3. INFLATION FORECAST OR FORECAST(S) TARGETING?[1]

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Abstract

The paper refers to L.E.O. Svensson's concept of inflation forecast targeting (IFT) and its implementation by central banks of Sweden, Norway and the Czech Republic. The study focuses on (1) inflation forecasts published by selected central banks, i.e. *headline inflation and core or monetary policy-relevant (MPR) inflation, which are made on the assumption of endogenous instrument rate, (2) one-year consumer inflation expectations, and (3) repo rate decisions. The aim of the paper is to investigate whether MPR and core inflation forecasts (in addition to headline inflation forecasts) are useful tools in implementing IFT. The authors take into consideration differences between forecasts deviations from the inflation target, dependencies between forecasts and consumer inflation expectations and relationships between repo rate decisions and forecasts. The methodology used includes nonparametric tests and statistics (Sign Test, Wilcoxon Matched Pair Test, Nonparametric Correlation coefficients) and forecast errors analysis. The results are sufficiently positive to conclude that the implementation of IFT in central banking practice should be supplemented by forecasts of core inflation.* The paper contributes to the literature on implementing monetary policy under the concept of IFT. It spotlights the importance of publication of core inflation forecasts that are not captured by other research undertakings, which tend to ignore the existence of them as such.

Keywords: inflation forecast, inflation targeting regime, inflation forecast targeting, monetary policy, inflation expectations

JEL Classification: E58, E52, E59

1. Introduction

The main idea addressed in the article is Svensson's concept of the inflation forecast targeting (IFT) regime (Svensson, 1997) and the use of inflation forecasts as a tool for implementing this regime and anchoring inflation expectations. The authors examined central paths of inflation forecasts published by central banks of the Czech Republic, Norway

[1] *The article presents the results of research financed by the National Science Center in Poland: "Forecasting inflation on the basis of DSGE models in the implementation of inflation targeting in selected central banks contract No.: 2013/09/N/HS4/03766" which were developed during the Dekaban Fellowship at University of Glasgow in 2017.*

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and Sweden, which are made on the assumption of an endogenous instrument rate. This assumption is connected with Svensson's optimal forecast targeting rule and assumes the use of an optimal instrument plan (Svensson and Woodford, 2003).

More and more central banks have opted for and implemented IFT, publishing at least two kinds of inflation forecasts. One of them is the headline inflation forecast (usually measured in terms of Consumer Price Index - CPI), while the other one is the core or monetary policy-relevant (MPR) inflation forecast. What differentiates one from the other is the inflation measure used. It is said that the measure of an inflation forecast (intermediate target in IFT) should be the same as the inflation target (Svensson, 1999). In the article inflation forecasts published by central banks are divided into two types: main inflation forecasts, and additional inflation forecasts. These two types are defined as follows. *The main inflation forecast is the inflation forecast published by the central bank, based on the inflation measure identical to the inflation target measure and consistent with the features of the forward looking intermediate target described by Svensson (1999) and Svensson & Tetlow (2005). The additional inflation forecast is the forecast published by the central bank, measured by the core or monetary policy-relevant inflation, assuming the same interest rate, using the same forecasting model and having the same characteristics as the main inflation forecast.*

Professional forecasters and central bankers may argue that, for an inflation targeting central bank producing a macroeconomic forecast under a general equilibrium model with assumed endogenous instrument rate, it is true, almost by construction that inflation forecasts converge at the inflation target in the medium term monetary policy horizon. For which measure of inflation this is true may depend on which specific measure of inflation is used in the central bank's reaction function included in the main forecasting model. Conceptually speaking, if the central bank is assumed to target CPI inflation in the model, then the forecasted CPI inflation should converge to the target. If the model assumes targeting core inflation, then this may hold for the core measure. This theoretical relationship should be true but it does not always hold in central banking practice. Firstly, inflation forecasts published by central banks are not simply products of a model but are a combined product of model results and experts' opinions. Hence, the inflation forecast published by a central bank may differ from the forecast generated by the original model. Secondly, the decision-making body may use some discretion to deviate from the endogenous interest rate path prescribed by the forecasting model. This is why it is assumed in this article that the central bank which has committed itself to implementing Svensson's concept of IFT publishes inflation forecasts to anchor inflation expectations to the inflation target. In this sense, the intermediate target of monetary policy does not have to be a forecast specified in the central bank's reaction function in the general equilibrium model, but one that is published by the central bank (to anchor inflation expectations) and attains or converges with the inflation target in the medium term horizon.

To ensure validity and avoid ambiguities in the study four main assumptions were made: (1) the central bank controls the price level and inflation is mainly determined by central banks; (2) the central bank has decided to publish additional forecasts based on the inflation measure which reflects the best tendencies in price changes in a given economy;(3) main and additional inflation forecasts are prepared on the basis of the same forecasting model but their outcome also depends on experts' opinions; (4) according to L.E.O. Svensson's IFT concept, main inflation forecasts made on the assumption of the endogenous interest rate should accomplish or be close to the inflation target at the end of the forecast horizon.

