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Central Bank Credibility in CEE Countries: Measurement and Determinants *

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Abstract

We use three different indicators based on inflation expectations to measure central bank credibility in 9 countries in Central and Eastern Europe. We quantify credibility using differences between official inflation targets and inflation expectations as well as differences between inflation expectations and implicit targets based on estimation of the Taylor rule. Determinants of central bank credibility are investigated using pooled OLS. According to our results, stable and low inflation and sound public finances are conductive to central bank credibility. We show that our results are in line with survey-based measures of trust in local currency.

Keywords: central banking, credibility, monetary policy
JEL Codes: E52, E58

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1 Introduction

In 2000, Alan S. Blinder (Blinder, 2000) interviewed 127 central bankers and 115 academic economists about the importance of central bank credibility. Among central bankers, average importance assigned to credibility was 4.83 on the scale from 1 (unimportant) to 5 (of the utmost importance). Academics gave average score of 4.23. Blinder listed seven possible reasons why the credibility of the central bank might be important, both practitioners and academics agreed with all of them and picked less costly disinflation and low inflation as the most important ones[1]. Four years later, similar answers were obtained from private-sector economists by Waller and de Haan (2004).

There are well-established theoretical foundations for above mentioned results. Inflationary bias of a central bank which can be overcome by *credible* commitment or by employing conservative central banker has been explained by Kydland and Prescott (1977) and Barro and Gordon (1983). A general negative relationship between credibility and costs of disinflation was worked out by Ball (1992).

However, eighteen years later central bank credibility remains under-investigated mainly because it is not only difficult to measure, but also to define. In the interviews, Blinder intentionally left credibility undefined and left it up to the interviewee to fill the void for himself/herself. In the article itself, Blinder states that a central bank is credible if '*people believe it will do what it says*'. Bordo and Siklos (2014) define credibility as a '*a commitment to follow well-articulated and transparent rules and policy goals*' but also borrow definition of Cukierman (1986) according to which credibility refers to '*the extent to which the public believes that a shift in policy has taken place when, indeed, such a shift has actually occurred*'. These quotations illustrate two basic approaches to defining credibility - one based on believes of the public, another on a commitment of a central bank. Blinder (1999, 2000) suggests that whereas practitioners of monetary policy tend to identify credibility with the ability to steer market expectations, academics tend to emphasise the existence of commitment mechanisms.

Despite the fact that there is no single definition, several approaches to measurement of central bank credibility have been developed in the literature.

The first one is based on measuring factors that are believed to be essential to establish credibility. In this way, Mackiewicz-Lyziak (2016) develops index of central bank credibility combining measures of inflation, public debt and transparency, independence and accountability of the central bank (last three factors are based on Fry et al., 2000). This approach was later used by Stephanos et al. (2014) who investigates impact of central bank credibility on macroeconomic performance in six emerging-market economies.

[1] Full list of reasons why credibility is important suggested by Blinder was: (i) to provide less costly disinflation, (ii) to keep inflation low, (iii) to change tactics, (iv) to serve as lender of last resort, (v) to defend the currency, (vi) public servants should be truthful, and (vii) to support independence.

Another approach exploits indirect evidence of credibility. Svensson (1993) compares market real interest rates with theoretical *ex-post* rates consistent with inflation target to asses credibility of inflation-targeting regimes in Canada, New Zeland and Sweden. Posen (1998) investigates a link between central bank independence and *desinflationary* credibility. In light of results of Ball (1992), he proxies central bank credibility by a sacrifice ratio (the higher the sacrifice ratio, the lower the credibility). Also, assuming that higher credibility of a central bank should allow to form contracts over longer time horizons, he proxies credibility by measures of wage rigidity.

The third approach focuses on Blinder's simple definition of credibility as having public believe that a central bank will do what it says. Following this definition, credibility can be quantified using a difference between explicit (or implicit) targets and expectations of economic agents. The most straightforward way of measuring central bank credibility is based on loss function (as done by Cecchetti and Krause, 2002; de Mendoca, 2007; de Mendoca and e Souza, 2009; Bordo and Siklos, 2015; Levieuge et al., 2015, differences in methodoologies of these articles will be discussed below). Alternatively, Bomfim and Rudebush (2000) define credibility as the weight given to the inflation target by economic agents when forming inflation expectations. Central bank credibility based on Bomfim and Rudebush (2000) can also by interpreted as speed of convergence of inflation expectations to the inflation target. This approach has been later used by Lyziak et al. (2007) and Demertzis et al. (2009).

One of the benefits of the third approach is that by using information on inflation expectations it provides the most direct measure of central bank credibility. This is the reason why we adopt this approach in this paper. Our goal is to provide answers to two research questions: What is the most informative way of transforming inflation expectations data into credibility index? What are the determinants of central bank credibility?

Our understanding of credibility is very close to Blinder's emphasis on people believing that central bank will do what it says, however, we argue that this does not necessarily mean that inflation expectations have to be always in line with official inflation target (or, in case of countries with currency fixed to euro, in line with inflation target of European Central Bank). We consider credibility to be much broader concept and therefore we calculate three indicators of credibility which allow central bank to be assessed as credible even if inflation expectations are only gradually (but quickly enough) converging to the inflation target or if they temporarily deviate from it. In particular, we use (i) simple quadratic loss function combined with explicit inflation targets, (ii) same loss function with implicit inflation targets calculated according to the methodology developed by Bordo and Siklos (2015) and (iii) speed-of-convergence approach of Bomfim and Rudebush (2000). We argue that these indicators represent different *aspects* of credibility.

Our sample consists of 9 countries in the region of Central and Eastern Europe (CEE). These group of countries not only represents a varied sample of experienced inflation targeters, recent inflation targeters, countries with fixed exchange rate, EU-members and non-members, but,

most importantly, by focusing on CEE countries we are able to correlate credibility measures derived from inflation expectations with results of OeNB Euro Survey conducted by Austrian National Bank (OeNB)[2]. In OeNB Euro Survey, households in CEE countries are asked about their perception of stability, development and predictability of prices and exchange rate in the short and medium run. Therefore, the survey provides an unique insight into trustworthiness of local currencies and local central banks. We also complement OeNB Euro Survey with European Commision's consumer survey (ECCS). Comparing indicators based on inflation expectations with results of OeNB Euro Survey and ECCS we are able to establish that when measuring central bank credibility, it is important to move beyond simple official inflation targets. We propose to measure overall credibility as a maximum value of the three above mentioned indicators.

Subsequently, we investigate determinants of central bank credibility by regressing the indicator of overall credibility on range of covariates including institutional variables, sustainability of government debt and inflation and exchange rate development.

We test robustness of our results by substituting LINEX loss function (based on Levieuge et al., 2015) both with and without tolerance bands for quadratic loss function. Once again, we compare results based on LINEX loss function with results of OeNB Euro Survey and ECCS and conclude that using LINEX loss function with modest tolerance bands provides results more in line with survey-based measures of credibility.

We recognize there is a drawback to the approach based on expected inflation, especially if short-term inflation expectations are used. Fluctuations in data due to reasons unrelated to credibility or due to approximation error (12-month ahead inflation expectations are usually approximated from annual data) can result in unreasonably volatile estimates of credibility. However, we show that this can be substantially mitigated by penalizing drop of inflation expectations below the target less severely by using LINEX loss function and by allowing for tolerance bands. This method produces less volatile and therefore more reliable results. Nevertheless, as argued for example by Bomfim and Rudebush (2000) and Domit et al. (2015), long-term inflation expectations tend to be better anchored to inflation target and are more informative about central bank credibility. However, even though data on expected inflation in the medium and long run are available for many developed economies (such as eurozone or United Kingdom), they are rarely collected for many emerging markets (including most countries in CEE region) for which central bank credibility is an important issue. This is what motivates us to develop and assess measures of central bank credibility derived from short-term inflation expectations.[3]

We contribute to the literature in three ways: First, by comparing different indicators derived

[2]Some of the data used in this analysis are derived from the OeNB Euro Survey which have been provided by the OeNB solely for research purposes. These data are obtained under special contractual arrangements from the OeNB and are not available from the authors.

[3]Twelve-month ahead inflation expectations were also used in Lyziak et al. (2007); Cecchetti and Krause (2002); de Mendoca (2007); de Mendoca and e Souza (2009); Bordo and Siklos (2015) and Levieuge et al. (2015). Demertzis et al. (2009) study sample of developed countries (Australia, Canada, New Zealand, Sweden, Norway, United Kingdom and eurozone) and they are therefore able to use 5-year and 10-year ahead inflation expectations.

from inflation expectations with results of OeNB Euro Survey and ECCS we demonstrate the importance of measuring central bank credibility in more sophisticated way than by simple quadratic loss function in which difference between inflation expectations and explicit inflation target enters as an argument. Second, we show that using LINEX loss function with moderate tolerance bands yields results that are less volatile and more in line with survey-based measures. Third, we provide investigation of determinants of central bank credibility showing evidence that credibility is promoted by favourable rating of government debt and that soundness of public finances is important contributor to central bank credibility mainly in countries with fixed exchange rate (result which is intuitive, but to the best of our knowledge new to the literature).

Section 2 discusses different indicators of credibility based on quadratic loss function and brings first empirical results. LINEX loss function and tolerance bands are introduced in section 3 which also includes further empirical results. Final section concludes.

2 Measuring central bank credibility

As mentioned in the introduction, credibility of the central bank is often measured using a loss function, difference between inflation target and expected inflation entering as an argument. However, despite the apparent simplicity, before choosing a particular functional form, following issues need to be addressed:

1. What is the relevant inflation target? It is necessarily the official target announced by the central bank? It is reasonable to assume that in countries struggling with high inflation central bank's priority is not necessarily to meet the target in the *very short run*. If economic agents assume that inflation will converge to the official target reasonably quickly, but the convergence will nevertheless take time, is the central bank to be considered non-credible?

2. What inflation target should be used in countries which do not use inflation targeting regime?

3. Should undershooting and overshooting be penalized in the same way by the credibility index?

4. How should tolerance bands be treated? If the central bank manages to keep inflation expectations within the tolerance bands, it is to be considered fully credible even if inflation expectations fluctuate? To appreciate the issue, assume two central banks. Bank A sets inflation target as $2\% \pm 1\%$, bank B's inflation target is 2% without a tolerance band. Inflation expectations in country A fluctuate between 1% and 3%, in country B between 1.5% and 2.5%. Is central bank A more credible?

