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Maria Siranova - Gabor David Kiss

Behind the curve? Application of Taylor rule to post-pandemic inflation dynamics in Europe

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AUTHORS

Maria Siranova, Institute of Economic Research, Slovak Academy of Sciences, Bratislava, Slovakia
Gabor David Kiss, University of Szeged, Hungary

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Behind the curve? Application of Taylor rule to post-pandemic inflation dynamics in Europe

ABSTRACT

In this paper, we quantitatively assess the 'behind-the-curve' behaviour of central banks in response to the recent surge in post-pandemic inflation in Europe. This concept describes a situation in which a central bank reacts with a time lag to a changing economic environment, resulting in situation when a policy rate that deviates from a Taylor rule-like rate. The 'behind-the-curve' measure calculates the duration of divergence between the two policy rates in terms of elapsed time, i.e. the number of months. The Taylor-rule-like policy rates for nine European inflation-targeting countries are computed using a long-T-small-N panel model with a rich set of time- and country-interacted fixed effects. Additionally, we identify the determinants of 'behind-the-curve' behaviour and assess its impact on post-episode inflation rates. Our preliminary findings suggest that higher inflation rates are observable within a short-term horizon of two to three months during the post-BTC tightening period, but disappear afterwards.

KEYWORDS: Taylor rule, behind the curve, inflation
JELCLASSIFICATION: E31, E43, E58

Zaostávanie za krivkou? Aplikácia Taylorovho pravidla na postpandemickú dynamiku inflácie v Európe

ABSTRAKT

V tomto príspevku kvantitatívne hodnotíme možné "zaostávanie v správaní" sa centrálnych bánk v reakcii na nedávny nárast inflácie v Európe po pandémii. Tento pojem opisuje situáciu, v ktorej centrálna banka reaguje s časovým oneskorením na meniace sa ekonomické prostredie, čo vedie k situácii, keď sa kľúčová úroková sadzba odchyľuje od sadzby určenej pomocou Taylorovho pravidla. Miera správania sa „za krivkou" určuje trvanie odchýlky medzi dvoma úrokovými sadzbami z hľadiska uplynutého času, t. j. počtu mesiacov. Úrokové sadzby určené pomocou Taylorovho pravidla pre deväť európskych krajín operujúcich v inflačnom cielení sú modelované pomocou panelového modelu s dlhým T a malým N s bohatou sadou časových a priestorových interakčných fixných efektov. Okrem toho identifikujeme determinanty správania sa „za krivkou" a hodnotíme jeho vplyv na mieru post-epizodickej inflácie. Naše predbežné zistenia naznačujú, že vyššia miera inflácie je pozorovateľná v krátkodobom horizonte dvoch až troch mesiacov počas obdobia sprísňovania menovej politiky po období oneskorenia reakcie centrálnej banky, ale následne tento efekt v čase vymizne.

KĽÚČOVÉ SLOVÁ: Taylorovo pravidlo, zaostávanie v reakcii centrálnej banky, inflácia
JEL KLASIFIKÁCIA: E31, E43, E58

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LAYOUT BY: Maria Siranova - Gabor David Kiss

Institute of Economic Research SAS
Ekonomický ústav SAV, v.v.i.
Šancová 56, 811 05 Bratislava
www.ekonom.sav.sk

CONTACT / KONTAKT: ekonedra@savba.sk

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Introduction

The high-profile conference held at the Hoover Institution (Stanford University) on 6 May 2022 addressed the issue of US monetary policy lagging in response to the pandemic-induced inflation hikes (i.e. the 'behind-the-curve phenomenon', BTC). The distinguished panel of speakers included several prominent macro and monetary policy economists, including three current members of the Federal Open Market Committee (FOMC) and two recent members of the FOMC. The event was covered by numerous members of the press, both in person and via live broadcast. According to the proceedings (Bordo et al., 2023) published almost a year after the conference (March 2023), the organizers were rather confident that: "the message and the style is creeping through to policy actions".

Indeed, the Federal Reserve System (Federal Reserve, FED), in its Monetary Policy Report released on June 16, 2022 (FED, 2022), decided to reinstate a dedicated section on policy rules, including the Taylor rule as the number one on the list. According to the Federal Reserve's own statement (FED, 2023): "Simple monetary policy rules, which relate a policy interest rate to a small number of other economic variables, can provide useful guidance to policymakers. (...) simple monetary policy rules considered here call for raising the target range for the federal funds rate significantly."

Furthermore, it was anticipated that the meeting's message would be communicated not only to the Federal Reserve but also to other central bankers in Europe, Asia, and the Southern Hemisphere. The primary objective of this paper motivated by the debate in conference proceedings (Bordo et al., 2023) is therefore rather straightforward. We model a Taylor rule-like monetary policy rate to assess the 'behind-the-curve' phenomenon on the set of European inflation targeters. Specifically, we: (i) estimate the pre-pandemic Taylor rules for inflation-targeting central banks in Europe (i.e. the training sample); (ii) test the 'behind-the-curve' stance of monetary policy during the pandemic and post-pandemic inflation window (i.e. the validation sample); (iii) determine the drivers of heterogeneous 'behind-the-curve' stance of monetary policy across countries; (iv) assess the impact of probability of BTC episode occurrences on post-BTC inflation rates.

This research aligns with a long-standing tradition in empirical monetary policy literature, aiming to approximate monetary policy decisions based on a prescribed monetary policy rule, at least to a certain extent (Taylor, 1993). The majority of studies has analyzed the implications of different combinations of variables included in the Taylor rule, introducing non-linearities and inertia into the central bank reaction function, changing and optimizing their coefficients, or replacing backward with forward-looking elements. However, only few of them assumed that the monetary authority delayed its reaction due to various reasons – the exception being the theoretical model presented in Walsh (2022) and Hakamada and Walsh (2024), and the empirical study of the European Central Bank's delayed monetary policy response in 2022 by Durko (2023). The findings of the latter one suggest that the European Central Bank (ECB) began tightening three quarters later than the forecasted monetary rule derived from its historical behavior indicated.

Given the well-known principal lags of the conduct of a stabilization policy (Mankiw, 2022), the limited discussion on the causes and consequences of delayed monetary policy reactions is troubling. The transmission lag introduced by Friedman (1961) has been studied so consistently in the literature (see the meta-analysis by Havranek and Rusnak (2013)) that it has been even given a specific term – The long and variable lag of monetary policy (Aruoba and Drechsel, 2024). Debate on topics related to recognition and implementation lags may focus on the role of nowcasting (Grauwe and Ji, 2023), the use of real-time data (Belke and Klose, 2019), the composition of policymakers' information datasets (Bachmann et al., 2022), and often includes political economy considerations (Bennani, 2018). As a secondary objective, this study therefore aims to facilitate a broader theoretical and empirical discussion of the possible macroeconomic causes and consequences of delays (as opposed to promptness) in the monetary policy reaction (i.e. recognition and implementation lags) by conceptualizing the 'behind-the-curve' phenomenon.

Using the working definition of the BTC concept illustrated on the recent post-COVID inflationary period in Europe, we conclude that an increase in the size of a central bank's balance sheet, a positive change foreign exchange reserves, and higher inflation rates are associated with a lower likelihood of entering 'behind-the-curve' episodes. In addition, prolonged tightening of monetary policy leads to an expected decrease in inflation rates in the post-OTC periods. In contrast, higher inflation rates in the post-BTC episodes are reported in the short term. Our empirical findings are consistent with the theoretical model presented by Hakamada and Walsh (2024), who argue that prolonged 'behind-the-curve' monetary policy conduct increases future inflationary costs nonlinearly.

The remainder of the paper is organized as follows. Section 2 outlines the relevant literature, and Section 3 describes the empirical methodology and introduces our data. The results are reported in Section 4, and Section 5 concludes the paper.

1 Literature Review

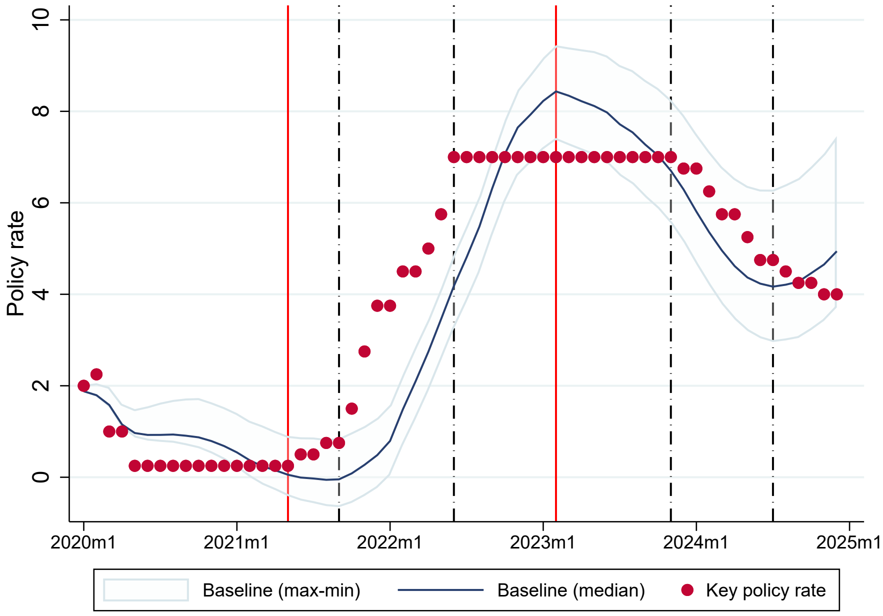
Rule-guided monetary policies in general are assumed to be efficient against monetary-induced financial crises. The literature argues that it is a policy choice between "rules" and "chaotic monetary policy", later is induced by discretionary decisions or exogenous events. Such rules should be robust, consistent and predictable under rational expectations hypothesis to affect long-term interest rates under price and wage rigidities (Taylor and Williams, 2011). What follows is a conceptualization of the 'behind-the-curve' phenomenon based on generalized Taylor rule. This rule is widely used to evaluate the conduct of monetary policy within an inflation-targeting framework (Hofmann et al., 2024). However, it should be noted that the proposed BTC concept can easily be transposed to any monetary policy rule, even utilized under the monetary or exchange rate targeting frameworks.

1.1 Behind-the-curve conceptual framework

The 'behind-the-curve' concept elaborated in this section builds upon the more general discussion in Bordo et al. (2023) and theoretical model designed in Hakamada and Walsh (2024). The disagreement between key policy rate set by a central bank and the prescription of a model key policy rate gives rise to the concern that a central bank lags behind if it were to follow the rule-based approach to the conduct of monetary policy (Taylor, 1993). The recent study by Durko (2023) advocates the use of similar approach to the recent inflationary period when assessing the conduct of the European Central Bank. Focusing on the latest ECB's tightening period, it examines the issue of whether the ECB started monetary tightening amidst the inflationary pressures of the 2020s later than it had done in the past. According to the simulation, the ECB started tightening later than the theoretical level, but by the end of 2022 the two rates had almost converged.

We illustrate the overall logic of our approach to capture the 'behind-the-curve' concept in Figure 1 which depicts an evolution of the Czech key policy rate ('Baseline (median)') and model key policy rate with confidence bands extracted from a set of heterogeneous Taylor rule specifications ('Baseline (min-max)'). The first window delimited by May 2021 and September 2021 shows a divergence between these two policy rates, with an continued downward pressure signaled by Taylor rule-like policy rate in a presence of rise in key policy rate. The first phase is followed by a nine-months window (phase 2) characterized by a tightening signaled by the Taylor rule-like policy rate

Figure 1: Behind-the-curve concept



Notes: The figure shows a stylized evolution of the policy rate and the Taylor rule-like policy rate ('Baseline'). Possible heterogeneity in the estimation of the Taylor rule-like policy rate is shown in the form of confidence bands ('Baseline (min-max)') around the median estimate ('Baseline (median)'). Red vertical lines mark the beginning and end of the 'behind-the-curve' episodes, defined as the divergence in the direction of change of the policy rate and the Taylor rule-like policy rate. Black dashed vertical lines mark the beginning or end of 'on-the-curve' episodes, defined as the congruity in the direction of change of the key policy rate and the Taylor rule-like policy rate.

accompanied by continuous increase in key policy rate. The next two windows see stabilization phase of key policy rate which is accompanied by a pressure for the continuation of the monetary policy tightening (phase 3), which is then replaced by a downward trend in the Taylor rule-like policy rate (phase 4). In the subsequent on-the-curve months (phase 5), we observe the policy rate synchronizing with the model rule prescription once again. As we approach the end of 2024, divergence between the two rates materializes (phase 6).

The four windows (phase 1, 3, 4, and 6) are characterized by the disagreement in the direction of change in policy rate, hence can be labeled as the 'behind-the-curve' (BTC) episodes. In contrast, the second and fifth windows (phase 2 and 5) can be labeled as the 'on-the-curve' (OTC) episodes of the monetary policy conduct.