The research goal is to verify the hypothesis: the implementation of the IFT concept in central banking practice, which normally involves headline inflation forecasts, should be supplemented by an additional inflation forecast based on the core or MPR inflation

measure. In other words, the aim of the study is to investigate whether additional inflation forecasts are a useful tool in the implementation of IFT. The hypothesis is related to 4 specific research questions: (1) do main and additional inflation forecasts meet requirements set by Svensson & Tetlow (2005) and accomplish the inflation target at the end of the forecast horizon? Do they differ significantly from each other? (2) Are main and additional inflation forecasts unbiased? Do values of absolute errors of main and additional forecasts differ from each other? (3) Do main and additional forecasts have an influence on consumers' inflation expectations? Is this impact similar? (4) Do main and additional inflation forecasts influence interest rates decisions made by Monetary Policy Committees (MPC)? Is this impact similar? The methodology used in the study includes nonparametric tests and statistics. The Sign Test and Wilcoxon Matched Pairs Test were used to determine the statistical significance of differences between analysed forecasts. The main variables considered in the analysis were central paths of inflation forecasts (the mode values of the forecasts). The impact of inflation forecasts on interest rates decisions and on consumer inflation expectations was determined on the basis of nonparametric correlation coefficients. Inflation expectations were quantified using the adjusted version of the Carlson-Parkin method. Unbiasedness of forecasts was expressed in terms of absolute forecast errors.

The following analysis is based on central paths of inflation forecasts published by the central banks of Norway, Sweden and the Czech Republic. The banks were selected because they implement the inflation forecast targeting strategy and publish inflation forecasts measured by CPI as well as core or MPR inflation. Their inflation forecasts are based on the assumption of the endogenous instrument rate during the entire forecast horizon.The central banks of the selected countries have been applying the inflation targeting strategy for at least 10 years; have inflation targets specified in terms of percentage points with a symmetrical tolerance range for deviations; have officially committed themselves to implementing the monetary policy according to Svensson's concept of inflation forecast targeting (IFT), especially optimal IFT; have published CPI and core or MPR inflation forecasts (based on the endogenous rate); have published values of central paths of forecasted inflation (together with areas of uncertainty); have forecast inflation using dynamic stochastic general equilibrium (DSGE) models; are not part of the Euro zone. In addition, the selected central banks have the largest comparative experience of implementing the IFT; thus, they are pioneers in the field of modelling and forecasting inflation. The three central banks forecast inflation using DSGE models. In each model, the central bank's reaction function includes headline inflation. The main forecasting model used by the Swedish National Bank (SNB) since 2007 is a DSGE model called RAMSES; in the Bank of Norway (NB) it is the NEMO model, used since 2006; in the Czech National Bank (CNB) – the G3 model, used since 2008 (Adolfson *et al.,* 2008; Brubakk *et al.,* 2006; Coats *et al.*, 2005).

The main body of the article consists of six parts. The first section provides some theoretical background about Svensson's concept of IFT and measures of inflation. The next two sections include a description of the methodology and the data. The results of the study, conclusions, commments and implications for countries implementing the IFT regime are presented in Sections 4 and 5.

2. Theoretical Background

The inflation targeting strategy requires central banks to implement a transparent monetary policy, which is supposed to affect the creation of inflation expectations of economic actors.

An integral part of such an inflation targeting strategy is the obligation to announce future inflation figures to the public, which takes the form of inflation forecasts (Svensson, 2009). Countries implementing the IT strategy have chosen the inflation target as the main objective of their monetary policy, specified in terms of percentage points and, in most cases, with a symmetrical tolerance range for deviations. Inflation forecast targeting (IFT) requires an intermediate goal - inflation forecasts (Svensson, 1999). Therefore, it is appropriate to verify published inflation forecasts from the perspective of their function as an intermediate goal.

Inflation forecasts produced by central banks differ from each other with respect to the main assumptions concerning the instrument rate, time horizon and the measure of inflation used in inflation forecasts. Firstly, inflation forecasts created by central banks which implement the inflation targeting strategy may be based on the assumption of a constant instrument rate (called CIR) during the entire forecast horizon, on the assumption of market expectations of future instrument rates (called ME) or on the assumption of the endogenous instrument rate (Svensson, 2006). The CIR assumption implies the use of the 'rule of thumb'. This means that if the inflation forecast, in the chosen horizon, is above the inflation target, then the central bank should raise the repo rate. If the inflation forecast for a given horizon is lower than the inflation target, then the central bank should reduce the repo rate. If the inflation forecast is equal to the inflation target, then the repo rate should remain unchanged (Svensson, 1997). Inflation forecasts based on the endogenous rate are connected with an optimal instrument rate plan (Svensson, 2006). According to Svensson and Tetlow (2005), an optimal instrument plan implies the publication of an inflation forecast which, at the end of the forecast horizon, (Svensson recommended 3-year forecast horizon) should attain or be very close to the inflation target. The algorithm for decisions about the interest rate, proposed by Svensson, assumes that they are made by Monetary Policy Committees on the basis of an instrument rate path forecast, which is consistent with the inflation and GDP forecast. Currently, out of the 27 countries implementing IT, 7 publish forecasts based on CIR assummption, 5 based on ME assumption and 15 based on endogenous rate assumption.

Secondly, the horizon of inflation forecasts is medium-term. Inflation forecasts based on the CIR assumption in practice usually have a two-year horizon. The forecast horizon for inflation forecasts based on the endogenous repo rate is longer (usually three years) (Svensson, 2013).

Thirdly, inflation forecasts are made on the basis of the headline (usually CPI[)] measure of inflation, the MPR and the core measure of inflation. Anchoring the inflation target in the CPI implies that the main inflation forecast is also the CPI, while other core inflation forecasts are treated as additional forecasts. Currently, out of the 27 countries implementing IT, 10 publish paralelly forecasts of CPI inflation and core or MPR inflation (Canada, Chile, Colombia, Czech Republic, Iceland, Norway, Sweden and Turkey).

