Has the ECB Implicitly Combined an Average Inflation Targeting Regime with an Inflation Tolerance Band?

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Abstract

In line with the consensus that price stability is the primary objective of monetary policy, central banks increasingly announce numerical inflation targets. However, recognising the inherent challenge of precisely meeting such targets, central banks often supplement these objectives with explicit or implicit tolerance bands. In the Eurozone, it remains unclear whether the ECB operates under a regime of point inflation targeting or employs an implicit point target with a tolerance band around the 2 per cent objective, potentially asymmetric prior to the July 2021 strategy review. This paper assesses whether, in practice, the ECB tolerated inflation deviations within a certain range, irrespective of the formal specification of its target. To identify the width of this range, we estimate a nonlinear monetary policy reaction function in which the response to inflation weakens within candidate intervals. The preferred specification is selected based on goodness of fit. We find that, until July 2021, the ECB's behaviour was consistent with an inflation range between 1.0 per cent and 1.7 per cent. This result points to a lower tolerance for inflation close to 2 per cent, contrasting with the "below but close to 2 per cent" formulation and previous estimates in the literature, and indicating an asymmetric policy stance prior to 2021.

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1. Introduction

Given recent comprehensive reviews of monetary policy strategies across various central banks, there has been heightened recognition of the critical importance of target formulation within the framework of inflation-targeting regimes. This acknowledgment arises from an understanding of the significant implications such formulations have for the effectiveness of monetary policy and the overall stability of macroeconomic conditions (see, for example, Chung *et al* 2020; Cecioni *et al* 2021; Ehrmann 2021; Bianchi *et al*

2021; ECB 2021a, b; Tosato 2022; Della Posta and Tamborini 2022, 2023; Le Bihan *et al* 2023; Davig and Foerster 2023).

In line with the widely shared consensus that price stability is the primary objective of monetary policy, central banks have increasingly embraced the practice of explicitly announcing a numerical target for inflation. However, recognising the inherent challenge in precisely meeting such a target, central banks often complement these objectives with explicit or implicit tolerance bands (Orphanides and Wieland 2000; Erceg 2002; Apel and Claussen 2017; Cleanthous 2020; ECB 2021a; Davig and Foerster 2023). Moreover, while there is widespread agreement regarding the detrimental consequences of high inflation or deflation, the effects of marginal changes in inflation near the threshold of price stability remain less clear (Orphanides and Wieland 2000).

The aim of this paper is to assess whether the ECB implicitly tolerated inflation deviations within a certain interval prior to its 2021 strategy review. In other words, we investigate whether the ECB, in practice, operated under a regime that entailed a zone of inaction, or weaker response, with respect to inflation fluctuations. This zone could be consistent either with a point inflation target accompanied by a tolerance band or with a range target, where no policy response is expected within the interval. Our empirical strategy does not impose a specific regime *ex ante*, nor does it allow us to distinguish between these two interpretations. Rather than assuming a particular target definition, we let the data reveal whether an interval existed within which inflation deviations did not trigger a strong monetary policy response.

Until 2021, the ECB defined price stability in the Eurozone as a year-on-year increase in the Harmonised Index of Consumer Prices (HICP) below, but close to, two per cent over the medium term. Since the 2021 strategy review, the ECB has reaffirmed its commitment to the 2 per cent target while acknowledging that both negative and positive deviations from this target are now equally undesirable.[2] The ECB's monetary policy strategy, as articulated by its executive board members,[3] aligns with the flexible forecast inflation targeting approach as described, for example, by Svensson (1997). However, the ECB's definition of price stability remains ambiguous in two respects.

A fundamental element of the ECB's monetary policy strategy, introducing a significant degree of ambiguity, is its commitment to achieving price stability over the medium term.[4] However, notably absent is any explicit reference to a predetermined monetary policy horizon. Consequently, the ECB retains flexibility regarding the exact period within which it seeks to achieve its price stability objective.[5] The question of the length of the ECB's policy horizon was examined by Mota and Fernandes (2022), who found evidence supporting the hypothesis that the ECB implicitly follows an average inflation targeting framework with a policy horizon of four and a half years.[6]

Another issue concerns whether the ECB operates under a point inflation target regime or an implicit point target with a tolerance band for inflation,

which may have been asymmetric around the 2 per cent objective, at least until the ECB's monetary policy review in July 2021.[7] Combining a monetary policy horizon referencing the medium term with a point target with a tolerance band regime provides the ECB with sufficient flexibility to conduct monetary policy (see Apel and Claussen 2017; Tosato 2022; Davig and Foerster 2023).

However, characterising the ECB's inflation target regime is challenging. It remains uncertain whether the ECB is adhering to a precise target of 2 per cent, a target with a margin of tolerance, potentially asymmetrical, or a range target, possibly leaning towards the upper boundary of 2 per cent (see Apel and Claussen 2017; Beechey and Österholm 2018; Hartmann and Smets 2018; Chung *et al* 2020; Cleanthous 2020; Davig and Foerster 2023; Ehrmann 2021; Le Bihan *et al* 2023; Della Posta and Tamborini 2022, 2023).[8] Cecioni *et al* (2021), for instance, suggest that the ECB adhered to a target range before 2003,[9] a range with a focal point between 2003 and 2021, and a point target since 2021.

To assess how the ECB has operationalised its inflation objective in practice, we estimate alternative specifications of its implicit policy reaction function over the period from September 2004 to June 2021, which corresponds to the timeframe preceding the revision of its monetary policy strategy in July 2021.[10] We use the shadow short-term interest rate as the independent variable.[11] This allows us to extend the analysis beyond March 2016, when the MRO interest rate reached zero, and to account for the effects of non-conventional monetary policy measures.

To determine the width of the inflation tolerance band around the 2 per cent target (if applicable), we estimate a non-linear implicit monetary policy reaction function. In this model, the coefficient on inflation decreases when inflation falls within a set of alternative band widths. We then select the width that yields the highest R^2 value. The innovation here is twofold. First, we assume that the ECB reacts to forecasts of average inflation rather than point inflation forecasts (in line with Mota and Fernandes 2022). Second, our model incorporates both interest rate smoothing[12] and policy rate stepping.[13]

The remainder of the paper is organised as follows. Section 2 discusses the differences between point targets, tolerance bands, and target range regimes, as well as their implications for the conduct of monetary policy. Section 3 outlines the empirical strategy, while Section 4 describes the data. Section 5 presents the estimation results, and Section 6 concludes.

2. Point Targets, Tolerance Bands and Target Ranges

Over the past three decades, central banks have embraced inflation targeting as a cornerstone of their monetary policy frameworks. Nonetheless, the practical implementation of inflation targeting varies across different dimensions. One critical aspect concerns the formulation of the target itself, meaning that the specifics of how inflation targets are set and pursued can differ significantly from one central bank to another.