Three particular features should be acknowledged when assessing the monetary policy conduct by our identification strategy. First, for some of the 'behind-the-curve' episodes, if characterized by a simple disagreement between two policy rates, we can observe the 'ahead of the curve' behavior rather than monetary policy lagging behind - this is true for first window in Figure 1. However, this is the question of a perspective rather than the flaw in the identification strategy – from this reason we keep the term 'behind-the-curve' denoting any period of divergence between two policy rates. Second, one can distinguish between the periods of upward (Taylor rule-like policy rate rises) and downward (Taylor rule-like policy rate decreases) pressure which we use to identify the BTC periods characterized by recommended tightening and loosening of monetary policy conduct.

Last, the BTC concept assesses the stance of monetary policy on the horizontal axis of the Figure 1 by calculating the number of months which can be attributed to the different BTC and OTC periods. In contrast, the literature assessing the monetary policy stance (e.g. Anderl and Caporale, 2023; Blot and Creel, 2024) can be translated into our conceptual framework by looking at the difference between two policy rates, one real and one imputed, at the vertical axis of the Figure 1. Loose monetary policy stance can then be characterized by a positive gap between the Taylor rule-like policy rate and the key policy rate at any point in time, and vice versa. Along these lines, Shevchuk (2023) showed how the Taylor rule deviations affect the inflation behavior in Central and Eastern European (CEE) inflation targeters.

We argue that both concepts represent two sides of the same coin and should therefore be considered together when assessing the overall conduct of monetary policy. A relatively small deviation from the Taylor rule may persist over the longer BTC periods. In contrast, the delay in the monetary policy response may come to an abrupt end once the rapid accumulation of deviations forces a central bank to catch up with the underlying pressures. Thus, any monetary policy could be assessed by both the size and the duration of the disequilibrium.

1.2 Heterogeneous Taylor rules

The literature inspired by the influential article by John Taylor Taylor (1993) is vast and ever expanding. Only in the last few years, new contributions assessing the possible use of Taylor rules for a set of CEE economies include several papers (e.g. Arsic et al., 2022; Fabris and Lazic, 2022; Pokorny and Chytilova, 2023). Wang et al. (2015) provide robust evidence that Taylor rules holds true for seven Central Eastern European countries and are influenced by external factors originating from the United States. The most recent estimates for the United Kingdom, Sweden and Euro Area are to be found in Anderl and Caporale (2024).

Taylor and Williams (2011) suggested that interest rate instruments had better performance than money supply rules as it reacted better both on inflation and output. While central banks define their de jure inflation targets with the possibility of symmetric response, the intensity of the de facto response depends on the nature of negative or positive deviation from it. According to Horvath (2008), this can often lead to undershoot their inflation targets. One main difference between large and open and small economies can be found in the behavior of the interest rate rules (Hoffmann and Kempa, 2009) – while they performed better in large economies under liquidity shocks, for open and small economies an interest rate rule is preferred under a foreign real shock. Similarly, foreign demand real shocks are better absorbed under a dirty floating, while foreign supply shocks are cushioned more under a fixed exchange regime, with an interest rate rule.

The empirical literature usually applies set different Taylor rule modifications that can be split into two distinct categories: backward looking expectations, and forward looking expectations. In addition, the question of inertia in the monetary policy decision making process is often considered by the inclusion of a lagged key policy rate.

For the group of backward looking expectations we distinguish the following classes. The baseline specification of the Taylor rule is where policy rate is linked to inflation and output gaps only ($\alpha = 0.5, \beta = 0.5$), with a “balanced" (with $\beta = 1$ as the weight of the output gap - Brayton et al. (1997); Yellen (2012)) and "revised" (with $\beta = 2$ in Orphanides and Williams (2002)) parametrization. The “inertial” form considers policy rate persistence with lagged interest rate term to represent slow adjustment (Bernanke et al., 2019). Piazzesi (2023) sets it to $\rho = 0.8$ under high inflation, to allow the gradual increase of the interest rate until the inflation reaches the recommended level. For Czechia during the 2000s, Horvath (2008) estimated a $\rho = 0.4$, but for Poland (Lindquist, 2023) and Greszta et al. (2020) suggested a $\rho = 0.7$ level.

$$i_t = r^* + \pi_t + \alpha(\pi_t - \pi^*) + \beta(y_t - y^*) \quad (1)$$

$$i_t = \rho i_{t-1} + (1-\rho)[r^* + \pi_t + \gamma_\pi(\pi_t - \pi^*) + \gamma_y(y_t - y^*)] \tag{2}$$

The balanced shortfalls rule is asymmetric, since it is more accommodative if unemployment is below the potential level but zero otherwise, with $\gamma_y = 1, 2$ (Bullard, 2023; FED, 2021).

$$i_t = r^* + \pi_t + 0.5(\pi_t - \pi^*) + \gamma_y min[(y_t - y^*), 0] \tag{3}$$

The first difference rule excludes the unobservable neutral real funds rate and the potential output to avoid estimation uncertainty. It also orients towards a more stable output (Orphanides and Williams, 2002).

$$i_t = i_{t-1} + \gamma_\pi(\pi_t - \pi^*) + \gamma_y(y_t - y_{t-4}) \tag{4}$$

Where $(y_t - y_{t-4})$ was later rephrased by the FED (2021) by extending it further with a longer unemployment difference and the potential unemployment: $[(u_t - u_t^*) - (u_{t-4} - u_{t-4}^*)]$

Forward looking models represent an another adjustment of original Taylor's model. In model by Batini and Haldane (1999) it is assumed that inflation forecasts were considered during key policy adjustments by the central bank. Such approach addressed the following distortions coming from the transmission lag, information about future inflation, and output (Batini and Haldane, 1999). The forecast horizon was later constrained by Taylor and Williams (2011), stating that there is no clear benefit to respond on inflation expectation more than one year and beyond the actual quarter for the output gap (under high inertia), as well as they may not provide substantial gains during stabilization (Levin et al., 2003). Levin et al. (2003) used $\rho = 1$ as inertia and $\alpha = 0.4, \beta = 0.4$, while Taylor (1999b) used a more reduced form for the Eurozone with $\rho = 0.32$ and $\alpha = 2.62, \beta = 0.$

$$i_t = \rho i_{t-1} + (1-\rho)[r^* + \pi_{t+j}^e + \gamma_\pi(\pi_{t+j}^e - \pi^*)] \tag{5}$$

The Quarterly Projections Model (QPM) of the IMF uses a version of the forward looking Taylor rule (Lindquist, 2023), but with a trend real interest rate instead of the r^*, with $\rho = 0.7, \alpha = 1.1, \beta = 0.4$ parametrization. Also, instead of the key policy rate, i is modeled as the 3M interbank market rate, as its developments are close to the key policy rate's.

$$i_t = \rho i_{t-1} + (1-\rho)[r^* + \pi_{t+j}^e + \gamma_\pi(\pi_{t+j}^e - \pi^*) + \gamma_y(y_t - y^*)] \tag{6}$$

Among the list of other economic determinants which a central bank may choose to pay attention to in its decision making, the exchange rate plays an important role. For open and small economies, Ball (1999) suggested an extension of the Taylor rule with the lagged real exchange rate h. Within this class of models (e.g. Taylor, 1999a, 2001; Choudhri and Hakura, 2006; López-Villavicencio and Mignon, 2017), the parametrization can vary between $h_0 = -0.45$ to -0.25, $h_1 = 0.15$ to 0.45 for an open economy and can be set to $h_0 = 0, h_1 = 0$ for a closed one.

$$i_t = r^* + \pi_t + \gamma_\pi(\pi_t - \pi^*) + \gamma_y(y_t - y^*) + h_0 e_t + h_1 e_{t-1} \tag{7}$$

In a low interest rate environment, the monetary policy is constrained to react on slowing economy and deflationary dangers due to the effective lower bound (assumed to be zero). However, a commitment towards low-policy rates under imperfect credibility can lead to inflation overshoot and un-anchored expectations. Still, (Bernanke et al., 2019) successfully tested the neutral nominal interest rate at $i = 0.03$ to make effective lower bound constraint less prominent. The "lower for longer" (L4L) Taylor rule variants are calibrated for a zero-lower bound environment. Flexible price level targeting sets a conditional price level gap, which activates during the zero lower bound (ZLB) episode only. In this case the P_t price-level gap has the same weight as the output gap, so this rule responds to nominal income gaps (Bernanke et al., 2019).

$$i_t = \rho i_{t-1} + (1-\rho)[r^* + \pi_t + 0.5(\pi^e_{t+j} - \pi^*) + 1(y_t - y^*) + P_t] \tag{8}$$

The natural rate of interest rate (r^*) is an unobservable central value or a trajectory, defined by the long-term steady state growth of the economy. Usually, it is assumed as 0.02 since it should be close to the real interest rate under stable inflation and zero output gap (Arena et al., 2020; FED, 2021; Lindquist, 2023). There are different estimations for the European economies: for the UK, Taylor and Davradakis (2006) estimated it as 0.035, for Czechia during the 2000s, Horvath (2008) estimated it as 0.03, for Poland, it was set as 0.02, for the Euro Area only 0.01 (Arena et al., 2020; Lindquist, 2023). Arena et al. (2020) assumed that its generalized decline was due to the unconventional monetary policy of the 2010s, while cross-country heterogeneity are caused by multiple reasons: currency union membership, capital flow volatility, pro-cyclical behavior and differences between the robustness for shocks between advanced and emerging economies.

Bernanke et al. (2019) defined inflation rate as the four-quarter percentage change in core consumer price index. Four different measurements were used in the literature to define π_t inflation rate (Hofmann and Bogdanova, 2012): current headline CPI, the current GDP deflator, the current core CPI inflation rate and the forward-looking inflation. Later was defined as the weighted average consensus forecast of CPI for the next four quarters (Gerlach et al., 2011). The Taylor rules for the US Federal Reserve System are implemented with the core PCE inflation rather than to headline PCE inflation since they are outperforming them (FED, 2021). IMF's QPM model for Poland used core inflation (without food and energy prices), since it was considered more endogenous to the model (Lindquist, 2023). For behind the curve calibrations, Bullard (2023) uses the Dallas FED trimmed mean inflation rate, measured from one year earlier. It is used to show the level of policy rate is less than the minimally reasonable level. For the UK inflation, Taylor and Davradakis (2006) used the annualized month-to-month percentage change of the retail price index (RPI) without mortgage interest payments, with an inflation target horizon of three months. For Czechia, Horvath (2008) used quarterly data inflation forecast at time t for 4 quarters ahead (to reflect monetary policy horizon of 4–6 quarters and due to data availability in the Czech National Bank Situation Reports). In their macro-financial model, Horvath et al. (2022) used a four-quarter moving average of inflation.

2 Methodology

2.1 Baseline specification

Since we do not know the exact form of a monetary policy rule used by inflation targeting central banks in Europe, we firstly specify a general form of Taylor rule that can be applied to a set of heterogeneous economies. This general form is an amalgam of heterogeneous approaches to specification of Taylor rule in relevant literature discussed in the Section 1.2. The formulation of the general form is close to the specification used in a short-term forecasting model for Poland where Taylor rule is utilized to capture monetary policy conditions (Lindquist, 2023):

$$i_{it} = \rho i_{it-1} + (1-\rho)[r^*_{it} + \pi^{e1}_{it+j} + \gamma_\pi(\pi^{e2}_{it+j} - \pi^*_{it}) + \gamma_y(y_{it} - y^*_{it})] \tag{9}$$

where i_{it} denotes the key policy rate of a central bank i, r^*_{it} natural rate of interest approx. by trend in real short-term interest rate, π^{e1}_{it+j} consumer 1-year ahead inflation expectations adjusting the natural rate of interest, π^{e2}_{it+j} consumer 1-year ahead inflation expectations entering the inflation gap, π^{*}_{it} inflation target set by a central bank i, $(y_{it} - y^{*}_{it})$ is the cyclical component (deviation from trend) of industrial production index extracted by the BN filter for a country i.

