rho) i_t^T \tag{3}$$

Inserting equation (2) in (3) thus leads to:

$$i_t = \rho i_{t-1} + (1 - \rho)[\overline{r}_t + (1 - \alpha_\pi)\pi_t^* + \alpha_\pi \pi_t + \alpha_Y (Y_t - Y_t^*)] \tag{4}$$

For estimation purposes we add a constant term to the Taylor reaction func-

[3] See e.g. Laubach and Williams (2003 and 2015) for the US or Belke and Klose (2017) for the Euro-area.

tion in order to capture potential other constant influences on the interest rate. Thus our estimation equation of the standard Taylor reaction function takes the following form:

$$i_t = \rho i_{t-1} + (1-\rho)[c + \overline{r}_t + (1-\alpha_\pi)\pi_t^* + \alpha_\pi \pi_t + \alpha_Y (Y_t - Y_t^*)] + \epsilon_t \tag{5}$$

Introducing asymmetries into equation (5) is done via an heavyside indicator which splits the sample into two groups according to whether one variable is above or below a certain threshold. Since the Taylor reaction function has two of this variables and thresholds - the inflation and its target and output and its potential - we can estimate asymmetric Taylor reaction functions in two ways:

$$i_t = \rho i_{t-1} + (1-\rho) \left\{ \begin{array}{l} [c^e + \overline{r}_t + (1-\alpha_\pi)\pi_t^* + \alpha_\pi \pi_t^e + \alpha_Y (Y_t - Y_t^*)^e] \; if \; \pi_t > \pi_t^* \\ [c^r + \overline{r}_t + (1-\alpha_\pi)\pi_t^* + \alpha_\pi \pi_t^r + \alpha_Y (Y_t - Y_t^*)^r] \; if \; \pi_t < \pi_t^* \end{array} \right\} + \epsilon_t \tag{6}$$

$$i_t = \rho i_{t-1} + (1-\rho) \left\{ \begin{array}{l} [c^e + \overline{r}_t + (1-\alpha_\pi)\pi_t^* + \alpha_\pi \pi_t^e + \alpha_Y (Y_t - Y_t^*)^e] \; if \; Y_t > Y_t^* \\ [c^r + \overline{r}_t + (1-\alpha_\pi)\pi_t^* + \alpha_\pi \pi_t^r + \alpha_Y (Y_t - Y_t^*)^r] \; if \; Y_t < Y_t^* \end{array} \right\} + \epsilon_t \tag{7}$$

Equation (6) introduces asymmetries in the inflation response. The inflation rate can be above or below the target level. The prior case is marked with the index e for expansionary and the latter with r for a restrictive environment. The same holds with respect to output asymmetries as given in equation (7). Here output above potential is indexed by e and below potential by r. Estimating the expansionary and restrictive coefficients in one equation, moreover, gives us the opportunity to test whether the central banks response in both situations is statistically different.

However, since the Taylor reaction functions proposes asymmetries which may stem from inflation or output, the question of interdependencies between both has to be raised. Thus, according to the Taylor reaction function a central bank may face for different states of the economy: First, both inflation and output are above target/potential, second, inflation is above target while output is below potential, third, inflation is below target while output is above potential and fourth, both are below target/potential. Figure 1 summarizes the four different states of the economy.

- *Figure 1 about here* -

These four states of the economy can also be estimated in one asymmetric Taylor reaction function:

$$i_t = \rho i_{t-1} + (1-\rho)\left\{\begin{array}{l} [c^{ee} + \overline{r}_t + (1-\alpha_\pi)\pi_t^* + \alpha_\pi \pi_t^{ee} + \alpha_Y (Y_t - Y_t^*)^{ee}] \; if \; \pi_t > \pi_t^* \cap \; Y_t > Y_t^* \\ [c^{er} + \overline{r}_t + (1-\alpha_\pi)\pi_t^* + \alpha_\pi \pi_t^{er} + \alpha_Y (Y_t - Y_t^*)^{er}] \; if \; \pi_t > \pi_t^* \cap \; Y_t < Y_t^* \\ [c^{re} + \overline{r}_t + (1-\alpha_\pi)\pi_t^* + \alpha_\pi \pi_t^{re} + \alpha_Y (Y_t - Y_t^*)^{re}] \; if \; \pi_t < \pi_t^* \cap \; Y_t > Y_t^* \\ [c^{rr} + \overline{r}_t + (1-\alpha_\pi)\pi_t^* + \alpha_\pi \pi_t^{rr} + \alpha_Y (Y_t - Y_t^*)^{rr}] \; if \; \pi_t < \pi_t^* \cap \; Y_t < Y_t^* \end{array}\right\} + \epsilon_t \quad (8)$$

Here the first index always signals asymmetries concerning inflation and the second towards output. With this estimation it is possible to distinguish between asymmetries. It is now possible to investigate whether an asymmetry in the inflation response is also depending on whether the output is above or below potential. The same holds the other way around. So we are able to test e.g. whether there are asymmetries in inflation given that output is above potential or below potential.

With equation (8) we are able to estimate significant differences in the reaction coefficients depending on the state of the economy. However, we are unable to estimate whether central banks react in a non-linear fashion within each state, i.e. whether the reaction is stronger or weaker the farer the realizations are from target/potential. This can be achieved by estimating in each state a Taylor reaction function including quadratic term for the inflation rate and the output-gap in order to capture possible non-linearities. So for every state the testable equation can be written as:

$$\begin{aligned} i_t^{xz} = \rho i_{t-1}^{xz} + (1-\rho)\{c^{xz} + \overline{r}_t + \alpha_\pi(\pi_t - \pi_t^*)^{xz} + \alpha_\sigma[(\pi_t - \pi_t^*)^{xz}]^2 \\ +\alpha_Y(Y_t - Y_t^*)^{xz} + \alpha_\nu[(Y_t - Y_t^*)^{xz}]^2\} \end{aligned} \tag{9}$$

Here x and z can be either e or r. We have to model explicitly the inflation deviation from the target because this is the threshold and we are interested whether the reaction is different if the inflation deviation from this threshold rises. This is no problem for the output-gap since this measure is modeled as deviations from potential and thus the threshold for the output-gap is zero. Assuming we have positive inflation and output deviations (state I), then positive estimates of the parameters α_σ or α_ν would signal a stronger reaction to larger deviations from target/potential. If we find significantly negative estimates of α_σ or α_ν in this situation we can conclude that the reaction to small deviations is more pronounced than to larger deviations. The reverse applies if we have negative deviations from target/potential. In this case a negative coefficient would signal a stronger reaction to larger deviations and vice versa.

4 Data

In section 3 we have seen that for estimations of Taylor reaction functions five variables are needed: First, the interest rate, second, the output-gap, third, the equilibrium real interest rate, fourth the inflation rate and fifth, the inflation target. We collected all these data for the four Eastern European countries that have announced to be official inflation targeters. These are: The Czech Republic, Hungary, Poland and Romania. We use monthly data which are generally collected from Eurostat. Our sample period starts in most cases in 2000M1 and ends in 2017M11 due to data availability. However, there are two exceptions: Hungary became a inflation targeter only since 2001M6 and Romania not before 2005M8. Therefore, our sample period starts at those dates in these two cases. As the relevant interest rate we take the intraday money market rate.

