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How the central bank's reaction function in small open economies evolved during the crisis

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Abstract

The experience of the global financial crisis caused central banks to change the way the monetary policy is conducted, in particular it changed their reaction function. This study investigates how four selected European central banks in small open economies have changed their reaction function in response to the GFC. To address this problem a logit model is used to see, firstly, how the relative importance of GDP growth forecasts in the process of setting interest rates evolved over time, secondly, how the CPI forecast horizon which central banks take into consideration has changed and, finally, how the monetary policy stance has changed. The outcomes indicate that all banks in the course of the crisis have become more flexible in the way they conduct monetary policy – Polish and Hungarian central banks increased the relative importance of GDP growth as compared to inflation development, Czech and Swedish central banks increased the forecast horizon for inflation and all but the Swedish central bank started to conduct a more accommodative monetary policy.

Keywords: central bank, reaction function, monetary policy, logit model, global financial crisis

JEL: C25, E52, E58

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1. Introduction

The outbreak of the global financial crisis provoked a change in thinking about monetary policy. This change may be reflected in the modification of the way monetary policy is conducted and hence in the reaction function of central banks. Even before the outbreak of the global financial crisis, the central bankers started to realize that monetary policy must focus also on macroeconomic stabilization issues. Admittedly, Issing (2012) underlines the opposite, namely that it puts the central bank's credibility at risk when aside from the price stability mandate it also has to take responsibility for the real economy. Those reservations notwithstanding, in the course of the global financial crisis, central banks admitted that keeping inflation within the target is not sufficient to stabilize the economy and apart from price stability they should also care more about financial and macroeconomic stability (e.g. Mishkin 2011; Cukierman 2013). According to Carney (2013)" (...) the experience of the crisis demonstrated the essential value of flexible inflation targeting as the dominant monetary policy framework" (p. 10). To achieve not only price but also broader macroeconomic and financial stability, central banks should look not only at inflation but also at other variables. It seems that there is a consensus among economists that output growth is one of the variables that should be taken into consideration during the process of formulating the monetary policy framework (Svensson 2009; Blanchard, Dell'Ariccia, Mauro 2010; Mishkin 2011; Issing, 2012; Carney 2013).

According to Svensson (1997) inflation targeting strategy entails that a central bank aims to target inflation forecast. This means that under such an approach, a central bank adjusts its interest rate to ensure that the inflation is in the target within a certain horizon. A lot of research has since been done determining the optimal targeting rule (among others: Rudebusch, Svensson 1998; Giannoni, Woodford 2004; Dieppe, Kster, McAdam 2005), the optimal targeting horizon (among others: Batini, Nelson 2001; Mishkin, Schmidt-Hebbel 2001; Plantier 2002) and the optimal target (among others: Svensson 1997; Uchida, Fujiki 2005; Antinolfi, Azariadis, Bullard 2012; Ball 2013). Central banks in general try to restore inflation to the target in a medium-term horizon of 6 to 8 quarters. However, as pointed out by Carney (2013), a longer targeting horizon can allow monetary policy to promote better adjustments to a prolonged weakness of the economy or financial imbalances. Moreover, he claims that central banks should recognize that the optimal targeting horizon may vary over time depending on the shocks that hit the economy.

Because of today's risk of the deflation trap, central banks may find themselves in a situation where they can either raise target inflation, or change the strategy of the monetary policy to price level targeting. There is an ongoing debate as to whether central banks should raise their target inflation (see e.g.: Blanchard, Dell'Ariccia, Mauro 2010; Gagnon 2010; McCallum 2011). As some economists point out, it raises some questions, e.g.: will a central bank still be credible when changing the target; will that not unanchor inflation expectations? (for the discussion see e.g.: Bernanke 2010; Mishkin 2011). Another issue, which the global financial crisis highlighted, is the horizon in which inflation should return to the target. The central bankers admitted that in some cases stabilizing the economy may require inflation to deviate from the target for an extended period of time (Weber 2015). Contrary to the proposition of increasing the targeted inflation, this idea stirs up less controversies.

The aim of this paper is to check empirically whether European central banks in small open economies outside the euro area that conduct autonomous monetary policy changed the way the monetary policy is conducted. In particular, the paper investigates if central banks enhanced

the flexibility of their inflation targeting strategy. In other words, do output developments gain relatively greater importance in comparison to pre-turmoil times? Additionally, it will be examined whether in the course of the crisis, central banks have extended the CPI forecast horizon which they take into consideration when setting the interest rate. And finally, it will be determined whether central banks started to conduct a more accommodative monetary policy.

The results indicate that all analysed banks have changed their reaction function. In particular, all banks have become more flexible targeters in order to maintain not just the stability of prices but also that of the whole economy. However, the changes implemented by the banks differ. Firstly, the Česká národní banka extended the inflation forecast horizon taken into consideration when setting the interest rate. Secondly, the Magyar Nemzeti Bank and Narodowy Bank Polski increased the relative importance of the GDP growth forecasts as compared with inflation forecasts. Additionally, all these three banks eased their monetary policy stance. Finally, Sveriges Riksbank extended the CPI forecast horizon taken into consideration when setting the interest rate.

The rest of the paper is organized as follows: Section 2 reviews the literature, Section 3 describes the data and the model used in the analysis, Section 4 contains the discussion of the results and Section 5 concludes.