Central banks worldwide commonly adopt various forms of targets, whether explicit or implicit. These targets, which serve as key benchmarks guiding monetary policy decisions, typically take one of three primary forms: *i*) point targets; *ii*) point targets with a tolerance band; and *iii*) target ranges (see Orphanidis and Wieland 2000; Andersson and Jonung 2017; Apel and Claussen 2017; Beechey and Österholm 2018; Cornand and M'baye 2018; Cleanthous 2020; Cecioni *et al* 2021; ECB 2021a, b; Ehrmann 2021; Le Bihan *et al* 2023). These regimes are often implemented alongside reference to a monetary policy horizon that extends well beyond the time lag implicit in the monetary policy transmission mechanism.

In a point target regime, the central bank states its objective as a single inflation figure, typically around 2 per cent, which is communicated to the public. In a point target regime with a tolerance band, the central bank sets a precise numerical inflation target but allows for certain deviations or fluctuations in observed inflation around that target (Apel and Claussen 2017; Beechey and Österholm 2018; Ehrmann 2021). In a target range regime, the central bank defines the inflation target as a range of values rather than a single point, which is then communicated to the public. This range typically covers a spectrum of inflation rates considered acceptable or desirable by the central bank (Apel and Claussen 2017; Beechey and Österholm 2018; Ehrmann 2021).

The fundamental difference between a point target regime with a tolerance band and a target range regime lies in how the central bank approaches inflation management. In a point target regime with a tolerance band, the central bank aims to steer inflation back toward a specific point target over the medium term. In contrast, under a target range regime, the central bank has the flexibility to target any inflation level within the specified interval (Apel and Claussen 2017; Cleanthous 2020).

The literature has highlighted the following advantages associated with point target regimes that include a tolerance band. The primary rationale for adopting a point target regime with a tolerance band lies in the flexibility it offers, allowing the central bank to accommodate short-term deviations from the target without necessitating immediate policy adjustments. This approach balances commitment to the point target with the need to avoid excessive volatility in output and interest rates that may result from reacting to minor or temporary inflation fluctuations. By providing this leeway, central banks can mitigate the risk of unnecessary volatility in output, unemployment, and interest rates (see Castelnuovo 2003; Apel and Claussen 2017; Beechey and Österholm 2018; Cleanthous 2020; Cornand and M'baye 2018; Ehrmann 2021; Della Posta and Tamborini 2022). Indeed, the flexibility afforded by a point target regime with a tolerance band is especially crucial for accommodating temporary and minor inflation shocks (Ehrmann 2021).

Another important advantage lies in the credibility enhancement argument. Recognising that achieving perfect precision in hitting the target may not always be attainable or advisable, given the inherent uncertainty surrounding

inflation expectations and the substantial transmission lags associated with monetary policy, central banks can bolster their credibility and mitigate the risk of policy missteps by adopting tolerance bands. Consequently, this approach can strengthen the anchoring of inflation expectations around the point target (see Bernanke *et al* 1999; Castelnuovo *et al* 2003; Apel and Claussen 2017; Andersson and Jonung 2017; Beechey and Österholm 2018; Cornand and M'baye 2018; Cleanthous 2020; Ehrmann 2021). Additionally, by refraining from immediate policy adjustments in response to minor deviations from the target, central banks can help maintain stability in financial markets. Indeed, sudden, and frequent policy changes can create uncertainty and volatility in asset prices, which may negatively impact investor confidence and market functioning (Le Bihan *et al* 2023).

However, it is important to note that, while point target regimes with tolerance bands or target ranges offer several advantages, they also entail certain disadvantages. One notable drawback of these regimes is the potential for ambiguity or a lack of clarity in monetary policy communication. Unlike point targets, which provide a specific numerical objective, tolerance bands or target ranges introduce some uncertainty about the central bank's precise inflation target. This ambiguity can cause confusion among market participants and policymakers, making it more challenging to interpret the central bank's policy intentions and to adjust market expectations accordingly (see Castelnuovo *et al* 2003; Mishkin and Westelius 2008).

Furthermore, regimes with tolerance bands or target ranges may face challenges in maintaining credibility and anchoring inflation expectations. While the flexibility offered by these regimes can be beneficial in accommodating short-term deviations from the target, it also raises concerns about the central bank's commitment to achieving its inflation objectives. Market participants may question whether the central bank will take timely and decisive action to steer inflation back towards the target if it exceeds the tolerance band or falls outside the target range. This uncertainty can undermine confidence in the central bank's ability to effectively control inflation, potentially leading to increased volatility in financial markets and inflation expectations (see Mishkin and Westelius 2008; Andersson and Jonung 2017; Apel and Claussen 2017; Beechey and Österholm 2018).

Regimes with tolerance bands or target ranges also introduce non-linearities in the conduct of monetary policy (see Orphanidis and Wieland 2000; Castelnuovo 2003; Ehrmann 2021; Le Bihan *et al* 2023), which can contribute to increased uncertainty in financial markets and greater macroeconomic volatility (Mishkin and Westelius 2008). Unlike point target regimes, where policy adjustments aim to return inflation to a specific numerical target, regimes with tolerance bands or target ranges involve more complex decision-making processes. The presence of tolerance bands or target ranges means that the central bank's response to deviations from the target may vary depending on the magnitude and persistence of the deviation. This introduces a degree of unpredictability

into monetary policy, as market participants may find it difficult to anticipate the central bank's actions in response to changing inflation dynamics.

Determining the width of the tolerance band or range interval therefore involves striking a delicate balance between the importance of anchoring inflation expectations, an element known to enhance macroeconomic stability, and the necessity of ensuring the operational feasibility of keeping realised inflation within the specified interval (Ehrmann, 2021; Tosato 2022). In general, a balanced trade-off exists among various target arrangements (see Tosato 2022, Table 1); systems that provide the most robust anchoring of inflation expectations, such as point targets, tend to offer limited flexibility, whereas more flexible systems, such as range targets, typically exert a weaker anchoring effect. Point target regimes with tolerance bands occupy an intermediate position between these extremes, and the broader the emphasis on output stabilisation, the wider the tolerance band tends to be (see Beechey and Österholm 2018; Cleanthous 2020; Ehrmann 2021).

The ECB's strategic framework, characterised by a medium-term monetary policy horizon and the possible adoption of a point target regime with a tolerance band, could be seen as leaning towards flexibility (see Tosato 2022).