Individual central banks may have different preferences in responding to the inflation gap, $(\pi^{e2}_{it+j} - \pi^{*}_{it})$, or the output gap, $(y_{it} - y^{*}_{it})$. For this reason, we introduce country-specific interaction terms for inflation gap, $\beta^{i}_{\pi}(\pi^{e2}_{it+j} - \pi^{*}_{it}) * \theta_i$, and for output gap, $\beta^{i}_{y}(y_{it} - y^{*}_{it}) * \theta_i$, which estimate the deviations in these preferences of individual central banks in our sample with respect to a baseline central bank. In addition, the set of country-specific time-fixed effects, $\theta_i * \tau^{y}_{t} + \theta_i * \tau^{m}_{t}$, adds an extra layer of complexity that allows us to identify the behavior of the natural rate of interest in individual economies.

$$\begin{aligned} i_{it} = \rho i_{it-1} + \alpha + \theta_i + \theta_i * \tau^{y}_{t} + \theta_i * \tau^{m}_{t} + \beta_1(r^{*}_{it} + \pi^{e1}_{it+j}) + \\ \beta_y(y_{it} - y^{*}_{it}) + \beta^{i}_{y}(y_{it} - y^{*}_{it}) * \theta_i + \\ \beta_\pi(\pi^{e2}_{it+j} - \pi^{*}_{it}) + \beta^{i}_{\pi}(\pi^{e2}_{it+j} - \pi^{*}_{it}) * \theta_i + \epsilon_{it} \end{aligned} \tag{10}$$

where θ_i the country fixed effects, τ^{y}_{t} the annual fixed effects, τ^{m}_{t} the monthly fixed effects, and the error term ϵ_{it} represents all disturbances. The specification in eq. 10 is estimated with the higher dimensional fixed effects model for unbalanced panel with robust standard errors.[2]

The use of forward- or backward-looking Taylor rules has been the subject of much debate for a long time. Batini and Haldane (1999) argue that the presence of monetary policy lags ensures the use of forward-looking rules. Orphanides and Williams (2002) or Levin et al. (2003) recommend that not longer than one year ahead for inflation and one quarter for output gap should be used for forward looking specification. In line with Lindquist (2023) we use forward looking one year-ahead inflation expectations for the specification 10.

In addition, our flexible, general specification enables us to set out our expectations regarding the behavior of the natural rate of interest during and after the pandemic. More generally, we can vary the assumptions about the behavior of the element $\alpha + \theta_i + \theta_i * \tau^{y}_{t} + \theta_i * \tau^{m}_{t} + \epsilon_{it}$ from the equation [10] as follows:

- $\theta_i * \tau^{y}_{t}$ excluded from the forecast (W/o year effects),
- fixed estimate evaluated at 2019m12 (Fixed last estimate),
- assumed auto-regressive dynamics based on 2016-2019 period (AR(1)),
- linear growth rate based on average growth rate from 2019 (Linear growth rate).

For the full specification in 10, the auto-regressive element, ρi_{it-1}, uses the imputed key policy rate from the previous period estimated at $t-1$. For illustrative purposes, we also report imputed key policy rate calculated from the true realization of key policy rate at time $t-1$ (Simple rolling prediction).

Last but not least, for the identification of the BTC and OTC periods we use simple median of all the four different forecasts as listed above, with the simple rolling forecast excluded due to its inherent forward bias stemming from the inclusion of true policy rate at $t-1$.

[2]The standard approach to addressing potential cross-sectional correlations is to adopt the Driscoll-Kraay standard errors. In our forecasting exercise, we are not aiming to test the statistical significance of the included variables; therefore, we are not specifically controlling for a more complex structure in the variance-covariance matrix. In addition, we expect the bias stemming from potential serial autocorrelation in our autoregressive term to be mitigated by the long T dimension (monthly frequency) used in our forecasting exercise.

2.2 Dataset

We prefer to use monthly frequency data, whereas several studies aggregate data on a quarterly basis (e.g. Horvath et al., 2022; Durko, 2023). Our primary objective is to estimate the extent of the 'behind-the-curve' stance, i.e. the lag in response, as approximated by the difference between the Taylor rule prediction and the realised key policy rate. With lower frequencies, however, this difference may be difficult to capture, as it may be averaged out or distorted by a counter-reaction from the central bank.

Our unbalanced panel data include nine inflation-targeting economies in Europe[3]. The training sample is set to the period 2001-2019, the forecasting sample covers the pandemic and post-pandemic years 2020-2024.[4]

Our list of explanatory variables for the estimation of the Taylor rule-like key policy rate includes:

- inflation target - officially declared inflation target by a inflation-targeting central bank (IMF AREAER database);
- inflation rate - HICP-based, headline, YoY change (Eurostat);
- output gap - deviation of the industrial production index from its trend, the trend component extracted by Kamber et al. (2018) modification of the Beveridge and Nelson (1981) decomposition (Eurostat);
- short-run nominal interest rate - 1-month *IBOR type (Eurostat, Datastream);

Calculation of consumer inflation expectations is based on the procedure by Benkovskis (2008) which uses the Carson-Parkin (Carlson and Parkin, 1975) and Batchelor-Orr (Batchelor and Orr, 1988) method. Data are gathered from the Business and Consumer Survey conducted by the European Commission. Respondents are asked to:

- evaluate the current consumer price level vis-à-vis that of 12 months ago (Question 5)
- to express their opinion concerning anticipated price movements in the next 12 months (Question 6)

The anchor inflation, i.e. the moderate inflation, was set as the one year rolling window historical inflation rate.

The list of determinants of the behind-the-curve episodes includes:

- term spread - difference between long-run nominal interest rate approximated by 10-year government bond yield (Eurostat, Datastream) and short-run money market rate - 3-month *IBOR type (Eurostat, Datastream);
- FED spread - difference between Federal Funds rate (Datastream) and key policy rate of a respective central bank (ECB, Datastream, central banks);
- central bank assets growth - nominal value of central bank total assets in domestic currency, MoM change (BIS);
- foreign exchange reserves growth - value of foreign exchange reserves excluding gold holdings, SDR volumes and IMF quota, MoM change (BIS);

[3] Albania, Czechia, Hungary, Euro Area, Poland, Romania, Serbia, Sweden, the United Kingdom.

[4] Our analysis exclusively covers periods following the official adoption of inflation targeting strategies by individual central banks.

- set of inflation rates - YoY change of the i) all-items HICP, ii) overall HICP index excluding administered prices, iii) overall HICP index excluding energy, food, alcohol and tobacco, iv) overall HICP index excluding housing, water, electricity, gas and other fuels (Eurostat);

The list of determinants of the post-OTC and post-BTC inflation periods includes:

- exchange rate - YoY growth rate of domestic currency value against USD, 3-months average preceding the end of the OTC or BTC period (IMF, Datastream);
- inflation rate - HICP-based inflation rates, 3-months average preceding the end of the OTC or BTC period (Eurostat);
- key policy rate - central bank policy rate, 3-months average preceding the end of the OTC or BTC period (ECB, Datastream, central banks);

3 Results

The estimates of the Taylor rule-like policy rate for unbalance panel of 9 European inflation targeters are reported in Table A.1 in column (1). Compared with other studies (Horvath, 2008; Greszta et al., 2020; Piazzesi, 2023), our sample exhibits relatively strong inertia for the key policy rate (0.881), which is likely due to the monthly frequency of our data rather than the quarterly frequency that is more prevalent in the literature (e.g. Horvath, 2008; Greszta et al., 2020; Lindquist, 2023). On average, the key policy rate responds positively to change in neutral interest rate and inflation gap. Country-specific interaction terms (Panel B and C) are to be interpreted as relative to the estimated coefficients in Panel A. In particular, while the coefficient for the output gap reported in Panel A is negative and statistically significant only at the 10% confidence interval, country-specific interaction terms reported in Panel C are positive and statistically significant for the majority of economies. Based on these baseline estimates, the key policy rate forecasts for the 2020-2024 period for eight economies are illustrated in Figures A.1 - Figures A.8.[5]

Figure 2 and Figure 3 show two examples (Czechia and the Euro Area) of the range of forecasted Taylor rule-like policy rates according to the five specifications listed in the Section 2.1. In both illustrative cases, the Taylor rule-like policy rate broadly replicates the behavior of the key policy rate – still, substantial differences ensue. In the Czech case, the tightening phase of monetary policy began in mid-2021, just a few months earlier than indicated by the Taylor rule. Indeed, the Czech National Bank was one of the first in the world to start raising its policy rate. On the other hand, the tightening period lasted shorter, as the key policy rate stabilized at the 7% interest rate – in contrast, the Taylor rule-like policy rate suggested the slight overshooting followed by a period of a looser monetary policy. Just before the end of 2023, the key policy rate aligned with the negative trend of the policy rule, with synchronization lasting until mid-2024. In the final months of 2024, we observed the beginning of a new divergence between the two policy rates. In terms of the level of policy rates, our policy rule follows closely with the key policy rate, indicating a smaller absolute deviations from the optimal policy stance.

For the eurozone, the zero-lower bound is breached by the Taylor rule-like policy rate practically from the onset of the COVID pandemics in 2020. The first swing indicates a short-term improvement in underlying economic conditions; however, it is only the second swing that is sustained enough to push the policy rate into positive territory. Indeed, during this period the ECB

[5] We do not produce Taylor rule-like policy rates for Romania due to the discontinued time series for consumer inflation expectations during the 2020-2024 period. However, Romania is included in the training sample to increase the sample size and the respective predicting power of our model.

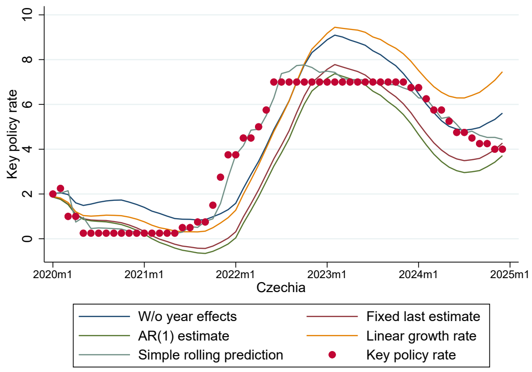


Figure 2: Key policy rate vs. Taylor rule-like policy rate - Czechia

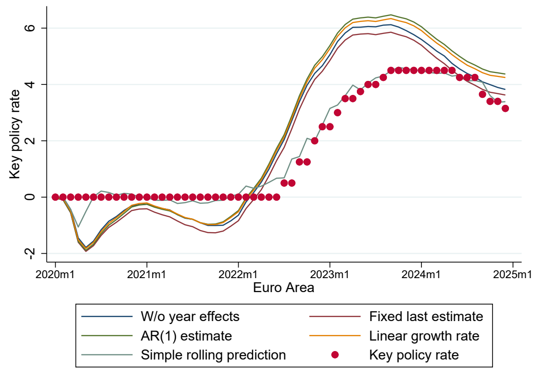


Figure 3: Key policy rate vs. Taylor rule-like policy rate - Euro Area

Note: Taylor rule-like policy rates are estimated from the equation 10..
Source: own calculation

activated new wave of quantitative easing policies to improve access to liquidity for stressed banks in Europe. The first increase in key policy rate came shortly after the Taylor rule-like policy rate surpassed zero lower bound in March 2022. Since then, both rates were rising, yet at a different pace. The initially delayed reaction of the ECB, albeit reported for three quarters rather than three months as in our exercise, was also reported by Durko (2023). The stabilization of the ECB's key policy rate came at the time when the policy rule indicated ease-in phase of the monetary policy cycle. As a point of interest, the latest period of ECB monetary easing policy, which began in May 2024, overlaps with lower-bound estimates of our Taylor-rule-like policy rate. Since then, the two rates have moved in tandem in terms of both dynamics and levels.

Regarding the levels of both policy rates, our modeling approach captures all three formative periods of the ECB's recent history: (1) the key policy rate falling into deep negative territory during the pandemic, which was avoided through the adoption of pandemic quantitative easing policies; (2) the key policy rate increasing sharply, which was more accommodating (though still rapid) than prescribed; and (3) the latest easing phase, with the policy rate moving almost perfectly in tandem with our predictions. A similar conclusion, i.e., the less restrictive monetary policy stance for post-COVID inflation (case #2), was also reported by Blot and Creel (2024).

We take these two illustrative examples as an indication that our approach is successfully able to replicate the general perception of the monetary policy behavior of central banks in our sample. Moreover, the findings of our study are supported by a few recent papers that assess the monetary policy stance and the possibly delayed reaction to recent inflationary pressures. (e.g. Durko, 2023; Blot and Creel, 2024). We therefore continue by preparing the database of the BTC and OTC episodes for the sample of eight European inflation targeters, according to the identification strategy described in Section 1.1.

The list of identified BTC and OTC periods with their characteristics is provided in Table A.2. We identify 23 OTC periods and 26 BTC periods in total. They are proportionally distributed across all five years of 2020-2024 period and include 26 periods of easing and 23 periods of tightening of monetary policy as prescribed by the Taylor rule-like policy rate.

3.1 Determinants of BTC periods

Anderl and Caporale (2023) argue that shadow rates generally provide a more accurate picture of the monetary policy stance during both, ZLB, and non-ZLB periods, since they reflect the full range of unconventional policy measures used by central banks. However, our identification strategy does not consider the potential use of unconventional monetary policy tools in its baseline specification (see eq. 10). Rather than modeling the monetary policy key rate using a set of shadow-rate-type policy rules, we investigate the determinants of the identified BTC and OTC periods in our sample of economies. This two-stage approach enables us to further disentangle the possible causes that lead individual central banks to delay their reaction to accumulated inflationary and real economic shocks. Alternatively, by accounting for the set of possible explanatory factors behind BTC (OTC) occurrences, we can better isolate the 'true' BTC periods from their possibly mis-specified equivalents.