2. Literature review

Discussion on monetary policy rules is well rooted in the literature. This issue has gained a lot of attention since the seminal paper by Taylor (1993), who describes with a simple rule the monetary policy conducted by the FOMC. In his rule, the monetary policy instrument (short term interest rate) is a linear function of the current inflation and the output gap. This rule (or similar) is nowadays often used to describe the behaviour of the inflation targeting of central banks. Taylor (1993) also argued that central banks that follow the rule improve their policy effectiveness.

The central banks very rarely reveal their loss function and the weight that they assign to the deviations of inflation from the target and the output gap. Therefore, instead of deriving a monetary policy rule by minimizing the loss function, the rule is usually estimated empirically.

There is still an ongoing debate regarding which variables, apart from inflation, a monetary policy rule should include. A central bank must decide whether it focuses only on bringing inflation to the target (Svensson 1999) or whether apart from the aforementioned goal its aim is also to stabilize output and/or other macroeconomic variables (e.g. asset prices – for discussion see Svensson 2009; Blanchard, Dell'Ariccia, Mauro 2010; Issing 2012; Carney 2013). There is extensive empirical research which attempts to find out the reaction function of central banks. Clarida, Gali and Gertler (2000) compare the monetary policy for the US in the pre-Volcker and the Volcker and Greenspan era. They conclude that the pre-Volcker era allowed the possibility of inflation and output burst, while Volcker and Greenspan led a strong anti-inflationary policy. Sutherland (2010) presents research on the reaction function of the central banks in OECD countries. His results suggest that there is a group of countries in which monetary policy reacts only to the developments of inflation (Austria, the Czech Republic, Hungary, Poland, Sweden and the UK). A second group consists of the countries where monetary policy takes into account changes in both expected inflation and output gap (Canada, Iceland, New Zealand, Switzerland and the US). The outcomes for the euro area are varied. The findings of most research

correlate the reaction of monetary policy to the inflation forecast and real economy condition's indicators (Gorter, Jacobs, de Haan 2007; Jansen, de Haan 2009; Boeckx 2011). Others indicate that developments in the output growth are less or not important (Belke, Klose 2009; Rosa 2010), whereas some also indicate that other variables matter (Gerdesmeier, Rosa 2004; Gerlach 2007).

Research on the reaction function in the Central and Eastern European countries (CEE) is also comprehensive. Strasky (2005), for example, analyses the optimal rule for the Česká národní banka, Arlt and Mandel (2014) formulate and empirically verify the backward looking model of monetary policy rules for three central European banks – ČNB (Česká národní banka), the MNB (Magyar Nemzeti Bank) and NBP (Narodowy Bank Polski) and find that the annual inflation rate, the exchange rate, the ECB repo rate and the yearly growth rate of M2 are significant in the formulation of monetary policy in these banks. Kotłowski (2006) analyses the reaction function of individual members of the monetary policy committee in Narodowy Bank Polski. The results show that most of the members are forward looking and their decisions as regards the reaction to the deviations of inflation from the target are asymmetric. However, the research both for the developed countries and for Central and Eastern Europe does not take into account the introduction of unconventional monetary policy measures by numerous central banks. Therefore, the aim of this paper is to fill the gap in the literature by incorporating negative interest rates, founding schemes or purchase of government bonds into the reaction function.

3. The data and the model

3.1. The data

This study uses macroeconomic forecasts published by four central banks in European small open economies – Česká národní banka, the Magyar Nemzeti Bank, Narodowy Bank Polski and Sveriges Riksbank (Riksbank). All those banks conduct autonomous monetary policy, they are inflation targeters and they provide the CPI and GDP growth forecasts. Additionally, these countries are outside the euro area but are tightly integrated with it. Macroeconomic projection of NBP and the MNB are conditional forecasts based on the assumption of constant interest rate. In turn, the Riksbank's and ČNB's projections have an endogenous interest rate.

The projections of the analysed central banks are published six times a year in the case of the Riksbank (three times a year a full projection and three times an update), and four times a year in the case of ČNB and the MNB, while NBP had prepared projections four times a year until 2008, switching to three times per year since the beginning of 2008.

When dealing with data, there are two problems to be solved. The first one is the change of the inflation target in the analysed sample by ČNB. That is why every inflation forecast has been corrected for the corresponding central bank's target. The second problem is the varying horizon of forecasts in the case of the MNB, NBP and the Riksbank. In the case of a varying forecast horizon, it would not be possible to distinguish whether the central bank looks at the end of the horizon or at a particular quarter ahead. Therefore, to solve this problem and to fix the forecast horizon, all forecasts beyond the eighth quarter (for NBP and the Riksbank) or the fifth quarter (for the MNB) have been aggregated using a simple average of forecasts for the subsequent quarters. In such a way the obtained projections provide forecasts for a fixed number of quarters.