3. The Monetary Policy Reaction Implicit Function

We assume that the ECB aims to stabilise average inflation around its target level, π*, over a specified horizon, while also placing weight on stabilising real economic activity. Additionally, we posit that the ECB faces both convex (e.g., quadratic) and non-convex (e.g., fixed, or piecewise-linear) adjustment costs associated with changes in the policy rate. Consistent with the frameworks developed by Svensson and Woodford (2005), Woodford (2007), and Svensson (2019, 2020), we further assume that the ECB seeks to minimise the expected deviations of projected inflation and unemployment from their respective targets. This policy approach is commonly referred to as flexible inflation-forecast targeting.[14]

Therefore, we consider that in each period t the ECB formulates monetary policy to minimise the intertemporal loss function $\mathcal{L}_t$, which represents the infinite discounted sum of the period t loss functions:

$$\mathcal{L}_t = E_t \sum_{\tau=0}^{T} \delta^{\tau} L_{t+\tau} = E_t \sum_{\tau=0}^{T} \delta^{\tau} \left[\omega_{\pi} d_t \left(\bar{\pi}_{j,t+\tau} - \pi^* \right)^2 + \omega_u (u_{t+\tau} - u^*)^2 + \omega_i [(\Delta i_t)^2 + c I_t] \right] \quad (1)$$

With $\omega_{\pi}, \omega_{u,} \omega_{i,} > 0$, $I_t = \begin{cases} 1 \; if \; \Delta i_t \neq 0 \\ 0 \; if \; \Delta i_t = 0 \end{cases}$, and $d_t = \begin{cases} 0, \; if \; \pi^* - \xi_L \leq \bar{\pi}_{j,t+\tau} \leq \pi^* + \xi_H \\ 0 \\ 1 \; otherwise \end{cases}$

Where E_t represents the ECB's expectations conditional on the information available in period t regarding the state of the economy and the monetary policy transmission mechanism. T denotes a finite horizon,[15] and δ^{τ} is a discount factor satisfying $0 < \delta^{\tau} \leq 1$. In Equation (1), π^* represents the inflation target (2 per cent for the Eurozone[16]), $u_{t+\tau}$ denotes the unemployment rate, u^* is the

estimated long-run (equilibrium) unemployment rate, and $\bar{\pi}_{j,t+\tau}$ denotes the forward looking average inflation rate.[17] The parameters ω_π, ω_u and ω_i represent the weights assigned to inflation, unemployment, and interest rate stabilisation, respectively. The parameter *j* denotes the timespan over which average inflation is computed, referred to as the 'monetary policy target horizon.' This horizon indicates the period within which inflation should be returned to the target level (see Batini and Nelson 2001; Nessén 2002; Smets 2003; Akram 2010; Mota and Fernandes 2022).

In this context, the central bank faces a trade-off involving zone quadratic losses arising from deviations of fundamentals from their targets, as represented by $(\bar{\pi}_{j,t} - \pi^*)^2$, and $(u_{t+\tau} - u^*)^2$.[18] In Equation (1), the central bank incurs a quadratic loss on the inflation gap only when it lies outside a tolerance band of width $\xi = \xi_L + \xi_H$, while the loss is close to zero within this band (see Orphanides and Wieland 2000; Apel and Claussen 2017).[19] Consequently, the focus on achieving unemployment (or output) objectives becomes more prominent when inflation remains within the specified range (Orphanides and Wieland 2000).

The central bank also incurs losses resulting from changes in the policy interest rate. These costs consist of a convex component, $(\Delta i_t)^2$, and a non-convex component, (see for more detail Battellino and Lowe 1997; Roszbach 1997; Eijffinger *et al* 1999; Guthrie and Wright 2004; and Mota and Fernandes 2022). This results in an optimal range of relative inaction for the central bank's policy interest rate (Eijffinger *et al* 2007).

According to Equation (1), we estimate an implicit forward-looking monetary policy equation, which helps to elucidate how the *ex-post* policy interest rate has responded to forecasts of both inflation and unemployment. For this purpose, we use the real-time database for the Eurozone developed by Mota and Fernandes (2022), which contains only the data available to the ECB Governing Council at the time of its policy rate decisions, as subsequently expanded by the authors. To capture the width of the inflation band around the 2 per cent target, our baseline specification for the ECB's desired policy interest rate, denoted as i_t^*, based on fundamentals, is formulated as follows:

$$i_t^* = \beta_0 + \beta_1 d_{1_{t,\xi}} \bar{\pi}^F_{(t,t+k_\pi),j} + \beta_2 u^F_{t,t+k_u} + \beta_3 d_{2_t} \bar{\pi}^F_{(t,t+k_\pi),j} + \varepsilon_t \quad (2)$$

and

$$d_{2_t} = \begin{cases} 1, & if\ i_t \leq \bar{\imath}_t \\ 0\ otherwise \end{cases}$$

In the empirical work, we use the shadow short-term interest rate as a proxy for i_t^*. The shadow rate captures the stance of monetary policy even when the MRO interest rate reaches the zero lower bound (see Wu and Xia 2017, 2020). This allows us to extend the scope of the analysis beyond March 2016, when the MRO rate hit zero.

Regarding the independent variables, and following Mota and Fernandes (2022), we assume that the ECB operates under an average inflation targeting

regime. This implies that inflation is intended to be stabilised, on average, over a period j consistent with the medium-term orientation of the monetary policy strategy. Hence, $\bar{\pi}^{F}_{(t,t+k_{\pi}),j}$ denotes the average inflation rate over the period j with a policy horizon k_{π} defined as: $\bar{\pi}^{F}_{(t,t+k_{\pi}),j} = \frac{1}{j}\sum_{s=0}^{j-1}\bar{\pi}^{F}_{t-s,t+k_{\pi}}$, where $\pi^{F}_{t,t+k_{\pi}}$, denotes the forecast of the inflation rate (measured as the year-on-year percentage change of the Harmonised Index of Consumer Prices) at time t for the forecast horizon k_{π}.

Building upon the empirical findings of Mota and Fernandes (2022), we set the ECB's monetary policy horizon to j = 54 months,[20] with a forecast horizon of k_{π} = 24 months.[21] This implies that the ECB considers the forecast of average inflation two years ahead, calculated as the average over a 54-month window comprising both past inflation values and forecasts. To assess the degree of resource utilisation, we rely on forecasts of unemployment rate, $U^{F}_{t,t+k_u}$, at two-year time horizon (k_u = 24 months).[22]

A zone quadratic loss function, as described in Equation (1), implies a non-linear monetary policy response to inflation. Specifically, the central bank is expected to respond more aggressively to inflation levels outside the tolerance band, ξ, than to those within it (see, Orphanides and Wieland 2000; Lengwiler and Orphanides 2002; Castelnuovo *et al* 2003; Apel and Claussen 2017; Chung *et al* 2020; Bianchi *et al* 2021; Le Bihan *et al* 2023). This asymmetry is captured by introducing a multiplicative dummy variable $d_{1_{t,\xi}}$ in Equation (2), which is expected to have a negative sign.