The inclusion of the nominal exchange rate in the general form of the Taylor rule policy rate has often been advocated, especially for small and open economies. Shevchuk (2023) shows that the nominal exchange rate is a significant factor influencing deviations from the Taylor rule, i.e. the monetary policy stance, in the CEE economies. As a result, we control for the change in the foreign exchange reserves as an additional monetary policy tool often used by small and open economies to steer the value of their own currency. To take into account the possible use of all types of unconventional monetary policy tools, as advocated by Anderl and Caporale (2023), we include the increase in the central bank balance sheet as a separate determinant. The possible activation of forward guidance policy, which might not be fully reflected in a change in the size of the central bank balance sheet, is approximated by the term spread, i.e. the difference between long-term and short-term interest rates. In addition, we control for the difference between the Federal Funds rate and the key policy rate of individual central banks – to approximate the global leading role of the FED monetary policy (Kalemli-Özcan, 2019), as well as to capture the possible peer effect in the behavior of central bankers (Horvath, 2020), as evidenced by the belief that the message issued at the Hoover Institution conference in 2022 will resonate worldwide.

The rise in post-COVID inflation has been perceived as a more temporary phenomenon caused by supply-side shocks and supply chain disruptions, rising energy prices due to the conflict in Ukraine and the consequent reaction in administered prices. For this reason, we include headline inflation in the list of determinants, along with the core inflation, which excludes energy and food prices (similar to Hofmann et al. (2024)), and inflation excluding administered prices and housing-related costs.

In Table 1, we present the average marginal effects for the list of determinants of the behind-the-curve episodes. The active use of foreign exchange reserves signals the lower likelihood of declaring the episodes as the BTC period. In other words, in selected periods the central banks may have decided to deviate from the forecasted policy rate due to the activation of other policy tools, the FX interventions in particular. As an alterative interpretation, the increase in foreign exchange reserves is associated with the appreciation tendencies of a domestic currency which may prompt a central bank to counter-react the underlying pressure. As our baseline specification does not account for the change in the nominal exchange rate, the importance of growth of foreign exchange reserves may signify that for several central banks the value of their domestic currency is taken into account when adjusting their overall monetary policy decisions.

The expansion of a central bank balance sheet is associated with the lower probability of BTC episodes – this finding needs to be viewed in light of the zero-lower bound policies adopted by few economies in our sample. For instance, our identification strategy counts three BTC periods for Euro Area during the two years of COVID pandemic (Table A.2) when the key policy rate was limited by its zero lower bound. During this period the ECB actively pursued expansionary balance sheet policies - as a result, these periods could be re-classified as the OTC episodes once taking into account the extent of unconventional monetary policy.

Table 1: Determinants of BTC episodes - average marginal effects

	Dep. = BHC episode (1=yes)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
FX reserves growth	-0.138***	-0.109**	-0.108**	-0.109**	-0.193***	-0.109**	-0.109**
	(0.041)	(0.046)	(0.044)	(0.044)	(0.045)	(0.044)	(0.043)
CB assets growth		-0.050	-0.055**	-0.057**	-0.052	-0.078**	-0.069**
		(0.031)	(0.028)	(0.029)	(0.032)	(0.036)	(0.031)
Term spread			-0.062	-0.059	-0.050	-0.109**	-0.054
			(0.040)	(0.045)	(0.045)	(0.055)	(0.044)
FED spread				-0.017	-0.017	-0.009	-0.024
				(0.059)	(0.070)	(0.056)	(0.061)
Inflation (headline)	-0.022	-0.034*	-0.050**	-0.053**			
	(0.017)	(0.020)	(0.020)	(0.022)			
Inflation (net of admin.)					-0.054**		
					(0.026)		
Inflation (net of energy)						-0.101**	
						(0.040)	
Inflation (net of house)							-0.064**
							(0.025)
Country FE	YES	YES	YES	YES	YES	YES	YES
N	49	49	49	49	42	49	49
Pseudo R2	0.257	0.286	0.320	0.321	0.411	0.331	0.329

Notes: Standard errors are reported in parentheses (p-values: * $<$ 0.10, ** $<$ 0.05, *** $<$ 0.01). FX reserves growth is calculated as the MoM change in value of foreign exchange reserves excluding gold and SDR volumes and IMF quota. CB growth is calculated as the MoM change in value of central bank balance sheet. Term spread is calculated as the difference between 10-year government bond yield and 3 months money market rate. FED spread is calculated as the difference between Federal Reserve funds rate and key policy rate of a respective central bank. Inflation (headline) is reported for all-items HICP. Inflation (net of admin) is calculated for the overall HICP index excluding administered prices. Inflation (net of energy) is calculated for the overall HICP index excluding energy, food, alcohol and tobacco. Inflation (net of house) is calculated for the overall HICP index excluding housing, water, electricity, gas and other fuels.

Among the set of unconventional monetary policy tools, the possible use of forward-guidance policies appears to be independent from the activation of other balance-sheet policies (column 3-7) and does not influence the speed of the reaction of a central bank. Similarly, the leading role of the Federal Reserve in international monetary system or the asymmetric monetary policy stance do not appear to influence our classification of the BTC and OTC episodes (column 4-7).

In periods characterized by heightened pressure on inflation growth, a central bank is more likely to adopt a proactive stance, thereby diminishing the likelihood of lagging behind the curve behavior. In economic terms, the most pronounced reaction is observed for the measure of core inflation net of energy, food, alcohol and tobacco prices (column 6). This finding aligns with the discourse on the role of demand versus supply-side shocks in monetary policy reaction function (Hofmann et al., 2024). Additionally, it corroborates the narrative by Walsh (2022) that central banks were initially reluctant to react to materialization of post-COVID inflation shocks due to their highly volatile and transitory nature. It was only subsequent to the combination of the threat of de-anchoring of inflation expectations (Bonatti et al., 2022) and the demand-side nature of shocks, which manifested as a change in core inflation, that central banks initiated swift action. In addition, the originally disguised nature of inflation shock (supply vs. demand) increased uncertainty in appropriate response of central banks; however, policy rates eventually caught up with the levels predicted by the targeted Taylor rules (Hofmann et al., 2024).

In Table A.4 we provide information about the probability scores of identified BTC and OTC periods calculated from the specifications (1)-(7) in Table 1. The possibly reclassified cases due to the distinction between core and headline inflation can also be identified in Figures A.9-A.11 are localized in the two off-diagonal quadrants. Note, that the reclassification can occur in both directions – from the BTC to OTC episodes and vice versa.

In our subsequent analysis we use the probability scores calculated for the specification (4) in Table 1, which includes all the relevant determinants and the headline inflation rates. As such, the continuous nature of probability scores introduces a more granular insight into the role of the 'behind-the-curve' behavior in influencing the post-BTC inflation rates.

3.2 Post-episodic inflation rates

In order to (theoretically) investigate the macroeconomic consequences of delayed response of major central banks in 2021 and 2022, Hakamada and Walsh (2024) construct a new Keynesian model with endogenous sources of persistence in which monetary policy is modeled by an inertial Taylor rule and agents hold rational expectations. In this model, not only the delay in rise in nominal key policy rate increases the peak rise in inflation, the inflation rate responds even at an marginally increasing rate suggesting a strong non-linearity over the more delayed periods. This nonlinear reaction is attributed to the sustained positive output gap, targeted by central bank in pursuit of a soft landing, which contributes to the accelerating growth in inflation rates.

In order to test the theoretical prediction outlined by Hakamada and Walsh (2024), a regression analysis was conducted on post-BTC and post-OTC inflation rates. The list of episode characteristics includes the probability scores associated with the BTC episodes (column 4 in Table A.4), dummy variable identifying the periods of BTC and OTC tightening (i.e., the suggested rise in the Taylor rule-like policy rate), and their combination. In addition, the episode's length in months is taken into consideration.

To address the issue of strong inertia in monthly inflation rates, the 3-month average inflation rate for the last three months of each of the BTC and OTC periods was included. In addition, the level or key policy rate (3-months average) is added to capture the static relationship between observed interest rates and inflation rates. As our sample includes the set of small and

Table 2: Determinants of post-BTC and post-OTC inflation rates

	Dep. = Inflation rate					
	F1.	F2.	F3.	F4.	F5.	F6.
Panel A: Episode characteristics						
Lag inflation (3m av.)	0.940***	0.789***	0.748***	0.744***	0.776***	0.767***
	(0.039)	(0.074)	(0.083)	(0.092)	(0.097)	(0.120)
Lag key policy (3m av.)	-0.254***	-0.360***	-0.437***	-0.590***	-0.732***	-0.877***
	(0.051)	(0.068)	(0.088)	(0.111)	(0.131)	(0.153)
Lag ER change (3m av.)	0.043**	0.074***	0.088***	0.087**	0.046	0.029
	(0.017)	(0.026)	(0.032)	(0.036)	(0.049)	(0.059)
Panel B: Macroeconomic determinants						
Prob(BTC=1)	0.623	1.251	1.521	2.267**	2.345*	3.266*
	(0.457)	(0.883)	(1.013)	(1.074)	(1.331)	(1.852)
Tightening (dummy=1)	-0.061	1.083	1.976*	2.630*	2.583	3.246
	(0.912)	(0.998)	(1.095)	(1.33)	(1.621)	(2.128)
BTC*Tightening	-0.117	-1.744	-2.087	-2.999*	-3.308	-4.128
	(1.074)	(1.353)	(1.461)	(1.705)	(1.971)	(2.566)
Length (# months)	-0.014	-0.014	-0.06	-0.086*	-0.112*	-0.111
	(0.026)	(0.035)	(0.040)	(0.047)	(0.059)	(0.074)
Constant	0.181	0.528	0.776	0.593	0.862	0.390
	(0.351)	(0.682)	(0.772)	(0.832)	(1.015)	(1.356)
Country FE	YES	YES	YES	YES	YES	YES
N	49	49	49	49	49	49
R2	0.953	0.872	0.799	0.741	0.685	0.603

Notes: Standard errors are reported in parentheses (p-values: * $<$ 0.10, ** $<$ 0.05, *** $<$ 0.01). Lag inflation (3m av.) is calculated as the 3-month mean of inflation rates preceding the beginning of the post-BTC and post-OTC episodes. Lag key policy rate (3m av.) is calculated as the 3-month mean of key policy rates preceding the beginning of the post-BTC and post-OTC episodes. Lag ER change (3m av.) is calculated as the 3-month mean of MoM exchange rate growth rate preceding the beginning of the post-BTC and post-OTC episodes. BTC stands for the probability of a BTC episode reported in Table A.4, column 4, with the BTC scores increasing for periods when there is a disagreement in direction of artificial Taylor-rule like policy rate and key policy rate. Tightening is a dummy variable identifying a period of upward pressure on change in key policy rate. Length reports the number of months for the associated BTC or OTC periods.

open economies, the 3-month average of change in nominal exchange rate is also considered.

At first glance (Panel A), we find no evidence that the behind-the-curve behavior of central banks affects future inflation rates in the short term once the standard macroeconomic factors are controlled for. It is only at the longer horizon — the fourth to sixth month following the end of the BTC or OTC period — that we observe an increase (decline) in inflation for periods characterized by a discrepancy between the forecast and realized policy rate. Aside from this, we do not find any statistically or economically significant patterns contributing to post-BTC inflation rates among this group of covariates. Among the standard macroeconomic determinants (Panel B), we observe strong yet declining inertia in the influence of past inflation rates, a strong and increasing effect of the key policy rate over time, and a short-lived positive contribution of the exchange rate to post-episodic inflation rates.[6]

In order to further disentangle a possibly conditional relationship between the lag in monetary policy response, its persistence, and the direction of a desired reaction, a triple interaction terms between the probability of the BTC occurrence, its length, and direction are introduced. We plot conditional response of inflation rate to a one unit (i.e., month) increase in the duration of the BTC period conditional on the pre-determined change in the key policy rate in Figure 4 (one month ahead) and Figure 5 (six months ahead). All the combinations of estimated AMEs are reported in Table A.5.

We report a few intriguing findings for the AMEs associated with the length of the BTC (OTC) episodes (see Panel A in Table A.5). First, inflation rates following the prescribed monetary policy path ($BTC \to 0$) react in line with expectations during tightening periods, with a reported decrease in inflation rates following the cut in the key policy rate, magnified by each additional month of unchanged policy. Conversely, the effect of prolonged monetary easing policies on inflation rates is not statistically significant across most horizons.

Next, the periods of "behind-the-curve" behavior (i.e. $BTC \to 1$) are associated with a statistically significant and positive reaction to policy tightening, but only over shorter time horizons. In other words, when central banks enter their tightening streak, they are fighting comparably higher inflation rates, with the inflation bias increasing for each additional month of the initial delay. However, across the longer horizons, a potentially stronger counter-reaction from central banks, driven by a perceived need to catch up, could offset the short-term effects of an initial no-reaction policy.