The dependent variable is the change of the monetary policy stance – easing, tightening or keeping it unchanged – which takes discrete values (see Section 3.2). However, in the analysed period, three banks went beyond the standard monetary policy framework. ČNB encountered the problem of zero lower bound (ZLB) and decided not to ease the stance any further by cutting the rates.[1] Instead, it started to conduct a more active exchange rate policy and introduced an exchange rate floor which was announced at the end of 2013. The Riksbank went further and decreased its main interest rate below zero and started the purchases of nominal government bonds (February/March 2015). Although the MNB did not reach the ZLB, in September 2013 it introduced the funding for growth scheme (FGS) which can be treated as an instrument of monetary policy easing. In the case of NBP, no unconventional instruments are used. Therefore, it will be assumed that the introduction of unconventional measures or the extension of the period in which they hold true is also a form of monetary policy easing.

The decisions of the monetary policy authorities are mostly made on a monthly basis but the projection of the CPI and GDP growth is disclosed less frequently. The Riksbank is an exception. Its Executive Board holds six monetary meetings a year at which it receives a Monetary Policy report with the newest forecasts. For the other three banks, it has been assumed that the forecast may influence not only the decision made during the meeting at which the projection is published but also that adopted at the following one. Monetary authorities may refrain from making the decision at the meeting during which the projection is presented due to e.g. unfavourable market conditions or increased uncertainty. Furthermore, monetary authorities may anticipate changes to the projection and decide to change the monetary policy stance before the projection is released. Therefore, in the case of ČNB, the MNB, and NBP, the dependent variable is also included for the decisions made at the meetings preceding and following the publication of the projections.

The explanatory variables are the CPI and GDP growth forecasts. As mentioned before, CPI forecasts are corrected for the inflation target of particular central banks. Usually in the research on the reaction function, the output gap is used. However, GDP growth forecasts are used instead of output gap for three reasons. Firstly, it is not always clear which gap (output or unemployment) central banks are taking into consideration. Moreover, it would be important to know the exact time when the gap was calculated due to revisions of data (especially the revisions of output growth). Secondly, not all central banks publish their forecast of the output gap. Thirdly, the use of estimates based on the HP filter leads to biased estimates especially at the end of the sample due to its shortness. Moreover, demeaning the GDP growth may also give biased estimates since after the crisis the potential GDP growth is probably lower than before (CEPR 2014).

Additionally, instead of introducing all forecasted horizons into the model, the whole path of the forecast (which has earlier been adjusted for the fixed horizon) is aggregated both for the CPI and GDP growth, using the weights normalized to sum up to one obtained from the Gaussian function:

$$f(h) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}} \tag{1}$$

In such a way, the whole path of inflation and the GDP growth forecast is aggregated, separately, to two variables, each of them described by two parameters – the mean (μ) and the standard deviation (σ).

[1] ČNB explained its decision not to lower the interest rates below zero by the fact that its financial market faced excess liquidity, and lowering interest rates would not bring the expected effect.

There are two reasons for this. Firstly, aggregation reduces the number of estimated parameters, which in the case of a short sample and potentially correlated forecasts may cause co-linearity problems. Secondly, when accounting for the whole distribution of the forecast instead of one particular horizon, allowance is made for the central bank taking into consideration the whole path of the forecast. Depending on the value of σ, the central bank may look at one particular horizon (low σ) or at the whole path (high σ).

The mean μ is allowed to range from 0 (nowcasting) to five quarters in the case of ČNB and the MNB or to eight quarters for NBP and the Riksbank (the end of the forecasting horizon). As for the standard deviation three different values are used – 0.5 (the central bank focuses more substantially on one particular horizon), 1 (the central bank focuses more on one particular horizon, but also takes into account the remaining horizons) and 1.5 (the central bank looks more at other horizons).

The estimation covers the period from 2006 Q1 (in the case of the Riksbank from 2007 Q1 – before that date the Riksbank's forecasts were conditional forecasts based on the assumption of a constant interest rate) up to the projection released before March 2015, which in the case of ČNB and the Riksbank is 2015 Q1 and in the case of the MNB and NBP is 2014 Q4 (Table 1 summarizes the features of the projections of the analysed central banks).

3.2. The model

In order to calculate the reaction function of central banks some authors (e.g. Batini, Haldane 1999; Clarida, Gali, Gertler 2000; Strasky 2005; Gorter, Jacobs, de Haan 2007) use models with a continuous variable. However, in the situation when a central bank encounters the problem of the ZLB and starts using unconventional policy measures to ease the policy stance further, it may not be an optimal choice. In this case researchers opt for discrete choice models where the dependent variable is the change of the interest rate (e.g. Eichengreen, Watson, Grossman 1985; Gascoigne, Turner 2004; Dolado, Maria-Dolores, Naveira 2005; Kotłowski 2005; Carstensen 2006; Gerlach 2007; Grabowski 2009; Jansen, de Haan 2009; Boeckx 2011; Brzoza-Brzezina, Kotłowski, Miśkowiec 2013). Following this stream in the literature and taking into account the discrete nature of unconventional policy measures, the present study employs the ordered logit model to address the formulated research problem.

