Monetary Policy and Inflation Tolerance Ranges: Applications to Rwanda

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Abstract

This paper studies the use of inflation tolerance ranges in the conduct of monetary policy. In doing so, the paper examines the appropriateness of the current official inflation tolerance band of the National Bank of Rwanda (5± 3%). In a stylized New Keynesian Model calibrated to Rwanda, the study adopts a state-dependent policy rule approach, in which monetary policy operates under two regimes: the lower-boundary regime (when inflation is below 2 percent) and the upper boundary regime (when inflation exceeds 8 percent). Within this framework, a controlled tolerance parameter is used to compare the 5± 3% tolerance range against wider inflation tolerance ranges, relying on impulse response functions to analyze the behavior of monetary policy in reaction to an unexpected inflation shock. We deliberately exclude narrower ranges from our analysis to avoid the pitfalls of unanchored inflation observed in the empirical data. We find the following main results across different iterations. First, higher inflation tolerance magnifies the asymmetric response of monetary policy, where it reacts aggressively to deviations from the upper boundary than in the lower boundary regime. Second, higher inflation tolerance reduces the likelihood of inflation convergence back to the benchmark target (middle value of a range) following an inflation shock. Third, we find that higher tolerance is costly, as the central bank must later compensate with aggressive measures to bring back inflation to the benchmark target, leading to a larger output loss. Compared to wider tolerance ranges, these results suggest that the 5± 3% tolerance range remains appropriate for Rwanda.

Key Words: Inflation Tolerance Ranges, Monetary Policy Rules, New Keynesian Model

JEL Codes*: E52, E31, C54, C68*

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1 Introduction

Since the introduction of inflation targeting (IT) by the central bank of New Zealand in 1990, it has gained popularity and raised several questions both in policy and academia. The IT has different characteristics and can be implemented in different ways; either as point targets [1], or as flexible targeting involving bands with soft edges (lower and upper), with the main target being the middle value of the band (Svensson, 2010; Ehrmann, 2021). Despite initial praise, different authors have argued that the use of point targets in the IT framework is ineffective in terms of response to supply shocks and terms of trade shocks (see for example, Frankel (2021) and Gillitzer & Simon (2015)), which is why since the IT revolution, several[2] countries have opted for inflation target bands instead of strict point targets.

To reflect developments in the practice of monetary policy, over time, studies have explored the feasibility of inflation tolerance ranges (or inflation tolerance bands in the realm of policy) where different arguments have been advanced in the face of this debate. Martin & Milas (2004), Iddrisu & Alagidede (2020), and Bianchi et al. (2021) have criticized the bias created by strict point inflation targeting, arguing that the inflation stabilization process should be sensitive to the nature and frequency of shocks, output stabilization, and financial stability considerations, hence calling for a system that grants more operational flexibility. Conceptually, Cœuré (2019) describes an inflation tolerance range as a range[3] of inflation outcomes in which the deviation of inflation from target may call for a less aggressive reaction of monetary policy compared to strict point targeting frameworks.

Since 2019, the National Bank of Rwanda (BNR) shifted from monetary targeting to a price targeting framework, with a medium-term inflation rate target of 5% with symmetric boundaries of ± 3% (National Bank of Rwanda, 2018a). However, over this period, various shocks, such as the COVID-19 Pandemic, the Russia-Ukraine War, and a slew of weather-related challenges, have led to high and volatile inflation in this period. Yet despite recent and past shocks, we note that over a long period, Consumer Price Index (CPI) inflation in Rwanda has been firmly anchored within the official 5± 3% tolerance range . The present study argues that the anchoring we observe in the data reflects that the 5± 3% tolerance range is appropriate for Rwanda.

[1] Which is hard to implement given the arguments from Apel & Claussen (2017).

[2] Central banks like the Bank of Canada and Bank of Sweden use similar ranges in their monetary policy frameworks. Both of these central banks aim to maintain total CPI inflation at 2% within a goal range of 1 to 3% in the medium term. Moreover, other prominent banks such as the Federal Reserve and the European Central Bank are expected to consider adopting them as they review their monetary policy frameworks in the future (Le Bihan et al., 2021).