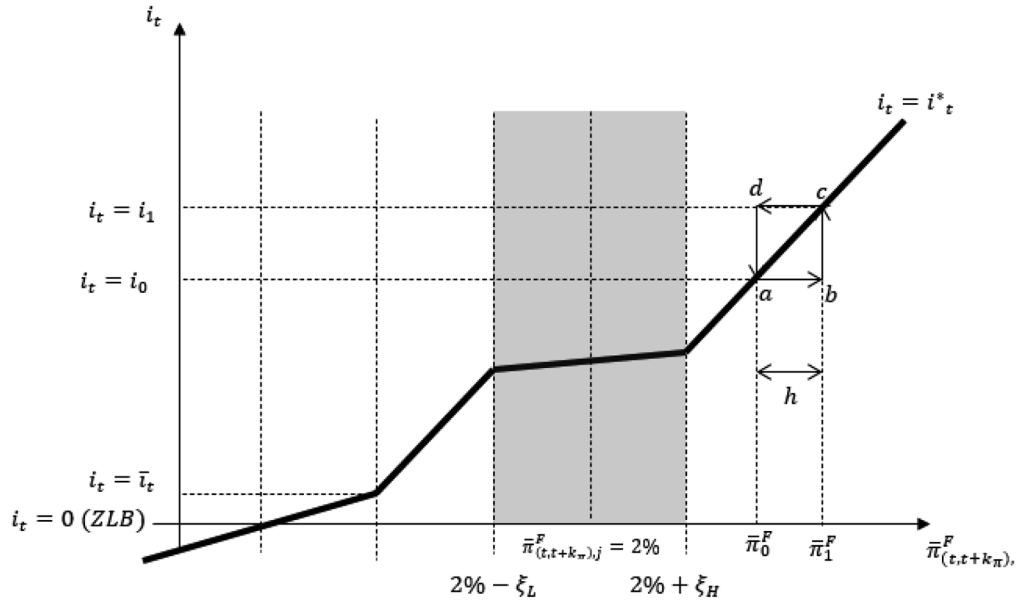
We also assume that the responsiveness of monetary policy diminishes as the policy interest rate approaches the effective lower bound, i.e., when the policy rate falls below the threshold $\bar{\imath}_t$. This feature is captured in Equation (2) through the inclusion of the dummy variable d_{2t}, which is expected to carry a negative coefficient, reflecting the reduced magnitude of policy adjustments near this bound. Accordingly, $\bar{\imath}_t$ represents the critical policy rate level below which the central bank's capacity for further conventional rate cuts becomes significantly constrained.

Following Orphanides and Wieland (2000) and Le Bihan *et al* (2023), we allow the data to inform the width of the inflation tolerance band around the 2 per cent target (if applicable). To this end, we estimate regressions using various alternative band widths, denoted as $\xi = \xi_L + \xi_H$. We start with ξ = 0.0 and increase it in increments of 0.2 percentage points, up to a maximum of ξ = 2.4. The optimal width is selected based on the specification that yields the highest R^2 value.[23] Additionally, we account for the possibility of an asymmetric band, or of a target range consistent with the 'below but close to 2 per cent' formulation.

Figure 1 provides a geometric interpretation of Equation (2). In line with the concept of a zone of relative inaction, we assume that the response of the policy interest rate is weaker, though not necessarily null, when average inflation forecasts fall within an unspecified band of width $\xi = \xi_L + \xi_H$ (see Cecioni *et al* 2021; Le Bihan *et al* 2023). This assumption allows us to capture empirically

the presence of a zone of inaction that may be consistent with either a tolerance band around a point target or a target range, without committing to either regime.

Figure 1: Non-Linear Monetary Policy Reaction to Average Inflation Forecast



In line with Mota and Fernandes (2022), to address the presence of smoothing[24] and stepping[25] in policy interest rates, we estimate Equation (2) using a modified forecast average inflation variable, following the approach proposed by Parsley and Wei (1993). This method accounts for path dependency and deviations from a linear response of the policy interest rate to its underlying fundamentals.[26]

Let us assume that the policy interest rate is determined by weighing the quadratic losses incurred by the central bank due to deviations of inflation from its target, represented as $(\bar{\pi}_{j,t} - \pi^*)^2$, against the costs associated with adjusting the policy interest rate. If the cost of changing the policy rate exceeds the quadratic losses caused by inflation deviations, the central bank refrains from altering the policy rate. Conversely, if the adjustment cost is lower than the losses from inflation deviations, the central bank responds immediately with an instantaneous jump in the policy rate.

Therefore, the central bank's adjustment behaviour can be represented by a history-dependent function of the gap between the current policy interest rate, i_t, and its frictionless (or desired) level, i^*_t, which corresponds to the optimal policy rate in the absence of adjustment costs.

$$i_t = \begin{cases} i_t = i_{t-1} \;\; if \;\; |i_t^* - i_{t-1}| < h \\ i_t = i_t^* \;\; if \;\; |i_t^* - i_{t-1}| \geq h \end{cases} \tag{3}$$

In Equation (3), h represents the threshold that determines when the deviation of the previous period's policy interest rate from the frictionless policy rate is large enough for the benefits of adjusting the rate to exceed the adjustment costs, thereby triggering a policy change. The dynamics of i_t and i_t^* are depicted in Figure 1. Starting at point a, an increase in the forecast of average inflation from $\bar{\pi}_0^F$ does not immediately lead to a change in the current policy rate because the benefits of adjusting it do not yet outweigh the associated costs. The optimal policy calls for maintaining the policy rate at i_0 until the difference between i_t and i_t^* reaches a critical threshold h. Only when $\Delta i_t^* \geq h$, *i.e.* when the forecast of average inflation reaches $\bar{\pi}_1^F$ (point b), will the central bank discretely adjust the policy interest rate toward the optimal level (point c). If the optimal policy rate subsequently falls, the policy rate remains at i_1 until $[i_t - i_t^*] > h$.

The adjusted forecast of average inflation that accounts for the adjustment costs associated with changes in the policy interest rate is constructed as follows:[27] First, we compute the cumulative change in the desired policy interest rate, i_t^*, over a specified period τ':

$$V_t = \sum_{j=0}^{\tau'} i_t^* - i_{t-1-j}^* \tag{4}$$

Second, we define a dummy variable, D_t, which indicates whether the most recent change in i_t is in the same direction as, or contrary to, the cumulative change observed over the previous τ' periods:

$$Dt = \begin{cases} 1, \text{ if } \Delta i_t^* > 0 \text{ } and \text{ } V_t > 0 \\ -1, \text{ } if \, \Delta i_t^* < 0 \text{ } and \text{ } V_t < 0 \\ \quad 0 \text{ } otherwise \end{cases} \tag{5}$$

Third, we construct a filtered policy interest rate variable $\text{ا}'_t$ as follows:

$$\text{ا}'_t = \sum_{J=0}^{t-1} \psi_{t-j}, \text{ with } \psi_t = D_t \Delta i_t^* V_t \tag{6}$$