The discrete choice model is used to incorporate information on unconventional policy measures. In such models one assumes that the central bank has an unobservable desired level of monetary policy stance (I_t^*) which depends on the deviation of future inflation from the target and future output gap. This monetary policy stance can be adjusted by the authorities on every meeting when a new projection of the CPI and GDP growth is available. The above-mentioned relation can be written as:

$$I_t^* = f(\tilde{\pi}_t^f(k), \tilde{y}_t^f(l)) \tag{2}$$

where:

$$\tilde{\pi}_t^f(k) = \sum_{h=0}^{k} f(h)(\pi_{t+h}^f - \bar{\pi}_{t+h}) \text{ and } \tilde{y}_t^f(l) = \sum_{h=0}^{l} f(h)(y_{t+h}^f)$$

$f(h)$ – a Gaussian function as in equation (1),
I_t^* – the monetary policy stance (unobservable) in the period t,
k – the number of forecasting horizons for inflation,
l – the number of forecasting horizons for GDP growth,
π_{t+h}^f – an inflation forecast formulated in time t for the period $t + h$,
y_{t+h}^f – a GDP forecast in time t for the period $t + h$,
$\overline{\pi}_{t+h}$ – the inflation target in the period $t + h$.

However, what the agents observe are the discrete changes of the interest rate (or changes in the scope of unconventional monetary policy instruments) made during the meetings. If the change of the desired monetary policy stance stemming from the changes in the CPI and GDP growth forecast exceeds a certain level, then the central bank adjusts the interest rate. In fact the central bank has two tolerance levels: α_1, below which the central bank relaxes its monetary policy and α_2, above which the central bank tightens its monetary policy; between α_1 and α_2 the monetary policy stance is kept unchanged.

Therefore, one can define the unobservable variable ΔI_t^*, which is the difference between the monetary policy stance as desired by the central bank (I_t^*) and as previously observed by agents (I_{t-1}) in the following manner:

$$\Delta I_t^* = I_t^* - I_{t-1} \tag{3}$$

which can be written out as:

$$\Delta I_t^* = X_t' \beta + \varepsilon_t, \quad \varepsilon_t \sim (0, \sigma_x^2) \tag{4}$$

where $X' = (\widetilde{\pi}_t^f(k), \widetilde{y}_t^f(l))$ expresses the set of explanatory variables from equation (2) and β is a vector of unknown parameters. Moreover, it is assumed that the error term in equation (4) is logistically distributed.

The relationship between the observable change of the monetary policy stance z_t and changes in stance ΔI_t^* preferred by the central bank can be written as:

$$\begin{cases} z_t = -1 & \text{if} \quad \Delta I_t^* < \alpha_1 \\ z_t = 0 & \text{if} \quad \alpha_1 < \Delta I_t^* < \alpha_2 \\ z_t = 1 & \text{if} \quad \Delta I_t^* > \alpha_2 \end{cases} \tag{5}$$

where the limit points α_1, α_2 are being estimated. Logit model parameters and limit points have been estimated with the use of the ML method (see Liao 1994 for details).

Combining equations (4) and (5) allows to express the probability of tightening, easing or keeping the monetary policy stance unchanged as a cumulative density function of the standard logistic distribution.

In this model, the dependent variable is a discrete one and may take the values of -1, 0 and 1. The value -1 is used to code the easing of monetary policy – easing means lowering the interest

rate, introducing unconventional policy measures, expanding them or prolonging their duration. The tightening of monetary policy is coded as 1 – and stands for the increase of interest rates, ending the unconventional policy measures or shortening their duration. "0" stands for all the remaining cases.

4. Results

The aim of this research is, in the first place, to investigate whether the relative relevance of GDP growth forecasts for the decisions on monetary policy change over time. Secondly, the paper investigates whether the CPI forecast horizon which central banks take into consideration when setting the interest rate has changed after the outbreak of the crisis. And its third concern is to establish whether there is a change in monetary policy stance. In order to address these questions, a two-step procedure is employed.

Firstly, an estimation is made of ordered logit model parameters (equation 5) which contain all possible combinations of aggregated forecasts (for all possible values of distribution function parameters μ and σ). In order to examine how the monetary policy evolved over time, the estimation is done in a rolling sample (a fixed window of 21 observations[2]). Secondly, for each central bank and each estimated subsample the best model is chosen based on the maximization of the log-likelihood criterion.[3]

Based on the model results, the following values are calculated: (1) the ratio of parameter estimates of the CPI forecast to the GDP growth forecast, which can be interpreted as relative importance of the GDP growth forecast for the decisions of the central bank, (2) the inflation forecast horizon which the central bank takes into consideration when setting the interest rate – the mean (μ) in inflation distribution function from the best model, and finally, (3) indicators that would denote changes of the monetary policy stance – the limit points from equation (5).

At first the parameters of model (5) for the whole sample are estimated (Table 2). For two out of four central banks (NBP and the MNB) the CPI and GDP growth forecasts are statistically significant with the correct signs in the estimated banks' reaction functions. For the Riksbank only the GDP growth forecast proves to be statistically significant. The contrary holds for ČNB, where only the CPI forecast is statistically significant. However, both insignificant variables (CPI in the case of the Riksbank and GDP growth in the case of ČNB) have the correct sign. The outcomes related to the marginal effects reveal some interesting conclusions. For all analysed banks there is an asymmetry in the reaction of central banks to the increase and decrease of inflation forecast. The marginal probability of easing the monetary policy by ČNB, the MNB and NBP following the drop of inflation by 0.1 percentage points is higher than the marginal probability of tightening in response to the increase of inflation by the same scale. In the case of the Riksbank this relation is reversed. It may indicate that the three other banks are more accommodative in the way they conduct monetary policy than the Riksbank.