The IT strategy and its implementation have been discussed many times on theoretical and empirical grounds, and are now being verified in the face of new challenges. There are two most popular types of research concerning Svensson's IFT concept. The first type of research involves studies of the accuracy of inflation forecasts. This kind of research was done by Dowd (2004) with respect to inflation forecasts published by the Swedish National Bank (SNB), and by Skrove-Falsch and Nymoen (2011) for inflation forecasts made by the Bank of Norway (NB). These studies are related to inflation forecasts assuming CIR. The credibility of inflation forecasts published by the central banks of Sweden, Norway and the Czech Republic was investigated by Tura (2015) and Tura-Gawron (2016). The second interesting type of research focuses on the influence of inflation forecasts on consumer inflation expectations. These kinds of studies, in relation to forecasts made by the Czech

National Bank (CNB) were conducted by Szyszko and Tura (2015), and Szyszko (2017). Results of these studies confirmed the impact of inflation forecasts on one-year consumer inflation expectations in Sweden, Poland, Hungary and the Czech Republic. However, the question of how inflation forecasts are related to particular inflation measures and features of the IFT strategy has not been widely discussed so far.

3. Data

The study focuses on the mode values of central paths of CPI and core or MPR inflation forecasts. The analysis tracks central paths of inflation forecasts published in Sweden and is based on data from the years 2009-2016, published in Norway from 2006-2016 and in the Czech Republic in the period 2008-2016. The data have been collected from inflation reports/monetary policy reports downloaded from the websites of the central banks of Norway and Sweden. Central paths of inflation forecasts published by the Czech National Bank (CNB) were collected and then forwarded by the bank's staff. The different reference periods for each bank are due to data availability; all forecasts are based on the assumption of the endogenous instrument rate.

Repo rates time series were collected from the banks' websites. It is assumed that the publication of an inflation forecast has an influence on repo rate changes and this influence is reflected by repo rate decisions published after MPC Meetings or repo rate decisions between publications of consecutive inflation forecasts. Repo rate changes in Sweden were analysed after each MPC Meeting and carefully matched with the already published inflation forecasts. In the years 2009-2016 MPC Meetings were held 6 or 7 times per year. For the SNB, repo rate changes were analysed after each MPC meeting; 31 times the meetings were held between 6 and 8 days after the publication of the first inflation forecast, 8 times they took place the following day, on single occasions they were held 14 days and 41 days later.

Table 1

Detailed Information on Inflation Forecasts Analysed in the Study

	NB			SNB			CNB	
	CPI	Core inflation		CPI	Core inflation		CPI	MPR
		CPI-ATE	CPIXE		CPIX	CPIF		
Years	2006-2016	2006-2008; 2013-2016	2008-2013	10.2009-12.2016	2007-01.2008	10.2009-12.2016	02.2008-11.2016	
Number of forecasts per year	4			2007-3 Since 2008- 6	3	6	4	
Forecast horizon	3 years						2 years	

Note: CPI- Consumer Price Index; CPI-ATE- CPI adjusted for tax changes and excluding energy products; CPIXE- CPI adjusted for tax changes and excluding temporary changes in energy prices; CPIX- CPI excluded from mortgage interest expenditure and effects of indirect taxes and subsidies; CPIF- CPI with a fixed mortgage rate; MPR- Headline inflation adjusted for first-round effects of changes in indirect taxes.

Source: (Giavazzi and Mishkin, 2006); (Monetary policy in…, 2010); (UND1X changes its…, 2007).

Data on inflation forecasts and repo rate decisions in Sweden are published monthly. Inflation forecast data of the CNB were carefully matched with repo rates decisions after each MPC meeting. During the years 2008-2016 the CNB held MPC Meetings 6 to 8 times

per year. Forecast data of the NB are published on a quarterly basis and its MPC Meetings were held depending on the economic situation without previous arrangements or a frequency commitment. MPC Meetings during the years 2007-2016 were held 3 to 10 times a year. Consequently, in the analysis repo rate changes made between consecutive forecasts were matched with the forecasts.