Last, the persistence of monetary policy action, i.e. the length of BTC or OTC episodes, economically magnifies the effect of the monetary shock on inflation rates over the time horizon ('Length' in Figure 4 and 5). In other words, each month of additional tightening (easing) contributes to a potential decrease (increase) in inflation rates – in economic terms, the effect expands over time. This finding corroborates the theoretical prediction of Hakamada and Walsh (2024), who argue that a more pronounced nonlinear response in the inflation rate is observed as the behind-the-curve behavior persists over time.

To complement our analysis, we report the AMEs for a more complex measure of monetary policy stance: the accumulated absolute value of the divergence between the key policy rate and the forecasted Taylor rule-like rate (Panel B, Table A.5). This corresponds to the product of the diverging monetary policy stance (y-axis) and period length (x-axis) in Figure 1. For the OTC episodes, we document a strong, statistically significant impact of increasing divergence in monetary policy stance for both, monetary easing and tightening ('Costs' in Figure 6 and 7). Compared to the statistically insignificant results reported in Panel A, the effect of monetary easing policies is therefore likely influenced by consistently looser actual policy than prescribed by the model, rather than the

[6] For interest, the increasing value of the coefficient associated with the key policy rate, which peaks in the sixth month, is consistent with the general literature on the speed of monetary policy transmission. This literature reports that the peak response to an exogenous monetary policy shock occurs between nine and twelve months.

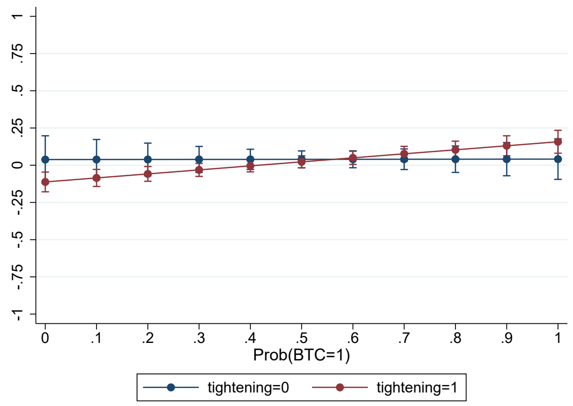


Figure 4: AME(Length) for post-BTC (OTC) inflation (1 month ahead)

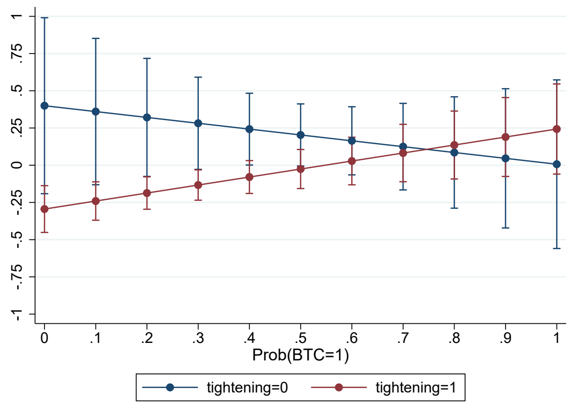


Figure 5: AME(Length) for post-BTC (OTC) inflation (6 months ahead)

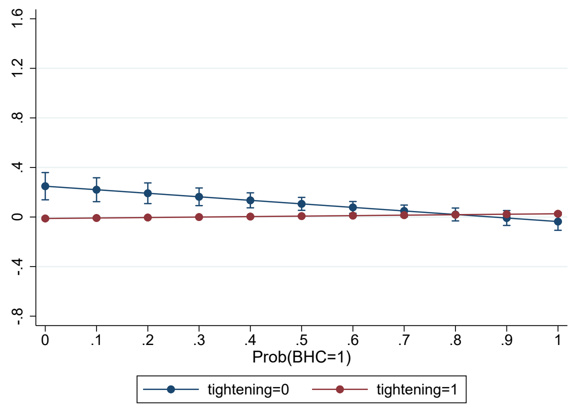


Figure 6: AME(Costs) for post-BTC (OTC) inflation (1 month ahead)

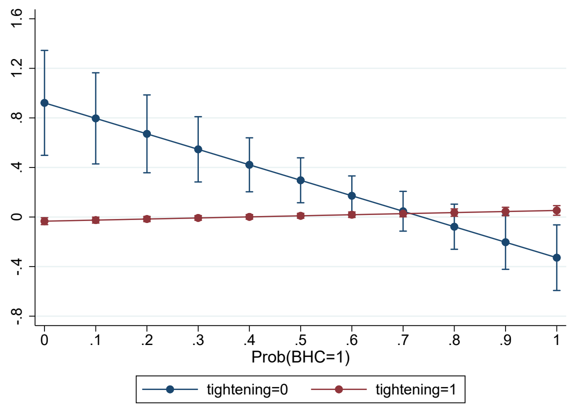


Figure 7: AME(Costs) for post-BTC (OTC) inflation (6 months ahead)

Note: Average marginal effects (AME) reported for the change in length or absolute costs of the BTC or OTC episodes. Full list of the BTC and OTC periods is reported in Table A.2. AME are calculated for the specifications reported in Table 2 with the triple interaction terms between Prob(BTC=1), Length(# months), and Tightening(dummy=1), or Costs respectively. AMEs reported with 90-percent confidence intervals. Length reports the number of months for the associated BTC or OTC periods. Abs. costs measure the accumulated absolute difference between the Taylor rule-like policy rate and key policy rate. The dependent variable is specified as a 1-month (6 months) ahead inflation rate materialized after the end of the BTC or OTC period. Tightening is a dummy variable identifying a period of upward pressure on change in key policy rate. Costs is a variable calculated as the accumulated sum of the difference between the key policy rate and the Taylor rule-like implied interest rate.
Source: own calculation

length of the easing period.

For the BTC periods, a delay in tightening of monetary policy brings about substantial inflationary costs for each additional unit of monetary policy divergence. The peak in inflationary response is achieved at the longest horizon ($6th$ month) after the end of the BTC period (Table A.5). As a result, while the time dimension of the delay in monetary response (x-axis in Figure 1) introduces an short-lived inflationary bias early on, the size of the monetary policy divergence (y-axis in Figure 1) may magnify the bias across longer horizons.

From this perspective, the length of the OTC periods may be an important factor to consider when discussing the optimal policy response to inflationary or deflationary pressures. An initial delay in policy action may introduce an inflationary bias, prompting central banks to react more forcefully in the initial phases of policy tightening. Conversely, the extent of disagreement in monetary policy stance may influence post-episodic inflation rates over longer periods, prompting central banks to extend their policies beyond what is usually considered. Our findings corroborate the recent argument put forward by ECB representatives, who emphasize that the 'last mile' is often the most difficult one (Schnabel, 2024).

3.3 Sensitivity analysis

First, we replace the forward looking inflation expectations in eq. [10] by a backward looking alternative, namely by the current inflation rate, and average annual inflation rate at $t-1$. Estimation results are reported in column 2 and 3 in Table A.1. None of the alternative specifications produced set of meaningful predictions of the the Taylor rule-like policy rates for the 2020-2024 forecasting period.

Second, we exclude all the BTC and OTC periods which only lasted less than three months. Central banks often do not held the governing council meetings every month which may result in a natural delay in the monetary policy decision. In addition, the regular updates of data inputs are usually lagging behind one or two months. As a result, the conservative central banker is expected to wait for the confirmation of an underlying trend in a data for at least one or two months to separate relevant information from the noise in the data. Not only the AMEs reported for majority of BTC determinants increase in magnitude, the statistical significance for change in official FX reserves and inflation rate improves as well (Table A.3). On the other hand, the role of cyclical elements in headline inflation, such as energy and housing prices (see Figures A.13 and A.9), is more pronounced, as illustrated by the observations being more dispersed across the diagonal – but, the probability scores from these specifications are not utilized in our next step. The estimated AMEs, along with their statistical significance, for periods longer than two months are very similar to the baseline AMEs reported in Table 1, with positive and statistically significant coefficients reported for the combination of policy tightening and a higher probability of a BTC episode in the first and second months (F1. and F2.).

Third, we calculate standard errors clustered at country level in Table 1 and Table 2 and for triple interaction terms reported in Table A.5. The statistical significance for all of the determinants remains practically unaffected at the 5% or 10% significance levels.

Fourth, as our variable of interest, i.e., the probability of experiencing the BTC period, is subject to uncertainty due to the use of fitted values from the first-stage probit estimation, we use jackknife standard errors with 50 replications to recalculate the statistical significance of the AMEs reported in Table A.5. The confidence intervals calculated for the periods of loose monetary policy (tightening=0) are statistically insignificant for the associated AMEs, regardless of the BTC likelihood. In contrast, the confidence intervals for the tightening periods with low BTC probability scores remain negative and statistically significant across all horizons. The combination of high BTC probability scores and tightened monetary policy over a short horizon (the first and second months) is associated with statistically significant and positive coefficients. In the case of interaction terms based on the absolute costs, the use of jackknife standard errors results in the loss of statistical significance for the AMEs reported for the higher BTC probability scores.

Fifth, the direct inclusion of nominal exchange rate into policy rule has been advocated by few studies (e.g. Choudhri and Hakura, 2006; López-Villavicencio and Mignon, 2017). We therefore replace the change in official FX reserves by the change in the nominal exchange rate in specifications (1)-(7) in Table 1. As anticipated, a decline in the value of the domestic currency is associated with a reduction in the probability of a central bank delaying its monetary policy response – however, the statistical significance is lost in the specifications with the central bank balance sheet growth included. We also exclude the change in nominal exchange rate from the specifications used to calculate conditional AMEs reported in Table 1 to mitigate the possible bias due to the presence of the same variable in the 2^{nd}-stage regression. Interestingly, the combination of the "behind-the-curve" behavior (i.e., $BTC \rightarrow 1$) and tightening monetary policy is statistically significant also over longer horizons (4^{th} to 6^{th} months), in addition to the first month. The interactions between exchange rate policies, balance sheet policies and standard monetary policy may therefore be more complex in nature, in particular in set of small and open economies.

4 Conclusions

In this paper, we quantitatively assess the 'behind-the-curve' behavior of central banks during the recent inflation surge in Europe. This concept describes a situation in which a central bank deviates in its response to the changing economic environment relative to a policy change implied by a Taylor rule. In contrast to the standard approach, which approximates the stance of monetary policy as the difference between the key policy rate and a Taylor rule-implied policy rate, the behind-the-curve measure focuses on the duration of the divergence between two policy rates in terms of elapsed time. The Taylor rule-like policy rates for nine European inflation targeting countries are computed from the long-T-small-N panel model with a rich set of time and country-interacted fixed effects.

We then identify a number of determinants that contribute to the presence of 'behind-the-curve' behavior in our sample. Among them, an increase in the size of a central bank's balance sheet, a positive change in the foreign exchange reserves and higher inflation rates reduce the likelihood of the 'behind-the-curve' episodes. A prolonged tightening of monetary policy leads to an expected decrease in inflation rates in the post-OTC periods. The inflationary bias, i.e., the comparably higher inflation rates in the post-BTC episodes, is reported only at a short-term horizon, which may possibly indicate a stronger counter-reaction by central banks at longer horizons. Our findings corroborate the theoretical prediction of Hakamada and Walsh (2024) who argue that each period of prolonged 'behind-the-curve' monetary policy conduct brings about additional inflationary costs.

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Appendix

Table A.1: Taylor rule estimation

	Dep. = Key policy rate (1)	(2)	(3)
Panel A: Key elements of Taylor rule			
L. Key policy rate	0.881***	0.883***	0.894***
	(-0.025)	(0.023)	(0.017)
Neutral interest rate	0.082*	0.023	0.067*
	(-0.040)	(0.021)	(0.035)
Inflation gap	0.487***	-0.067***	0.142***
	(-0.005)	(0.001)	(0.007)
Output gap	-0.001*	-0.001**	-0.003***
	(-0.001)	(0.000)	(0.000)
Panel B: Country-specific reaction function to inflation gap			
Czechia	-0.396***	0.132***	-0.152***
	(-0.027)	(0.004)	(0.013)
Euro Area	-0.448***	0.143***	-0.161***
	(-0.035)	(0.008)	(0.024)
Hungary	-0.543***	0.107***	-0.246***
	(-0.033)	(0.005)	(0.045)
Poland	-0.457***	0.180***	-0.130**
	(0.048)	(0.014)	(0.045)
Romania	-0.571***	0.101***	-0.230***
	(0.035)	(0.009)	(0.047)
Serbia	-0.526***	0.102***	-0.141***
	(0.03)	(0.001)	(0.032)
Sweden	-0.275***	0.128***	-0.235***
	(0.038)	(0.004)	(0.014)
United Kingdom	-0.403***	0.051***	-0.269***
	(0.026)	(0.003)	(0.014)
Panel C: Country-specific reaction function to output gap			
Czechia	0.016***	0.011***	0.011***
	(0.002)	(0.002)	(0.000)
Euro Area	0.053***	0.048***	0.049***
	(0.002)	(0.002)	(0.001)
Hungary	-0.006*	-0.011***	-0.001
	(0.002)	(0.003)	(0.003)
Poland	0.035***	0.034***	0.035***
	(0.002)	(0.004)	(0.001)
Romania	-0.021***	-0.019***	-0.015***
	(0.003)	(0.004)	(0.004)
Serbia	0.023***	0.023***	0.023***
	(0.002)	(0.002)	(0.003)
Sweden	0.024***	0.028***	0.027***
	(0.002)	(0.002)	(0.001)
United Kingdom	0.046***	0.047***	0.048***
	(0.001)	(0.001)	(0.001)
Panel D: Fixed effects			
Constant	1.451***	0.065	0.237***
	(0.037)	(0.036)	(0.031)
Country	YES	YES	YES
Year	YES	YES	YES
Month	YES	YES	YES
N	1646	1646	1646
R2 adj.	0.995	0.995	0.995
RMSE	0.231	0.230	0.231

Notes: Standard errors clustered at country level reported in parentheses (p-values: * $<$ 0.10, ** $<$ 0.05, *** $<$ 0.01). Equation estimated from specification 10. Key policy rate is a function of persistence (L.Key policy rate), the deviation of inflation from the target (inflation gap), and the output gap. In column 1, the inflation gap is calculated as the difference between consumer inflation expectations and the inflation target. In column 2, the inflation gap is calculated as the difference between current inflation rate and the inflation target. In column 3, the inflation gap is calculated as the difference between 1-year rolling inflation rate and the inflation target. The neutral interest rate is the sum of the short-term trend real interest rate and inflation expectations. In panel B we report country-specific coefficients from interaction between country fixed effect and inflation gap. In panel C we report country-specific coefficients from interaction between country fixed effect and output gap.