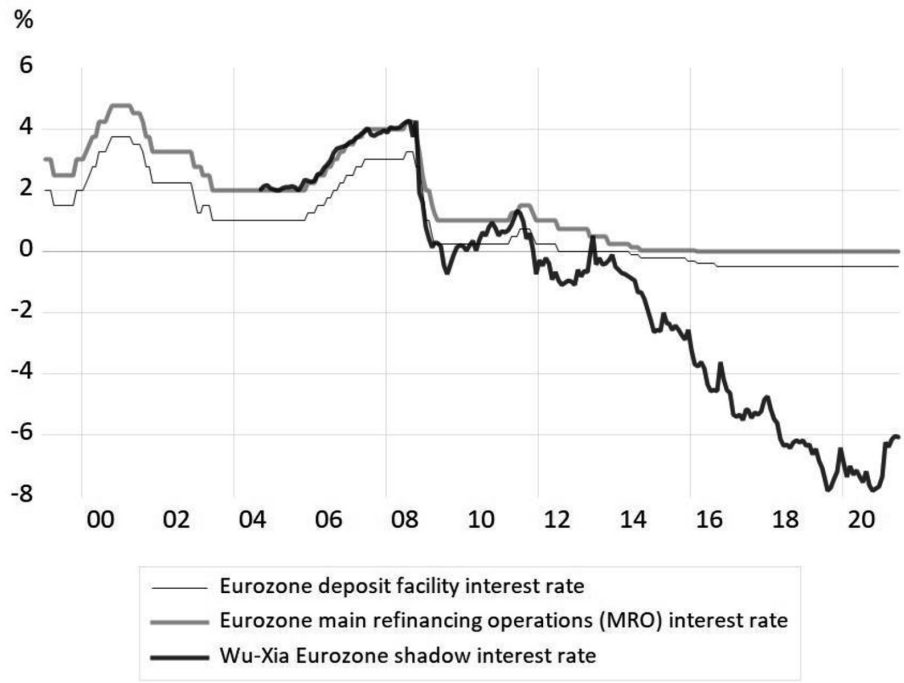
Intuitively, $\text{ا}'_t$ captures whether a given policy rate adjustment is consistent with a sustained trend in the desired policy stance. Rather than treating each rate change in isolation, it places greater weight on movements that reinforce the prevailing direction of policy – that is, those aligned with cumulative shifts in the frictionless interest rate i_t^*. Conversely, adjustments that run counter to this broader trend are treated as noise and filtered out. This construction helps isolate the component of policy action that reflects deliberate and persistent responses to inflation dynamics, abstracting from short-lived or erratic fluctuations that may not represent meaningful changes in the monetary stance.

4. The Data

The dataset covers the period from September 2004 to June 2021, starting from the earliest availability of Eurozone shadow rate data by Wu and Xia (2017). As the ECB Governing Council set the MRO interest rate at its first meeting of each month until 2015, and subsequently every six weeks, the analysis is conducted at a monthly frequency to ensure consistency with the timing of policy decisions.[28] The Eurozone shadow rate, computed following Wu and Xia (2017, 2020), is used as the main indicator of the monetary policy stance.[29]

Figure 2 illustrates the dynamics of the ECB's MRO interest rate, the deposit facility rate, and the Eurozone shadow rate. When interest rates were higher, the shadow rate closely tracked movements in the MRO rate. After the deposit rate was first reduced to 0.25 per cent in 2009, the shadow rate briefly turned negative. Following a temporary increase in 2011, the deposit rate returned to 0.25 per cent, and the shadow rate again entered negative territory. From July 2012 onwards, as the deposit rate reached zero conventional policy rates became constrained, while the shadow rate displayed greater fluctuations. During this period, it oscillated between 0.0 per cent and -1.0 per cent. After the introduction of negative interest rate policy in June 2014, the shadow rate exhibited a sustained downward trend.[30]

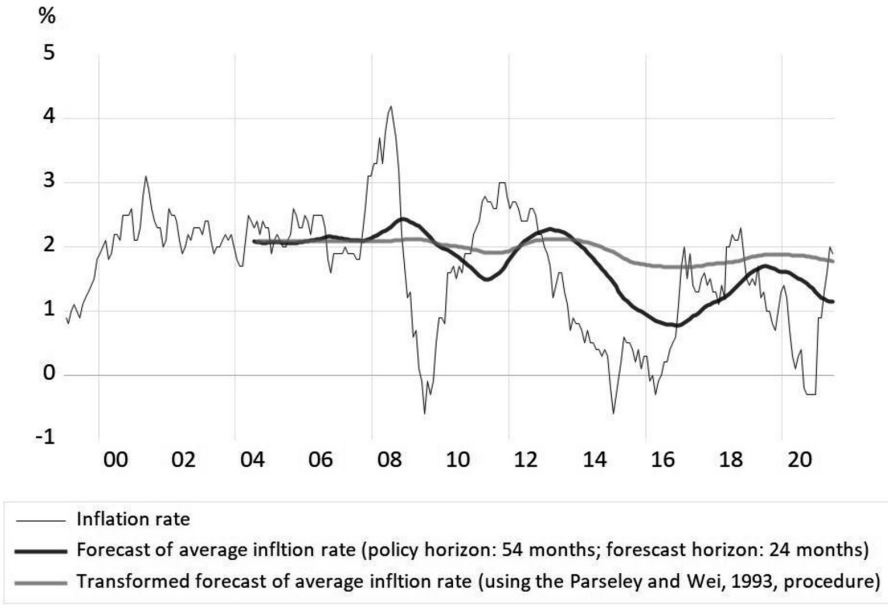
Figure 2: ECB Policy Rates and the Shadow Rate



The independent variables in Equation (2) are sourced from the ECB's Survey of Professional Forecasters (SPF). To ensure accuracy, we align the dates of the ECB Governing Council meetings, where decisions on key interest rates are made, with the release dates of the SPF. This approach guarantees that, for each month, the values of the independent variables reflect information already available at the time the ECB Governing Council determines the monetary policy stance.[31]

Figure 3 illustrates the dynamics of current inflation and the forecast of average inflation, calculated with a monetary policy horizon of 54 months and a forecast horizon of 24 months. Additionally, Figure 3 presents the transformed series of the average inflation forecast based on the procedure outlined in Equations (4) to (6).

Figure 3: Forecast of the Average Inflation Rate



5. Results

As the series are not stationary,[32] we have estimated a total of 128 different specifications of Equation (2) using Fully Modified Least Squares (FM-OLS), based on various combinations of $(2\% - \xi_L)$ and $(2\% + \xi_H)$, where ξ_L and ξ_H range from 0.1 to 1.2 percentage points in increments of 0.1 percentage points. We also consider the hypothesis of an asymmetric band and a range of relative policy inaction.

The maximum R^2 of the estimation is achieved for an inflation range between 1.0 per cent and 1.7 per cent (see Appendix 1). The results of the estimation

of Equation (2) by FM-OLS for the inflation range that maximises the R^2 are shown in Table 1 (column I).[33]

The Eurozone shadow interest rate has shown a positive response to the average inflation rate forecast, statistically significant at the conventional 5 per cent level.[34] However, our analysis reveals that the ECB has responded weakly to the average inflation rate when inflation falls within the range of 1.0 per cent to 1.7 per cent. This outcome is captured by the coefficient associated with the dummy variable $d_{1_{t,\xi}}$.