It is not clear how these questions should be answered to provide the most informative way of turning inflation expectations data into credibility index. Different answers imply different functional forms of a loss function and therefore different estimates of credibility. In this study we construct different indicators of credibility and use collerations with OeNB Euro Survey and ECCS to support an argument that it is desirable to move beyond official explicit targets, to treat undershooting and overshooting differently and to include tolerance bands in a loss function. However, we show that when looking for determinants of central bank credibility, results are robust with respect to different choices of a loss function.

2.1 Anchoring inflation expectations to explicit targets

To begin our analysis we resolve above mention difficulties in the most drastic way. We ignore tolerance bands and undershooting-overshooting asymmetry. In inflation targeting countries (Albania, Serbia, Czech Republic, Hungary, Poland and Romania) we consider official targets to be relevant targets.

Other countries in our sample (Croatia, Macedonia and Bulgaria) fix their currency to the euro and thus do not announce official inflation targets. We assume that under relatively free capital flows, fixed exchange rate cannot be credibly held if inflation rate in domestic economy is much higher than inflation rate in the eurozone (which is one of the manifestations of so called impossible trinity, going back to Mundell, 1963). Furthermore, as argued for example in Bleaney and Francisco (2005), fixed exchange rate regimes are often used not to ensure stable exchange rate per se, but as a commitment mechanism ensuring low inflation. Because of these two reasons, we find it reasonable to assume that inflation expectations in economies with fixed exchange rates contain information about central bank credibility.

We use the ECB's target of $\bar{\pi}^{ECB} = 1.9\%$ to which we add additional percentage points $\bar{\pi}_t^{conv}$ to allow for price convergence. To take into consideration fact that price convergence tend to slow down as difference in price levels decreases, we quantify $\bar{\pi}_t^{conv}$ for each country using the following regression:

$$\Delta p_{i,t} = \beta_0 + \beta_1 p_{i,t-1} + \epsilon_t, \tag{1}$$

where $p_{i,t} = \log \frac{PPP_{i,t}^{IC}}{e_{i,t}}$ is a log relative price level in country i with respect to the euro area (i.e. inverse of the real exchange rate), $PPP_{i,t}^{IC}$ being purchasing power parity for individual consumption normalized such that for the euro area $PPP_{EA,t}^{IC} = 1$ for each period and $e_{i,t}$ being nominal exchange rate. We deliberately do not include neither additional controls, nor country-specific fixed effects in equation (1). Our intention is to make allowance for price convergence dependent solely on relative price level in a given country. When estimating equation (1), our sample consist of annual data for countries either using euro as a legal tender or fixing their

exchange rate to euro during the period from 2008 to 2017.[4] We obtain $\beta_0 = -0.0010$ (t-stat = 0.607) and $\beta_1 = -0.0086$ (t-stat = -2.23). Fitted values of $\Delta p_{i,t}$ are turned into monthly frequency using quadratic-average match method in EViews. Subsequently, they are used as allowances for price convergence $\bar{\pi}_t^{conv}$ in Croatia, Macedonia and Bulgaria.

Table 1 gives relative price levels of these countries with respect to the euro area in 2008 and 2017 as well as estimated allowance for price convergence $\bar{\pi}_{i,t}^{conv}$. Observe that since price level in Croatia is closer to the level of the euro area, the allowance for price convergence is smaller. Adding this to the ECB's inflation target of 1.9% leads to inflation target of 2.3%-2.4% in Croatia, whereas values for both Macedonia and Bulgaria are slightly higher. We use term *explicit* target in case of these countries as well mainly because ECB's explicitly announces the target. Furthermore, we would like to distinguish between targets based on officially - explicitly - announced values and targets implied from policy function of a central bank. Nevertheless, we acknowledge that allowance for price convergence used in countries with fixed exchange rate is not of explicit character.

Table 1: Allowing for price convergence in countries with fixed exchange rate

	$\frac{PPP_{i,2008}^{IC}}{e_{i,2008}}$	$\frac{PPP_{i,2017}^{IC}}{e_{i,2017}}$	$\bar{\pi}_{i,2008}^{conv}$	$\bar{\pi}_{i,2017}^{conv}$	$\bar{\pi}_{2008}^{exp}$	$\bar{\pi}_{2017}^{exp}$
Bulgaria	43.1%	46.9%	0.8%	0.7%	2.7%	2.6%
Croatia	66.6%	62.5%	0.4%	0.5%	2.3%	2.4%
Macedonia	39.1%	42.8%	0.9%	0.8%	2.8%	2.7%

Credibility indicator based on simple loss function and explicit target takes the following form[5]:

$$CRED_t^{SLF} = \frac{1}{1 + (100 \times E_t\pi_{t+12} - 100 \times \bar{\pi}_{t+12}^{exp})^2},$$

where $E_t\pi_{t+12}$ are 12-month ahead inflation expectations in time t and $\bar{\pi}_{t+12}^{exp}$ is explicit inflation target. $CRED_t^{SLF}$ takes values between 0 (non-credibility) and 1 (full credibility). If inflation expectations deviate from the target by 1 pp., the indicator takes value of $CRED_t^{SLF} = 0.5$.

[4]This includes Belgium, Bulgaria, Germany, Estonia, Ireland, Spain, France, Croatia, Italy, Luxembourg, Netherlands, Austria, Portugal, Macedonia, Finland, Montenegro, Greece, Lithuania, Latvia, Slovenia, Cyprus, Malta from 2008 to 2017 and Slovakia from 2009 to 2017. Number of observations is 2 336, data are from Eurostat. In Bulgaria, currency board fixing the lev to the German mark (DM) and later to the euro has been operative since July 1997. Croatia uses *de facto* currency board since 1994 when modern kuna was pegged initially to the DM, later to the euro. Macedonian denar has been pegged to the DM and later to the euro. Similarly, before the adoption of the euro in 2011, Estonian kroon has been pegged to the DM followed by peg to the euro. Montenegro unilaterally adopted the DM in 1996 as a *de facto* currency, the DM being substituted by the euro in 2002. Lithuanian litas and Latvian lats were pegged to the euro during the period 2002-2015 and 2004-2014 respectively, subsequently the euro was adopted. We do not automatically include countries after entering European Exchange Rate Mechanism (ERM2) since this does not guarantee stable exchange rate. For example, between November 2005 (when Slovakia entered ERM2) and December 2008 (the euro was adopted in January 2009), Slovak koruna appreciated by 22%.

[5]Quadratic loss function has been used for example by Bordo and Siklos (2015). However, instead of inflation expectations, authors use difference of *realized* inflation from the target to quantify credibility.

To obtain data on inflation expectations, we use forecast survey provided by Consensus Economics which compiles predictions of professional analysts in each country[6]. Levieuge et al. (2015) argue that professionals are more forward-looking than other segments of population, for example consumers. Naturally, alternative way of quantifying inflation expectations based on surveys among households might produce different outcomes, however, high-frequency quantitative data on household's expectations are not available for all CEE countries for sufficiently long period of time[7]. Nevertheless, we later compare results based on forecasts of analysts with results of OeNB Euro Survey conducted by Austrian National Bank in which, among others, respondents are asked to express their confidence in currency stability (see Table 8 in section 2.4). We also compare our estimates of credibility with results of European Commission's consumer survey.

Table 2: Inflation targets and realized inflation (annual averages)

	from 2008 to 2009			from 2016 to 2017		
	$\bar{\pi}$	t. band	π	$\bar{\pi}$	t. band	π
Serbia	9.0%	4.0%	7.8%	3.0%	3.0%	1.1%
Albania	3.0%	2.0%	2.3%	3.0%	0.0%	1.3%
Macedonia	3.0%	-	-0.7%	2.9%	-	-0.2%
Croatia	2.4%	-	2.2%	2.5%	-	-0.6%
Czechia	3.0%	2.0%	0.6%	2.0%	2.0%	0.7%
Poland	2.5%	2.0%	4.0%	2.5%	2.0%	-0.2%
Bulgaria	2.9%	-	2.5%	2.8%	-	-1.3%
Romania	3.5%	2.0%	5.6%	2.5%	2.0%	-1.1%
Hungary	3.0%	0.0%	4.0%	3.0%	2.0%	0.5%

*Explicit targets for these countries evuluated as 1.9% + $\bar{\pi}^{conv}$

Although Consensus Economics forecasts are produced monthly, they are provided for the current and next calendar year. To construct 12-month ahead forecasts, we follow Dovern and Fritsche (2008), Dovern et al. (2012) and Levieuge et al. (2015) and define inflation expectations in the following way:

$$E_t\pi_{t+12} = \frac{(12-m) \times E_t\pi_{current} + m \times E_t\pi_{next}}{12},$$

[6]To provide idea of representativeness of consensus forecasts we give number of individual forecasts for each country in April 2009 and September 2018 (number of forecasters who report to Consensus Economics increases in time): Serbia - 7 and 13, Albania - 7 and 13, Macedonia - 7 and 13, Croatia - 10 and 17, Czech Republic - 10 and 17, Poland - 16 and 20, Bulgaria - 11 and 15, Romania - 12 and 17, Hungary - 15 and 22.

[7]Serbian central bank started collecting monthly data on inflation expectations of households in 2015. Albania collects data on quarterly basis since 2005, consumers are asked about expected inflation having option to choose between (a) increase 0%-2%, (b) increase 2%-4%, (c) increase more than 4% and (d) decrease. National bank of Macedonia conducts surveys also with quarterly frequency and only among professional forecasters. In Croatia, inflation expectations of households are also not collected. In Czech Republic, central bank stopped interviewing households about inflation expectations in 2007. Hungary conducts surveys among households but data are not publicly available. In Poland, only qualitative data are available analogical to OeNB Euro Survey and ECCS. No data on inflation expectations are provided by central banks in Bulgaria and Romania.

where m denotes month (1 = January, 12 = December), $E_t\pi_{current}$ and $E_t\pi_{next}$ are inflation forecast for current and next year[8].

Table 3 brings average values of $CRED^{SLF}$ for years 2008 and 2017. The third column reports annual trend (computed by regressing credibility index on monthly time variable and multiplying by 12). Standard deviation of $CRED^{SLF}$ is also reported. Last column indicates percentage of time a particular country reached credibility index over 0.8 (this corresponds to keeping absolute difference between inflation expectations and explicit target down to 0.5 pp.).