Table A.2: List of BTC periods and their characteristics

Country	Period beginning Year	Month	Period characteristics Length	Upward	Costs	FX growth	CB growth	Term spread	BHC determinants FED spread	INF full	INF energy	INF house	INF admin	Post-BHC inflation determinants Key rate*	Inflation*	ER change*
Panel A: On the curve (OTC) episodes																
Albania	2020	6	2	0	1.352	15.27	2.59	2.22	-0.42	2.19	1.18	2.35		0.50	2.19	2.06
Albania	2020	12	9	0	3.829	3.90	0.56	2.33	-0.42	1.85	1.26	1.95		0.50	2.47	-6.10
Albania	2022	2	23	1	144.010	-1.72	0.29	2.56	1.09	6.04	3.65	6.24		3.17	4.58	-16.32
Czechia	2020	3	4	0	2.128	1.84	1.65	-0.61	-0.42	3.33	3.04	3.24	3.24	0.50	3.25	6.90
Czechia	2020	9	9	0	2.973	0.29	0.19	-0.08	-0.17	2.63	2.90	3.04	2.80	0.25	2.68	-9.77
Czechia	2021	9	18	1	32.400	-0.74	-1.08	-4.57	-3.66	13.00	10.66	12.06	13.31	7.00	18.08	2.72
Czechia	2023	12	8	0	6.201	1.08	1.29	-5.42	-0.42	3.15	4.40	2.28	1.63	4.92	2.47	6.96
Euro area	2021	2	9	0	6.278	0.27	1.96	0.84	0.08	2.26	1.20	1.89	2.18	0.00	3.46	0.49
Euro area	2022	7	15	1	34.290	0.35	-1.42	0.96	1.39	7.69	5.10	7.01	7.76	4.25	4.96	-6.07
Hungary	2020	6	6	0	1.974	2.44	4.90	1.98	-0.54	3.33	2.81	3.57	3.83	0.60	3.07	2.19
Hungary	2021	6	7	1	3.081	3.63	3.33	2.41	-1.57	5.98	4.15	6.36	6.60	2.10	7.13	2.00
Hungary	2022	2	20	1	140.110	0.78	0.45	-4.13	-7.67	18.09	13.07	17.92	18.64	13.00	14.63	-10.81
Hungary	2024	1	9	0	9.407	1.99	0.88	-0.72	-2.39	3.61	6.24	3.89	3.92	6.67	3.50	4.34
Poland	2020	3	3	0	1.685	0.35	6.93	0.62	-0.28	3.38	3.50	2.85	2.91	0.53	3.38	6.65
Poland	2021	10	21	1	50.806	0.50	0.49	-0.11	-2.82	12.64	9.54	10.93	12.78	6.75	12.51	-1.34
Serbia	2020	3	3	0	0.406	2.41	3.94	2.09	-1.33	1.35	1.62	1.22	1.15	1.58	1.35	2.16
Serbia	2020	10	16	0	8.721	1.39	0.93	2.60	-0.95	3.83	2.25	3.70	4.29	1.00	7.91	4.26
Serbia	2022	4	18	1	40.172	2.98	2.59	3.74	-1.05	13.16	8.98	12.72	15.02	6.50	11.32	-6.18
Serbia	2023	12	3	1	5.329	1.15	0.92	0.93	-1.17	6.54	5.73	6.05	6.73	6.50	6.54	-2.40
Sweden	2020	8	2	1	2.706	-1.18	2.14	0.27	0.10	0.80	1.48	0.93	0.48	0.00	0.80	-10.55
Sweden	2021	6	22	1	45.620	1.42	0.63	0.70	0.77	6.58	4.05	5.81	7.41	2.75	9.14	12.56
Sweden	2023	7	4	1	17.702	-0.24	-0.71	-0.82	1.46	4.62	6.78	7.01	4.63	3.85	4.05	1.73
United Kingdom	2020	3	3	0	1.114	9.33	9.80	0.09	0.13	0.96	1.43	1.12	1.06	0.13	0.96	3.95
Panel B: Behind the curve (BTC) episodes																
Albania	2020	3	3	0	2.17	2.03	2.07	2.60	-0.25	2.57	0.81	2.73		0.50	2.57	2.82
Albania	2020	8	4	1	2.80	-2.44	1.09	2.11	-0.41	2.36	1.36	2.51		0.50	2.45	-5.27
Albania	2021	9	5	0	4.24	5.50	0.72	2.23	-0.42	3.23	1.21	3.30		0.50	3.67	2.91
Albania	2024	1	5	1	45.22	-6.04	-2.71	1.54	2.08	2.76	3.00	2.87		3.25	2.41	-8.21
Czechia	2020	2	1	0	0.46	-0.32	0.45	-1.89	-0.67	3.75	3.29	3.75	3.66	2.25	3.75	1.05
Czechia	2020	7	2	1	1.36	-2.18	-1.47	-0.08	-0.16	3.55	3.33	3.55	3.51	0.25	3.55	1.07
Czechia	2021	6	3	0	1.84	0.08	1.05	-0.27	-0.49	2.76	2.84	3.36	3.13	0.58	2.76	-9.07
Czechia	2023	3	9	0	6.52	0.08	0.64	-6.62	-1.88	11.16	8.99	7.84	8.61	7.00	8.58	-7.73
Czechia	2024	8	4	1	1.18	0.27	0.25	-3.86	0.73	2.83	3.90	2.28	1.82	4.17	2.97	0.28
Euro area	2020	6	8	1	6.03	-1.05	2.96	0.57	0.09	0.03	0.59	0.20	-0.05	0.00	0.12	-6.71
Euro area	2021	11	8	1	5.86	0.90	0.62	1.83	0.35	6.55	3.02	5.01	6.54	0.00	8.05	11.30
Euro area	2023	10	8	0	8.81	1.00	-0.92	-0.75	0.83	2.62	3.25	3.44	2.74	4.50	2.46	0.55
Hungary	2020	12	6	1	1.70	-1.51	1.65	2.23	-0.52	3.89	2.47	4.22	4.53	0.60	4.78	-4.97
Hungary	2022	1	1	0	1.51	-3.26	-4.78	1.79	-2.82	7.94	6.14	8.40	8.68	2.90	7.94	9.34
Hungary	2023	10	3	1	14.39	1.54	-0.14	-3.89	-6.17	7.60	9.97	9.07	9.09	11.50	7.60	-12.87
Poland	2020	6	16	1	35.33	1.47	1.70	1.57	-0.02	4.17	4.74	3.76	3.90	0.10	5.10	1.00
Poland	2023	7	2	0	9.23	2.79	0.26	-1.65	-1.53	9.89	9.20	9.26	9.41	6.75	9.89	-11.45
Serbia	2020	6	4	1	1.27	-2.37	-1.89	2.72	-1.16	1.95	1.72	1.90	1.89	1.25	1.99	-4.34
Serbia	2022	2	2	1	2.15	-5.82	-3.76	4.57	-0.86	8.96	4.61	9.58	10.65	1.00	8.96	8.21
Serbia	2023	10	2	0	3.72	0.14	-0.04	1.20	-1.17	8.18	6.93	7.62	8.72	6.50	8.18	-7.17
Serbia	2024	3	5	0	9.32	2.39	2.43	0.78	-1.02	4.59	5.02	4.31	4.21	6.25	4.26	1.34
Sweden	2020	2	6	0	5.95	0.51	5.75	0.13	0.42	0.60	1.43	1.09	0.27	0.00	0.58	0.77
Sweden	2020	10	8	0	13.66	-0.63	0.58	0.49	0.08	1.51	1.75	1.40	1.43	0.00	2.42	-12.32
Sweden	2023	4	3	0	12.26	-0.97	-3.21	-0.69	1.66	6.91	6.97	7.96	7.43	3.33	6.91	8.72
Sweden	2023	11	6	0	21.54	0.95	-1.22	-1.36	1.33	2.65	4.52	3.73	2.15	4.00	2.45	0.43
United Kingdom	2020	6	5	1	1.22	0.84	2.84	0.25	-0.01	0.65	1.39	0.85	0.82	0.10	0.49	-7.02

Notes: *variable is calculated as the 3-months average of preceding the beginning of a post-BTC (OTC) episode. Length reports the number of months for the associated BTC (OTC) period. Upward defines the type of the BTC (OTC) episode with '1' denoting a BTC (OTC) period of an upward pressure on change in key policy rate, and loosening otherwise. Costs measure the accumulated absolute difference between the Taylor rule-like policy rate and key policy rate. FX growth is calculated as the MoM change in value of foreign exchange reserves excluding gold and SDR volumes and IMF quota. CB growth is calculated as the MoM change in value of central bank balance sheet. Term spread is calculated as the difference between 10-year government bond yield and 3 months money market rate. FED spread is calculated as the difference between Federal Reserve funds rate and key policy rate of a respective central bank. Inflation (headline) is reported for all-items HICP. Inflation (admin) is calculated for the overall HICP index excluding administered prices. Inflation (energy) is calculated for the overall HICP index excluding energy, food, alcohol and tobacco. Inflation (house) is calculated for the overall HICP index excluding housing, water, electricity, gas and other fuels. ER growth denotes change in nominal bilateral exchange rate against US dollar.

Table A.3: Determinants of BTC episodes longer than two months - average marginal effects

	Dep. = BHC episode (1=yes)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
FX reserves growth	-0.116***	-0.092**	-0.088**	-0.089**	-0.148***	-0.081**	-0.085**
	(0.039)	(0.045)	(0.044)	(0.044)	(0.040)	(0.040)	(0.043)
CB assets growth		-0.042	-0.047*	-0.049*	-0.045	-0.075**	-0.064**
		(0.030)	(0.027)	(0.027)	(0.031)	(0.030)	(0.027)
Term spread			-0.071*	-0.062	-0.050	-0.127**	-0.055
			(0.042)	(0.048)	(0.050)	(0.055)	(0.048)
FED spread				-0.037	-0.049	-0.035	-0.054
				(0.059)	(0.067)	(0.055)	(0.059)
Inflation (headline)	-0.029	-0.040*	-0.055***	-0.062***			
	(0.018)	(0.022)	(0.020)	(0.022)			
Inflation (net of admin.)					-0.061***		
					(0.023)		
Inflation (net of energy)						-0.126***	
						(0.039)	
Inflation (net of house)							-0.080***
							(0.024)
Country FE	YES	YES	YES	YES	YES	YES	YES
N	41	41	41	41	35	41	41
Pseudo R2	0.218	0.241	0.288	0.292	0.380	0.319	0.317

Notes: Standard errors are reported in parentheses (p-values: * $<$ 0.10, ** $<$ 0.05, *** $<$ 0.01). FX reserves growth is calculated as the MoM change in value of foreign exchange reserves excluding gold and SDR volumes and IMF quota. CB growth is calculated as the MoM change in value of central bank balance sheet. Term spread is calculated as the difference between 10-year government bond yield and 3 months money market rate. FED spread is calculated as the difference between Federal Reserve funds rate and key policy rate of a respective central bank. Inflation (headline) is reported for all-items HICP. Inflation (net of admin) is calculated for the overall HICP index excluding administered prices. Inflation (net of energy) is calculated for the overall HICP index excluding energy, food, alcohol and tobacco. Inflation (net of house) is calculated for the overall HICP index excluding housing, water, electricity, gas and other fuels.