[3] Cœuré (2019) adds that this range of values must be reasonably close to the main/benchmark inflation target

Inflation tolerance range selection criteria: For an appreciation of the paper's objectives, contributions, and justification, it is crucial to first understand the literature's recommendations on the criteria considered by a central bank when choosing a specific inflation tolerance range. Riksbank (2016) and Apel & Claussen (2017) are notable studies in this regard. In general, like previous literature, these studies first explain that a tolerance range's main benefit is the added operational flexibility it grants when there is uncertainty surrounding inflation outcomes.

However, Apel & Claussen (2017) argue that if it proves to be very costly to be outside the specified interval, tolerance ranges can reduce flexibility due to a loss in central bank credibility, stemming from a loss in confidence that the central bank can durably achieve its price stability mandate. Examples of such costs include the loss in output and/or welfare, as well as potential financial instability arising from tight financial conditions (Apel & Claussen, 2017). Further, the same authors explain that another criterion is that a tolerance range should be designed to illustrate uncertainty and the impossibility of fine-tuning, meaning that the tolerance range helps monetary policy give the impression that it can not fine-tune inflation with accuracy. Our paper emphasizes that the Rwandan inflation tolerance range is more akin to such an uncertainty range, reflecting the volatile nature of inflation outcomes (see section 3).

Lastly, Apel & Claussen (2017) and Hammond (2012) explain that an inflation tolerance range must be well-adapted. As they define it, this entails that inflation should stay inside the band the most of the time, but it should not be so wide that inflation always falls within. Nor should it be overly narrow. Once again, empirical evidence suggests that this is the case for Rwanda (see section 3 and appendix B). Indeed, the above considerations also help confirm that the Rwandan inflation targeting framework is one of a point target with tolerance bands around it, reflecting the difficulty associated with hitting the point target in a short-run.

As such, the general objective of the paper is to document the appropriateness of the existing tolerance range of the National Bank of Rwanda, along the criteria explained above. Specifically, the paper aims to achieve the following objectives: (1) investigating how tolerance affects the asymmetric response of monetary policy across the upper and lower regimes following an inflation shock, (2) researching how, following an inflation shock, tolerance affects the probability of inflation convergence, and (3) examining the associated policy aggressiveness required for that convergence. Finally, to ensure that we do justice of the frictions within the monetary environment in Rwanda, we also aim to study the implications of higher tolerance when there is a weak transmission of monetary policy.

To achieve this, we use a stylized New Keynesian (NK) model calibrated for Rwanda, with a state-dependent policy rule framework of inflation tolerance ranges following Le Bihan et al. (2021). The use of state-dependent policy rules is prevalent in the macroeconomics literature, with examples including Farmer et al. (2007), Rossi (2014), and Castelnuovo & Pellegrino (2018). As a preview of the findings, The study finds that higher inflation tolerance ranges, subsequent to an inflation shock, are associated with a more asymmetric reaction of monetary policy, the lack of inflation convergence, alongside cost implications of higher interest rates and output losses. Cognizant of the frictions associated with the transmission of monetary policy in Rwanda (Kigabo, 2021; Nyalihama et al., 2023; Musekera et al., 2023) the study conducts an alternative iteration in which the transmission of monetary policy is constrained, and find that weak monetary policy transmission exacerbates the negative effects of high tolerance on the lack convergence. These results are supported by the views on the " ***credibility enhancement hypothesis***" and view that "***tolerance ranges do not imply zones of inaction***" as presented in Ehrmann (2021) and Le Bihan et al. (2021), respectively.