Table 3: Credibility based on simple loss function and explicit inflation targets

	2008	2017	trend	st. dev.	over 0.8
Serbia	0.373	0.958	0.050***	0.337	29%
Albania	0.924	0.880	-0.020***	0.169	58%
Macedonia	0.663	0.361	-0.051***	0.291	43%
Croatia	0.241	0.491	-0.041***	0.315	45%
Czech Republic	0.362	0.965	0.013*	0.223	48%
Poland	0.427	0.770	-0.034***	0.268	27%
Bulgaria	0.038	0.463	-0.021**	0.342	32%
Romania	0.129	0.771	0.044***	0.297	17%
Hungary	0.297	0.891	0.008	0.256	17%

Note: ***, **, * denote significance on 1%, 2% and 5% level.

Several important results are worth pointing out: Our calculations suggest that there are significant differences in central bank credibility among CEE countries. When assessed by frequency of $CRED^{SLF}$ exceeding 0.8, Albania scores the best followed by Czech Republic, Croatia and Macedonia. In most countries, central bank credibility in 2017 tend to be higher than in 2008, Macedonia being the only exception. Nevertheless, in five countries, trend is negative. The most simple methodology suggests that despite results for 2008 and 2017, credibility in CEE region actually deteriorates. This is an unexpected result for countries targeting inflation as well as for countries with fixed exchange rate. Closer look on inflation expectations reveals that loss of credibility (as calculated by $CRED^{SLF}$) is due to the fact that during economic crisis inflation expectations dropped below the targeted levels. Since 2014, $E_t\pi_{t+12}$ was below $\bar{\pi}^{exp}_{t+12}$ during 85% of time (82% for inflation targeters, 86% for countries with fixed exchange rate). Simple quadratic loss function penalizes central banks for this harshly and as we will show in section 3, this results vanishes after switching to LINEX loss function and incorporating tolerance bands in the loss function.

[8]Yetman (2018) studies approximation error introduced by approximating fixed-horizon forecasts using fixed-events forecasts. The study is based on U.S. data from the Survey of Professional Forecasters collected by Federal Reserve Bank of Philadelphia. The author shows that in the U.S. data, above mentioned approximation results in error of around 0.2-0.3 pp. what corresponds to approximately 10% of actual level of inflation.

2.2 Anchoring inflation expectations to implicit targets

As mentioned earlier, explicit inflation target may not be always the relevant target for measuring central bank credibility. During the disinflation period or in the presence of adverse shocks, economic agents may expect that central bank would tolerate temporary deviations of the inflation from the target and form their inflation expectations accordingly. Furthermore, Bordo and Siklos (2015) argue that *price stability* can be considered important objective of a central bank even in countries without explicit targets. Therefore, above mentioned authors calculate *implicit inflation targets* based on central bank's reaction to different kind of shocks. Assuming that economic agents are able to 'read' central bank's policy, credibility can be measured using a deviation of inflation expectations from *implicit target*.

To estimate implicit inflation target, Bordo and Siklos (2015) assume that a central bank follows a Taylor rule (Taylor, 1993) according to which the policy rate of a central bank is given by:

$$i = \bar{\rho} + \bar{\pi} + c_\pi(\pi - \bar{\pi}) + c_y(y - \bar{y}),$$

where $\bar{\rho}$ is the natural real interest rate, $\bar{\pi}$ is inflation target, $y - \bar{y}$ is log output gap and c_π and c_y were originally calibrated to 0.5.

To estimate implicit inflation target using the Taylor rule, Bordo and Siklos adapt methodology developed by Kozicki and Tinsley (2009)[9]. Output growth term is included in the equation to correct for measurement type errors (see Woodford, 2003). Instead of current values of inflation, monetary policy is supposed to react to inflation forecasts. Since our focus is on relatively small and open economies in CEE region, we also include exchange rate depreciation in the Taylor rule assuming that central banks can choose exchange rate stability over price stability in the short run. Furthermore, the Taylor rule is assumed to produce *interest rate target* $i_t^{targeted}$ which can differ from realized interest rate. This leads to:

$$i_t^{targeted} = \bar{\rho}_t + \bar{\pi}_t + c_2(E_t\pi_{t+1} - \bar{\pi}_{t+1}) + c_3(y_t - \bar{y}_t) + c_e\Delta e_t + c_g\Delta y_t, \tag{2}$$

where c_g and c_e are parameters and e_t stands for log of exchange rate. Finally, dynamic adjustment of the policy rate is permitted. This yields a following expression for *realized* interest rate $i_t^{realized}$ (parameters β_1-β_5 will be introduced shortly):

[9] In recent paper Bordo and Siklos (2017) estimate central bank credibility for large sample of 70 countries. Data restriction prevents estimating implicit inflation target using Taylor-rule approach, therefore, authors assume that targets are influenced by their forecasts over a two-year horizon. Since central bank forecasts are not avaiable, they use Consensus Economics forecasts. However, they acknowledge that Taylor-rule approach is superior to this methodology.

$$i_t^{realized} = \beta_6 \Delta i_{t-1}^{realized} + (1-\beta_7) i_t^{targeted} + \beta_7 i_{t-1}^{realized} + \epsilon_t, \tag{3}$$

where ϵ_t is random error.

Combining (2) and (3) leads to estimable equation:

$$\begin{aligned} i_t^{realized} =& \beta_{1,t} + \beta_2 E_t \pi_{t+1} + \beta_3 (y_t - \bar{y}_t) + \beta_4 \Delta e_t + \beta_5 \Delta y_t + \beta_6 \Delta i_{t-1}^{realized} ... \\ & ... + \beta_7 (i_{t-1}^{realized} - \bar{\rho}_t) + \bar{\rho}_t + \epsilon_t \end{aligned} \tag{4}$$

Mapping parameters from (4) to (2) (analogically to Kozicki and Tinsley, 2009) allows to express *implicit* inflation target in period $t+1$ as:

$$\bar{\pi}_{t+1}^{imp} = \frac{\beta_{1,t}}{1-\beta_2-\beta_7}, \tag{5}$$

Important feature of equation (4) is that it allows for time variation of coefficient $\beta_{1,t}$ which in turn yields time-varying inflation target $\bar{\pi}_t^{imp}$. We restrict β_1 to follow random walk process[10].

It might seem as a stretch to assume that economic agents are able to infer implicit inflation target from the changes in monetary policy following Taylor-rule logic. However, recall that Consensus Economics gives inflation expectations of professional forecasters. This includes institutions like Deutsche Bank, The Vienna Institute for International Economic Studies, BNP Paribas, Moody's Analytics and so on. Secondly, observe that the only time-varying parameter in (5) is $\beta_{1,t}$. From (4) it is clear that *ceteris paribus*, $\beta_{1,t}$ tend to be higher when key interest rates of central bank are higher. In other words, *ceteris paribus*, forecasters should equate higher key interest rates with higher inflation target using the logic of Fisher effect[11]. This process is not so involved as might seem from the above exposition. Finally, we will show that credibility index based on implicit targets tend to correlate more closely with results of OeNB Euro Survey and ECCS than $CRED^{SLF}$ what gives further support to using implicit targets.

To measure central bank credibility we use deviations of inflation expectations $E_t \pi_{t+12}$ from implicit target $\bar{\pi}_{t+12}^{imp}$ and credibility indicator based on Bordo and Siklos (2015) takes the following form (note that $\bar{\pi}_{t+12}^{imp}$ denotes inflation central bank aims to achieve between time t and $t+12$):

[10] Kozicki and Tinsley (2009) also estimate version of equation (4) in which all other β's are time-varying and follow AR(1) process.

[11] According to Fisher effect, in the long run, nominal interest rates tend to equal sum of (i) natural real interest rate determined by real factors (such as propensity to save or marginal product of capital) and (ii) rate of inflation.

$$CRED_t^{BS} = \frac{1}{1 + (100 \times E_t\pi_{t+12} - 100 \times \bar{\pi}_{t+12}^{imp})^2}$$

Again, values of $CRED^{BS}$ range between 0 and 1, $CRED^{BS} = 1$ signalling full credibility.

We estimate equation (4) using monthly data on CPI, GDP and key policy rate in each country during the period 2004M1-2017M12 (GDP was turned into monthly frequency using quadratic-sum match method in EViews, in case of Croatia, sample is reduced to 2008M1-2017M12 due to data availability[12]). Following Bordo and Siklos (2015), potential output was estimated using Hodrick-Prescott filter and inflation forecasts were generated using AR(1) model. Key policy rate in countries conducting standard operations of monetary policy was identified according to key policy instrument[13]. However, Croatian National Bank did not use open market operations between October 2009 and October 2016 and conducted monetary policy using solely foreign exchange interventions (Croatian monetary regimes is often referred to as *de facto* currency board). Moreover, since Bulgaria implemented official currency board in 1997, role of central bank is even more limited. Estimating implicit inflation target using Taylor-rule approach in these countries is less straightforward due to absence of key policy rate. We bypass this obstacle using day-to-day money market interest rates in these countries[14]. Natural real interest rate $\bar{\rho}_t$ was quantified as a trend component of $i_t - E_t\pi_{t+12}$ obtained by Hodrick-Prescott filter. Estimation was done using maximum likelihood method.

Table 4 shows estimates of credibility indicator based on Bordo and Siklos (2015) analogical to Table 3. Moreover, two additional information are provided in 7th and 8th column - minimal and maximal value of implicit targets $E_t\bar{\pi}_{t+12}^{imp}$. It is useful to note that in most countries implicit targets are close to official targets. Serbia and Bulgaria are two exceptions.

Comparing Tables 3 and 4 reveals that using implicit targets in the calculation of central bank credibility leads to several differences, most important being identification of positive trend in most countries even though countries are not necessarily assessed as more credible. Credibility

[12]Alternatively, it is possible to use industrial production instead of GDP. This variable has an advantage of being avialable in monthly frequency for all countries except Albania. However, with the exception of Bulgaria, substituting industrial production for GDP does not lead to singificantly different estimates of implicit inflation target. In Bulgaria, implicit inflation target based on industrial production is lower than estimate based on GDP.

[13]For Albania, Czech Republic, Poland and Romania, repo rate was used. For Hungary and Macedonia, interest rate on bills issued by respective central bank were used. For Serbia, during the period 2004M1-2005M12 interest rates on central bank bills were used, since 2007M1 repo rate was used.

[14]By using actual money market rates in place of policy rate we implicitly assume that central banks in Croatia and Bulgaria consciously chose not to interfere with market interest rates. Realized interest rates therefore coincides with desired rate. Moreover, federal funds rate which is a key policy rate in the United States (and therefore commonly stands as a explained variable in estimations of Taylor rules of different kinds) is also a money market rate, even though influenced by open market operations by the Federal Reserve System (at least before moving to the floor system). Bordo and Siklos (2014) argue that since theoretical models can produce equivalence results, it is possible to think about monetary decisions as determined by Tylor-rule-like thinking even though different monetary regime is in place. We also compared repo rates of Croatian National Bank with money market rates during the period when repo-purchases were conducted. Correlation between the two rates is 0.855.