One-year consumer inflation expectations in Norway were collected from the central bank's website, and the corresponding data for Sweden and the Czech Republic were collected from the *European Commission Business and Consumer Survey*. Inflation expectations for Norway are surveyed quarterly and for Sweden and the Czech Republic-monthly. The relevant survey question is as follows: *'compared with the past 12 months, how do you expect consumer prices to develop in the next 12 months? They will: increase more rapidly, increase at the same rate, increase at a slower rate, stay about the same, fall, don't know'.* The aggregate respondents' answers were quantified using the adjusted Carlson-Parkin method (1975), introduced and developed by Łyziak (2003). The Carlson-Parkin method assumes that inflation expectations are normally distributed with unknown mean and variance. Studies conducted by Carlson (1975) and Batchelor & Dua (1987) found inflation expectations to be centrally distributed and not strictly normal (Batchelor & Orr, 1988, p. 4). The Carlson-Parkin method is not ideal but it includes, for estimation purposes, the actual inflation rate, which in the present study may be headline inflation or core or MPR inflation. As a result, inflation expectations can be calculated on the basis of CPI inflation or a selected core/MPR inflation measure. Such expectations may be more consistent with different inflation indices in inflation forecasts. The method can be briefly described as follows: Let small letters denote the percentage of respondents who claim that: *a-the prices will increase more rapidly, b- the prices will increase at the same rate, c- the prices will increase at a slower rate, d- the prices will stay about the same, e- the prices will fall.* The following equations can be formulated (originally derived by Łyziak (2003)): $A = Nz^{-1}(1-a), B = Nz^{-1}(1-a-b), C = Nz^{-1}(1-a-b-c), \quad D = Nz^{-1}(E)$, where Nz^{-1} is the inverse cumulative standardized normal distribution function. Following from this, the mean expected rate of inflation (*m*) can be expressed as: $m = \frac{\pi_0(C+D)}{C+D-(A+B)}$, where π_0 is the perceived rate of price changes over the previous 12 months (Łyziak 2003, pp. 11-15). In this study inflation expectations were calculated on the basis of CPI inflation and core or MPR inflation, according to the equation: $m_I = \frac{\pi_{0,I}(C+D)}{C+D-(A+B)}$, where *I* is the selected inflation index $I = \{CPI, CPIF, CPIXE, CPI-ATE, MPRI\}$. In the analysis quantified inflation expectations were lagged by two months.

Data on the inflation rate measured by different indices were collected from the central banks' webpages, from the ARAD database of the CNB, and from the database of Statistics Sweden.

4. Methodology and Research Assumptions

The study was divided into five stages. The first stage involved data collection and the quantification of consumers' inflation expectations. Point values of central paths (the mode values) of inflation forecasts measured by different inflation indices for the first, second and third year of the forecast horizon were identified. The database was created containing inflation rates measured by headline, core or MPR inflation indices, point values of central

paths of inflation forecasts measured by different inflation indices for the first, second and third year of the forecast horizon, one-year consumers' inflation expectations and repo rate changes made by the central banks of Norway, Sweden, the Czech Republic.

According to Svensson (2006), the optimal inflation forecast targeting rule implies that central paths of inflation forecasts, made assuming the endogenous instrument rate, converge with the inflation target as the forecast horizon becomes longer. At the end of the forecast horizon, the inflation forecast reaches the inflation target. These relationships were to be verified in the second stage of the study for CPI and core or MPR inflation forecasts. Firstly, absolute deviations of inflation forecasts from the inflation target for the selected central banks were calculated for the first, second and third year of the forecast horizon. In the case of the CNB, the analysis only included one- and two-year forecast horizons. In the comparison of absolute deviations for CPI and core or MPR inflation forecasts assuming different forecast horizon the following notation was used: i – inflation forecast horizon (years), $i \in \{1,2,3\}$, x_j – inflation forecast central path, $j \in N$, x_{ji} – value of inflation forecast central path in the selected horizon $x_{ji} \in \{x_{j1}, x_{j2}, x_{j3}\}$, π^* – inflation target. Svensson's (2006) optimal inflation forecast targeting idea can be briefly presented in the following formula: $\lim_{\substack{i \to 3 \\ j \to \infty}} \left| x_{j_i} - \pi^* \right| = 0$

Basic descriptive statistics were calculated for absolute deviations of CPI and core or MPR inflation forecasts from the inflation target. Samples of the deviations were small but matched, although not all of them were normally distributed. To check the significance of differences between absolute deviations of CPI and core or MPR inflation projections from the inflation target for the selected forecast horizons, two nonparametric tests were used: the Sign Test and the Wilcoxon Matched Pairs Test (W). The tests were performed for each central bank, for the first, second and third year of the forecast horizon, and between CPI and core or MPR inflation projections.

Stage 3 consisted in calculating mean absolute errors of inflation forecasts for the first, second and third year of the forecast horizon measured by different inflation indices for each central bank, according to the formula $\frac{\sum_{i=1}^{n} \left| x_{I,j_i} - x_{I,i} \right|}{n}$, where: i – inflation forecast horizon (years), $i \in \{1,2,3\}$, x_j – inflation forecast central path, $j \in N$, x_{ji} – value of inflation forecast central path in the chosen horizon $x_{ji} \in \{x_{j1}, x_{j2}, x_{j3}\}$, $x_{I,i}$ – inflation rate measured by index *I*, $I = \{CPI, CPIF, CPIXE, CPI-ATE, MPRI\}$. The results were compared.

Main inflation forecasts produced by central banks should shape consumer inflations expectations in the 12-month monetary policy transmission horizon by anchoring them to the inflation target at the end of the forecast horizon. The purpose of Stage 4 was to investigate dependencies between inflation forecasts at the first year of the forecast horizon and one-year inflation expectations in the three countries. The following notation was adopted: $\pi_{I,t+12|i_\pi}$ - central path of *I*-type inflation rate forecast in the first year of the forecast conditioned by the endogenous repo rate from the model, $E\pi_{I,t-2}$ - one-year inflation expectations (lagged by two months) quantified for inflation measure *I* - $I \in \{CPI, CPIXE, CPIF, CPI-ATE, MPRI\}$, *t* – time. In order to test correlations between

forecasts and expectations, three nonparametric correlation coefficients were used: Spearman's rank correlation coefficient $^{\rho}E\pi_{I,t-2;}\pi_{CPI,t+12}|i_{\pi}$, Kendall rank correlation coefficient $^{\tau}E\pi_{I,t-2;}\pi_{CPI,t+12}|i_{\pi}$ and Goodman and Kruskal's gamma rank correlation coefficient $^{\gamma}E\pi_{I,t-2;}\pi_{CPI,t+12}|i_{\pi}$. At the end of this stage, the results obtained for different inflation measures in the forecasts were compared.