While banks' reaction functions may be expected to vary over time the results will not be discussed further, and we will focus on the rolling window estimation instead.

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[2] The parameters' statistics in logit models have an asymptotic *t* distribution. Therefore, for small samples, which is the case in this instance, when analyzing the results of the models, one has to interpret them with caution.

[3] As a robustness check the maximum values of the log-likelihood function are derived for the different values of the investigated parameters in the rolling window. It allows to assess whether the change in forecast horizon resulting from changes in the value of the likelihood function is not coincidental (the results are available on request).

Estimation results for the rolling sample (Figure 1) show that in all examined central banks (with Sweden being the exception in 2012–2013) the inflation forecast was statistically significant for the reaction functions over the whole analysed period. In turn, the GDP growth forecast proved to be statistically significant in the case of the Riksbank (with the exception of the last few observations) while its significance in the case of the Polish and the Hungarian central bank was restricted to the second part of the sample.

The comparison of the CPI forecast coefficient in relation to the coefficient for GDP growth forecasts (Figure 2) indicates that with the increase of the vulnerabilities on the global financial markets, the flexibility of the Polish and Hungarian monetary policy (in the sense of paying more attention to the behaviour of the GDP growth) started to grow (however, in the case of Hungary this development followed a significant decrease in this respect at the beginning of the sample – Figure 2). In turn, over time the Riksbank paid more attention to inflation probably due to the growing concern about the deflation risk in the Swedish economy, which resulted in a series of interest rate cuts. Finally, in the analysed period, ČNB focused solely on inflation, therefore it is not possible to calculate the forecasts' relative importance.

Secondly, we focus on how the forecast horizon for the CPI evolved over time. The changes of the CPI forecast horizon show that in ČNB and the Riksbank the horizon taken into consideration while setting the interest rate increases steadily at the end of the sample (Figure 3). However, the interpretation of the results for ČNB and the Riksbank is conducted slightly different than for the other two banks. In the case of these two banks the projection of future GDP growth and inflation is derived with the endogenous interest rate. Therefore, it is not possible to identify the exact horizon taken into account by the central bank when setting the interest rate, because the model is usually set up in such a way as to bring the inflation to the target within the forecast horizon. However, it does not change the conclusions as to the shortening or extension of the forecast horizon. In the case of these two central banks, research seems to point to the horizon prior to bringing the inflation back to target. Moreover, if the results indicate the extension or shortening of the period preceding the return of inflation to the target, they also indicate the postponing or bringing forward of the moment of inflation reaching the target, under the assumption of the similarity of the trajectory of this return. Thus the conclusions from the analysis remain valid. In Poland, on the other hand, the horizon for the CPI remains unchanged. Additionally, NBP may be perceived as not a forward-looking bank – in the case of the CPI, the important horizon is nowcasting. There was a time when the MNB shortened the CPI forecast horizon taken into consideration, however, the last quarters of the sample show a reversion of the trend.

The result showing no change of horizon for NBP may stem from the fact that Poland is the only analysed country that has not been affected significantly by the global financial crisis. All the analysed countries faced no significant stress on financial stability and their banking sector was resilient to the crisis. However, in terms of GDP growth Poland was the only country in which there was no recession.

The small value of the standard deviation in the selected models indicate that all central banks focus more on one particular forecast horizon than on the whole path.

Finally, the limit points indicate the general attitude of central banks towards monetary policy. As in the logit models, the values of the limit points differentiate between the decisions of the central bank to lower (raise) the interest rates or to keep them unchanged. If the limit points increase (or decrease) in time it means that the monetary policy becomes more accommodative (or tighter).

The end of the sample shows that the monetary policy stance of ČNB, the MNB (barring the last two quarters) and NBP has become more accommodative over time (Figure 4). The results for the Riskbank, on the other hand, may be a little surprising since, over time, its monetary policy has become more restrictive. This means that the Riksbank facing the ZLB could not or did not want to lower the interest rate below zero. The interpretation of this may be twofold. Firstly, it is difficult to predict the influence of the negative interest rate on the real economy, therefore the Riksbank wanted to avoid this for as long as possible. Secondly, the Riskbank was concerned about the growing bubble on the housing market, which showed in the communiques following the meetings (the summary of all the results is provided in Table 3).

One more outcome may also be interesting. The parameters estimated in the rolling window for the Czech, Hungarian and Polish central banks seem rather smooth. However, the parameters for the Riksbank are very volatile. Reasons for such behaviour may be twofold. Firstly, after 2010 there were major changes in the composition of the Executive Board, which could have led to the change in the way this body voted – the amplitude and volatility of the repo rate's changes was the biggest among the analysed central banks. Secondly, as the Riksbank publishes its repo rate path, one can observe some substantial revisions e.g. between October 2011 and February 2012. These two factors could lead to the very frequent changes in the Riskbank reaction function, which translated into volatile estimates of parameters.

5. Conclusions

The aim of this research is to check empirically how the behaviour of central banks changed in the course of the global financial crisis. The results indicate that all analysed banks have changed their way of setting interest rates. However, in each case the change is different.

The Česká národní banka extended the CPI forecast horizon, which it takes into consideration while setting the interest rate. Additionally, the ČNB's monetary stance became more accommodative.