Table 4: Credibility based on simple loss function and implicit inflation targets

	2008	2017	trend	st. dev.	over 0.8	min($E\bar{\pi}$)	max($E\bar{\pi}$)
Serbia	0.123	0.183	0.023**	0.300	13%	0.4%	17.7%
Albania	0.955	0.371	-0.055***	0.211	23%	0.7%	3.4%
Macedonia, FYR	0.739	0.453	-0.005	0.267	23%	-0.2%	6.4%
Croatia	0.569	0.597	0.053***	0.319	28%	-2.2%	13.4%
Czech Republic	0.553	0.659	0.009	0.181	57%	0.6%	4.4%
Poland	0.419	0.546	0.053***	0.281	41%	0.2%	4.6%
Bulgaria	0.098	0.023	0.002	0.122	0%	-5.7%	6.0%
Romania	0.031	0.387	0.078***	0.297	11%	-0.3%	2.0%
Hungary	0.492	0.556	0.001	0.278	35%	-0.1%	10.5%

Note: ***, **, * denote significance on 1%, 2% and 5% level.

of Bank of Albania is rated significantly lower when implicit target is used. This is the result of the fact that responses of Albanian central bank to shocks suggest implicit target about 1% but inflation expectations are much better anchored to the official three-percent target. This is a general pattern, $CRED^{BS}$ tend to be lower than $CRED^{SLF}$ in low-inflation environment when central bank does not seem to be willing to be more expansionary (i.e. implicit target is below official target), but inflation expectations stay anchored to the official target. We argue that in this case central bank should still be considered credible. In section 2.4 we construct indicator of overall credibility which assess central bank as credible if it is credible according to at least one partial indicator.

2.3 More lenient approach to disinflating countries

The third method of measurement of central bank credibility is based on Bomfim and Rudebush (2000). In this approach, inflation expectations are assumed to be weighted average of inflation target and past inflation, in particular:

$$E_t\pi_{t+12} = \lambda_t\bar{\pi}^{exp}_{t+12} + (1-\lambda_t)\tilde{\pi}_{t-q},$$

where λ_t is a weight put on inflation target by economic agents when estimating future inflation and therefore it can be used as a indicator of central bank credibility. Variable $\tilde{\pi}_{t-q}$ is average rate of inflation over previous q months. Parameter λ_t can also be interpreted as speed of convergence of inflation expectations to a target, $\lambda_t = 1$ signalizing instant convergence.

Value of parameter λ_t can be quantified in several ways, most straightforward being evaluation of fraction $\frac{E_t\pi_{t+12}-\tilde{\pi}_{t-q}}{\bar{\pi}^{exp}_{t+12}-\tilde{\pi}_{t-q}}$ for each period separately. This creates an obvious problem that if an average of past inflation $\tilde{\pi}_{t-q}$ approaches future inflation target $\bar{\pi}^{exp}_{t+12}$, the denominator

approaches zero. If inflation target is constant, this amounts to a desirable situation where a central bank has on average managed to meet the target over the past q periods. Because of that, we choose to estimate the following equation with time-varying parameter β_t:

$$E_t\pi_{t+12} - \tilde{\pi}_{t-q} = \beta_t(\bar{\pi}^{exp}_{t+12} - \tilde{\pi}_{t-q}) + \epsilon_t, \tag{6}$$

in which we allow β_t to follow random walk process. Our sample consists of 9 CEE countries during the period 2008M1-2017M12. We use $q = 12$. Explicit targets for Macedonia, Croatia and Bulgaria were chosen as previously (ECB's target plus allowance for price convergence $\bar{\pi}^{conv}_{i,t}$). Subsequently, we define the indicator of credibility based on Bomfim and Rudebush (2000) in the following way:

$$CRED^{BR}_t = \begin{cases} 0, & \beta_t < 0 \\ \beta_t, & 0 \leq \beta_t \leq 1 \\ 1, & 1 < \beta_t \end{cases}$$

One aspect in which $CRED^{BR}_t$ differs from previous indicators of credibility is how past inflation is taken into account. Assume two countries A and B with identical explicit and implicit inflation targets $\bar{\pi}^A_t = \bar{\pi}^B_t = 2\%$ and identical inflation expectations $E_t\pi^A_{t+12} = E_t\pi^B_{t+12} = 3\%$. The countries will achieve the same value of $CRED^{SLF}_t = CRED^{BS}_t = 0.5$. However, since $CRED^{BR}_t$ is a measure of speed of convergence of inflation expectations to the target, it also depends on *past inflation*. Assume history of relatively high inflation for country A and of low inflation for country B. In this case $CRED^{BR}_{t,A}$ will be higher than $CRED^{BR}_{t,B}$. Country A is 'rewarded' for being able to keep inflation expectations low despite inflationary history.

There is also another reason why countries with low and stable inflation expectations are penalized by $CRED^{BR}$. Inflation expectations as provided by Consensus Economics are rounded to the nearest tenth. Therefore, measurement error due to rounding is relative high if inflation expectations follow inflation target closely and with little variance. This increases attenuation bias and pushes estimates of β closer to zero.

Estimation results are reported in Table 5. One of the most notable results is relatively low value of $CRED^{BR}$ in Albania even though Albania is scoring well when explicit target is used with simple loss function. As mentioned, this is a natural result for a country in which realized inflation, expected inflation and inflation target all move very closely around a single value. Since β in equation (6) is a measure of *relative distance* between past inflation, inflation target and inflation expectations, in can be low even if absolute distance between inflation target and

inflation expectations is minuscule.[15]

Table 5: Credibility based on Bomfim and Rudebush (2000)

	2008	2017	trend	st. dev.	over 0.8
Serbia	0.579	0.930	0.034***	0.331	29%
Albania	0.514	0.656	0.019***	0.221	3%
Macedonia, FYR	0.661	0.464	-0.032***	0.245	31%
Croatia	0.162	0.484	-0.026**	0.311	35%
Czech Republic	0.283	0.970	0.003	0.337	43%
Poland	0.058	0.655	0.003	0.301	23%
Bulgaria	0.303	0.612	0.003	0.283	27%
Romania	0.208	0.862	0.035***	0.332	18%
Hungary	0.486	0.745	0.014	0.280	13%

Note: ***, **, * denote significance on 1%, 2% and 5% level.

2.4 Comparing and combining different indicators of credibility

It is useful to compare the three notions of credibility corresponding to the three different indicators used above:

Simple loss function and explicit targets: The indicator $CRED^{SLF}$ is based on assumption that the official target is the only thing that matters, each deviation is considered to be a loss of credibility. *Credibility measured in this way is likely to be high in countries which have already managed to bring inflation to low levels.* However, at a given point in time, central banks in countries with high inflation will most likely be considered non-credible regardless of whether inflation expectations have been converging to the target. Assume a country with 3% inflation target which already managed to decrease inflation expectations from 20% to 7%; central bank will not be considered credible yet despite very good record and high probability that 3% target will be reached in near future.

Simple loss function and implicit targets: The indicator $CRED^{BS}$ is a more benevolent way of quantifying central bank credibility. Even central banks with inflation exceeding the target can be considered credible provided that inflation expectations are in line with the target implied by policy rate.

Method based on Bomfim and Rudebush (2000): Measuring central bank credibility by $CRED^{BR}$ is the most benevolent approach for countries which fight high inflation. A central bank is considered reasonably credible even if inflation expectations are several

[15]We have compared estimates of β_t based on equation (6) with simple estimate $\frac{E_t\pi_{t+12}-\tilde{\pi}_{t-q}}{\bar{\pi}^{exp}_{t+12}-\tilde{\pi}_{t-q}}$. We have computed correlations of two estimates for each country *excluding* observations where $|\bar{\pi}^{exp}_{t+12} - \tilde{\pi}_{t-q}| < 0.5\%$. Average correlation between two indices is 0.733. In all countries except Poland correlation is higher than 0.7.

percentage points higher than the inflation target provided that *they are sufficiently below past inflation*. Above mentioned illustrative country with 3% inflation target and inflation expectations driven from 20% to 7% will most likely score relatively well (depending on how quickly inflation expectations decrease). Unlike previous two indices, $CRED^{BR}$ explicitly takes past inflation into consideration. However, as already mentioned, in countries with both inflation and inflation expectations close to the target, estimated value of β in equation (6) can be close to zero. Therefore, $CRED^{BR}$ is not suitable for measuring central bank credibility in countries with successful central banks.

It follows that indicators $CRED^{SLF}$, $CRED^{BS}$ and $CRED^{BR}$ do not measure a single phenomenon, instead, they quantify *different aspects* of central bank credibility (correlation between the three indicators can be found in Table 6, we report simple correlation in the panel of 9 countries spanning 2008M1-2017M12 not controlling for individual or time-specific effects).

Table 6: Correlation between different indicators of credibility

	SLF	*BS*	*BR*	*MAX*
SLF	1.000			
BS	0.138	1.000		
BR	0.621	-0.029	1.000	
MAX	0.720	0.482	0.615	1.000

To include different aspects of credibility in a single indicator, we define *overall* credibility $CRED^{MAX}$ (correlations with other indicators are also reported in Table 6):

$$CRED_t^{MAX} = \max(CRED_t^{SLF}, CRED_t^{BS}, CRED_t^{BR})$$

Our primary motivation for using *maximum* of the three indicators instead of weighted average is the fact that different aspects of credibility tend to be *substitutes*, not complements. Since Albania manages to keep inflation expectations anchored to the official target, it cannot be considered credible using Bomfim-Rudebush methodology. Serbia can be considered credible if we take into consideration central bank's relative success in driving down inflation expectations; this produces high values of $CRED^{BR}$, but $CRED^{SLF}$ is low.

Another way of thinking about $CRED^{MAX}$ is as of *or*-operator. Central bank is credible if:

1. Inflation expectations meet official target, or...
2. ...inflation expectations meet implicit target (this allows central banks which temporarily allow inflation to deviate from official target to be considered credible), or...

3. ...inflation expectations converge quickly enough to official target (this allows to assess as credible central banks which are successful in fighting inflation but have not yet achieved to bring down rate of growth of prices to the inflation target).

Using *maximum* operator is in line with our concept of credibility outlined in the introduction. Central bank is credible if economic agents believe it will do what it says it will do, but this does not mean that inflation expectations have to meet the inflation target all the time.