When it comes to the construction of the output-gap, we take data on industrial production (excluding construction, seasonally adjusted) since no data on economic output are available in a monthly frequency. However, industrial production is generally seen as the cycle-maker (Belke and Polleit, 2007). Potential output is constructed by using the Hodrick-Prescott- (HP-) filter to the output series (Hodrick and Prescott, 1997). The smoothing parameter is chosen to be 14400 as it is commonly done when monthly data are employed. To overcome the well-known end of sample bias in the HP-filter the sample period is expanded by an AR(3)-forecast for the period 2017M12 to 2018M6. The log of output is finally subtracted by the log of the estimated potential to form the output-gap. For the four countries the output-gaps can be seen in Figure 2:

- Figure 2 about here -

A somewhat similar approach is followed when it comes to the estimation of the equilibrium real interest rate. In a first step we construct the real rate simply by applying the Fisher equation with adaptive expectations, thus the nominal rate is simply subtracted by the current inflation rate. In a second step, the HP-filter to the resulting real rate is applied (Klose, 2011a). Again a smoothing parameter of 14400 is chosen and the series is extended by forecasts for the following seven months to circumvent the end of sample bias. While this is probably the easiest way to estimate a time-varying equilibrium real interest rate it is still better than simply assuming this variable to be constant for our set of countries. Indeed, we find that equilibrium real rates have decreased considerably for our four countries under investigation (Figure 3).

- Figure 3 about here -

The inflation rate is calculated as the year on year percentage growth in the harmonized index of consumer prices (HICP). The inflation target is set according to announcements of the respective central banks. Since all central banks underwent a process of disinflation in our sample period, also the inflation targets were frequently lowered. Moreover, all central banks introduced target bands for the inflation rate. We simply take the mean of this band as our threshold inflation target. So e.g. if a central bank announced an inflation target band of one to three percent our threshold target is two percent. Whether the central banks indeed react more when inflation tends to rise above or fall below the band, i.e. larger deviations from target, will then be tested with our non-linear Taylor reaction functions. The inflation rates with its corresponding targets for all four central banks can be seen in Figure 4.

- Figure 4 about here -

The most important characteristics of all variables are summarized in the descriptive statistics (Tables 1 to 4). Most importantly in order to generate reliable estimates for each state enough observations have to be generated. The descriptive statistics show that this is given for almost all countries and states. Only in State II for the Czech Republic and State IV for Romania the number of observations tends to be low. So the results in these two cases have to be interpreted more cautiously.

- Tables 1 to 4 about here -

5 Empirical results

In this section we will present the results of our estimation equations (5) to (9). In the first part we will present the results for the standard Taylor reaction function and those taking only asymmetries either in inflation or output into account. In the second part the results of the asymmetric Taylor reaction functions taking all four states of the economy into account are shown. In the final third part the non-linear Taylor reaction functions for each state are presented. All equations are generally estimated using GMM, since real-time data are not available for the countries under investigation and thus this estimator models the decision making process of the central banks best. This is because central bankers may not have the full set of information when taking their interest rate decision (Belke and Polleit, 2007). Therefore, we use up to twelve lags of the interest rate, inflation rate, output-gap and equilibrium real interest rate besides a constant since we can be sure that the central bankers had these information at hand at time of decision making. This choice of instruments makes us pass the J-test of the validity of over-identifying restrictions to check for the appropriateness of our selected set of instruments in all cases. The results are available upon request. As the relevant weighting matrix we choose, as usual, the heteroskedasticity and autocorrelation consistent HAC matrix by Newey and West (1987).

5.1 Standard Taylor reaction function and simple asymmetries

The results for the standard Taylor reaction function and simple asymmetries concerning either inflation or output are presented in Table 5.

- Table 5 about here -

The results of the standard Taylor reaction functions are broadly comparable to those of previous studies. More precisely, interest rate smoothing is rather high in all four countries with values of 0.83 to 0.94. The Taylor principle is in no country fulfilled even though inflation is always found to exhibit the expected significantly positive influence on the interest rate. Finally, the output-gap is also found to have a significantly positive effect on interest rates although the coefficients vary considerably being only 0.15 in the Czech Republic but 1.28 in Romania.

Columns 2, 5, 8 and 11 present the results when only asymmetries concerning the inflation rate as proposed by equation (6) are taken into account. Here we find substantial differences between the four countries. Only in the case of Poland the reaction coefficients are found to be significantly higher when inflation rates exceed the target as can be seen by the Wald tests performed for coefficient equality. In this case also the Taylor principle is fulfilled with a coefficient of 1.14. For the three other countries the reaction coefficients tend to be higher when inflation is below its target. However, only for Hungary the difference in the response coefficients to expansive and restrictive inflation rates is found to be statistically different.

The results for output asymmetries are presented in columns 3, 6, 9 and 12 of Table 5 and thus correspond to equation (7). With respect to this variable the central banks of the Czech Republic, Hungary and Romania appear to react rather symmetric, meaning that we do not find any significant differences in the expansionary or restrictive output coefficients. Only for the Polish central bank the reaction is asymmetric, i.e. the central bank reacts stronger when output is below potential than when it is above.[4]

However, whether those results found when applying simple asymmetries still hold when both thresholds are simultaneously taken into account will be verified in the next part.

[4] More precisely, the Polish central bank seems to only react significantly to output below potential while the reaction coefficient towards output above potential is even insignificantly negative.

5.2 Asymmetric Taylor reaction functions and the state of the economy

Table 6 presents our results of the asymmetric Taylor reaction function measuring the state of the economy as introduced in equation (8).

- Table 6 about here -

It is now found that in three of the four central banks we find asymmetries. Only in the case of Hungary no asymmetries can be identified, which is quite surprising since we found significant asymmetries in inflation rates in the previous part. However, this result is mainly driven by the now higher standard errors. Especially in a situation where output is above potential the inflation response tends to be considerably higher for inflation rates below target (1.24) than when it is above target (0.34).

The identified asymmetries of the Polish central bank we found in the previous part stem solely from two state comparisons. So asymmetries in inflation are only given when output is below potential. Here it is again found that the reaction is stronger if inflation is above target. The same holds also in an environment of output below potential, but the differences are insignificant here. The stronger reaction towards output if it is below potential is solely driven by the situation when inflation is above target. Even the reverse is true when inflation is below target but in an insignificant way.

While we were unable to find any asymmetries in the reaction function of the Czech central bank when only taking simple asymmetries into account, we now find that there are asymmetries in inflation and output depending on the state of the economy. In fact, the inflation response is significantly higher if inflation is above target than when it is below given that output is below potential. However, the reverse is true when output is above potential although the reaction coefficients are not statistically different in this case. These opposing reactions to inflation depending on whether output is above or below potential are also driving our result of no asymmetries when we look only at the inflation rate as in the previous part. When it comes to asymmetries in output it is now found that the Czech central bank reacts stronger when output is above potential than when it is below given that inflation is below target. When inflation is above target no significant differences in output can be found which tend to drive also our results of no asymmetries in output in the previous part.

Finally, the Romanian central bank is now found to react asymmetrically in three of four comparisons. With respect to inflation asymmetries we now find two opposing reactions which have led to the result of a symmetric response when only asymmetries in inflation are taken into account. On the one hand the Romanian central bank reacts more to inflation rates below target than to rates above this threshold when output is above potential. On the other hand the reverse is true if output is below potential. Here also the restrictive inflation coefficient is found to be significantly negative. The output response is only significantly asymmetric when inflation is below target. In this case the Romanian central bank reacts stronger when output is also below potential than when it is above this threshold. The reverse is again true for a situation where inflation is above target although in an insignificant way.