The Magyar Nemzeti Bank increased the weight put on GDP growth after the outbreak of the global financial crisis. Similarly to ČNB, the MNB started to conduct a more accommodative monetary policy.

Although in the case of Narodowy Bank Polski we do not observe changes of the forecast horizon, this bank has also started to put more weight on the GDP growth forecast as compared to CPI forecast. Besides, NBP monetary policy has become more accommodative.

In the case of the Riksbank, we cannot discern an increase in the importance of GDP growth, however, CPI forecast horizon taken into consideration while setting the interest rate has been extended.

The results show that all the banks are ready to accept more prolonged or larger deviations of inflation from the target in order to maintain the stability of the whole economy and that they have become more flexible inflation targeters.

Moreover, it seems that the change of the way the interest rates are set is rather permanent. The modification of the inflation targeting strategy into a more flexible one constitutes the current state of the art and central banks will stick to it as long as it does not lead to the de-anchoring of inflation expectations, and as long as negative impact on the financial sector or real economy can be avoided.

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Appendix

Table 1
Features of the sample and CPI and GDP projection

	No. of observations	Sample	Forecasting horizon	Target	Unconventional policy	No. of projections per year
CNB	37	2006 Q1 – 2015 Q1	5 quarters	2% (3% until end of 2009)	Exchange rate floor (starting date November 2013 – till now)	4
MNB	36	2006 Q1 – 2014 Q4	5–10 quarters	3%	Funding for growth scheme (starting date September 2013 – till now)	4
NBP	29	2006 Q1 – 2014 Q4	8–11 quarters	2,5%	None	3 (until 2007 4 times a year)
Riksbank	47	2007 Q1 – 2015 Q1	8–13 quarters	2%	Negative interest rate (February 2015 – till now) and purchases of nominal government bonds (March 2015 – till now)	6

Source: central banks' documents and websites.