During Stage 5 analysis focused on the repo rates changes made by the central banks and how they were related to inflation forecasts deviations from the inflation target. The following notation was adopted: $\Delta i_{j+1} = i_{j+1} - i_j$ - repo rate change after an MPC Meeting or differences between the repo rate at the moment of publishing the inflation forecast *(j)* and the repo rate during the next forecast publication moment *(j+1), j* – number of the published inflation forecast, π^* – inflation target, $m \in \{1,2,3\}$ - the prognostic moment (year) within the forecast horizon, i_{π} – endogenous repo rate assumed in the inflation forecast, $\pi_{I,t+m}|i_{\pi}$ – central path of *I*-type inflation rate forecast at prognostic moment m conditioned by the endogenous repo rate. To test the correlations and compare the results we applied nonparametric correlation coefficients: Spearman's rank correlation coefficient $^{\rho}\Delta i_{j+1;}(\pi_{I,t+m}|i_t - \pi^*)$, Kendall rank correlation coefficient $^{\tau}\Delta i_{j+1;}(\pi_{I,t+m}|i_t - \pi^*)$, and Goodman and Kruskal's gamma rank correlation coefficient $^{\gamma}\Delta i_{j+1;}(\pi_{I,t+m}|i_t - \pi^*)$.

5. The Results

Table 2 provides an overview of the development of inflation forecasts, showing whether the main and additional forecasts were different or similar in the chosen forecast horizon and whether they met the inflation target.

Table 2

Inflation Forecasts Formation

Horizon	Feature	SNB		NB				CNB	
		CPI	CPIF	CPI	CPI-ATE	CPI	CPIXE	CPI	MPRI
One year	Data	2010-2014		2007-2009; 2014		2009-2014		2009-2014	
	Forecasts compared*	Different		Different		Different		Different	
	Inflation target Achieved	No	No	No	No	No	No	No	No
Two years	Data	2011-2015		2008-2010; 2015		2010-2015		2010-2015	
	Forecasts compared*	Different		Similar		Similar		Similar	
	Inflation target Achieved	No	Yes	Yes	Yes	No	No	No	No*
Three years	Data	2012-2016		2009-2011; 2016		2011-2016			
	Forecasts compared*	Different		Similar		Similar			
	Inflation target achieved	No	Yes	Yes	Yes	Yes	Yes		

*Note: *Comparison between main and additional forecasts.*

The following observations could be made on the basis of descriptive statistics calculated for deviations of central paths of inflation forecasts from the inflation target at selected moments of the forecast horizon. In Sweden, at year three of the forecast horizon, the average deviation of central paths from the inflation target was relatively lower for core inflation forecasts than for CPI inflation forecasts. In Norway, in the third year of the forecast horizon, the average deviations of central paths from the inflation target for CPI inflation forecasts and core inflation forecasts were similar. The results of the Sign Test and Wilcoxon Matched Pairs Test validate the previous results. The differences between deviations of central paths from the inflation target for CPI and core inflation forecasts at year two and three of the forecast horizon were significant only in Sweden (α=0.001).

Table 3

Deviations of the Central Paths of the CPI and Core Inflation Forecasts from the Inflation Target - Descriptive Statistics and Differences Tests

Horizon	Statistics	SNB		NB				CNB	
		CPI	CPIF	CPI	CPI-ATE	CPI	CPIXE	CPI	MPR
Inflation forecasts data		10.2009-12.2016		06.2006-12.2008; 06.2013-12.2016		06.2008-03.2013		02.2008-11.2016	
1 year	Sample	44	44	23	23	14	14	36	36
	Mean	0.52	0.49	0.54	0.41	0.94	0.78	0.47	0.41
	Median	0.46	0.53	0.35	0.35	0.94	0.73	0.35	0.40
	Min.	0.01	0.05	0.04	0.01	0.15	0.47	0.00	0.00
	Max.	1.3	1.13	1.77	1.04	1.55	1.21	2.30	1.00
	Std. Dev.	0.35	0.25	0.48	0.29	0.43	0.24	0.43	0.26
	Skewness	0.38	0.08	1.19	0.87	-0.05	0.64	2.26	0.42
	Excess	-0.73	-0.23	0.56	0.30	-0.93	-0.75	8.06	-0.19
	Sign test	p=0.29		p=0.67		p=1.00		p=0.84	
	W	p=0.45		p=0.37		p=0.28		p=0.96	
2 years	Mean	0.75	0.15	0.35	0.31	0.31	0.36	0.27	0.24
	Median	0.66	0.10	0.23	0.27	0.28	0.30	0.20	0.20
	Min.	0.32	0.00	0.00	0.00	0.00	0.16	0.00	0.00
	Max.	1.89	0.52	1.64	0.78	0.71	0.68	1.20	0.60
	Std. Dev.	0.32	0.14	0.35	0.21	0.20	0.18	0.24	0.18
	Skewness	1.70	1.24	2.4	0.62	0.41	0.74	1.87	0.20
	Excess	4.08	0.78	7.59	-0.14	-0.17	-0.76	5.12	-1.17
	Sign test	**p=0.00*** **		p=1.00		p=0.18		p=1.00	
	W	**p=0.00*** **		p=0.72		**p=0.04***		p=0.57	
3 years	Mean	0.91	0.06	0.42	0.34	0.13	0.14		
	Median	0.89	0.05	0.32	0.32	0.08	0.10		
	Min.	0.53	0.0000	0.04	0.04	0.04	0.04		
	Max.	1.49	0.18	2.32	0.78	0.50	0.48		
	Std. Dev.	0.25	0.05	0.49	0.26	0.12	0.12		
	Skewness	0.57	0.79	2.87	0.42	2.48	2.34		
	Excess	-0.29	-0.24	10.6	-1.32	6.48	5.45		
	Sign test	**p=0.00*** **		p=1.00		p=0.75			
	W	**p=0.00*** **		p=0.29		p=0.07			