The study contributes to the literature on Rwandan monetary policy in two main ways. First, despite the use of official tolerance ranges in by the National Bank of Rwanda, no study has yet documented their implication on monetary policy. Second, although some studies on Rwanda have previously researched loosely related concepts, no study has explicitly studied the appropriateness of the current official tolerance range of the National Bank of Rwanda. Ndahiriwe et al. (2017) assessed Rwanda's preparedness towards inflation targeting, while Uwilingiye et al. (2021) estimated the welfare loss (in terms of output) associated with the 5 percent medium-term inflation benchmark target for Rwanda. Understanding the appropriateness of a given tolerance range is particularly relevant to monetary authorities, as the width of said range is, in effect, the goal posts that signal a commitment to average inflation around a point target over time (Ehrmann, 2021). Further, insofar as monetary policy may be tempted to operate within wider inflation tolerance ranges to gain flexibility, especially during high inflation periods as recently observed in Rwanda, the paper's relevance lies in arguing that when choosing an inflation tolerance range, it is important to consider the trade-offs between central bank credibility, monetary policy aggressiveness, and associated economic losses.

The rest of the paper is organized as follows: Section 2 discusses the related literature, section 3 presents the empirical facts that motivate this study, while Section 4 presents the model, its calibration, and discusses the main results, leaving Section 5 to conclude.

2 Related Literature

The paper is connected to a small body of academic literature on inflation tolerance ranges. Ehrmann (2021) and Orphanides & Wieland (2000) are notable studies. These studies mostly carry out empirical comparisons to evaluate the varying macroeconomic performances of countries with or without inflation bands, although Orphanides & Wieland (2000) offer some theoretical motivation in a simple backward-looking model, consisting of an IS and a Phillips Curve. The concept of inflation tolerance ranges is often adapted to the particular motivations of a study, where, for instance, Le Bihan et al. (2021) interpret it as the asymmetry in the aggressiveness of a central bank's response to inflation when in the upper or lower regions of a predefined target range. Other studies such as Chung et al. (2020) go with a more micro-founded interpretation of tolerance ranges, in which the monetary authority's optimal reaction function is based on the trade-offs it faces when inflation lies in different regions of a range, including an "indifference" region.

Chung et al. (2020) offer three ways to think about the inflation tolerance ranges of central banks: as uncertainty ranges, operational ranges, and indifference ranges. While these authors do not offer a quantitative assessment of the efficacy of any given type of inflation tolerance ranges, they warn against a misinterpretation of the objectives of a range. For instance, while a central bank could have in place a tolerance range for reflecting the uncertainty of hitting a specific target, the aforementioned could be misinterpreted as an indifference to a given range of inflation outcomes.

That being said, other approaches to inflation tolerance ranges such as the indifference tolerance range have gathered support in the literature. That is, indifference tolerance ranges can be interpreted as, in effect, reflecting a choice between a socially acceptable level of inflation and unnecessarily active monetary policy that leads to indeterminancy and multiple equilibria in several monetary models (Benhabib et al., 2001).

Still on the topic of tolerance ranges, Ehrmann (2021) provides a clear difference between types of inflation targets where they mention point, target ranges, and tolerance ranges, respectively. Moreover, Berg (2000) elaborate the role of inflation tolerance "interval" by showing that the tolerance ranges are used as a measure for the possibly anticipated fluctuation of inflation. They later use the following quoted sentence; *"In other words, the degree of tolerance can be interpreted as a confidence interval in the statistical sense, implying that inflation may lie outside the interval for a certain percentage of time."* Tolerance can be driven by different aspects, including the hope of central bank that the agents will respond to the signals of the monetary policy communications and unforeseen events like second round spillovers (Blinder et al., 2022; Mbotu, 2010).

Beyond literature that describes the properties of inflation tolerance ranges, other studies such as Bianchi et al. (2021) suggest that above-target inflation levels can be tolerated, advocating for asymmetric inflation targeting rules to correct the downward bias caused by symmetric policy rules of inflation targeting. Although their results are formulated in an environment in which the Zero-lower bound is a binding constraint[4], they nonetheless suggest that tolerance ranges can arise not merely due to the volatile nature of inflation or the operational flexibility of the central bank, but also due to past monetary policy actions.