Furthermore, we observe a weakened reaction from the ECB to forecasts of average inflation after November 2013, as interest rates approached their effective lower bound. In that month, the ECB's MRO rate reached 0.25 per cent, which corresponds to the mode of the absolute changes in the ECB policy rate during the sample period. Therefore, we set the dummy variable d_{2_t} equal to one for months after November 2013, and zero otherwise.

Table 1: Results of the Estimation of Equation (2)

Independent Variables	Dependent Variable: Wu-Xia Eurozone Shadow Interest Rate Sample Period: 2004:09-2021:06			
	Estimation Method: FM-OLS		Estimation Method: GMM	
	I	II	III	IV
const	-5.811*** (-3.087)	-14.887*** (-3.156)	-7.826*** (-3.337)	-19.59*** (-3.372)
$\Psi\bar{\pi}^F_{(t,t+2),54}$	–	8.913*** (3.8612)	–	11.094*** (3.779)
$\Psi\bar{\pi}^F_{(t,t+2),54} \times d_{1_{t,\xi}}$	–	-0.969*** (-3.431)	–	-1.875*** (-4.858)
$\Psi\bar{\pi}^F_{(t,t+2),54} \times d_{2_t}$	–	-2.466*** (-6.646)	–	-1.433*** (-2.317)
$U^F_{t,t+2}$	-0.002 (-0.014)	-0.166 (-1.058)	0.167 (0.922)	-0.101 (-0.628)
$\bar{\pi}^F_{(t,t+2),54}$	3.876*** (6.437)	–	4.306*** (5.760)	–
$\bar{\pi}^F_{(t,t+2),54} \times d_{1_{t,\xi}}$	-1.342*** (-4.113)	–	-2.333*** (-4.269)	–
$\bar{\pi}^F_{(t,t+2),54} \times d_{2_t}$	-2.961*** (-7.301)	–	-1.994*** (-7.301)	–
R^2	0.7395	0.767	0.652	0.676
Trace Test Statistic[+]	28.882 (Rank 1)	28.820 (Rank 1)		

t-statistics are in parentheses.
***, **, * Significant at 1, 5, and 10 per cent respectively
[+]critical value 29.792

As the monetary policy reaction function already includes an explicit unemployment term, albeit estimated as statistically insignificant, along with an interest rate smoothing component, the estimated width of the tolerance band should not be interpreted merely as reflecting a stronger emphasis on unemployment stabilisation (as suggested by Beechey and Österholm 2018; Cleanthous 2020; Ehrmann 2021). Instead, it may capture a distinct dimension of monetary policy conduct: the central bank's tolerance for temporary deviations of inflation from target without immediate corrective action. Such tolerance may reflect concerns about excessive policy activism, the need to preserve communication credibility, or uncertainty surrounding the strength and timing of monetary transmission.

In a second step, we also estimate Equation (2) considering policy interest rate smoothing and stepping; that is, we use as an explanatory variable the transformed series of the forecast of average inflation, constructed according to Equations (4) to (6). We introduce a moderate degree of interest rate smoothing by setting the parameter τ' in Equation (4) equal to 6.[35] This parameter is related to h in Equation (3): the higher the value of h, the stronger the implied degree of interest rate inertia, and consequently, the higher τ' should be.

The results are consistent with a range of relative inaction for inflation in between 1.0 per cent and 1.7 per cent. The R^2 of the estimation of Equation (2) with different tolerance bands and ranges of relative inaction is displayed in Appendix 2. The results of the estimation of Equation (2) by FM-OLS for the inflation range that maximize the R^2 are shown in Table 1 (column II).

To address potential simultaneity bias between inflation and unemployment forecasts and current monetary policy, we also re-estimate Equation (2) using the Generalised Method of Moments (GMM), employing twelve lags of the independent variables as instruments. We find that the results concerning the inflation range remain unchanged. The estimation results of Equation (2) by GMM for the inflation zone with a weak monetary policy reaction, ranging between 1.0 per cent and 1.7 per cent, are presented in Table 1 (columns III and IV).

To assess whether the ECB's muted response to low inflation stems from financial constraints rather than policy preference, we conduct a robustness check by estimating an alternative reaction function. Specifically, we use the Krippner (2013) shadow rate as the dependent variable.[36] In this specification, we incorporate the Composite Indicator of Systemic Stress (CISS), developed by the ECB, as a measure of financial stress. The CISS aggregates data from five financial market segments (money, bond, equity, foreign exchange, and financial intermediaries) and dynamically accounts for cross-market correlations, making it particularly suited to identify episodes of systemic stress or financial fragmentation. To evaluate whether such stress may have limited the ECB's capacity to respond to inflation dynamics, we include an interaction term between the CISS and average inflation forecasts. This enables us to examine

whether financial market conditions moderated the ECB's response to inflation expectations, thereby helping to distinguish between deliberate policy choices and externally imposed constraints.

The estimation results, presented in Table 2, show that neither the financial stress indicator (CISS) nor its interaction with average inflation forecasts are statistically significant. This suggests that financial market stress did not systematically moderate the ECB's response to inflation expectations.

Table 2: Estimation Results of the Alternative Reaction Function

Independent Variables	Dependent Variable: Krippner Eurozone Shadow Interest Rate Sample Period: 2004:09–2021:06 Estimation Method: FM-OLS
const	-2.799 (-0.812)
$\Psi\bar{\pi}^{F}_{(t,t+2),54}$	5.194*** (2.906)
$\Psi\bar{\pi}^{F}_{(t,t+2),54} \times d_{1_{t,\xi}}$	-0.479*** (-3.644)
$\Psi\bar{\pi}^{F}_{(t,t+2),54} \times d_{2_t}$	-1.200*** (-5.681)
$U^{F}_{t,t+2}$	-0.735*** (-0.946)
$CISS_t$	1.466 (-0.086)
$CISS_t \times \Psi\bar{\pi}^{F}_{(t,t+2),54}$	-0.112 (-0.013)
R^2	0.843
Trace Test Statistic⁺	28.882 (Rank 1)

t-statistics are in parentheses.
***, **, * Significant at 1, 5, and 10 per cent respectively
⁺critical value 29.792

Crucially, the core finding of a weak ECB reaction to average inflation forecasts between 1.0 per cent and 1.7 per cent remains robust (see Appendix 3). This reinforces the interpretation that the observed pattern reflects a policy preference, or tolerance, rather than an externally imposed constraint caused by financial fragmentation or impaired transmission.

These results differ from previous literature, which has suggested the target range to be between 1.6 per cent and 1.9 per cent, particularly regarding its lower bound (see Hartmann and Smets 2018; Rostagno *et al* 2019; Paloviita

et al 2021). They also contradict the ECB's official pre-2021 definition of price stability as "below, but close to, 2 per cent."