*Note: W- Wilcoxon Matched Pairs Test.*significant at 0.05 level;** significant at 0.01 level; *** significant at 0.001 level.*

Unbiasedness of forecasts was verified using mean absolute forecast errors calculated for main and additional forecasts. Considerable differences between errors of main and additional forecasts were only found in the case of the SNB. Those differences were present for each forecast horizon and errors in headline inflation forecasts were larger than those for core inflation by over 1 p.p. No such pattern was found in the case of the NB and the CNB.

Table 4

Inflation Forecasts Errors

	Forecasts	Forecasts horizon	*N*	*I*	Forecasts Errors*
SNB	10.2009-12.2016	*t+1*	38	CPI	1.14
			38	CPIF	0.60
		t+2	32	CPI	2.32
			32	CPIF	0.98
		t+3	26	CPI	2.61
			26	CPIF	1.10
NB	06.2006-12.2008; 06.2013-12.2016	*t+1*	19	CPI	0.68
			19	CPI-ATE	0.93
		t+2	15	CPI	0.81
			15	CPI-ATE	0.84
		t+3	11	CPI	1.01
			11	CPI-ATE	0.83
	06.2008-03.2013	*t+1*	15	CPI	0.75
			15	CPIXE	0.56
		t+2	15	CPI	0.83
			15	CPIXE	1.05
		t+3	15	CPI	0.87
			15	CPIXE	0.87
CNB	02.2008-11.2016	*t+1*	32	CPI	0.81
			32	MPR	1.05
		t+2	28	CPI	1.06
			28	MPR	1.19

*Note: *Mean absolute forecasts error, measured as mean absolute difference between the mode of the inflation forecast in the chosen horizon and inflation rate in the chosen horizon.*

Another aspect of inflation forecasts analysed during Stage 4 was the question whether headline inflation forecasts or core/MPR inflation forecasts affect one-year consumer inflation expectations in the three countries. These relationships were tested using nonparametric coefficients of correlation between central paths of CPI inflation forecasts at year one of the forecast horizon and one-year inflation expectations. The coefficients of correlation between core / MPR inflation forecasts and inflation expectations were larger than those found between headline inflation forecasts and inflation expectations. The correlations were significant for core inflation forecasts in Sweden and Norway (at the significance level of 0.06). In the Czech Republic, the correlations were not found to be significant.

Table 5

One-year Consumers' Inflation Expectations- Descriptive Statistics

	SNB		NB				CNB	
Data	10.2009-12.2016		06.2006-12.2008; 06.2013-12.2016		06.2008-03.2013		02.2008-11.2016	
Inf. Exp.	$E\pi_{I,t-2}$		$E\pi_{I,t-2}$				$E\pi_{I,t-2}$	
I	CPI	CPIF	CPI	CPI-ATE	CPI	CPIXE	CPI	MPR
N	44	44	21	21	15	15	36	36
Mean	0.79	1.16	1.95	1.85	1.82	1.83	1.72	1.19
Median	0.47	1.08	1.96	1.77	1.87	1.58	1.47	0.94
Min	-1.18	0.59	-0.35	0.61	0.13	0.81	0.46	0.07
Max	3.07	2.23	3.12	3.12	3.31	3.21	4.99	3.81
Stand. Dev.	0.96	0.42	0.72	0.74	1.00	0.83	1.27	1.05
Skewness	0.89	1.03	-1.46	0.11	-0.19	0.24	1.29	1.40
Excess	0.64	0.52	4.24	-1.02	-0.78	-1.5	1.04	1.34

Table 6

Dependencies among the Consumers' Inflation Expectations and Inflation Forecasts- Nonparametric Correlation Analysis Results