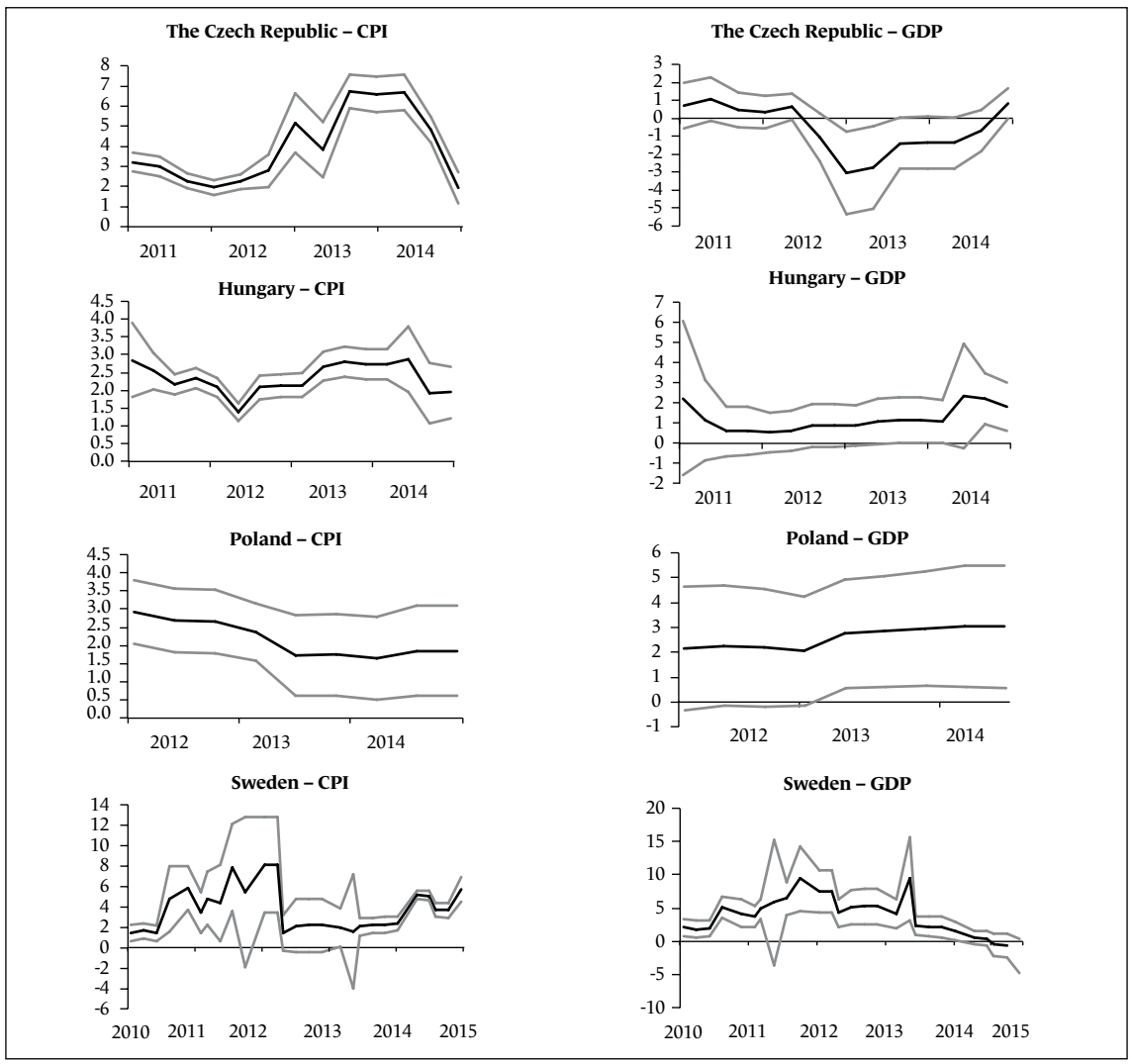
Table 2
Whole sample estimation

	Horizon	Coeff.	z-Statistic	p-value	Probability of interest rate	
					increase when variable rises by 0.1 percentage points (CPI) / 1.0 percentage point (GDP)	**decrease when variable decreases by 0.1 percentage points (CPI) / 1.0 percentage point (GDP)**
The Czech Republic						
CPI	2	2.102	2.424	**0.015**	0.013	0.014
GDP	3	0.225	0.695	0.487	0.030	0.032
pseudo R^2	0.273					
% of correct predictions	67.57					
Hungary						
CPI	4	1.580	3.085	**0.002**	0.019	0.035
GDP	3	0.618	2.716	**0.006**	0.073	0.137
pseudo R^2	0.252					
% of correct predictions	61.11					
Poland						
CPI	0	1.380	2.696	**0.007**	0.007	0.008
GDP	1	1.728	3.253	**0.001**	0.091	0.102
pseudo R^2	0.477					
% of correct predictions	82.76					
Sweden						
CPI	2	0.719	0.909	0.363	0.014	0.110
GDP	3	0.565	3.568	**0.000**	0.012	0.091
pseudo R^2	0.522					
% of correct predictions	64.0					

Table 3
Summary of the results in the rolling window

	Relative importance of the GDP growth	Forecast horizon	Monetary policy stance
ČNB	–	longer	more accommodative
MNB	growing	shorter, but at the end of the sample increasing	more accommodative
NBP	growing	no change	more accommodative
Riksbank	decline	longer	more restrictive

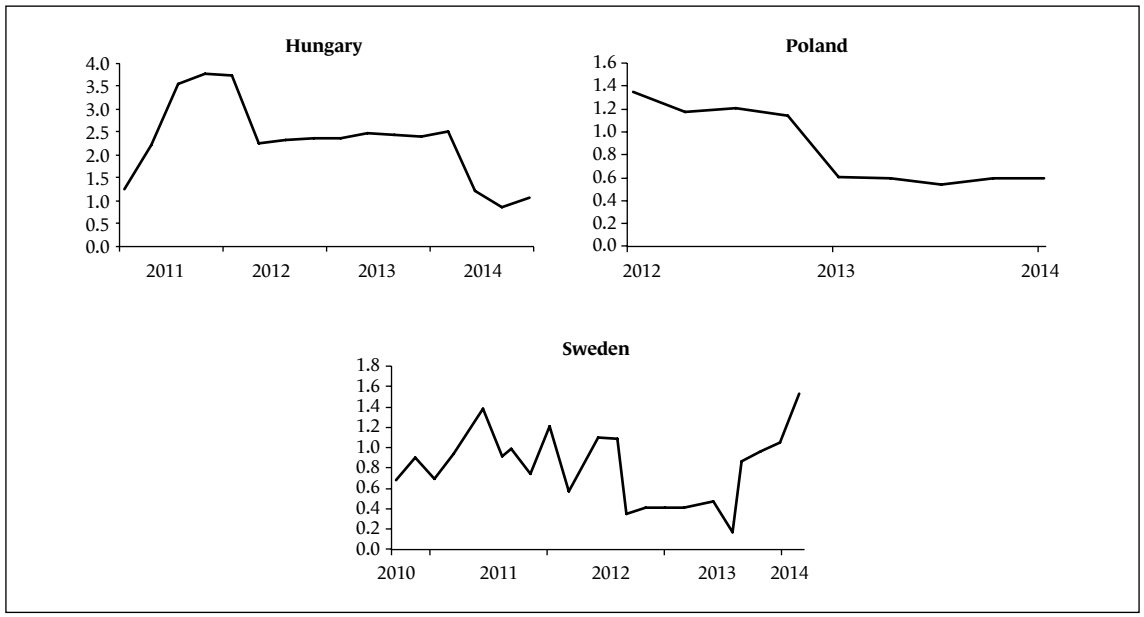
Figure 1
The parameter and the 90% confidence interval for the CPI and GDP growth forecast in the rolling window



Note: the date on the horizontal axis indicates the date of the last observation in the rolling window.