In the domestic literature, to our knowledge, no authors have specifically studied inflation tolerance ranges, although some authors have previously researched related concepts. For instance, Gichondo et al. (2018) estimate an optimal level for Rwandan inflation and find a threshold level of 5.9%, consistent with a targeted annual GDP growth of rate 9%[5]. This literature is part of a series of studies that supported the adoption of a novel monetary policy price-based framework in Rwanda. One other related study is Uwilingiye et al. (2021) that finds a potential economic welfare loss equivalent to 0.51% and 0.85% of annual real GDP, based on the medium-term inflation benchmark target of 5 percent. Lastly, Ndahiriwe et al. (2017) asseessed Rwanda's preparedeness towards inflation targeting and found that Rwanda was prepared to adopt an inflation targeting framework, owing to price stability being the premier mandate of the central bank, an adequate forecasting and policy analysis system, the lack of fiscal dominance, and a fairly developed communication strategy.

3 Recent Inflation Developments and Anchored Inflation in Rwanda

Before explaining the paper's empirical motivation, we start by documenting inflation developments in Rwanda over the past decade, particularly focusing on episodes marked by headline inflation evolving outside of BNR's official inflation target . Figure (1)[6] below illustrates the evolution of headline inflation (on a year-on-year basis), together with the National Bank of Rwanda's (BNR) inflation target bands (the equivalent of established tolerance ranges in the context of this study). The range is $5 \pm 3\%$, with 5% being the medium-term benchmark target. Broadly, as depicted in Figure (1), headline inflation evolved within the band $5 \pm 3\%$, although with few noted exceptions in 2018 to 2019, in 2021, as well as 2022 and onward.

Starting with the period from the third quarter of 2018 to the first half of 2019, headline inflation evolved

[4]Persistently low inflation and the associated failure to meet inflation targets in several advanced economies (In the pre-pandemic period) are cited as motivation in this study.

[5]Rwanda has a long-term objective of attaining high-income status by 2050 and this requires a GDP growth rate of 9.0% and above per annum

[6]Sources: BNR (2023) and National Institute of Statistics of Rwanda (NISR)(2023)

outside the lower boundary of the target band and slightly below zero at some point in 2018Q4. By 2018Q3, headline inflation had dropped below the lower boundary at 1.8%, reflecting declining food[7] prices (vegetables in particular)[8] due to a strong agricultural performance in Season C, 2018 (National Bank of Rwanda, 2018b). Robust agricultural performance is similar to what happened in the last quarters of 2021, prompting annual headline inflation (quarter-on-quarter) to average 0.8% at the end of the year (National Bank of Rwanda, 2022), while headline inflation exceeded the upper boundary in 2022 and remained in double digits throughout 2023, owing to several international commodity price shocks and weak domestic agriculture food production.