NB, Data: 06.2006-12.2008; 06.2013-12.2016, *N=21*		NB, Data: 06.2008-03.2013, *N=15*	
$\rho_{E\pi_{CPI,t-2};\pi_{CPI,t+12}\mid i_t}$	0.14	$\rho_{E\pi_{CPI,t-2};\pi_{CPI,t+12}\mid i_t}$	0.4
$\rho_{E\pi_{CPI-ATE,t-2};\pi_{CPI-ATE,t+12}\mid i_t}$	**0.66****	$\rho_{E\pi_{CPIXE,t-2};\pi_{CPIXE,t+12}\mid i_t}$	**0.7*****
$\tau_{E\pi_{CPI,t-2};\pi_{CPI,t+12}\mid i_t}$	0.15	$\tau_{E\pi_{CPI,t-2};\pi_{CPI,t+12}\mid i_t}$	0.3
$\tau_{E\pi_{CPI-ATE,t-2};\pi_{CPI-ATE,t+12}\mid i_t}$	**0.44***	$\tau_{E\pi_{CPIXE,t-2};\pi_{CPIXTE,t+12}\mid i_t}$	**0.5*****
$\gamma_{E\pi_{CPI,t-2};\pi_{CPI,t+12}\mid i_t}$	0.15	$\gamma_{E\pi_{CPI,t-2};\pi_{CPI,t+12}\mid i_t}$	0.29
$\gamma_{E\pi_{CPI-ATE,t-2};\pi_{CPI-ATE,t+12}\mid i_t}$	**0.45****	$\gamma_{E\pi_{CPIXE,t-2};\pi_{CPIXE,t+12}\mid i_t}$	**0.5****
SNB, Data: 10.2009-12.2016 , *N=44*		CNB, Data: 02.2008-11.2016, *N=36*	
$\rho_{E\pi_{CPI,t-2};\pi_{CPI,t+12}\mid i_t}$	0.18	$\rho_{E\pi_{CPI,t-2};\pi_{CPI,t+12}\mid i_t}$	0.19
$\rho_{E\pi_{CPIF,t-2};\pi_{CPIF,t+12}\mid i_t}$	**-0.35**	$\rho_{E\pi_{MPRI,t-2};\pi_{MPRI,t+12}\mid i_t}$	0.24
$\tau_{E\pi_{CPI,t-2};\pi_{CPI,t+12}\mid i_t}$	0.12	$\tau_{E\pi_{CPI,t-2};\pi_{CPI,t+12}\mid i_t}$	0.16
$\tau_{E\pi_{CPIF,t-2};\pi_{CPIF,t+12}\mid i_t}$	**-0.22***	$\tau_{E\pi_{MPRI,t-2};\pi_{MPRI,t+12}\mid i_t}$	0.17
$\gamma_{E\pi_{CPI,t-2};\pi_{CPI,t+12}\mid i_t}$	0.12	$\gamma_{E\pi_{CPI,t-2};\pi_{CPI,t+12}\mid i_t}$	0.17
$\gamma_{E\pi_{CPIF,t-2};\pi_{CPIF,t+12}\mid i_t}$	**-0.23***	$\gamma_{E\pi_{MPRI,t-2};\pi_{MPRI,t+12}\mid i_t}$	0.18

*Note: *Significant at 0.05 level. **Significant at 0.01 level. ***Significant at 0.001 level.*

The last aspect analysed at this stage was the relationship between repo rate changes and inflation forecasts (headline, core, MPR inflation) for the first, second and third year of the forecast horizon. No consistent pattern was found in the data. There is no conclusive evidence to support the existence of a significant and consistent influence of headline inflation forecasts or core/MPR inflation forecasts on repo rate decisions.

Table 7

Dependencies among Repo Rates Decisions and Inflation Forecasts-Nonparametric Correlation Analysis Results

NB forecasts	*I*	CPI			CPIXE		
	M	1	2	3	1	2	3
	Data, *N=14*	06.2008-03.2013					
	$\rho_{\Delta i_{j+1};(\pi_{I,t+m}\mid i_t-\pi^*)}$	0.66*	0.57*	0.06	0.37	0.48	0.26
	$\tau_{\Delta i_{j+1};(\pi_{I,t+m}\mid i_t-\pi^*)}$	0.57*	0.44*	0.08	0.27	0.39	0.22
	$\gamma_{\Delta i_{j+1};(\pi_{I,t+m}\mid i_t-\pi^*)}$	0.65*	0.51*	0.1	0.3	0.45	0.25
	I	CPI			CPI-ATE		
	M	1	2	3	1	2	3
	Data, *N=23*	06.2006-12.2008; 06.2013-12.2016					
	$\rho_{\Delta i_{j+1};(\pi_{I,t+m}\mid i_t-\pi^*)}$	0.2	0.05	-0.4	0.59*	-0.09	-0.44*
	$\tau_{\Delta i_{j+1};(\pi_{I,t+m}\mid i_t-\pi^*)}$	0.16	0.04	-0.26	0.47*	-0.09	-0.29
	$\gamma_{\Delta i_{j+1};(\pi_{I,t+m}\mid i_t-\pi^*)}$	0.18	0.05	-0.31	0.55*	-0.11	-0.34
SNB Forecasts	*I*	CPI			CPIF		
	M	1	2	3	1	2	3
	Data, *N=44*	10.2009-12.2016					
	$\rho_{\Delta i_{j+1};(\pi_{I,t+m}\mid i_t-\pi^*)}$	0.48*	-0.24	-0.37*	-0.19	-0.36*	0.04
	$\tau_{\Delta i_{j+1};(\pi_{I,t+m}\mid i_t-\pi^*)}$	0.39*	-0.18	-0.29*	-0.15	-0.28*	0.02
	$\gamma_{\Delta i_{j+1};(\pi_{I,t+m}\mid i_t-\pi^*)}$	0.50*	-0.23	-0.38*	-0.19	-0.36*	0.03
CNB Forecasts	*I*	CPI			MPRI		
	M	1	2		1	2	
	Data, *N=36*	02.2008-11.2016					
	$\rho_{\Delta i_{j+1};(\pi_{I,t+m}\mid i_t-\pi^*)}$	0.23	0.13		0.27	0.13	
	$\tau_{\Delta i_{j+1};(\pi_{I,t+m}\mid i_t-\pi^*)}$	0.18	0.11		0.24*	0.11	
	$\gamma_{\Delta i_{j+1};(\pi_{I,t+m}\mid i_t-\pi^*)}$	0.26	0.16		0.35*	0.16	