This discrepancy may arise from our use of a longer and more recent sample period, spanning from 2004 to mid-2021, which captures extended intervals, particularly between 2013 and 2019, when inflation persistently remained well below 2 per cent, accompanied by only muted policy responses. Whether the observed tolerance for inflation between 1.0 per cent and 1.7 per cent reflects a deliberate choice by the ECB to refrain from acting within this range or an inability to bring inflation closer to the 2 per cent target via the use of unconventional measures in the presence of the effective lower bound on interest rates remains an open question.

In either case, the evidence indicates that inflation within this range often did not lead to prompt corrective measures, revealing a *de facto* inaction band wider and lower than both the official target and prior literature estimates.

6. Conclusions

Up to July 2021, the ECB's de *facto* framework, anchored on a medium-term horizon, appears to have involved a zone of inaction for inflation deviations within an estimated range of 1.0 per cent to 1.7 per cent. This finding is consistent with either a point target accompanied by a tolerance band or a range target. While our empirical approach does not allow us to distinguish between these interpretations, the ECB's behaviour during this period can be seen as resembling a form of average-inflation targeting within a bounded interval.

Although this arrangement afforded the ECB considerable operational flexibility, it risked anchoring inflation at a persistently low level, a concern explicitly acknowledged in its July 2021 strategy review. Accordingly, the ECB has since refined its price-stability objective to treat positive and negative deviations from the 2 per cent target as equally undesirable, shifting from an interval-based regime to a symmetric point-target framework. This change not only clarifies the nominal anchor for inflation expectations but also strengthens the buffer against the effective lower bound.

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Appendix 1: R^2 of the Estimation of Equation (2) with Different Ranges of Relative Policy Inaction
(dependent variable: Wu and Xia Eurozone shadow rate;
independent inflation variable: average inflation forecast)

Lower limit of the band \ Upper limit of the band	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2
2.0			-	-	0.6986	-	-	-	-	-							
1.9			-	-	0.7017	0.7011	-	-	-	-							
1.8			-	0.7105	0.7061	0.7050	0.7023	-	-	-							
1.7			0.6984	0.7028	0.7009	0.7006	0.6994	0.7007	-	-							
1.6		0.6992	0.6970	0.6988	0.6979	0.6979	0.6975	0.6962	0.6978	-							
1.5	0.6984	0.7012	0.6975	0.6974	0.6970	0.6972	0.6970	0.6971	0.6973	0.6972							
1.4	0.7028	0.7068	0.7003	0.6863	0.6965	0.6968	0.6972	0.6963	0.6974	0.6966	0.6971						
1.3	0.7127	0.7158	0.7067	0.6984	0.6989	0.6991	0.6998	0.6978	0.7000	0.6985	0.7000	0.7002					
1.2	0.7214	0.7268	0.7153	0.7028	0.7036	0.7038	0.7049	0.7019	0.7050	0.7028	0.7055	0.7059	0.7066				
1.1	0.7247	0.7300	0.7181	0.7045	0.7054	0.7056	0.7066	0.7034	0.7070	0.7047	0.7078	0.7082	0.7089	0.7089			
1.0	0.7336	**0.7395**	0.7255	0.7089	0.7099	0.7099	0.7112	0.7073	0.7117	0.7091	0.7130	0.7136	0.7144	0.7144	0.7150		
0.9	0.7266	0.7331	0.7203	0.7055	0.7066	0.7068	0.7080	0.7041	0.7086	0.7058	0.7096	0.7100	0.7186	0.7109	0.7115	0.7071	
0.8	0.7172	0.7236	0.7127	0.7006	0.7015	0.7017	0.7027	0.6991	0.7032	0.7003	0.7032	0.7033	0.7039	0.7039	0.7041	0.7001	0.6988

Appendix 2: R^2 of the Estimation of Equation (2) with Different Ranges of Relative Policy Inaction
(dependent variable: Wu and Xia Eurozone shadow rate;
independent inflation variable: transformed average inflation forecast)

Lower limit of the band \ Upper limit of the band	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2
2.0			-	-	0.7372	-	-	-	-	-							
1.9			-	-	0.7387	0.7381	-	-	-	-							
1.8			-	0.7443	0.7411	0.7399	0.7385	-	-	-							
1.7			0.7373	0.7398	0.7384	0.7379	0.7374	0.7375	-	-							
1.6		0.7375	0.7363	0.7373	0.7369	0.7367	0.7365	0.7368	0.7367	-							
1.5	0.7373	0.7389	0.7369	0.7366	0.7365	0.7365	0.7366	0.7362	0.7369	0.7367							
1.4	0.7410	0.7433	0.7393	0.7363	0.7367	0.7370	0.7377	0.7368	0.7382	0.7376	0.7385						
1.3	0.7462	0.7489	0.7436	0.7380	0.7388	0.7392	0.7402	0.7389	0.7411	0.7403	0.7417	0.7415					
1.2	0.7539	0.7570	0.7500	0.7417	0.7388	0.7434	0.7449	0.7431	0.7460	0.7450	0.7473	0.7472	0.7478				
1.1	0.7547	0.7578	0.7508	0.7424	0.7435	0.7442	0.7457	0.7439	0.7470	0.7460	0.7484	0.7484	0.7490	0.7490			
1.0	0.7636	**0.7671**	0.7585	0.7473	0.7486	0.7495	0.7513	0.7492	0.7530	0.7520	0.7550	0.7552	0.7561	0.7561	0.7567		
0.9	0.7613	0.7654	0.7570	0.7465	0.7480	0.7490	0.7509	0.7485	0.7527	0.7516	0.7547	0.7545	0.7553	0.7553	0.7559	0.7525	
0.8	0.7575	0.7616	0.7540	0.7443	0.7456	0.7467	0.7485	0.7461	0.7503	0.7490	0.7517	0.7511	0.7516	0.7516	0.7515	0.7525	0.7466

Appendix 3: R^2 of the Estimation of Equation (2) with Different Ranges of Relative Policy Inaction
(dependent variable: Krippner Euro Zone shadow rate;
independent inflation variable: average inflation forecast)

Lower limit of the band \ Upper limit of the band	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2
2.0					0.8249												
1.9					0.8286	0.8289											
1.8				0.8324	0.8317	0.8320	0.8296										
1.7			0.8248	0.8268	0.8271	0.8275	0.8266	0.8280									
1.6		0.8259	0.8244	0.8255	0.8260	0.8265	0.8260	0.8272	0.8262								
1.5	0.8250	0.8263	0.8249	0.8253	0.8258	0.8263	0.8259	0.8270	0.8260	0.8281							
1.4	0.8260	0.8282	0.8258	0.8244	0.8247	0.8251	0.8251	0.8257	0.8250	0.8263	0.8251						
1.3	0.8286	0.8317	0.8282	0.8245	0.8246	0.8247	0.8251	0.8250	0.8248	0.8250	0.8248	0.8250					
1.2	0.8325	0.8363	0.8316	0.8256	0.8254	0.8253	0.8260	0.8252	0.8259	0.8247	0.8256	0.8263	0.8266				
1.1	0.8310	0.8345	0.8303	0.8250	0.8249	0.8249	0.8255	0.8249	0.8251	0.8245	0.8252	0.8258	0.8201	0.8261			
1.0	0.8386	**0.8432**	0.8369	0.8279	0.8274	0.8270	0.8282	0.8265	0.8274	0.8255	0.8280	0.8295	0.8230	0.8302	0.8326		
0.9	0.8353	0.8397	0.8343	0.8266	0.8262	0.8250	0.8270	0.8256	0.8262	0.8247	0.8268	0.8279	0.8285	0.8261	0.8304	0.8296	
0.8	0.8351	0.8396	0.8345	0.8267	0.8262	0.8260	0.8270	0.8255	0.8264	0.8247	0.8268	0.8280	0.8285	0.8285	0.8303	0.8295	0.8299

Endnotes

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2. See ECB (2021a).