Table A.4: List of BTC and OTC periods and their associated probabilities

Country	Period beginning Year	Month	Specification (1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: On the curve (OTC) episodes									
Albania	2020	6	0.000	0.000	0.000	0.000		0.000	0.000
Albania	2020	12	0.715	0.774	0.791	0.805		0.788	0.835
Albania	2022	2	0.635	0.639	0.538	0.502		0.455	0.452
Czechia	2020	3	0.360	0.354	0.208	0.210	0.073	0.162	0.189
Czechia	2020	9	0.662	0.718	0.550	0.559	0.559	0.468	0.522
Czechia	2021	9	0.600	0.511	0.502	0.536	0.608	0.433	0.483
Czechia	2023	12	0.505	0.503	0.770	0.754	0.761	0.824	0.776
Euro area	2021	2	0.582	0.528	0.571	0.589	0.592	0.607	0.588
Euro area	2022	7	0.496	0.565	0.494	0.464	0.454	0.436	0.447
Hungary	2020	6	0.174	0.096	0.023	0.016	0.002	0.023	0.015
Hungary	2021	6	0.060	0.045	0.004	0.003	0.000	0.005	0.003
Hungary	2022	2	0.093	0.042	0.035	0.044	0.013	0.119	0.025
Hungary	2024	1	0.388	0.479	0.505	0.490	0.479	0.378	0.556
Poland	2020	3	0.435	0.237	0.246	0.233	0.163	0.221	0.194
Poland	2021	10	0.419	0.435	0.355	0.377	0.359	0.415	0.418
Serbia	2020	3	0.305	0.253	0.261	0.275	0.184	0.279	0.280
Serbia	2020	10	0.411	0.485	0.420	0.428	0.396	0.601	0.447
Serbia	2022	4	0.032	0.012	0.000	0.000	0.000	0.000	0.000
Serbia	2023	12	0.379	0.392	0.415	0.408	0.406	0.392	0.406
Sweden	2020	8	0.512	0.474	0.469	0.495	0.410	0.568	0.577
Sweden	2021	6	0.272	0.248	0.127	0.121	0.020	0.225	0.172
Sweden	2023	7	0.453	0.536	0.566	0.542	0.429	0.311	0.370
United Kingdom	2020	3	0.256	0.030	0.063	0.053	0.003	0.012	0.024
Panel B: Behind the curve (BTC) episodes									
Albania	2020	3	0.736	0.687	0.654	0.663		0.695	0.662
Albania	2020	8	0.910	0.897	0.912	0.919		0.921	0.927
Albania	2021	9	0.094	0.176	0.158	0.162		0.223	0.170
Albania	2024	1	0.947	0.984	0.993	0.991		0.990	0.994
Czechia	2020	2	0.622	0.645	0.605	0.611	0.610	0.672	0.584
Czechia	2020	7	0.774	0.863	0.740	0.748	0.858	0.727	0.763
Czechia	2021	6	0.561	0.577	0.399	0.411	0.302	0.325	0.342
Czechia	2023	3	0.294	0.203	0.372	0.351	0.363	0.477	0.493
Czechia	2024	8	0.654	0.704	0.831	0.808	0.869	0.856	0.821
Euro area	2020	6	0.889	0.808	0.883	0.895	0.983	0.858	0.880
Euro area	2021	11	0.411	0.377	0.245	0.245	0.173	0.287	0.299
Euro area	2023	10	0.654	0.765	0.898	0.897	0.924	0.879	0.852
Hungary	2020	12	0.965	0.937	0.824	0.794	0.996	0.932	0.826
Hungary	2022	1	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Hungary	2023	10	0.296	0.373	0.601	0.650	0.504	0.520	0.573
Poland	2020	6	0.496	0.620	0.584	0.577	0.547	0.540	0.597
Poland	2023	7	0.653	0.707	0.816	0.813	0.925	0.826	0.791
Serbia	2020	6	0.973	0.991	0.993	0.994	1.000	0.999	0.998
Serbia	2022	2	1.000	1.000	0.998	0.998	1.000	1.000	0.998
Serbia	2023	10	0.608	0.611	0.586	0.579	0.761	0.523	0.577
Serbia	2024	3	0.303	0.275	0.333	0.326	0.276	0.239	0.308
Sweden	2020	2	0.824	0.517	0.503	0.513	0.727	0.477	0.495
Sweden	2020	10	0.770	0.777	0.764	0.788	0.889	0.869	0.868
Sweden	2023	4	0.762	0.862	0.861	0.845	0.929	0.843	0.822
Sweden	2023	11	0.449	0.616	0.738	0.727	0.644	0.736	0.723
United Kingdom	2020	6	0.937	0.888	0.965	0.965	0.997	0.955	0.965

Notes: The probabilities reported in columns (1)-(7) are calculated from the specifications (1)-(7) in Table 1. The probabilities approximate the likelihood of a BTC period occurring.

Table A.5: Conditional AMEs for post-BTC (OTC) inflation over different time horizons

Prob(BTC=1)	MP type	F1.	F2.	F3.	F4.	F5.	F6.	MP type	F1.	F2.	F3.	F4.	F5.	F6.
Panel A: Estimated AMEs for the length of BTC and OTC periods														
0.0	Loosening	0.038	-0.149	-0.039	0.126	0.322	0.400	Tightening	-0.112***	-0.119***	-0.176**	-0.222**	-0.263***	-0.294***
0.1	Loosening	0.038	-0.113	-0.016	0.123	0.291	0.360	Tightening	-0.085**	-0.090**	-0.145**	-0.186**	-0.221***	-0.241***
0.2	Loosening	0.039	-0.078	0.007	0.120	0.260	0.321	Tightening	-0.058*	-0.061*	-0.114**	-0.150**	-0.179***	-0.187***
0.3	Loosening	0.039	-0.042	0.030	0.118	0.229	0.282	Tightening	-0.031	-0.032	-0.083*	-0.114**	-0.137**	-0.133**
0.4	Loosening	0.039	-0.006	0.053	0.115	0.198	0.243*	Tightening	-0.004	-0.003	-0.052	-0.078	-0.096*	-0.079
0.5	Loosening	0.040	0.030	0.077	0.113	0.167	0.203	Tightening	0.023	0.026	-0.021	-0.042	-0.054	-0.026
0.6	Loosening	0.040	0.065	0.100	0.110	0.136	0.164	Tightening	0.045*	0.055	0.010	-0.006	-0.012	0.028
0.7	Loosening	0.040	0.101	0.123	0.107	0.104	0.125	Tightening	0.077**	0.084*	0.041	0.030	0.030	0.082
0.8	Loosening	0.040	0.137	0.146	0.105	0.073	0.085	Tightening	0.104***	0.113*	0.072	0.066	0.072	0.136
0.9	Loosening	0.041	0.173	0.169	0.102	0.042	0.046	Tightening	0.131***	0.142**	0.103	0.102	0.113	0.189
1.0	Loosening	0.041	0.208	0.192	0.099	0.011	0.007	Tightening	0.158***	0.171**	0.134	0.139	0.155	0.243
Panel B: Estimated AMEs for the abs. costs of BTC and OTC periods														
0.0	Loosening	0.249***	0.219	0.389*	0.509**	0.681***	0.921***	Tightening	-0.012*	-0.013	-0.024**	-0.034***	-0.036***	-0.033*
0.1	Loosening	0.220***	0.196	0.343*	0.443**	0.589***	0.796***	Tightening	-0.008	-0.009	-0.019**	-0.027***	-0.028**	-0.025*
0.2	Loosening	0.192***	0.173	0.297**	0.378**	0.497***	0.671***	Tightening	-0.004	-0.005	-0.014*	-0.019**	-0.020**	-0.016
0.3	Loosening	0.163***	0.150	0.251**	0.313**	0.405***	0.546***	Tightening	0.000	0.000	-0.008	-0.012	-0.011	-0.007
0.4	Loosening	0.135***	0.127	0.205**	0.248***	0.313***	0.422***	Tightening	0.004	0.004	-0.003	-0.005	-0.003	0.001
0.5	Loosening	0.106***	0.104*	0.159**	0.183**	0.221***	0.297***	Tightening	0.007**	0.008	0.002	0.003	0.005	0.010
0.6	Loosening	0.078***	0.081**	0.114**	0.118**	0.130*	0.172*	Tightening	0.011***	0.013	0.007	0.010	0.014	0.019
0.7	Loosening	0.049*	0.058*	0.068	0.053	0.038	0.047	Tightening	0.015***	0.017	0.013	0.017*	0.022**	0.027*
0.8	Loosening	0.021	0.035	0.022	-0.012	-0.054	-0.078	Tightening	0.019***	0.021	0.018	0.025**	0.030**	0.036**
0.9	Loosening	-0.008	0.011	-0.024	-0.077	-0.146	-0.203	Tightening	0.023***	0.026*	0.023	0.032**	0.039***	0.045**
1.0	Loosening	-0.036	-0.012	-0.070	-0.142	-0.238*	-0.328**	Tightening	0.027***	0.030*	0.028*	0.039**	0.047***	0.053**

Notes: P-values: * $<$ 0.10, ** $<$ 0.05, *** $<$ 0.01. Average marginal effects calculated by delta method. The probabilities reported in column Prob(BTC=1) are calculated from the specifications (4) in Table 1. The probabilities approximate the likelihood of a BTC period occurring. Tightening defines the type of the BTC (OTC) episode with '1' denoting a BTC (OTC) period of an upward pressure on change in key policy rate, and loosening otherwise. Estimated horizons following the end of a BTC and OTC episode denoted as F1. - one month inflation ahead, F2. - two months inflation ahead, F3. - three months inflation ahead, F4. - four months inflation ahead, F5. - five months inflation ahead, F6. - six months inflation ahead.