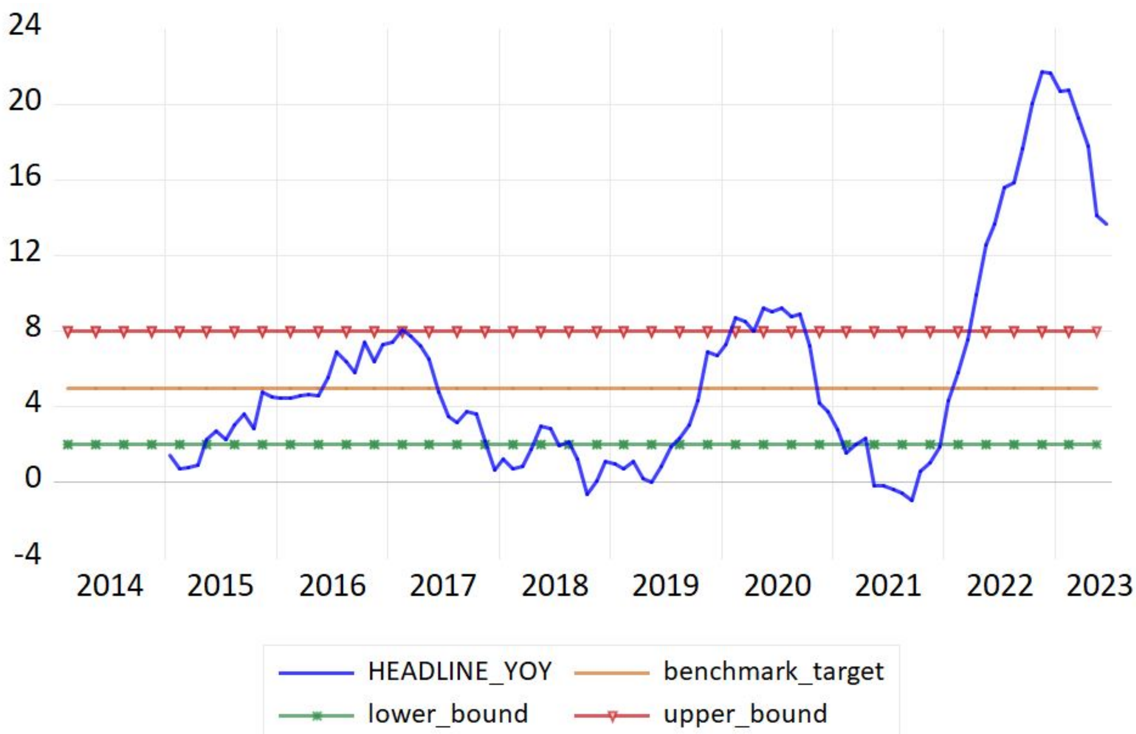


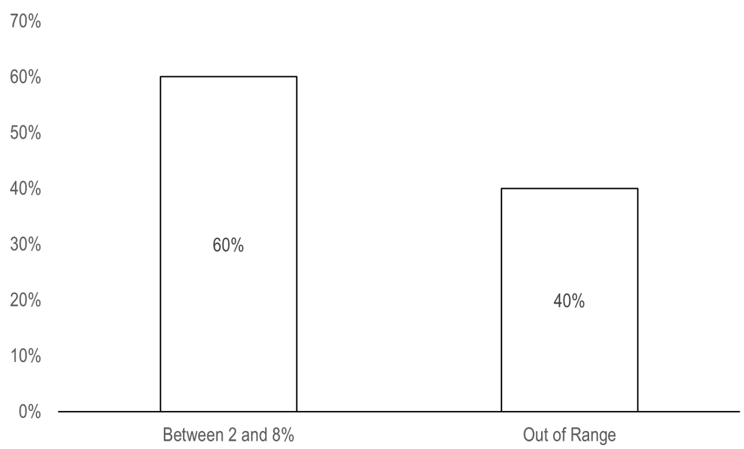
Figure 1: **Rwandan Central Bank Inflation Tolerance Range & Quarterly Headline Inflation (Percentage, y-o-y)**

Rwanda's vulnerability and exposure to commodity price shocks and climate change has long been a key driver of overall pricing dynamics. The country has consistently experienced high food inflation when agri-

[7]Food items in general account for almost 30 percent of the total CPI basket (NISR)
[8]Food inflation referred to here encompasses COICOP 1 international classifications code of the UN, as used by NISR

culture production is low due to bad weather shocks that impair supply, as well as when international prices of key imported food are rising. Nonetheless, when looking at a long period from 2007 to 2021, headline inflation has evolved within the official tolerance range 60 percent of the time, suggesting relatively anchored inflation around the official tolerance range. Even with the inclusion of the period since the start of 2022 through the end of 2023, a period characterized by a combination of all the shocks mentioned above, headline inflation still evolved within the official tolerance range for a majority 55.1 percent of the time.

The above considerations motivate the study to document the appropriateness of the official tolerance range for the first time in the domestic literature, as well as understanding the implications of tolerance range in the conduct of monetary policy. Given the increasing magnitude and frequency of adverse shocks Rwanda has experienced lately, we are interested in comparing the optimality of the current official tolerance range vis-a-vis wider ranges. The rationale behind our exclusion of smaller tolerance ranges from the iterative analyses we conduct (as described in section 4) is due to the empirical observation that smaller tolerance ranges for Rwanda would lead to substantially unanchored inflation. For example, if the official tolerance range had been 4 to 6 percent, headline inflation from 2007 to 2023 would fall in that range only 20 percent of the time (see appendix B).