3. See, e.g., Constâncio (2018).

4. This medium-term focus extends beyond the projected time lag inherent in the monetary policy transmission mechanism.

5. The ECB (2011 p 68) acknowledges this ambiguity and further reinforces it in its monetary policy strategy statement released alongside the press release of July 8, 2021 (see ECB 2021a). This statement emphasises that specifying a precise horizon for the conduct of monetary policy in advance is not advisable, given that the transmission mechanism operates over a variable and uncertain period.

6. Wyplosz (2021) also suggests that, although not explicitly stated, the ECB follows a strategy akin to average inflation targeting, like that of the Federal Reserve.

7. In the revision of its monetary policy strategy unveiled on 8 July 2021, the ECB introduced a notable shift by acknowledging that deviations both above and below the 2 per cent target are equally undesirable. This reflects a more balanced and nuanced approach to price stability.

8. It is important to emphasise that the ECB's newly announced monetary policy strategy in July 2021 remains vague regarding the tolerance margin for inflation and the policy horizon for monetary policy (Wyplosz 2021).

9. See also Rostagno *et al* (2019).

10. We have estimated a sufficiently general equation that captures succinctly how the policy interest rate, in hindsight, has been linked to inflation and unemployment forecasts. In other words, our reduced-form equation should be regarded as "the endogenous end point rather the exogenous starting point of monetary policy" (Svensson 2003 p 444).

11. See Krippner (2013) and Wu and Xia (2017, 2020) for examples of using the shadow short-term interest rate as a measure of the monetary policy stance in a zero lower bound environment.

12. Policy interest rate smoothing refers to the typical central bank practice of gradually adjusting policy rates through a series of small steps in the same direction, with few reversals, thereby avoiding abrupt and substantial changes in interest rates (see, *e.g.*, Lowe and Ellis 1997; Goodhart 1999; Bernanke 2004).

13. Interest rate stepping refers to the practice of central banks maintaining their policy interest rate constant despite changing economic conditions and adjusting it by discrete increments even when the underlying fundamentals change continuously (see, Eijffinger *et al* 1999; Verhagen 2002).

14. While not always stated explicitly, it is generally assumed that central banks conduct monetary policy through some form of forecast targeting (see, e.g., Bernanke

2004; Woodford 2004, 2007; Svensson 2019, 2020). Evidence of this approach can also be found in the case of the ECB, as illustrated in the ECB Monthly Bulletins of January 1999 and July 2000.

15. The loss function is sometimes defined over an infinite horizon. However, in practice, it is often considered finite, for example, spanning twenty quarters, as noted by Svensson (2019).

16. This value serves as a reference benchmark rather than an explicitly announced target during the sample period. This approach allows us to examine whether the ECB's policy tended to stabilise inflation around this reference level, potentially within an informal tolerance range.

17. See Nessén (2002), Nessén and Vestin (2005), and Mota and Fernandes (2022).

18. In the case of the ECB, we narrow the secondary objectives of monetary policy down to a single focus: stabilising economic activity (ECB, 2021).

19. We allow for $\xi_L \neq \xi_H$ as there is evidence that the ECB may respond asymmetrically to inflation overshooting compared to undershooting (see Hartmann and Smets 2018; Rostagno *et al* 2019; Maih *et al* 2021; Paloviita *et al* 2021).

20. This is consistent with the five-year horizon considered by Hartmann and Smets (2018).

21. This is in line with the typical length of the monetary policy transmission lag reported in the literature (see, e.g., Bernanke *et al* 1999; Goodhart 2001).

22. We follow Mota and Fernandes (2022).

23. The question of what constitutes an appropriate level of tolerance for deviations of inflation from the target remains open. Nonetheless, the literature commonly adopts a bandwidth of ±1 percentage point around the target (see, e.g., Orphanides and Wieland 2000; Erceg 2002; Castelnuovo *et al* 2003; Mishkin and Westelius 2008; Andersson and Jonung 2017; Apel and Clausen 2017; Beechey and Österholm 2018; Cornand and M'baye 2018; Cleanthous 2020). It is important to note that this approach does not allow us to discern whether the central bank implicitly follows a point target regime with a tolerance band of width ξ, or a target range of the same width.

24. This refers to the well-established practice by central banks of adjusting policy interest rates gradually through a series of small, consistent steps in the same direction, with relatively few reversals, while avoiding large abrupt changes.

25. It refers to the practice of central banks maintaining a constant policy interest rate despite changing economic conditions, and adjusting the rate in discrete steps, even when economic fundamentals evolve continuously.

26. This methodology is based on three observed patterns in the behaviour of policy interest rates. First, substantial changes in economic fundamentals are required to prompt adjustments in the policy interest rate. Second, the historical trajectory of these fundamentals influences the setting of the policy rate. Third, the policy interest rate reacts differently to comparable minor fluctuations in fundamentals depending on the recent path. For example, an increase following a series of successive rises differs in effect from one following a sequence of successive declines, and vice versa (see, e.g., Lowe and Ellis 1997; Goodhart 1999; Bernanke 2004).

27. See Parsley and Wei (1993), and Mota and Fernandes (2022).

28. The ECB explicitly recognises the MRO interest rate as the instrument that signals the monetary policy stance to the public.

29. Data are available at: https://sites.google.com/view/jingcynthiawu/shadow-rates

30. See Wu and Xia (2017).

31. We follow Mota and Fernandes (2022).

32. Using the augmented Dickey-Fuller unit root test, we have determined that the series are integrated of order one, I(1).

33. To rule out the possibility of spurious regression and confirm the existence of a genuine equilibrium relationship among the variables, we conducted cointegration tests using the Johansen procedure. Table 1 presents the results of the trace test, including the test statistic, the critical value at the 5 per cent significance level for rejecting the null hypothesis of no cointegration, and the estimated cointegration rank.

34. The coefficient associated with the unemployment rate forecast is not statistically significant.

35. This choice is grounded empirically in the average duration between changes in the ECB's main refinancing operations (MRO) rate.

36. The use of the Krippner shadow short rate serves as a robustness check, since the shadow rate series can be sensitive to methodological choices in its estimation (Krippner 2020).

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