Table 7 gives indicator of overall central bank credibility in a structure analogous to tables given previously. Furthermore, last three columns report *structure* of credibility, i.e. fraction of time overall credibility was driven by $CRED^{SLF}$, $CRED^{BS}$ and $CRED^{BR}$.

Table 7: Overall credibility

						credibility type		
	2008	2017	trend	st. dev.	over 0.8	*SLF*	*BS*	*BR*
Serbia	0.746	0.976	0.019**	0.282	48%	37%	20%	43%
Albania	0.984	0.880	-0.026***	0.158	64%	74%	24%	2%
Macedonia, FYR	0.888	0.501	-0.040***	0.196	52%	28%	18%	56%
Croatia	0.543	0.701	-0.006	0.216	68%	30%	42%	30%
Czech Republic	0.618	0.991	0.013**	0.158	79%	22%	43%	35%
Poland	0.493	0.822	0.018***	0.191	65%	41%	45%	15%
Bulgaria	0.342	0.614	-0.012	0.234	37%	25%	5%	70%
Romania	0.255	0.892	0.065***	0.287	33%	38%	19%	44%
Hungary	0.683	0.891	-0.002	0.189	48%	18%	56%	27%

Note: ***, **, * denote significance on 1%, 2% and 5% level.

However, note that if we are interested in ranking countries based on credibility, much like in Table 3, Czech Republic, Croatia, Albania and Macedonia are the most credible ones. Nevertheless, combining different aspect of credibility reveals Czech National Bank as the most credible in the region.

Combining three different indicators of credibility still leads to rather surprising result that credibility in Albania and Macedonia deteriorates (trend in Hungary and Bulgaria is also negative, but not statistically significant). As explained in section 2.1, this is due to the fact that during the crisis, inflation expectations tended to be below inflation targets. However, this result will vanish after switching to LINEX loss function and after incorporating tolerance bands into the loss function.

Figures 1 and 2 give monthly development of overall credibility in each country. Note relatively low credibility of Bulgaria, Romania and Hungary during the whole period as well as sharp drop in credibility in Serbia between 2011 a 2014 when inflation expectations reached over 10% despite the fact that National Bank of Serbia targeted inflation in the range 2.5%-5.5% (on the other hand, during 2009 inflation expectations reached 7% but these was within than-targeted

interval and Serbia was successfully desinflating; therefore our indicator do not penalize Serbian central bank during this period).

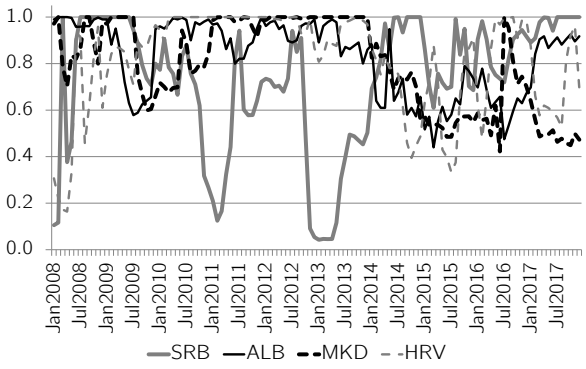

Figure 1: Overall credibility: Part I.

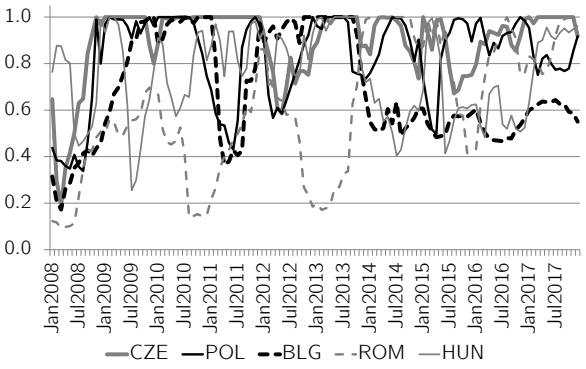

Figure 2: Overall credibility: Part II.

Also, note pronounced fluctuations in credibility $CRED^{MAX}$ in most countries. As explained in the introduction, this can be due to changes in expected inflation unrelated to credibility, as well as to approximation error introduced by calculating fixed-horizon forecasts from fixed-event forecasts as explained by Yetman (2018). Therefore, it is more informative to look at trends and on the average values of $CRED^{MAX}$ over longer periods of time (as given in Tables 3, 4, 5 and 7). We will show in section 3 that if undershooting of inflation target is penalized less severely and tolerance bands are included in the loss function, estimates of credibility are less volatile.

To establish importance of going beyond simple difference between explicit targets and inflation expectations, we compare four indicators of credibility with results of OeNB Euro Survey conducted by National Bank of Austria in CEE countries (OeNB, 2018). In particular, we compute correlations of four credibility indicators with average extent of agreement with the following statements (1-3) and average responses to the following questions (4-7): [16]

1. Over the next year, prices will strongly increase in my country
2. Currently, the local currency is a very stable and trustworthy currency.
3. Over the next five years, the local currency will be very stable and trustworthy.

[16]Extent of agreement with statement 1 is available for the period 2009-2014 and year 2015. Extents of agreement with statements 2 and 3 are available for period 2007-2016 and 2007-2017 respectively. Data are originally coded on the scale from 1 (strongly agree) to 6 (strongly disagree). Responses to questions 4-7 are available only for period 2011-2013. Responses to question 4 are originally coded on the scale from 1 (will increase more rapidly) to 5 (will fall); responses to question 5 and 7 on the scale from 1 (very predictable) to 4 (very unpredictable); responses to question 6 on the scale from 1 (will lose value) to 3 (will gain value).

4. By comparison with the past 12 months, how do you expect that prices in your country will develop in the next 12 months?

5. How predictable do you think the development of prices over this period is?

6. How do you think will the exchange rate of the local currency against the euro develop over the next five years?

7. How predictable do you think the exchange rate of the local currency vis-a-vis the euro over the next 12 months is?

Question 4 is also asked in European Commission's consumer survey, therefore, we included this survey in the comparison as well.

Answers were normalized on the scale from 0 to 1, higher value indicating higher credibility[17]. Unlike our indicators which assess relatively short-run credibility (since one-year ahead expectations are used) based on expectations of professional analysts, OeNB Euro Survey provides measure of central bank credibility as perceived by households not only in the short run but also in the medium run.

Table 8: Correlations between indicators of credibility and results of OeNB Euro Survey and ECCS

	SLF	*BS*	*BR*	*MAX*
1. Prices will strongly increase	0.119	0.556	0.031	0.229
2. Currency is currently stable and trustworthy	0.410	0.368	0.261	0.401
3. Currency will be stable and trustworthy over the next 5 years	0.223	0.260	0.189	0.220
4a. Prices over the next year compared to prev. year	-0.043	0.301	0.064	0.178
4b. Prices over the next year compared to prev. year (ECCS)	0.102	0.284	0.025	0.172
5. Predictability of prices	0.309	0.240	0.141	0.202
6. Exchange rate over the next year compared to prev. year	0.576	0.369	0.374	0.534
7. Predictability of the exchange rate	0.120	-0.237	-0.032	0.006

The most important result of this simple exercise is that in the case of statement 1 and question 4, there is a higher correlation between OeNB Euro Survey results and overall credibility $CRED^{MAX}$ than between survey results and measure computed using explicit targets $CRED^{SLF}$. This is caused by relatively high correlation with indicator based on *implicit* target, $CRED^{BS}$. This is not surprising. As argued above, one of the shortcomings of approach based on explicit targets is the fact that economic agents understand that short-run deviations from the target will be tolerated by the central bank. Therefore, such deviations will not damage central bank's credibility.

[17]For example, if a respondent answers 'strongly agree' (originally coded as 1) to question 1, this is interpreted as zero credibility. Answer 'strongly disagree' (originally coded as 6) is interpreted as full credibility. On the other hand, if respondent answers 'strongly agree' to question 3, this is considered full credibility, whereas 'strongly disagree' signifies zero credibility.

2.5 Determinants of central bank credibility

To investigate determinants of central bank credibility, we regress $CRED^{MAX}$ on range of covariates including institutional variables, sustainability of government debt and inflation and exchange range development[18]. To decide between pooled OLS estimation, random-effect model and fixed-effect model, we first performed Breusch-Pagan test. We rejected H0 (assumption of no constant effects) neither in full data sample, nor in sub-samples (see Table 9). In reality, random-effect model and pooled OLS yield same point estimates and estimated variance of random effects is zero in all samples. Therefore, we proceed with pooled OLS approach.

Estimation results obtained using full sample of data are given in column 1 of Table 9. Since it is possible than in high-inflation environment central bank credibility is driven by different determinants than in low-inflation environment, we also report estimation results obtained on three sub-samples: sample including observations when inflation exceeded inflation target by at least 1 pp. (column no. 2), sample including observations when absolute distance of realized inflation from the target was less or equal to 1 pp. (column no. 3) and sample consisting of observations when inflation was at least 1 pp. lower than explicit target (column no. 4). Furthermore, it is also possible that different determinants are important for central bank credibility in economies targeting inflation than in economies with fixed exchange rate. Therefore, estimation results based on sub-sample of inflation targeters (column no. 5) and sub-sample countries with fixed exchange rate (column no. 6) are also reported.

Several results are worth pointing out, some of them rather surprising:

- Fixed exchange rate or the exchange rate target is connected with higher levels of credibility.
- Our estimation suggests that EU-member countries have *ceteris paribus* lower central bank credibility than non-members. On the other hand, in high-inflation sample we detect positive link between rule of law and central bank credibility.

[18]We include (1) dummy variable for countries with fixed exchange rates, this includes Czech Republic during the period of November 2013 - April 2017 when exchange rate target was in place; (2) dummy variable for the EU-membership; (3) index of rule of law from World Governance Indicators (value for 2017 was obtained by extrapolation based on period 2014-2016); (4) index of central bank independence (CBI) from Bodea and Hicks (2015) (indices are provided until 2014 or, occasionally, 2015; since index is based on Cukierman et al. (1992) methodology, we checked legislative changes in all CEE countries and did not find changes wich would lead to need to adjust CBI index; therefore, we use values reported for 2014 or 2015 for subsequent periods as well); (5) GDP per capita in international 2011 dollars from World Development Indicators (WDI); (6) GDP growth rate (from Eurostat and national statistical offices); (7) Standard & Poor's (S&P) rating of sovereign bonds (we turn S&P into numerical values according to following scheme: AAA = 10; AA+ = 9.33 and each further downgrading is penalized by loss of 0.33 points, i.e. AA = 9.00, AA- = 8.67, ..., C- = 1.67); (8,9) ratio of government debt to GDP and its annual change (from WDI), since information on debt in period t are only avaiable in period $t+1$, we use one-period lag; (10) absolute difference between rate of inflation and explicit inflation target (from national central banks and Eurostat); (11) average inflation rate over the past 5 years; (12) standard deviation of inflation rate over last 12 months (according to Eurostat); (13) annual change of log of exchange rate (according to Eurostat); (14) standard deviation of rate of depreciation over last 12 months (according to Eurostat). Data from WDI, WGI and Bodea and Hicks (2015) enter regression in yearly frequency.