5.3 Non-linear Taylor reaction functions

The results for our non-linear Taylor reaction functions as given by equation (9) can be found in the Tables (7) to (10).

- Table 7 about here -

With respect to the Czech central bank the results are shown in Table (7). It is obvious that the Czech central bank reacts non-linear towards inflation or output in different states. When output is above potential (states I and III) the inflation response is non-linear in that smaller deviations are tackled more actively than larger deviations. This can be seen by the significantly negative coefficient on the quadratic inflation term in State I and the corresponding significantly positive coefficient in state III. Moreover, from these results it can be calculated up to which inflation deviation the Czech central bank reacts in the fashion supposed by the Taylor reaction function, i.e. lowering (increasing) the interest rate when inflation decreases below (rises above) target.[5] This threshold is reached by inflation rates being about 4 percentage points above target in state I or 1.9 percentage points below target in state III. In state II however, the reverse is true. Here the Czech central banks reacts even negative to small inflation rates above target by decreasing the interest rate and only larger deviations are tackled by interest rate increases. The threshold in this case would be 1.9 percentage points above target. But please keep in mind that in this state the number of observations is rather low, so the results have to be interpreted with caution.

[5] This threshold can be calculated by $-\frac{\alpha_\pi}{\alpha_\sigma}$ if inflation rates are above target or $\frac{\alpha_\pi}{\alpha_\sigma}$ if they are below. The same holds with respect to the output response. Here α_π has to be substituted by α_Y and α_σ by α_ν.

When it comes to non-linearities in the output response we find only in the states where output is above potential (states I and III) significant estimates. In both states the Czech central bank reacts stronger to larger positive deviations from potential. However, in state III the reaction to small deviations is even negative, thus interest rates are decreased while output rises further above potential. The threshold in this case is about 7 percentage points above target.

- Table 8 about here -

The results for the Hungarian central bank are presented in Table 8. For Hungary almost no non-linearities in the different states can be identified. Only with respect to output if the output-gap is negative (states II and IV) there tend to be non-linearities. However, the interpretation in both cases is completely different. While the Hungarian central banks reacts as expected in state II, meaning that interest rates are lowered more aggressively the more output falls below potential, the reverse is true in state IV. Here the central bank increases interest rates when the output-gap is negative. Moreover, these increases are estimated to be higher the lower the output-gap.

- Table 9 about here -

The Polish central bank reacts non-linear in almost all states and with respect to both variables (Table 9). Only the output response in state I is found to be linear. When it comes to the inflation response the Polish central bank reacts indeed stronger to larger deviations in the states I, III and IV. In these cases smaller deviations from target are not even tackled. The thresholds deviations from target for the three states are about 1.6, 1.7 and 4.2 percentage points, respectively. Only in state II larger deviations are tackled less effectively. Here the threshold is estimated to be about 3.9 percentage points above target.

Concerning the output reaction, larger deviations from potential are tackled more in the states II and III. However, in both states small deviations do not even result in interest rate changes in the direction intended by the Taylor reaction functions. This holds only for larger deviations with the thresholds being 4.3 and 4.1 percentage points below or above potential. In state IV larger deviations from potential lead to a lower interest rate response. For large deviations the response turns even negative. The threshold for this is about 3.9 percentage points deviation.

- Table 10 about here -

Finally, the Romanian central bank reacts also non-linear to inflation and output in most states (Table 10). Only in state I the reaction tends to be linear. When it comes to the inflation response the Romanian central banks increases interest rates more aggressively the larger the deviation in state II but lowers the interest rate to a lesser extend when inflation move further below target (states III and IV). Smaller deviations in state II lead even to interest rate increases. The threshold is about 3.5 percentage points above target. On the other side large inflation rates below target tend to raise interest rates. The corresponding thresholds are 5.4 (state III) and 6.4 percentage points (state IV) below target.

In states III and IV the Romanian central bank reacts stronger to larger deviations of output from potential. At least for state IV the response to small deviations is even an increase in interest rates. The threshold here is about 4.1 percentage points below potential. In state II the response is, however, lower for larger deviations or even negative when they become too large. The threshold in this case is about 8.7 percentage points below potential.

6 Conclusions

In this paper we have investigated whether four inflation targeting central banks in Eastern Europe react asymmetrically and in a non-linear fashion towards inflation, output and the combination of both, the so-called state of the economy. We did so by expanding the standard Taylor reaction function. Indeed, we find substantial asymmetries in the reaction functions. Only for the Hungarian central bank evidence points to almost no asymmetries and non-linearities, thus the standard Taylor reaction function is good to describe the interest rate setting of the monetary authority in this country.

For the remaining three central banks we find as substantial degree of asymmetries in the reaction function. These asymmetries depend crucially on whether inflation is above or below target and output is above or below potential. In all three cases we find asymmetries using this concept in the inflation and output response. Those asymmetries become only visible if one compares different states of the economy and not by simple comparisons of inflation and output above or below certain thresholds.

Moreover, we were able to find a substantial degree of non-linearities for the Czech, Polish and Romanian central bank. These non-linearities depend on the states of the economy. All three central banks show non-linearities to inflation and output at least in some states. Those non-linearities are found to move in both directions, meaning we found stronger and weaker reactions to larger deviations from target or potential.

From a policy perspective asymmetries and non-linearities make the predictability of central bank behavior an even tougher task. While a clearly communicated policy rule which is moreover easy to understand makes a central bank predictable thus lowering uncertainty is the financial markets and wider public about the course of monetary policy, this becomes considerably more difficult if e.g. an asymmetric reaction function with potential non-linearities is implemented. This is for at least two reasons: First, a policy rule which comprises four or even more different states, all with different reaction coefficients and potential non-linearities, is rather complex. Thus, communicating this rule so that all understand it in full is almost impossible. Second, even if the rule would be fully understood by all market participants, it is still unclear in what state the central bank thinks it currently is or will be in the near future. Therefore, the market participants need to form also expectations about the current and future state of the economy. However, mistakes in forming the correct expectations may lead to large disturbances as reaction coefficients of the central bank and with this the interest rate policy may be completely different from what the markets expect. Therefore, it is advisable to implement an easy, symmetric and linear reaction function to circumvent these issues.

References

[1] Altavilla, C. and Landolfo, L. (2005): Do Central Banks Act Asymmetrically? Empirical Evidence from the ECB and the Bank of England, Applied Economics, Vol. 37, pp. 507–519.

[2] Angeloni, I., Flad, M. and Mongelli, F. (2007): Monetary Integration of the new EU Member States: What Sets the Pace of Euro Adoption?, *Journal of Common Market Studies*, Vol. 45(2), pp. 367–409.

[3] Bec, F., Collard, F. and Salem,M. (2002). Asymmetries in Monetary Policy Reaction Function: Evidence for U.S. French and German Central Banks; *Studies of Nonlinear Dynamics and Econometrics*, 6(2), 3. Art.

[4] Belke, A. and Klose, J. (2011): Does the ECB Rely on a Taylor Rule During the Financial Crisis? Comparing Ex-Post and Real Time Data with Real Time Forecasts, *Economic Analysis and Policy*, Vol. 41(2), pp. 147-171.

[5] Belke, A. and Klose, J. (2017): Equilibrium Real Interest Rates and Secular Stagnation: An Empirical Analysis for Euro Area Member Countries, *Journal of Common Market Studies*, Vol. 55(6), 1221-1238.