*Note: N-sample, I-index, M-horizon. *significant at 0.05 level.*

The empirical analysis of inflation forecast targeting implemented in the central banks of Sweden, Norway and the Czech Republic might be more elaborate due to reaching the ZLB on policy rate. The key policy rate close to ZLB (at least 0.5 p.p.) has been experienced by SNB since 2009, by NB since 2016 and by CNB since 2012. Under the ZLB on policy rate,

the Monetary Policy Committee cannot decrease any more the instrument rate to stimulate the economy and may tend to influence the inflation expectations such that raising them will reduce the real interest rates (Clinton *et al.,* 2015). In such a case, a central bank that implements the IFT concept may keep the instrument rate forecast close to zero for a certain period of time and publish the 'stimulative' inflation forecast. The 'stimulative' inflation forecast may intentionally overshoot the inflation target at the end of the forecast horizon to increase the inflation expectations (Clinton et al., 2015). As our period of analysis starts when SNB experienced the ZLB on policy rate, our presumption is that it might publish the 'stimulative' inflation forecasts. The CPI inflation forecasts in SNB overshot the inflation target at the end of the forecast horizon and differed significantly from the CPIF inflation forecasts (which reached the target at the end of the forecast horizon). This result may indicate (from a conceptual point of view) that CPI inflation forecasts were used as the central banks 'stimulative' devices. Nonetheless, they seem to be less effective in shaping the expectations than CPIF inflation forecasts.

6. Conclusions and Implications for Countries Implementing Inflation Forecast Targeting

Headline, core and MPR inflation forecasts published by the CNB and the NB met requirements set by Svensson & Tetlow (2005), achieved the inflation target. They did not differ significantly from each other at the end of the forecast horizon. In the case of the Swedish National Bank, CPIF inflation forecasts, unlike those for CPI inflation, met the inflation target at the end of the forecast horizon. This difference is significant. CPIF is not a typical core inflation measure (in the traditional sense), but rather a monetary policy-relevant measure. CPIF assumes constant mortgage interest rates to cancel direct effects of monetary policy changes on inflation. If mortgage rates are expected to follow a certain trend over the forecast horizon in line with the endogenous path for the short term interest rate, then CPI and CPIF will differ and the difference may actually increase over time. In view of the above, it can be seen that the SNB effectively targets CPIF, even though officially its target is set for CPI. It cannot be determined whether core or MPR inflation forecasts were more unbiased than those for headline inflation and whether repo rates decisions made by MPCs were based exactly on one type of inflation forecasts. Nevertheless, the main outcome of the study is that additional (core) inflation forecasts were indeed found to have a larger influence on one-year inflation expectations than headline inflation forecasts.

The analysis conducted in the study, in generally does not provide evidence to suggest that core or MPR inflation forecasts deviate less from the inflation target at the end of the forecast horizon, that they are characterized by smaller forecast errors or have a larger impact on repo rate decisions than headline inflation forecasts. Nonetheless, core inflation forecasts were found to have a larger, statistically significant influence on one-year inflation expectations than headline forecasts.

This has a clear implication for the implementation of the IFT strategy. Central banks pursuing Svensson's IFT concept should publish both main and additional inflation forecasts, as they improve the implementation of inflation forecast targeting.

Our paper contributes to the existing literature as it noticed the importance and practical use of additional (core or MPR) inflation forecasts in the implementation of the concept of IFT. It perceived such forecasts as useful tools in central banking practice and analysed them simultaneously with the main (headline, CPI) inflation forecasts. Such research has not been

done, to our knowledge, so far.Difficulties in the analysis of inflation forecasts are due to the fact that the IT strategy has been evolving in the course of implementing the guidelines. First, theoretical works were based on a contemporary paradigm of treating inflation forecasts as an intermediate target. In fact, given that inflation forecasts may have a wide range of different features, central banks should decide which of them should be emphasised. In the authors' opinion, it is very difficult to achieve a compromise between properties of the prognostic function and forecast targeting. At the same time, characteristics of inflation forecasts are often overlooked as an operational factor within the IT strategy. The aim of this study was to compare forecasted CPI inflation and core inflation in Sweden, Norway and the Czech Republic, under the assumption that an inflation forecast is treated as an intermediate target and is used to anchor inflation expectations. The scope of the subject was narrowed down considerably. This analysis represents only part of the entire spectrum of possible research to be conducted. The authors' attention focused on the function of forecasting, in other words, on its effect of shaping only consumer inflation expectations.

The analysis was deliberately limited to selected aspects of inflation forecasts. However, additional information regarding inflation forecasts was taken into account. The study was based only on the values of central paths of inflation forecasts, with areas of uncertainty remaining beyond the scope of the study; however, upon further analysis, these may also play a very important role. The authors did not take into account the economic situation, the financial sphere, or new challenges in central banking. On the one hand, these factors may well have affected the outcome. On the other hand, they contributed to making results more interesting by enabling comparisons of inflation forecasts in more extreme conditions. One obvious limitation is the fact that the conclusions are based on central path data published only by three central banks. Thus, the article indicates directions for further research on the adjustment of inflation forecasts as an operational tool in the IT strategy.

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