Table 9: Determinants of central bank credibility (pooled OLS)

	(1)	(2)	(3)	(4)	(5)	(6)
Sample:	full	high π	π in target	low π	IT	non-IT
Fixed e. r.	0.047	0.312***	0.130***	-0.069	-0.111	-
	(0.026)	0.041)	(0.030)	(0.041)	(0.127)	
EU	-0.128**	-0.338***	-0.259**	-0.129**	-0.414*	0.029
	(0.042)	(0.076)	(0.106)	(0.042)	(0.165)	(0.224)
Rule of law	-0.020	0.171***	-0.110	-0.077	0.032	-0.244
	(0.064)	(0.040)	(0.103)	(0.080)	(0.076)	(0.133)
CBI	0.058	-0.797**	-0.159	0.339	0.074	0.398
	(0.165)	(0.268)	(0.358)	(0.191)	(0.524)	(0.339)
GDP p. c.	-0.087	-0.058	0.560**	0.192	0.367	-0.690
	(0.135)	(0.130)	(0.199)	(0.166)	(0.200)	(0.452)
GDP growth rate	-0.576	0.660	1.363	-0.403	-0.037	-0.687
	(0.446)	(1.002)	(1.257)	(0.733)	(0.522)	(0.811)
S&P rating	0.119*	-0.014	0.024	0.103***	0.022	0.303
	(0.052)	(0.035)	(0.054)	(0.021)	(0.024)	(0.106)
Gov. debt (% GDP; 1-year lag)	0.220*	0.337***	0.320**	0.047	-0.060	0.637
	(0.106)	(0.071)	(0.126)	(0.117)	(0.113)	(0.260)
Δ_{12} G. debt (1-year lag)	-0.570*	-0.450	-0.879	-0.102	-0.592	-1.848**
	(0.278)	(0.656)	(0.540)	(0.508)	(0.314)	(0.270)
$\lvert\pi - \bar{\pi}\rvert$	-6.261***	-2.380**	-20.211**	-3.168	-6.859***	-5.044*
	(0.582)	(0.777)	(7.616)	(2.804)	(0.799)	(1.209)
Average π over previous 5 years	-0.889	-0.084	1.225	1.598	-1.984	-4.659**
	(1.093)	(0.987)	(1.631)	(0.980)	(1.509)	(0.517)
σ_π	1.556	-9.975**	-5.031	-3.101	-0.795	6.177
	(3.635)	(3.584)	(5.834)	(3.395)	(4.012)	(5.291)
$\Delta_{12}e$	0.277	0.198	0.691	-0.975	0.536**	0.709
	(0.231)	(0.376)	(0.630)	(0.723)	(0.166)	(1.520)
$\sigma_{\Delta_{12}e}$	-0.073	1.236	0.146	-1.564	0.884	6.447
	(0.721)	(0.990)	(0.714)	(1.613)	(0.992)	(4.512)
Time dummies	yes	yes	yes	yes	yes	yes
No. of obs.	1080	348	153	579	720	360
R^2	0.37	0.71	0.65	0.48	0.49	0.72
Breusch-Pagan test (p-value)	1.000	1.000	1.000	1.000	1.000	1.000

Note: Clustered standard errors in parentheses; ***, **, * denote significance on 1%, 2% and 5% level.

- Even though coefficient corresponding to central bank independance is in most cases positive, it is non statistically significant. Only in high-inflation sub-sample it occurs with statistical significance and in this case it is negative. Nevertheless, closer look on *de jure* CBI data based on Bodea and Hicks (2015) suggests that they measure true independence with considerable measurement error. As already suggested by Cukierman et al. (1992), there is a significant difference between legal and actual independence.[19] Recently, this might have been recently the case for example in Hungary. [20]

[19] This is why Cukierman et al. (1992) supplement they analysis of central bank legislation with analysis of rate of turnover of central bank governors as well as with survey-based measures.

[20] According to Bodea and Hicks (2015), CBI in Hungary is stable and higher than in Czech Republic. However, in 2011, attempt to increase number of political appointees participating in decisions on monetary policy in Hungary has been described by the head of the central bank, Andras Simor, as an *'almost total takeover'* (Kulish, 2011) and written protest by Mario Draghi was issued. In December 2011, new legislation was passed (criticized by ECB, 2011), but it is not reflected in Bodea-Hicks data. Hungarian central bank has been subject to ECB's criticism on numerous occasions, for example, in 2016 real estate investment projects, programmes to promote financial literacy, and the purchase of Hungarian artworks and cultural property was described by ECB is *'being*

- We do not find negative effect of the *level* of government debt on the credibility of the central bank, surprisingly, the coefficients have positive sign. This is the result which has been also obtained by Bordo and Siklos (2014, 2015). However, we also find that slow growth of debt-to-GDP ratio as well as its low riskiness (as measured by Standard & Poor's rating) does promote credibility. The effect is significant not only in statistical sense, but also economically. Moving from S&P rating of CC (rating = 3.00) to BB (rating = 6.00) or from BB to AA (rating = 9.00) increases credibility by 0.357 points which is analogous to decreasing gap between realized and targeted inflation by 5.7 pp. ($3 \times 0.119 \approx -0.057 \times -6.261$).

- We find evidence that ability of a central bank to meet its target, low inflation in general and non-volatile inflation are all conductive to higher central bank credibility. Keeping inflation low is especially important for countries with fixed exchange rate (see statistically significant coefficient corresponding to average inflation over previous 5 years).

- We found positive link between currency depreciation and central bank credibility for inflation targeters. This effect disappears once we deal with overshooting-undershooting asymmetry (see next section). Nevertheless, it is important to note that there is no reason to assume that stable exchange rate should automatically lead to more credible monetary regime. Bordo and Siklos (2014) suggest that if low volatility of exchange rate is a result of central bank's interventions on foreign exchange market, this can suggest low commitment to inflation target and can *reduce* credibility.

One of the often mentioned determinants of central bank credibility not included in the estimates in Table 9 is the transparency of a central bank[21]. The earliest quantifications of central bank transparency were provided by Fry et al. (2000). The most recent update produced by Dincer and Eichengreen (2014) covers only period 1998-2010 and does not include National Bank of Serbia (see Table 10). Therefore, we did not include this factor as explanatory variable in main regressions. However, we have reestimated regressions (1)-(5) with Dincer and Eichengreen's measure of transparency included (this covariate cannot be included in regression (6) due to multicollinearity). This requires excluding Serbia from the sample and reducing sample to period 2008-2010[22]. Coefficient corresponding to transparency has positive sign in all regressions, however, it is not statistically significant. However, it gains significance once tolerance bands

potentially in conflict with the monetary financing prohibition, to the extent that they could be viewed as the MNB taking over state tasks or otherwise conferring financial benefits on the state' (ECB, 2016). On the other end of the spectrum, the independence of Czech National Bank is rarely questioned in public discourse but Bodea and Hicks (2015) rate Czech central bank as the least independent in our sample. Similar unfavourable assessment of Czech National Bank (with respect to Hungary) was produced by Dincer and Eichengreen (2014) whose estimates of CBI cover period from 1998 to 2010. According to these authors, in 2010, CBI_{CZE}=0.64, whereas $\text{CBI}_{HUN} = 0.77$. As mentioned below, since Dincer and Eichengreen (2014) do not cover Serbia and estimates are available only until 2010, we decided to proceed with Bodea-Hicks data.

[21] Bordo and Siklos (2017) also find VIX (volatility index published by Chicago Board Options Exchange) to be a robust determinant of central bank credibility. It our estimation changes in market volatility are captured by time dummies.

[22] Results are available on request.

are used in construction of index of central bank credibility (see next section). This provides some support to the hypothesis that transparency promotes credibility.

Table 10: Central bank transparency on scale 0-15 by Dincer and Eichengreen (2014) during 2008-2010 (no time variation)

Albania	8.0	Poland	9.0
Macedonia	7.0	Bulgaria	5.5
Croatia	2.5	Romania	7.5
Czechia	12.0	Hungary	9.0

Estimations reported in Table 9 were also conducted with $CRED^{SLF}$, $CRED^{BS}$ and $CRED^{BR}$ as dependant variables. Results are in line with estimations where overall credibility $CRED^{MAX}$ is regressed on credibility determinants[23].

We have also tested the hypothesis that short run deviations from the inflation target should lead to loss of credibility mostly in cases of central banks which are not considered credible. To test this, we have included interaction term $|\pi - \bar{\pi}| \times (1 - CRED^{MAX}_{t-1})$ in the regression. We find that coefficient corresponding to the interaction term is negative and statistically significant, i.e. that less credible central banks are more affected by missing the target. Other results remain unchanged[24].

3 Dealing with undershooting-overshooting asymmetry and tolerance bands

Calculation of $CRED^{SLF}$ and $CRED^{BS}$ was based on the quadratic loss function $f^Q(x) = x^2$ where $x = (100 \times E\pi_{t+1} - 100 \times \bar{\pi}_{t+1})$. As mentioned in the introduction, this entails two important assumptions: (1) to undershoot one's inflation target is as bad as to overshoot and (2) a central bank is not fully credible unless inflation expectations are equal to the target.

Instead of quadratic loss function, Levieuge et al. (2015) propose using LINEX loss function which combines linear and exponential terms. In particular, loss function takes form $f^{LINEX}(x) = \exp(x) - x - 1$. Observe that both f^Q and f^{LINEX} achieve minimum for $x = 0$. However, whereas quadratic loss function is symetric ($f^Q(x) = f^Q(-x)$) LINEX loss function is not and for positive x, $f^{LINEX}(x) < f^{LINEX}(-x)$. It follows that LINEX loss function penalizes a central bank more severely for letting inflation expectations increase above the target and is more lenient if inflation expectations fall below.