[6] Belke, A. and Polleit, T. (2007): How the ECB and the US Fed Set Interest Rates, *Applied Economics*, Vol. 39(17), pp. 2197-2209.

[7] Bunzel, H. and Enders, W. (2010): The Taylor rule and "opportunistic" monetary policy, *Journal of Money, Credit and Banking*, Vol. 42(5), pp. 931-949.

[8] Cukierman, A. and Muscatelli, A. (2008): Nonlinear Taylor Rules and Asymmetric Preferences in Central Banking: Evidence from the United Kingdom and the United States, *The B.E. Journal of Macroeconomics*, Vol. 8(1), 7. Art.

[9] Dolado, J., Maria-Dolores, R. and Naveira, M., (2000): *Asymmetries in Monetary Policy Rules: Evidence for Four Central Banks*, Centre of Economic Policy Research Discussion Paper, No. 2441.

[10] Dolado, J., Maria-Dolores, R. and Naveira, M. (2005). Are Monetary-Policy Reaction Functions Asymmetric? The Role of Nonlinearity in the Phillips Curve, *European Economic Review*, Vol. 49, pp. 485–503.

[11] Frömmel, M., Garabedian, G. and Schobert, F. (2011) Monetary Policy Rules in Central and Eastern European Countries: Does the Exchange Rate Matter?, *Journal of Macroeconomics*, Vol. Vol. 33(4), pp. 807-818.

[12] Frömmel, M. and Schobert, F. (2006): *Monetary Policy Rules in Central and Eastern Europe*, Discussion Paper No. 341, University of Hannover.

[13] Hodrick, R. and Prescott, E. (1997): Postwar U.S. Business Cycles: an Empirical Investigation, *Journal of Money, Credit and Banking*, Vol. 29(1), pp. 1-16.

[14] Kahn, G. (2012): Estimated Rules for Monetary Policy, *Federal Reserve Bank of Kansas City Economic Review*, Vol. 4, pp. 5-29.

[15] Klose, J. (2011): Asymmetric Taylor Reaction Functions of the ECB: An Approach Depending on the State of the Economy, *North American Journal of Economics and Finance*, Vol. 22(2), pp. 149-163.

[16] Klose, J. (2011): A Simple Way to Overcome the Zero Lower Bound of Interest Rates for Central Banks: Evidence from the Fed and the ECB within the Financial Crisis, *International Journal of Monetary Economics and Finance*, Vol. 4(3), pp. 279-296.

[17] Klose, J. (2014): *Changes in Central Bank Reaction Functions of Central and Eastern European Countries in the Financial Crisis*, Progress in Economics Research, Nova Publishers, Vol. 28, pp. 37-55.

[18] Laubach, T. and Williams, J. (2003): Measuring the Natural Rate of Interest, *The Review of Economics and Statistics*, Vol. 85(4), pp. 1063–1070.

[19] Laubach, T. and Williams, J.C. (2015): *Measuring the Natural Rate of Interest Redux*, FRBSF Working Paper 2015–16.

[20] Maria-Dolores, R. (2005): Monetary Policy Rules in Accession Countries to EU: Is Taylor Rule a Pattern?, *Economics Bulletin*, Vol. 5(5), pp. 1-16.

[21] Miyazawa, K. (2011): The Taylor Rule in Japan, *The Japanese Economy*, Vol. 38(2), pp. 79-104.

[22] Newey, W. and West, K. (1987): A Simple, Positive Definite, Heteroscedasticity and Autocorrelation Consistent Covariance Matrix, *Econometrica*, Vol. 55(3), pp. 703–708.

[23] Paez-Farrell, J. (2007): Understanding Monetary Policy in Central European Countries Using Taylor-Type Rules: The Case of the Visegrad Four, *Economics Bulletin*, Vol. 5(3), pp. 1-11.

[24] Popescu, I. (2014): Analysis of the Behavior of Central Banks in Setting Interest Rates. The Case of Central and Eastern European Countries, *Procedia Economics and Finance*, Vol. 15, pp. 1113-1121.

[25] Orlowski, L. (2010): Monetary Polocy Rules for Convergence to the Euro, *Economic Systems*, Vol. 34(2), pp. 148-159.

[26] Ruge-Murcia, F. (2003): Inflation Targeting under Asymmetric Preferences, *Journal of Money Credit and Banking*, Vol. 35(5), pp. 763–785.

[27] Sauer, S. and Sturm, J. (2007): Using Taylor Rules to Understand European Central Bank Monetary Policy, *German Economic Review*, Vol. 8(3), pp. 375-398.

[28] Sznajderska, A. (2014): Asymmetric Effects in the Polish Monetary Policy Rule, *Economic Modelling*, Vol. 36, pp. 547-556.

[29] Su, C., Chang, H. and Zhang, C. (2016): Nonlinear Taylor Rules in Central Eastern European Countries, *The Journal of International Trade Economic Development*, Vol. 25(3), pp. 357-376.

[30] Surico, P. (2003): Asymmetric Reaction Functions for the Euro area, *Oxford Review of Economic Policy*, Vol. 19(1), pp. 44–57.

[31] Surico, P. (2007): The Fed's Monetary Policy Rule and U.S. Inflation: The Case of Asymmetric Preferences, *Journal of Economic Dynamics and Control*, Vol. 31, pp. 305–324.

[32] Surico, P. (2007a): The Monetary Policy of the European Central Bank, *Scandinavian Journal of Economics*, Vol. 109(1), pp. 115–135.

[33] Taylor J. (1993): Discretion versus Policy Rules in Practice, *Carnegie-Rochester Conference Series on Public Policy*, Vol. 39, pp. 195-214.

[34] Taylor M. and Davradakis, E. (2006): Interest Rate Setting and Inflation Targeting: Evidence of a Nonlinear Taylor Rule for the United Kingdom, *Studies in Nonlinear Dynamics Econometrics*, Vol. 10(4), 1. Article.

[35] Vasicek, B. (2009): *Monetary Policy Rules and Inflation Process in Open Emerging Economies: Evidence for 12 New EU Members*, William Davidson Institute Working Paper, No. 968.

[36] Vasicek, B. (2012): Is Monetary Policy in New Members States Asymmetric?, *Economic Systems*, Vol. 36(2), pp. 235-263.