Figure 2

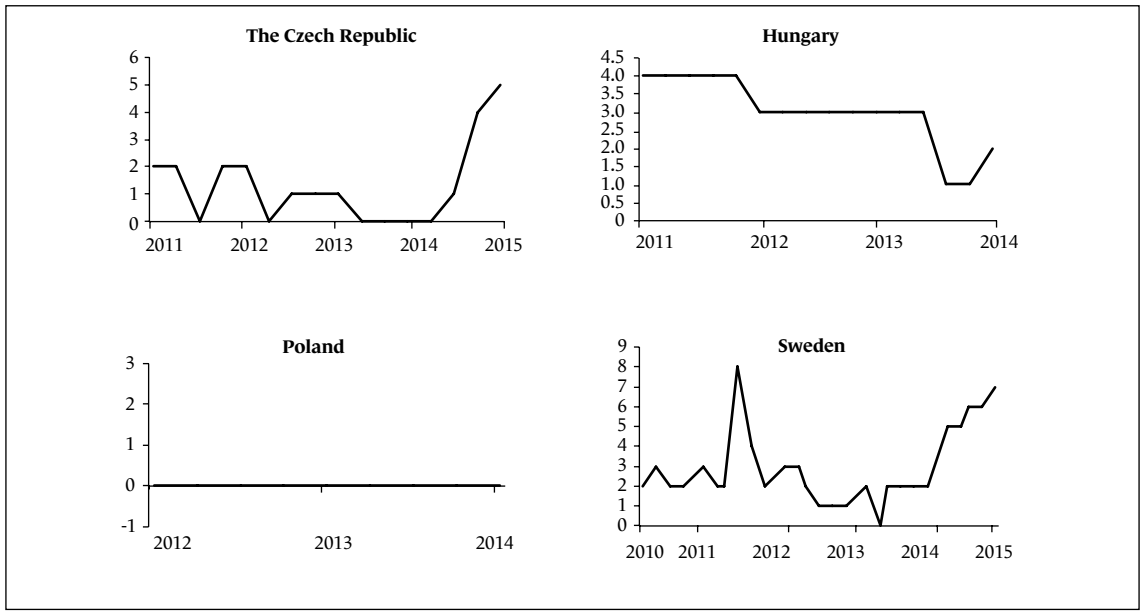
The relative importance of the CPI to the GDP growth forecast in the rolling window



Note: the date on the horizontal axis indicates the date of the last observation in the rolling window. A downward slope indicates the growing importance of the GDP growth forecast in comparison to the CPI forecast.

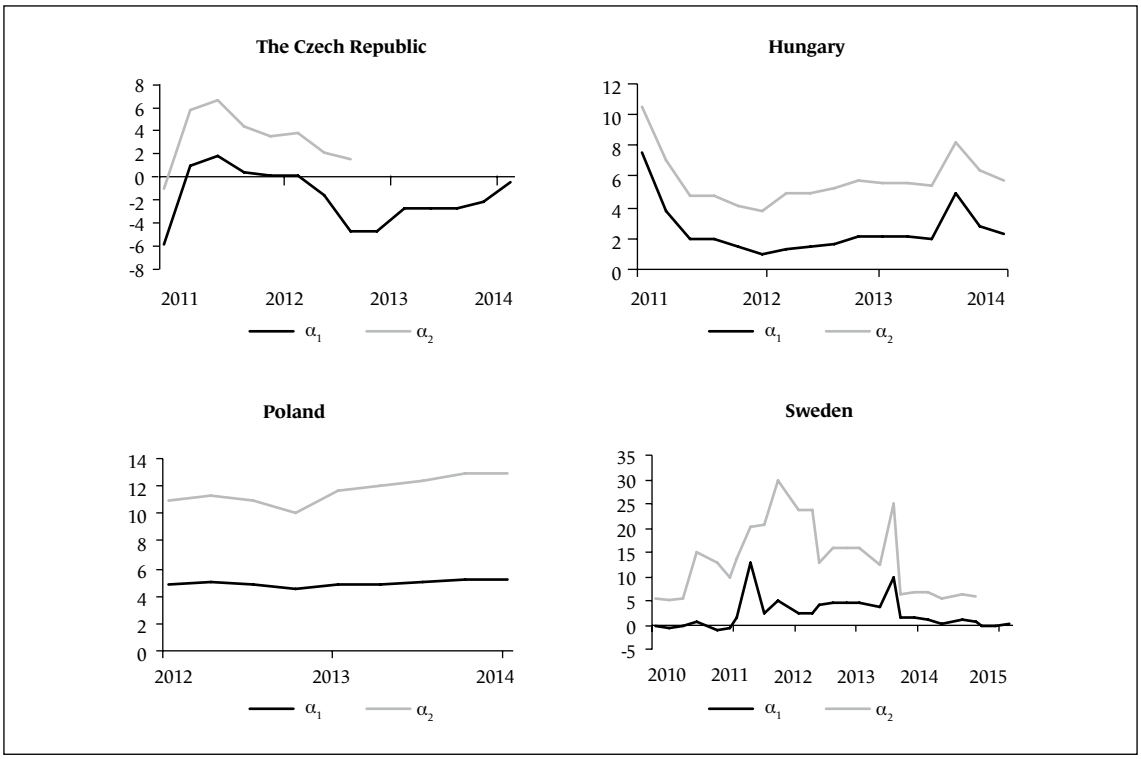
Figure 3

The forecast horizon which central banks take into consideration when setting the interest rate



Notes: the date on the horizontal axis indicates the date of the last observation in the rolling window. The horizontal axis indicates the quarter of the forecast taken into consideration by the monetary policy authorities when setting interest rate.

Figure 4
The monetary policy stance



Notes: the date on the horizontal axis indicates the date of the last observation in the rolling window. α_1 and α_2 denote the limits points obtained from the equation (5). An upward slope indicates a more relaxed monetary policy stance. In case of the Czech Republic and Sweden one line at the end of the sample indicates that during this window of the estimation central bank did not increase the interest rates.