Furthermore, Levieuge et al. (2015) adapt loss function for the existence of tolerance bands. If inflation expectations are kept within a tolerance band, $x = 0$. Otherwise, x is equal to

[23]Results are available on request.
[24]Results are available on request.

the difference between inflation expectations and the upper (in case of overshooting) or the lower bound (in case of undershooting). This leads to the following formula for $CRED^{SLF}$ and $CRED^{BS}$:

$$CRED_t^{SLF/BS} = \begin{cases} \frac{1}{\exp\left[100\times(E_t\pi_{t+1}-\bar{\pi}_{t+1}^{min})\right]-100\times(E_t\pi_{t+1}-\bar{\pi}_{t+1}^{min})}, & E_t\pi_{t+1} < \bar{\pi}_{t+1}^{min} \\ 1, & E_t\pi_{t+1} \in [\bar{\pi}_{t+1}^{min}, \bar{\pi}_{t+1}^{max}] \\ \frac{1}{\exp\left[100\times(E_t\pi_{t+1}-\bar{\pi}_{t+1}^{max})\right]-100\times(E_t\pi_{t+1}-\bar{\pi}_{t+1}^{max})}, & E_t\pi_{t+1} > \bar{\pi}_{t+1}^{max} \end{cases} \quad (7)$$

However, using official tolerance bands leads to the following problem: If a central bank decides to increase a width of the tolerance interval, it automatically leads to higher value of calculated credibility. On the other hand, reducing or eliminating tolerance bands (what is usually a signal that central bank is confident in its ability to control the inflation) decreases value of credibility indicator. Consider two countries - Hungary and Albania. In October 2017, both countries targeted inflation at 3% and inflation expectations in both countries were at the level of 2.7%. However, whereas Hungary targeted 3%-inflation with 2%-tolerance band (i.e. rate of inflation 2%-4%), no tolerance band was used in Albania. If official tolerance bands were used to assess central bank credibility, Hungary will rank higher than Albania. One year earlier, in October 2016, inflation expectations in Albania and Hungary were 2.3% and 1.7% respectively. Once again, using measures based on official tolerance bands would assess Hungarian central bank as more credible. Also, consider elimination of tolerance bands in Albania in 2015. This would be assessed as a drop in credibility. On the other hand, in 2009, Serbia changed targeted interval from 3%-6% to 8%-12% what would be reflected in higher value of credibility indicator, but this is hardly a policy conducted when central bank is successful in anchoring inflation expectations. Official tolerance bands cannot be used to assess credibility because they vary in time and across countries.

Because of that, we calculate credibility indicators based on formula (7) for three different versions of tolerance bands b. We assume $b = 0\%$, $b = 1\%$ and $b = 2\%$ and calculate upper and lower bounds as $\bar{\pi}_t^{min} = \bar{\pi}_t - b/2$ and $\bar{\pi}_t^{max} = \bar{\pi}_t + b/2$.

Figure 3 depicts credibility indices evaluated using different loss functions assuming that explicit (or implicit) inflation target is equal to 2%.

Of course, other loss functions are possible. Cecchetti and Krause (2002) use loss function $f(x) = 1$ for $x < 0$, $f(x) = 0$ for $x > 20$ and $f(x) = 1 - 1/(20 - x)$ otherwise (where $x = 100 \times (E_t\pi_{t+1} - \bar{\pi}_{t+1})$). Loss function based on Cecchetti and Krause (2002) with tolerance bands have been used by de Mendoca and e Souza (2009). Bordo and Siklos (2017) combine linear and quadratic approach, $f(x) = |x|$ for $|x| \leq 1$ and $f(x) = x^2$ otherwise.

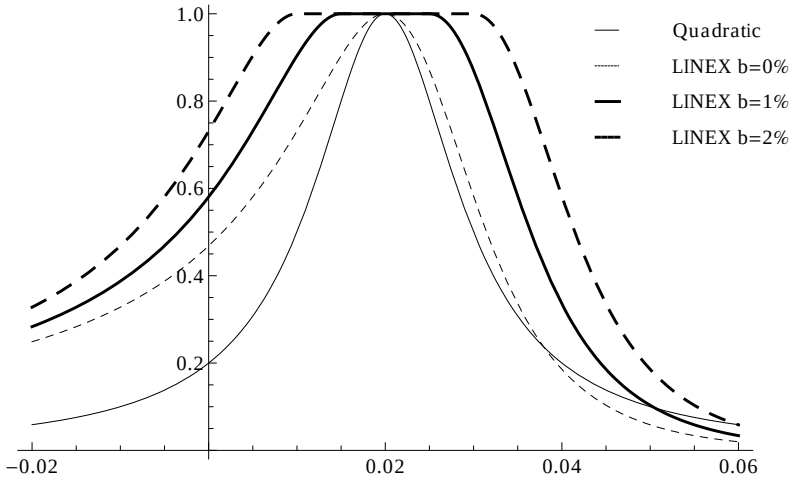

Figure 3: Credibility indices $CRED^{SLF/BS}$ based on different loss functions; $\bar{\pi} = 2\%$

We have redone calculations in section 2 substituting three different LINEX loss functions (with $b = 0\%$, $b = 1\%$ and $b = 2\%$) for a quadratic function what leads to alternative estimates of $CRED^{SLF}$, $CRED^{BS}$ and $CRED^{MAX}$. Note that $CRED^{BR}$ remains unchanged since methodology based on Bomfim and Rudebush (2000) does not require use of loss function.

Table 11 gives overall credibility $CRED^{MAX}$ for different b's for 2008 and 2017 (annual averages were computed). Note that values of credibility are higher than those in Table 7 since LINEX loss function and/or application of tolerance bands leads to more lenient assessment of deviations of inflation expectations from the targets. Since reported expectations were in 2017 very close to the inflation targets in all CEE countries, using $b = 1\%$ or $b = 2\%$ leads to results of full credibility for almost all countries. The result that credibility deteriorates in several countries either vanishes completely or is reduced to economically insignificant levels (in Albania and Macedonia).

Table 11: Overall credibility $CRED^{MAX}$ computed using LINEX loss function (values)

	$b = 0\%$		$b = 1\%$		$b = 2\%$	
	2008	2017	2008	2017	2008	2017
Serbia	0.828	0.988	0.875	1.000	0.914	1.000
Albania	0.991	0.942	1.000	0.999	1.000	1.000
Macedonia, FYR	0.928	0.643	0.997	0.832	1.000	0.983
Croatia	0.598	0.811	0.748	0.955	0.864	1.000
Czech Republic	0.664	0.995	0.838	1.000	0.942	1.000
Poland	0.547	0.912	0.788	1.000	0.968	1.000
Bulgaria	0.342	0.705	0.386	0.867	0.448	0.977
Romania	0.235	0.930	0.261	0.996	0.313	1.000
Hungary	0.765	0.947	0.890	0.997	0.972	1.000
Rank corr. w/QLF	1.000	0.950	0.967	0.837	0.837	0.826

However, it is noteworthy that using LINEX loss function does not significantly change ordering of countries according to credibility. For example, in 2008 rank correlation between credibility indicators based on LINEX loss function with different tolerance bands and indicators using quadratic loss function is 1.000, 0.967 and 0.837 respectively (last row in Table 11).

Another desirable results obtained by using LINEX loss function (especially with tolerance bands) is reduced volatility of credibility index. To see this, compare standard deviations in Table 7 with those in Table 12. Whereas average standard deviation of $CRED^{MAX}$ obtained in section 2 is 0.212, it decreases to 0.187, 0.144 and 0.101 if LINEX with $b = 0\%$, $b = 1\%$ and $b = 2\%$ is employed.

Table 12: Overall credibility $CRED^{MAX}$ computed using LINEX loss function (trends and standard deviations)

	$b = 0\%$		$b = 1\%$		$b = 2\%$	
	trend	st. dev.	trend	st. dev.	trend	st. dev.
Serbia	0.015*	0.263	0.012	0.269	0.007	0.258
Albania	-0.014***	0.088	-0.003***	0.026	0.000	0.001
Macedonia, FYR	-0.031***	0.160	-0.017***	0.091	-0.003***	0.022
Croatia	0.002	0.181	0.007*	0.128	0.007***	0.077
Czech Republic	0.014***	0.137	0.009***	0.083	0.003**	0.044
Poland	0.023***	0.165	0.013***	0.080	0.002***	0.014
Bulgaria	-0.007	0.233	0.002	0.214	0.015**	0.190
Romania	0.075***	0.304	0.073***	0.306	0.061***	0.268
Hungary	-0.002	0.155	0.001	0.095	0.002**	0.031

Note: ***, **, * denote significance on 1%, 2% and 5% level.

Furthermore, even though using loss function of Levieuge et al. (2015) does not change ordering of the countries, comparison of results based on LINEX with results of OeNB Euro Survey and ECCS suggests (see Table 13) that there is a reason both to treat overshooting-undershooting asymmetry with LINEX approach as well as to include modest tolerance bands. Correlations for all statements and questions increase once LINEX loss function is introduced (except for questions about predictability, where correlations are slightly reduced). In case of statements 2 and 3 which explicitly ask about stability and trustworthiness of the currency, introduction of tolerance bands further increases the correlations.

We have also computed correlations with OeNB Euro Survey and ECCS separately for inflation targeters and countries with fixed exchange rate. Economies fixing the exchange rate to euro have in general lower values of correlations. However, in case of questions 2 and 3 (asking about current and future stability and trustworthiness of the currency), in countries with fixed exchange rate LINEX loss function with tolerance bands produces credibility indicators even more in line with households' perceptions than in inflation targeters.

Figures 4 and 5 give monthly development of overall credibility based on LINEX loss function

Table 13: Overall credibility $CRED^{MAX}$ based on LINEX loss function and results of OeNB Euro Survey and ECCS

	$b = 0\%$	$b = 1\%$	$b = 2\%$
1. Prices will strongly increase	0.271	0.243	0.177
2. Currency is currently stable and trustworthy	0.423	0.447	0.448
3. Currency will be stable and trustworthy over the next 5 years	0.260	0.299	0.324
4a. Prices over the next year compared to prev. year	0.238	0.281	0.310
4b. Prices over the next year compared to prev. year (ECCS)	0.249	0.302	0.313
5. Predictability of prices	0.177	0.144	0.104
6. Exchange rate over the next year compared to prev. year	0.534	0.529	0.470
7. Predictability of the exchange rate	-0.008	0.005	0.020

using one-percent tolerance band. Relatively low credibility of Bulgarian, Romanian and Hungarian central banks is clearly distinguishable as well as sharp drop in credibility of National Bank of Serbia in the middle of the period. On the other hand, once central banks manage to bring inflation expectations sufficiently close to the target, their are all assessed as fully credible.