Figures

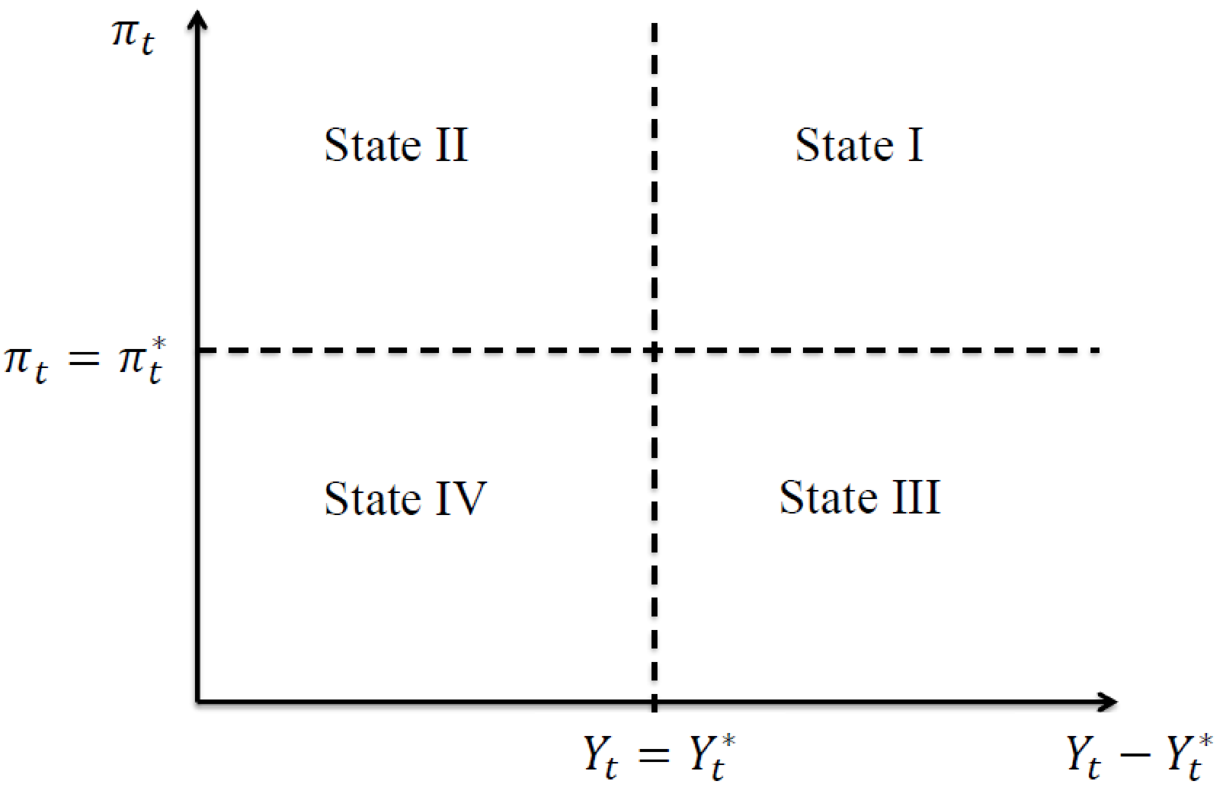

Figure 1: State Definition

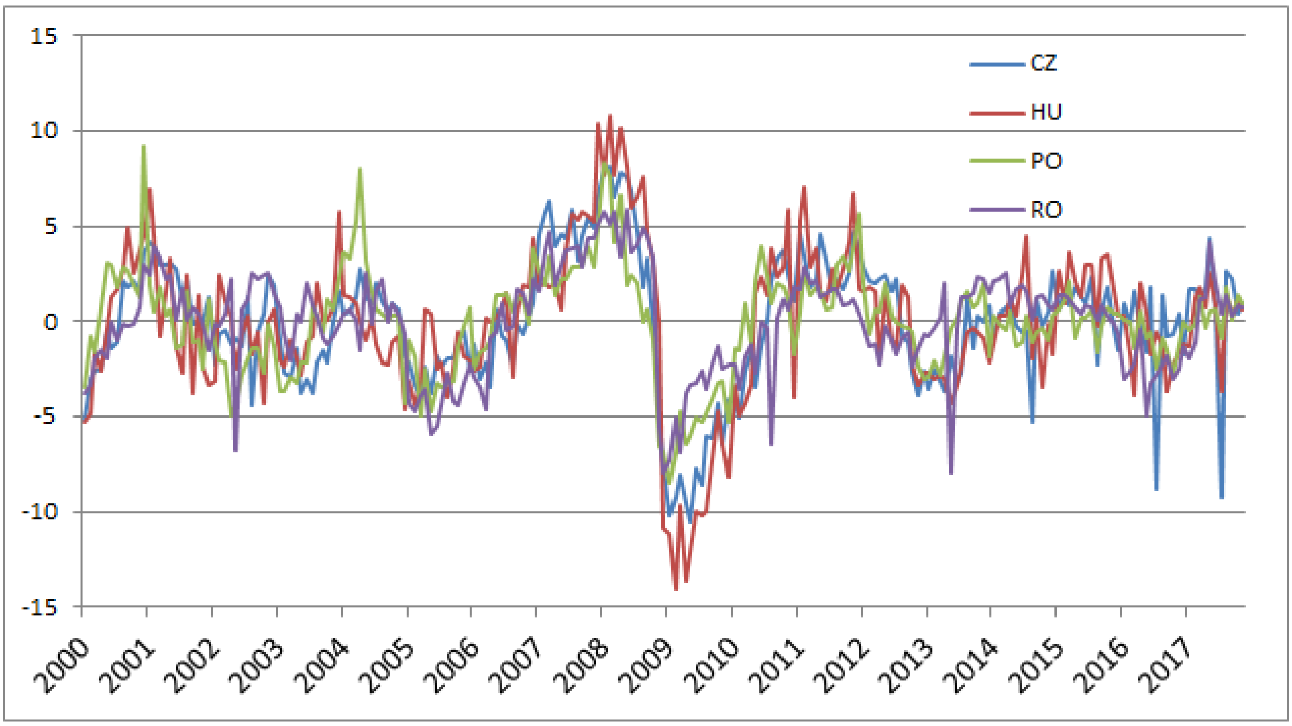

Figure 2: Output-Gaps, Source: Eurostat and own calculations.

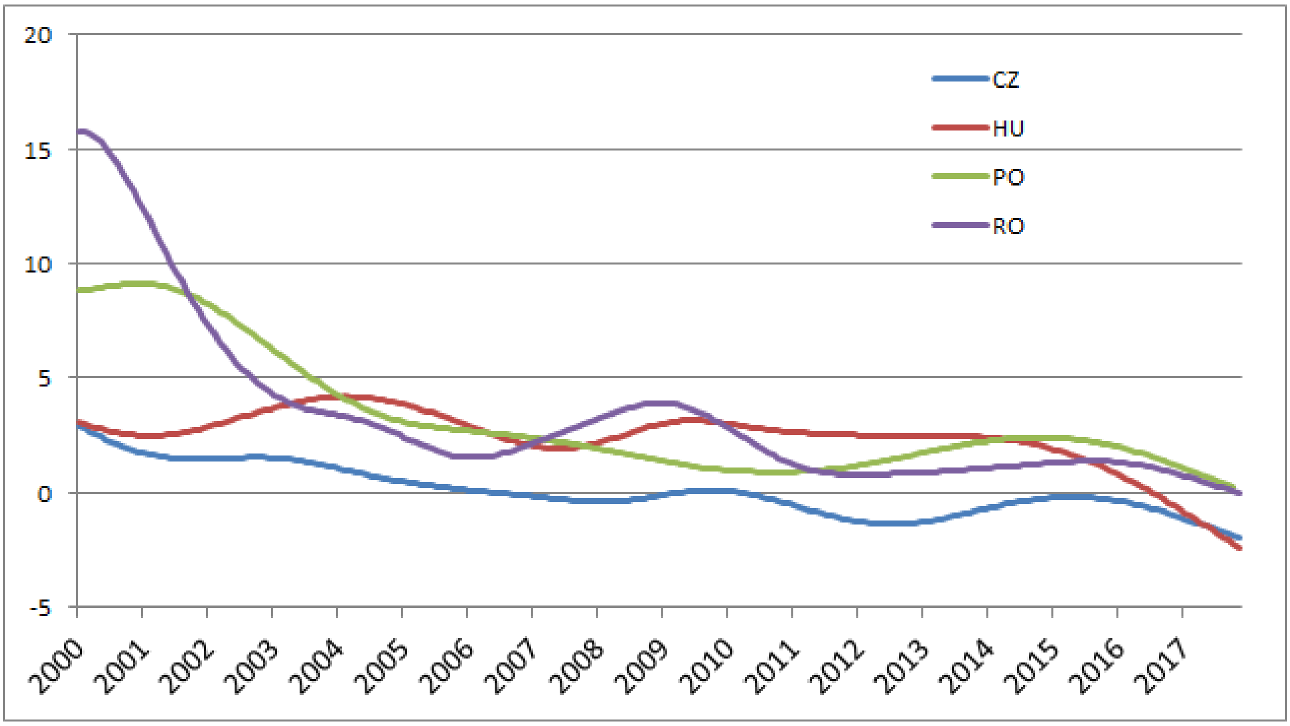

Figure 3: Equilibrium Real Interest Rates, Source: Eurostat and own calculations.