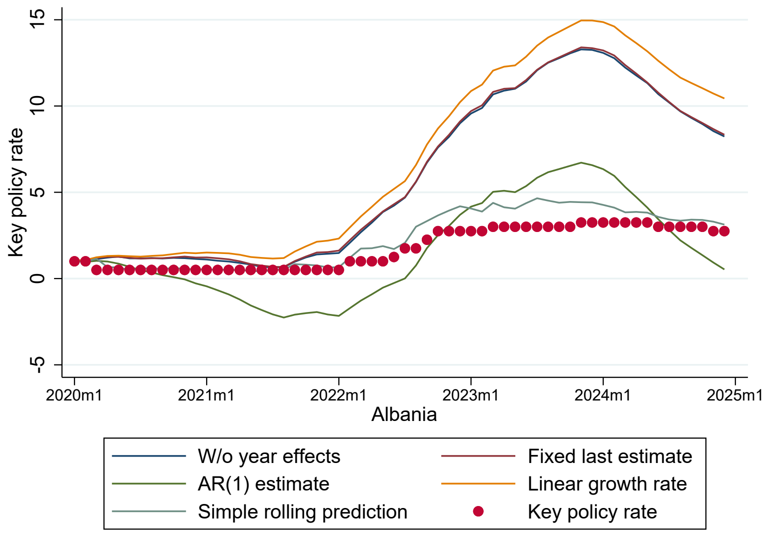

Figure A.1: Key policy rate vs. Taylor rule-like policy rate - Albania

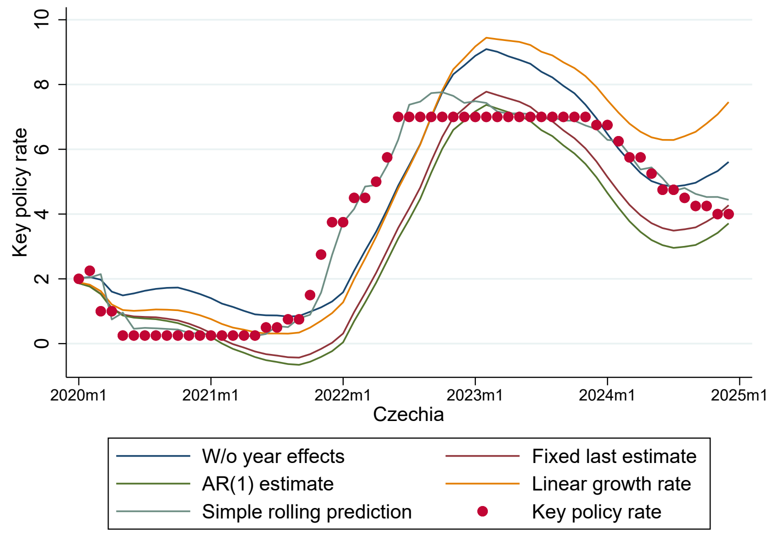

Figure A.2: Key policy rate vs. Taylor rule-like policy rate - Czechia

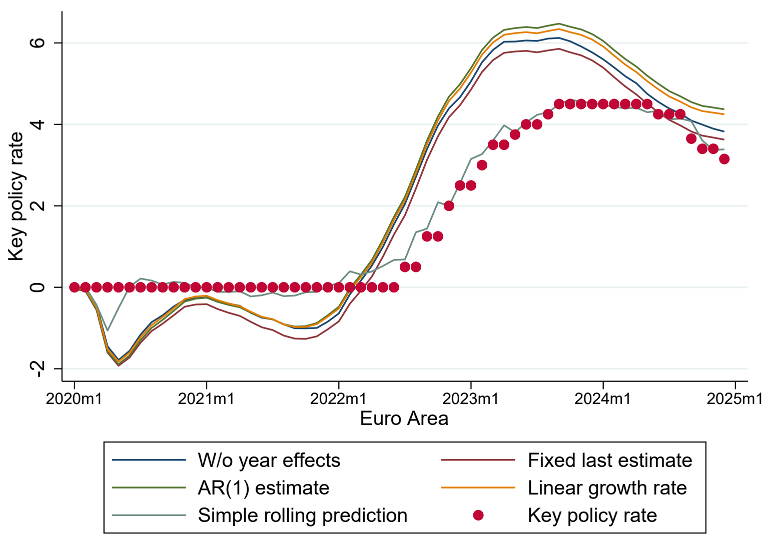

Figure A.3: Key policy rate vs. Taylor rule-like policy rate - Euro Area

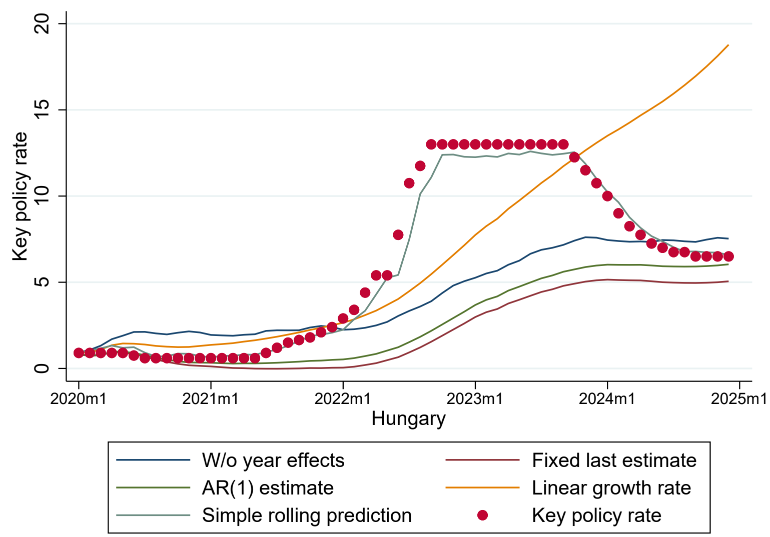

Figure A.4: Key policy rate vs. Taylor rule-like policy rate - Hungary

Note: Taylor rule-like rates are estimated from the equation 10.
Source: own calculation

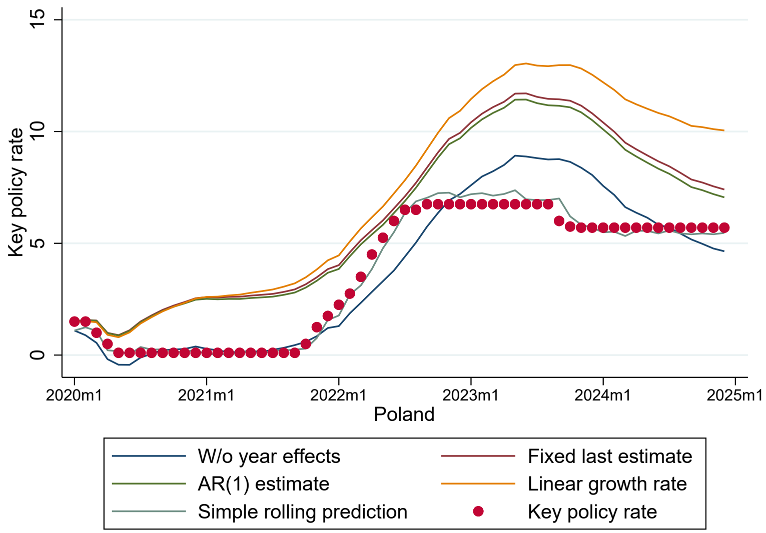

Figure A.5: Key policy rate vs. Taylor rule-like policy rate - Poland

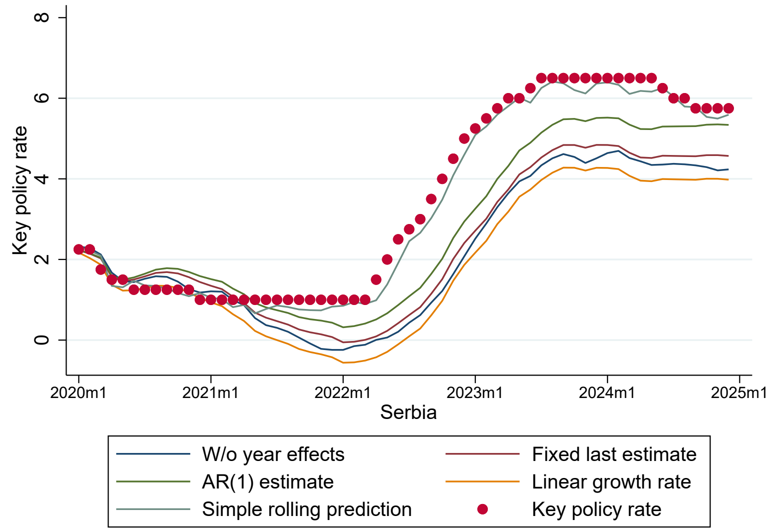

Figure A.6: Key policy rate vs. Taylor rule-like policy rate - Serbia

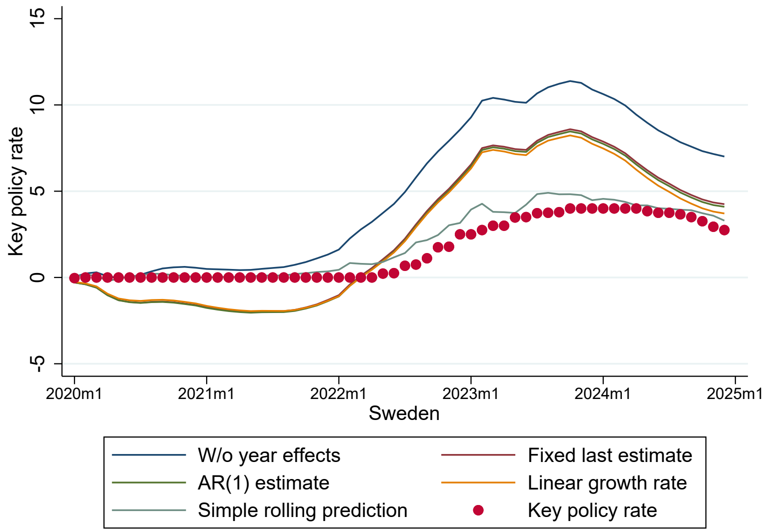

Figure A.7: Key policy rate vs. Taylor rule-like policy rate - Sweden

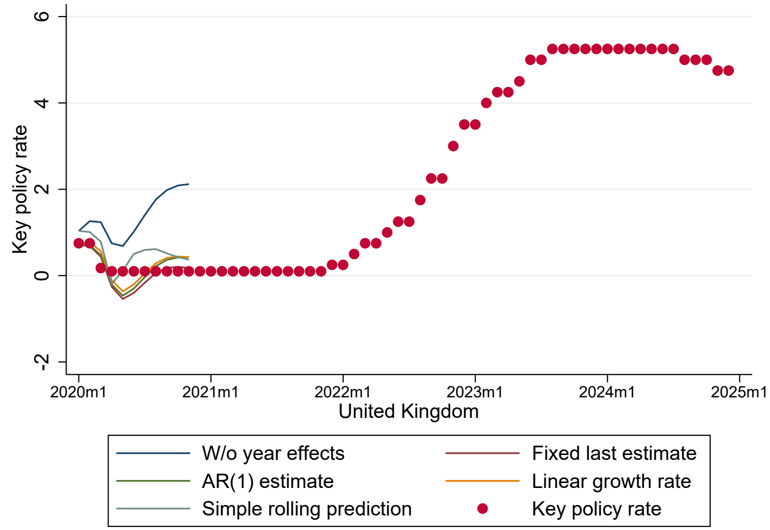

Figure A.8: Key policy rate vs. Taylor rule-like policy rate - UK

Note: Taylor rule-like rates are estimated from the equation 10.
Source: own calculation

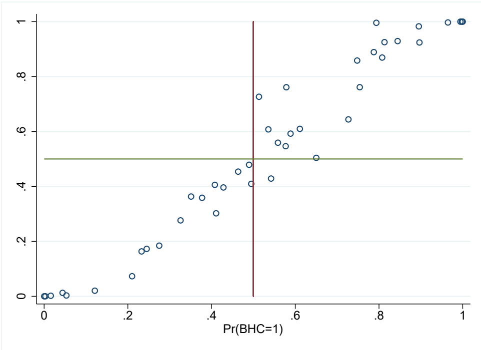

Figure A.9: Inflation net of administrative prices (N=42)

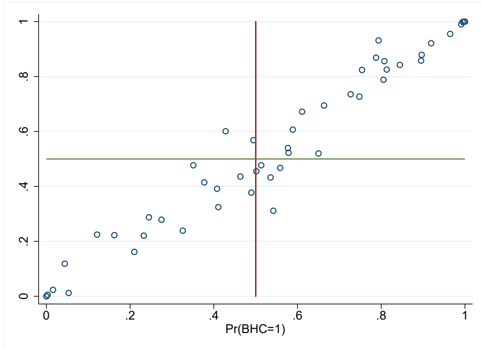

Figure A.10: Inflation net of energy and food prices (N=49)

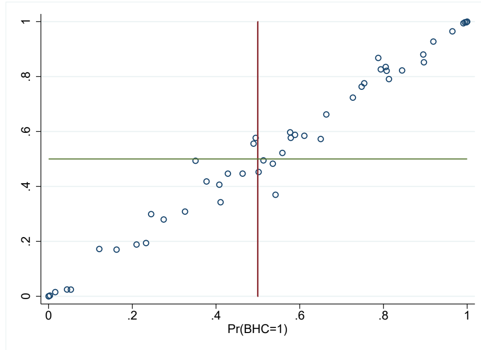

Figure A.11: Inflation net of housing prices (N=49)

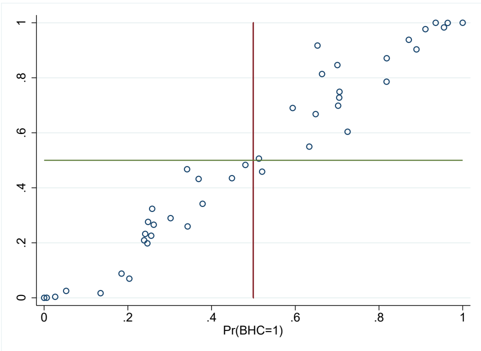

Figure A.12: Inflation net of administrative prices (N=35)

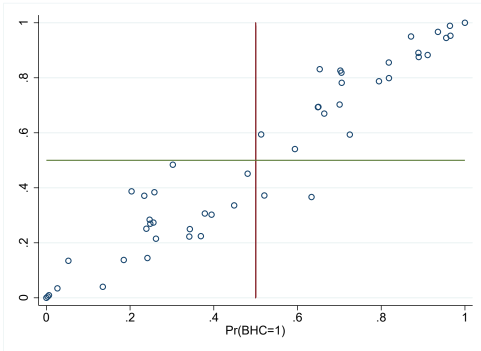

Figure A.13: Inflation net of energy and food prices (N=41)

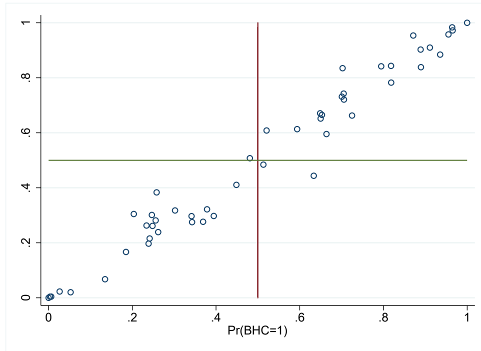

Figure A.14: Inflation net of housing prices (N=41)

Note: Scatter plots depict the likelihood of a BTC episode calculated from the specification (4) in Table 1 on x-axis against the likelihood of a BTC episode calculated from the specification (5) - net of administrative prices, (6) - net of energy and food prices, and (7) - net of housing prices in Table 1. Inflation (headline) is reported for all-items HICP. Inflation (admin) is calculated for the overall HICP index excluding administered prices. Inflation (energy) is calculated for the overall HICP index excluding energy, food, alcohol and tobacco. Inflation (house) is calculated for the overall HICP index excluding housing, water, electricity, gas and other fuels.
Source: own calculation