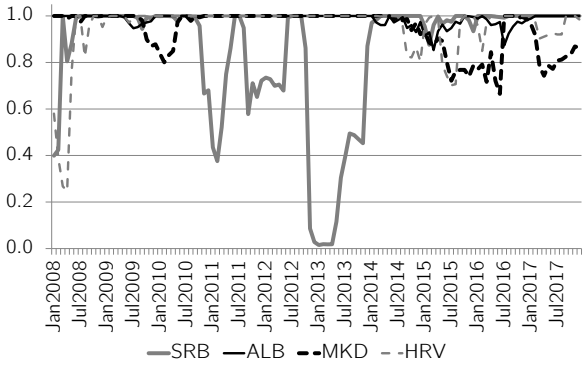

Figure 4: Overall credibility using LINEX; $b = 1\%$: Part I.

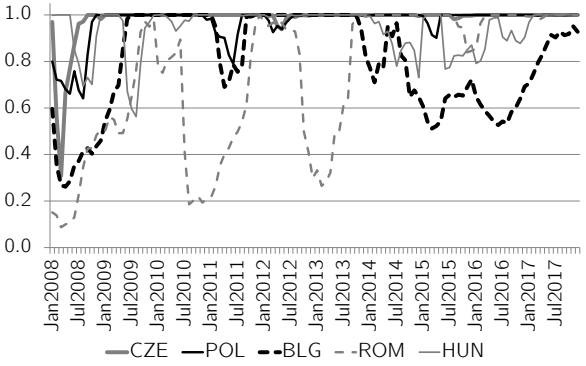

Figure 5: Overall credibility using LINEX; $b = 1\%$: Part II.

Table 14 brings estimation results analogical to those in Table 9. Since one of the motivations behind using LINEX loss function with tolerance bands is to better aggregate situations when inflation is above, close to and below the target, we perform only estimations on full sample of observations, sub-sample of inflation targeters and sub-sample of countries with fixed exchange rate.

Comparing full-sample estimations based on LINEX loss function *without* a tolerance band (i.e. $b = 0\%$) with estimations based on quadratic loss function indicates that there is little difference between two approaches. However, introducing tolerance bands enables to identify an important difference between inflation targeters and countries with fixed exchange rate. Our results suggest that for inflation targeters, meeting the target is of paramount importance,

Table 14: Determinants of central bank credibility using LINEX loss function (pooled OLS)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Sample:	full	full	full	IT	IT	IT	non-IT	non-IT	non-IT
Tolerance band	0.0%	0.5%	1.0%	0.0%	0.5%	1.0%	0.0%	0.5%	1.0%
Fixed e. r.	0.035	0.020	0.012	-0.134	-0.120	-0.077			
	(0.024)	(0.017)	(0.011)	(0.113)	(0.073)	(0.047)			
EU	-0.150***	-0.152***	-0.118***	-0.360*	-0.313**	-0.262*	-0.145	-0.485*	-0.507*
	(0.040)	(0.032)	(0.026)	(0.143)	(0.115)	(0.115)	(0.184)	(0.148)	(0.154)
Rule of law	-0.010	0.036	0.055	-0.001	-0.023	-0.037	-0.194	0.025	0.112***
	(0.058)	(0.047)	(0.036)	(0.067)	(0.067)	(0.061)	(0.125)	(0.082)	(0.006)
CBI	0.051	0.168	0.199	-0.079	0.041	0.218	0.811	1.317	0.932
	(0.168)	(0.151)	(0.118)	(0.465)	(0.414)	(0.393)	(0.570)	(0.697)	(0.620)
GDP p. c.	-0.075	-0.067	-0.045	0.343	0.381*	0.389*	-0.418	0.113	0.248
	(0.125)	(0.084)	(0.049)	(0.194)	(0.181)	(0.175)	(0.418)	(0.373)	(0.349)
GDP growth rate	-0.645	-0.656**	-0.642***	0.132	0.096	-0.312	-0.957	-0.719	-0.422
	(0.379)	(0.269)	(0.191)	(0.477)	(0.295)	(0.242)	(0.504)	(0.575)	(0.908)
S&P rating	0.111**	0.079*	0.038	0.032	0.017	-0.004	0.338**	0.422***	0.401*
	(0.047)	(0.034)	(0.023)	(0.021)	(0.009)	(0.019)	(0.072)	(0.035)	(0.094)
G. debt (% GDP)	0.284**	0.245**	0.121	0.112	0.203***	0.162**	0.530	0.207	0.134
(1-year lag)	(0.097)	(0.076)	(0.068)	(0.087)	(0.042)	(0.057)	(0.292)	(0.279)	(0.275)
Δ_{12} G. debt	-0.676**	-0.438**	-0.174	-0.719*	-0.539	-0.384	-1.973**	-1.737**	-0.888**
(1-year lag)	(0.267)	(0.187)	(0.154)	(0.320)	(0.326)	(0.313)	(0.398)	(0.351)	(0.101)
$\lvert\pi - \bar{\pi}\rvert$	-5.651***	-4.863***	-3.858***	-5.888***	-5.603***	-5.119**	-4.940*	-4.249	-4.025
	(0.500)	(0.806)	(0.922)	(0.849)	(1.320)	(1.459)	(1.258)	(2.186)	(2.189)
Av. π over pr. 5 y.	-1.119	-1.264	-1.439	-1.878	-1.835	-2.038	-4.461***	-3.900***	-3.858***
	(1.191)	(1.138)	(0.957)	(1.498)	(1.522)	(1.348)	(0.348)	(0.180)	(0.092)
σ_π	1.153	0.084	-0.580	-0.627	-0.835	-0.284	6.958	8.449	6.190
	(3.441)	(3.057)	(2.320)	(4.087)	(4.110)	(3.230)	(4.716)	(3.524)	(3.318)
Δ_{12^e}	0.302	0.152	0.012	0.454*	0.194	-0.017	0.542	0.011	-0.780**
	(0.224)	(0.201)	(0.149)	(0.184)	(0.259)	(0.279)	(1.403)	(0.580)	(0.136)
$\sigma_{\Delta_{12^e}}$	-0.329	-0.600	-0.552*	0.675	0.088	-0.356	4.563	2.791	-5.145
	(0.706)	(0.458)	(0.272)	(0.850)	(0.519)	(0.513)	(2.671)	(3.300)	(2.432)
Time dummies	yes	yes	yes	yes	yes	yes	yes	yes	yes
No. of obs.	1080	1080	1080	720	720	720	360	360	360
R^2	0.41	0.45	0.43	0.53	0.57	0.55	0.74	0.75	0.76
Breusch-Pagan p-value	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Note: Clustered standard errors in parentheses; ***, **, * denote significance on 1%, 2% and 5% level

whereas coefficient corresponding to average inflation over previous 5 years is not important. On the other hand, central bank credibility in countries with fixed exchange rate depends primarily central bank's record of keeping the inflation low for longer period of time, term $|\pi - \bar{\pi}|$ is not statistically significant. In addition to this, sound public finances are more important for central bank credibility in countries with fixed exchange rate - see high absolute value of coefficient corresponding to S&P rating and growth rate of government debt, whereas coefficient corresponding to level of government debt is not significant.

Since LINEX loss function with tolerance bands is our preferred way of quantifying credibility (due to high correlations with OeNB Euro Survey and ECCS), we believe that we can summarize our findings in the following way: There are two important ingredients to central bank credibility: (i) good track record of monetary policy and (2) favourable outlook with regard to sustainability of public finances. Whereas track record od monetary policy is more important in countries targeting inflation, central bank credibility in economies with fixed exchange rate is more dependant on sustainability of public finances. There is economic logic to this. With fixed exchange rate, central bank has little direct control over inflation. Therefore, price development is more sensitive to changes in fiscal policy, to changes in public debt and to government budget in general. With unsustainable public finances it is much more difficult to persuade the public that value currency will remain stable. Nevertheless, fixed exchange rate helps to promote

central bank credibility since it serves as a commitment device.

Focusing on track record of monetary policy and outlook of sustainability of public finances it is possible to explain relative success of Czech Republic and Albania. These two countries have lower and more stable inflation than rest of the CEE and government debt is both better rated and grows less rapidly. Central bank credibility is also relatively high in Croatia despite the fact that debt-to-gdp ratio is rising relatively quickly. However, Croatia operates *de facto* currency board and fixed exchange rate in general helps to anchor inflation expectations to foreign inflation. The lowest central bank credibility in Romania is also easy to explain by the combination of flexible exchange rate (i.e. no commitment mechanism), high and unstable inflation and rapid rise in government debt with relatively unfavourable rating.

As mentioned in section 2.5, we have also estimated models (1)-(5) in Table 14 with central bank transparency included (from Dincer and Eichengreen, 2014, this requires excluding Serbia and reducing the sample to period 2008-2010). We have found positive and significant relationship between transparency and credibility in the full sample as well as in the sub-sample of high-inflation economies.[25] This provides some evidence that central bank transparency is conductive to central bank credibility.

4 Conclusion

One of the most intriguing aspects of central bank credibility is how difficult it is to define. Even though credibility is often measured as a deviation of inflation expectations from inflation targets, most central bankers and academics have much more nuanced understanding of this vital aspect of a central bank. In this paper, we move beyond simple differences between the expectations and the official targets and we compute alternative indicators of central bank credibility based on *implicit* targets (as proposed by Bordo and Siklos, 2015) as well as on speed of convergence of inflation expectations to the explicit targets (based on Bomfim and Rudebush, 2000).We also define overall credibility as the maximum value of three different credibility indicators. This enables to assess central bank as credible, if (i) inflation expectations meet official target, or (ii) inflation expectations meet implicit target derived from the policy function of the central bank, or (iii) if inflation expectations converge quickly enough to official target. Our results suggest that in the CEE region, Czech National Bank is the most credible. Investigation of determinants of central bank credibility further suggests that in addition to stable and low inflation, sound public finances are an important factor of central bank credibility. Sustainability of public finances is an important factor particularly in countries with fixed exchange rate. This has straightforward policy implications. To ensure credibility, it is desirable not only to have a good record of low inflation and stable the exchange rate, but also to ensure that economic agents do not have reason to doubt government's ability to service the

[25] Results are available on request.

debt. Our results suggest that these conclusions are not especially sensitive to the choice of loss function. However, using LINEX loss function with tolerance bands produces indicator which is most correlated with the results of OeNB Euro Survey and ECCS. Such an indicator has most information value, carrying not only information about confidence of professional analysts in central bank's ability to keep it promises, but also about medium-term expectations of households. In addition to this, using LINEX loss function with tolerance bands results in less volatile indicator of credibility.

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