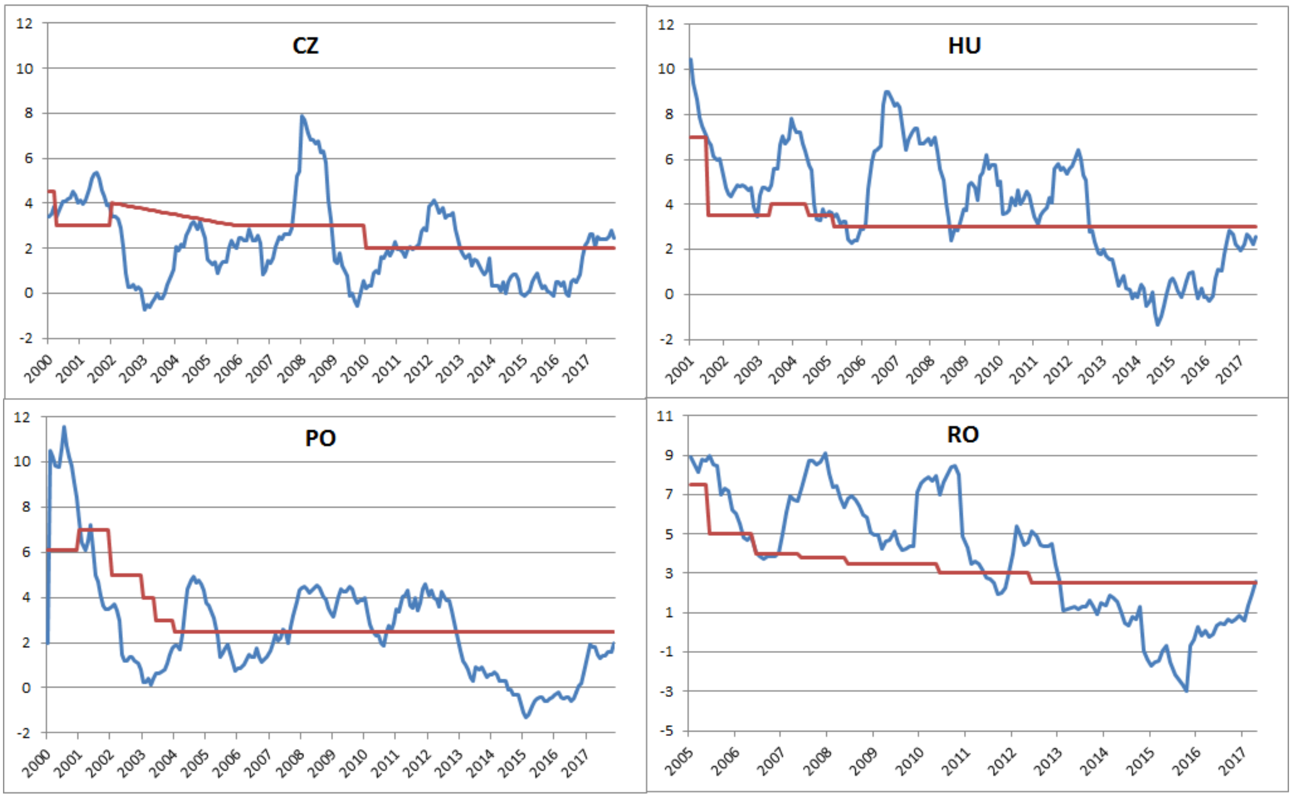

Figure 4: Inflation Rates and Inflation Targets, Source: Eurostat and National Central Banks.

Tables

Table 1: Descriptive Statistics Czech Republic

	linear	$\pi_t > \pi_t^*$	$\pi_t < \pi_t^*$	$Y_t > Y_t^*$	$Y_t < Y_t^*$	*State I*	*State II*	*State III*	*State IV*
$\bar{i}$	2.10	2.91	1.68	2.12	2.07	2.87	3.04	1.51	1.90
σ_i	1.61	2.05	1.23	1.69	1.51	2.00	2.27	1.07	1.26
$\overline{\pi}$	2.11	4.02	1.24	2.65	1.51	4.15	3.60	1.37	1.13
σ_π	1.77	1.50	1.06	1.90	1.40	1.62	0.93	1.02	1.09
π_{max}	7.87	7.87	3.83	7.87	5.79	7.87	5.79	3.21	3.84
π_{min}	-0.76	2.05	-0.76	-0.10	-0.76	2.05	2.11	-0.10	-0.76
$\overline{Y - Y^*}$	-0.03	1.78	-0.81	2.49	-2.81	3.13	-2.52	1.96	-2.87
σ_{Y-Y^*}	3.45	3.28	3.21	1.90	2.52	2.08	2.66	1.57	2.51
$(Y\text{-}Y^*)_{max}$	8.15	8.15	6.28	8.15	-0.02	8.15	-0.10	6.29	-0.02
$(Y\text{-}Y^*)_{min}$	-10.48	-9.20	-10.48	0.01	-10.48	0.01	-9.20	0.14	-10.48
N	215	67	148	113	102	51	16	62	86

Notes: x̄ stands for the mean of the respective variable, x_{max} and x_{max} for the maximum and minimum realization, while σ_x is the standard deviation, N= number of observations.

Table 2: Descriptive Statistics Hungary

	linear	$\pi_t > \pi_t^*$	$\pi_t < \pi_t^*$	$Y_t > Y_t^*$	$Y_t < Y_t^*$	*State I*	*State II*	*State III*	*State IV*
$\bar{i}$	6.37	8.34	2.92	6.12	6.64	8.16	8.55	1.98	3.77
σ_i	3.36	1.79	2.61	3.42	3.30	1.68	1.89	1.98	2.84
$\overline{\pi}$	3.99	5.55	1.26	4.23	3.73	5.80	5.25	1.04	1.45
σ_π	2.54	1.58	1.27	2.71	2.33	1.60	1.52	1.33	1.20
π_{max}	10.48	10.48	3.48	9.00	10.48	9.00	10.48	3.46	3.48
π_{min}	-1.37	3.11	-1.37	-1.37	-0.84	3.12	3.11	-1.37	-0.84
$\overline{Y - Y^*}$	-0.15	0.22	-0.81	2.66	-3.21	3.26	-3.44	1.46	-2.85
σ_{Y-Y^*}	4.03	4.43	3.13	2.45	3.07	2.08	3.17	1.20	2.91
$(Y\text{-}Y^*)_{max}$	10.82	10.82	4.45	10.82	-0.01	10.82	-0.01	4.45	-0.06
$(Y\text{-}Y^*)_{min}$	-14.09	-13.67	-14.09	0.02	-14.09	0.02	-13.67	0.15	-14.09
N	198	126	72	103	95	69	57	34	38

Notes: See Table 1

Table 3: Descriptive Statistics Poland

	linear	$\pi_t > \pi_t^*$	$\pi_t < \pi_t^*$	$Y_t > Y_t^*$	$Y_t < Y_t^*$	*State I*	*State II*	*State III*	*State IV*
$\bar{i}$	5.86	7.31	4.93	6.17	5.52	8.25	5.85	4.44	5.36
σ_i	4.57	5.03	3.99	5.14	3.84	5.72	3.32	3.87	4.08
$\overline{\pi}$	2.63	4.76	1.25	3.08	2.12	5.14	4.16	1.36	1.15
σ_π	2.50	2.23	1.50	2.78	2.05	2.46	1.69	1.63	1.38
π_{max}	11.55	11.55	6.51	11.55	10.53	11.55	10.53	6.51	6.31
π_{min}	-1.29	2.52	-1.29	-1.29	-0.79	2.52	2.55	-1.29	-0.79
$\overline{Y-Y^*}$	-0.04	0.22	-0.20	1.92	-2.19	2.42	-3.18	1.51	-1.71
σ_{Y-Y^*}	2.74	3.54	2.08	1.80	1.84	2.08	2.45	1.40	1.22
$(Y\text{-}Y^*)_{max}$	9.21	9.21	9.21	8.15	-0.04	9.21	-0.04	7.97	-0.05
$(Y\text{-}Y^*)_{min}$	-8.49	-8.49	-4.93	0.06	-8.49	0.09	-8.49	0.06	-4.93
N	214	84	130	112	102	51	33	61	69

Notes: See Table 1

Table 4: Descriptive Statistics Romania

	linear	$\pi_t > \pi_t^*$	$\pi_t < \pi_t^*$	$Y_t > Y_t^*$	$Y_t < Y_t^*$	*State I*	*State II*	*State III*	*State IV*
$\bar{i}$	5.46	7.75	2.45	5.05	5.97	7.38	8.09	2.83	1.73
σ_i	3.85	3.10	2.39	3.62	4.09	3.07	3.13	2.56	1.88
$\overline{\pi}$	3.89	6.15	0.93	3.81	3.99	6.34	5.97	1.40	0.03
σ_π	3.16	1.84	1.80	3.09	3.28	2.03	1.64	1.65	1.76
π_{max}	9.11	9.11	4.91	9.11	8.96	9.11	8.96	4.91	2.79
π_{min}	-2.96	2.57	-2.96	-1.68	-2.96	2.57	3.08	-1.68	-2.96
$\overline{Y-Y^*}$	0.04	-0.24	0.40	2.05	-2.47	2.56	-2.79	1.56	-1.83
σ_{Y-Y^*}	2.83	3.32	1.97	1.51	1.95	1.72	2.17	1.09	1.22
$(Y\text{-}Y^*)_{max}$	5.84	5.84	4.68	5.84	-0.05	5.84	-0.05	4.68	-0.10
$(Y\text{-}Y^*)_{min}$	-7.99	-7.99	-4.98	0.03	-7.99	0.14	-7.99	0.03	-4.98
N	148	84	64	82	66	40	44	42	22

Notes: See Table 1

Table 5: Standard Taylor Reaction Functions and Simple Asymmetries

	Czech Republic			Hungary			Poland			Romania		
	1	2	3	4	5	6	7	8	9	10	11	12
i_{t-1}	0.93***	0.93***	0.93***	0.92***	0.89***	0.94***	0.83***	0.88***	0.88***	0.94***	0.95***	0.92***
	(0.02)	(0.01)	(0.01)	(0.02)	(0.03)	(0.03)	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)
c	0.57***			-0.31			-0.01			0.51		
	(0.13)			(0.49)			(0.08)			(0.86)		
c^e		1.33**	0.30*		-5.86***	-1.07		-0.68	0.41***		0.36	-3.69***
		(0.64)	(0.15)		(1.45)	(1.25)		(0.76)	(0.14)		(1.96)	(0.67)
c^r		0.38***	0.92***		-0.32	0.16		0.10	-0.65***		-0.23	4.97***
		(0.12)	(0.20)		(0.41)	(1.73)		(0.11)	(0.21)		(0.53)	(1.16)
π	0.52***			0.76***			0.87***			0.58***		
	(0.06)			(0.12)			(0.03)			(0.18)		
π_t^e		0.32*	0.46***		-0.22	1.10***		1.14***	1.07***		0.86***	1.33***
		(0.17)	(0.06)		(0.30)	(0.28)		(0.20)	(0.07)		(0.27)	(0.11)
π_t^r		0.72***	0.49***		0.38	0.03		0.37***	0.89***		1.13***	0.01
		(0.08)	(0.12)		(0.30)	(0.47)		(0.09)	(0.07)		(0.34)	(0.18)
$(Y_t - Y_t^*)$	0.15*			0.51**			0.23***			1.28***		
	(0.08)			(0.24)			(0.02)			(0.42)		
$(Y_t - Y_t^*)^e$		0.20**	0.32***		0.47***	0.42		0.21***	-0.07		2.26***	1.24***
		(0.08)	(0.08)		(0.17)	(0.36)		(0.04)	(0.05)		(0.46)	(0.32)
$(Y_t - Y_t^*)^r$		0.17**	0.23***		-0.01	0.47		0.49***	0.25***		-1.31**	1.29***
		(0.04)	(0.08)		(0.15)	(0.53)		(0.07)	(0.06)		(0.51)	(0.24)
$\pi_t^e = \pi_t^r$		4.48**	0.03		2.71	2.95*		8.59***	3.21*		0.38	30.33***
		(0.04)	(0.86)		(0.10)	(0.09)		(0.00)	(0.07)		(0.54)	(0.00)
$(Y_t - Y_t^*)^e = (Y_t - Y_t^*)^r$		0.36	0.82		14.94***	0.01		25.84***	15.62***		19.17***	0.02
		(0.55)	(0.37)		(0.00)	(0.93)		(0.00)	(0.00)		(0.00)	(0.89)
$adj.R^2$	0.99	0.99	0.99	0.94	0.94	0.94	1.00	0.99	0.99	0.97	0.97	0.97
N	215	215	215	198	198	198	214	214	214	148	148	148

Notes: Estimation method: GMM; standard errors in parentheses, for Wald-tests p-values in parentheses; */**/*** signal significance at the 10%/5%/1% level.

Table 6: Two-Way Asymmetric Taylor Reaction Functions

	Czech Republic	Hungary	Poland	Romania
i_{t-1}	0.82***	0.93***	0.87***	0.94***
	(0.04)	(0.03)	(0.01)	(0.01)
c^{ee}	-0.90	3.50	-0.14	1.71
	(0.95)	(2.24)	(0.82)	(2.91)
c^{er}	-3.18	26.11**	-0.59	-0.09
	(3.34)	(11.23)	(1.59)	(3.50)
c^{re}	-0.67	-2.35	0.37	0.60
	(0.56)	(3.30)	(0.27)	(1.60)
c^{rr}	0.70	0.18	-0.72**	10.04*
	(0.45)	(2.39)	(0.31)	(6.03)
π_t^{ee}	0.76***	0.34	1.15***	-0.19
	(0.25)	(0.42)	(0.22)	(0.43)
π_t^{er}	1.48**	-3.95*	1.20***	1.44***
	(0.69)	(2.03)	(0.41)	(0.55)
π_t^{re}	1.04***	1.24	0.75***	2.78***
	(0.34)	(0.82)	(0.22)	(0.64)
π_t^{rr}	0.25	-4.23**	0.10	-2.92**
	(0.18)	(2.11)	(0.15)	(1.39)
$(Y_t - Y_t^*)^{ee}$	0.12	0.35	-0.07	3.72***
	(0.15)	(0.42)	(0.07)	(0.90)
$(Y_t - Y_t^*)^{er}$	-0.24	1.21**	0.32***	2.75***
	(0.25)	(0.60)	(0.08)	(0.64)
$(Y_t - Y_t^*)^{re}$	0.57***	0.75	0.19*	-3.71**
	(0.16)	(1.47)	(0.11)	(1.47)
$(Y_t - Y_t^*)^{rr}$	-0.16	-1.04***	-0.05	4.54*
	(0.11)	(0.32)	(0.11)	(2.54)
$\pi_t^{ee} = \pi_t^{re}$	0.31	0.82	1.36	8.02***
	(0.58)	(0.37)	(0.24)	(0.01)
$\pi_t^{er} = \pi_t^{rr}$	3.13*	0.03	4.94**	7.97***
	(0.08)	(0.85)	(0.03)	(0.01)
$(Y_t - Y_t^*)^{ee} = (Y_t - Y_t^*)^{er}$	1.55	2.31	11.05***	1.70
	(0.21)	(0.13)	(0.00)	(0.19)
$(Y_t - Y_t^*)^{re} = (Y_t - Y_t^*)^{rr}$	10.55***	1.34	2.00	7.28***
	(0.00)	(0.25)	0.16	(0.01)
$adj.R^2$	0.99	0.94	0.99	0.97
N	215	198	214	148

Notes: Estimation method: GMM; standard errors in parentheses, for Wald-tests p-values in parentheses; */**/*** signal significance at the 10%/5%/1% level.

Table 7: Non-Linear Taylor Reaction Functions for each State: Czech Republic

	State I	State II	State III	State IV
i_{t-1}	0.97***	0.98***	1.00***	0.97***
	(0.00)	(0.01)	(0.01)	(0.01)
c^{xz}	-3.00***	4.14	3.48***	2.17**
	(0.44)	(4.07)	(0.86)	(1.01)
$(\pi_t - \pi_t^*)^{xz}$	4.96***	-15.59**	2.97***	0.37
	(0.47)	(5.05)	(0.97)	(0.81)
$[(\pi_t - \pi_t^*)^{xz}]^2$	-1.25***	8.01**	1.59***	0.05
	(0.14)	(2.50)	(0.38)	(0.18)
$(Y_t - Y_t^*)^{xz}$	0.59**	1.27	-2.38***	0.58
	(0.26)	(1.42)	(0.70)	(0.48)
$[(Y_t - Y_t^*)^{xz}]^2$	0.08**	0.14	0.34***	0.00
	(0.04)	(0.17)	(0.12)	(0.06)
$adj.R^2$	1.00	0.99	0.99	0.99
N	51	16	62	86

Notes: Estimation method: GMM; standard errors in parentheses, for Wald-tests p-values in parentheses; */**/*** signal significance at the 10%/5%/1% level.

Table 8: Non-Linear Taylor Reaction Functions for each State: Hungary

	State I	State II	State III	State IV
i_{t-1}	0.92***	0.79***	1.00***	0.93***
	(0.04)	(0.04)	(0.03)	(0.02)
c^{xz}	3.79	12.05***	3.61	-6.73
	(5.80)	(1.41)	(5.29)	(4.24)
$(\pi_t - \pi_t^*)^{xz}$	2.89	-0.44	-5.98	-3.61
	(3.77)	(1.63)	(5.94)	(2.51)
$[(\pi_t - \pi_t^*)^{xz}]^2$	-0.50	0.03	-0.92	-0.83
	(0.65)	(0.40)	(0.99)	(0.53)
$(Y_t - Y_t^*)^{xz}$	1.68	2.25***	-3.33	-1.74**
	(2.23)	(0.44)	(4.70)	(0.70)
$[(Y_t - Y_t^*)^{xz}]^2$	-0.13	0.17***	0.16	-0.11*
	(0.22)	(0.03)	(0.80)	(0.05)
$adj.R^2$	0.76	0.71	0.98	0.99
N	69	57	34	38

Notes: Estimation method: GMM; standard errors in parentheses, for Wald-tests p-values in parentheses; */**/*** signal significance at the 10%/5%/1% level.

Table 9: Non-Linear Taylor Reaction Functions for each State: Poland

	State I	State II	State III	State IV
i_{t-1}	0.97***	0.96***	0.95***	0.96***
	(0.00)	(0.00)	(0.00)	(0.00)
c^{xz}	7.23***	-6.16***	4.52***	-1.59
	(1.20)	(1.63)	(0.83)	(1.37)
$(\pi_t - \pi_t^*)^{xz}$	-4.36**	11.07***	-1.52**	-4.89***
	(1.73)	(2.06)	(0.62)	(1.19)
$[(\pi_t - \pi_t^*)^{xz}]^2$	2.66***	-2.84***	-0.89***	-1.15***
	(0.71)	(0.70)	(0.15))	(0.27)
$(Y_t - Y_t^*)^{xz}$	0.89**	-1.63***	-0.78**	2.11***
	(0.42)	(0.21)	(0.36)	(0.59)
$[(Y_t - Y_t^*)^{xz}]^2$	-0.09	-0.38***	0.19***	0.54***
	(0.05)	(0.04)	(0.06)	(0.11)
$adj.R^2$	1.00	0.96	1.00	1.00
N	51	33	61	69

Notes: Estimation method: GMM; standard errors in parentheses, for Wald-tests p-values in parentheses; */**/*** signal significance at the 10%/5%/1% level.

Table 10: Non-Linear Taylor Reaction Functions for each State: Romania

	State I	State II	State III	State IV
i_{t-1}	1.00***	0.89***	0.82***	1.00***
	(0.05)	(0.01)	(0.01)	(0.00)
c^{xz}	10.88*	16.03***	8.07***	22.99***
	(5.79)	(2.44)	(0.20)	(4.89)
$(\pi_t - \pi_t^*)^{xz}$	-0.83	-8.03***	6.59***	17.99***
	(2.22)	(2.26)	(0.18)	(3.24)
$[(\pi_t - \pi_t^*)^{xz}]^2$	0.18	2.27***	1.21***	2.82***
	(0.45)	(0.60)	(0.04)	(0.52)
$(Y_t - Y_t^*)^{xz}$	-3.50	3.92***	-0.02	-4.67***
	(4.76)	(0.96)	(0.13)	(1.22)
$[(Y_t - Y_t^*)^{xz}]^2$	0.41	0.45***	0.07**	-1.13***
	(0.80)	(0.10)	(0.03)	(0.27)
$adj.R^2$	0.91	0.93	0.98	0.98
N	40	44	42	22

Notes: Estimation method: GMM; standard errors in parentheses, for Wald-tests p-values in parentheses; */**/*** signal significance at the 10%/5%/1% level.