Notes: The methodology used is simple tallying and percentage counts to identify the percentage of quarters in which inflation lied in the specific tolerance range

Figure 2: **Frequency of Headline Inflation in the 2-8 percent Tolerance Range (2007Q1-2021Q4)**

4 Conceptual Framework

To analyze the optimality of the 5± 3% tolerance range, we adopt a state-dependent policy rule approach, similar to Bianchi et al. (2021), where subsequent to a stochastic inflation shock, the convergence of inflation back to the main benchmark target depends on the explicitly specified tolerance set up. That is, we explicitly specify a tolerance parameter in two policy rule equations in an otherwise standard three-equation New Keynesian (NK) model (described in 4.1). To specify two policy rules, we rely on regime-switching parameters (as explained in 4.1.4), one for when the inflation deviation is below the lower boundary of the tolerance range (2%) and another for when the inflation deviation is above the upper boundary of the tolerance range (8%). Therefore, the central bank conducts its monetary policy in two different regimes: the lower boundary regime (when inflation is below 2%) , and the upper boundary regime (when inflation exceeds 8%).

In practice, it means that we run the NK model with different tolerance ranges for inflation. To iterate across different tolerance ranges, we set different positive values for the tolerance parameter, tol, which is a parameter for measuring deviation from either the lower or upper boundary value of the official tolerance range. In other words, when we set, for instance, $tol = 1$, the tolerance ranges specified across both policy rules are 1 % and 9 %, while setting $tol = 2$ adjusts the tolerance ranges to 0% and 10% . This is done so as to understand the behavior of the central bank under different levels of the tolerance ranges, and the implications of its decisions on output and inflation. The selection of these levels of the tolerance parameter (and hence the associated tolerance ranges) is guided by the selection criteria explained in section 1 above, wherein tolerance ranges wider than the existing official tolerance range meet both the uncertainty and adaptability conditions, but are yet to be judged in terms of their inflation convergence potential and policy sacrifice ratio as explained in Apel & Claussen (2017).

4.1 The Model

We use a standard off-the-shelf New Keynesian (NK) model with infinitely-lived representative agents. The only main deviation from Galí (2015)'s description of the model is the specification of the central bank's policy rule.

4.1.1 Households

The representative household derives utility from present and future consumption. The lifetime utility of the household is often (Woodford & Walsh, 2005a; Galí, 2015) modeled as the sum of discounted utility from consumption over time:

$$U = \sum_{t=0}^{\infty} \beta^t u(c_t) \tag{4.1}$$

where $u(c_t)$ is the utility derived from consumption in period t, β is the discount factor ($0 < \beta < 1$) representing the household's time preference, and c_t is the consumption level in period t.

The household also faces an intertemporal budget constraint, which can be expressed as the present value of consumption over time being less than or equal to the present value of income plus initial wealth:

$$\sum_{t=0}^{\infty} \frac{c_t}{(1+r)^t} \leq \sum_{t=0}^{\infty} \frac{y_t}{(1+r)^t} + w_0 \tag{4.2}$$

where r is the real interest rate, y_t is income in period t, and w_0 is initial wealth.

Therefore, the household seeks to maximize lifetime utility, stemming from present and future consumption, subject to the budget constraint. The Lagrangian for this problem is:

$$\mathcal{L} = \sum_{t=0}^{\infty} \beta^t u(c_t) + \lambda \left[\sum_{t=0}^{\infty} \frac{y_t}{(1+r)^t} + w_0 - \sum_{t=0}^{\infty} \frac{c_t}{(1+r)^t} \right] \tag{4.3}$$

where λ is the Lagrange multiplier associated with the budget constraint. The first-order conditions from this optimization problem yield the Euler equation, obtained by differentiating the Lagrangian with respect to c_t and c_{t+1}.

$$u'(c_t) = \beta(1+r)u'(c_{t+1}) \tag{4.4}$$

Propositions From the Euleur equation, we make the following few simplifying assumptions to derive the IS curve estimated in our simple model:

1. Using a standard approximation of the fisher identity, we substitute the real interest rate by the nominal policy rate (in this case, named the central bank rate, cbr_t) and a forward-looking measure of future inflation à la Fisher & Barber (1907):

$$r_t = i_t - \pi_{t+1} \tag{4.5}$$

2. Further, we assume that the marginal utility of consumption is linear, so that: $u'(c_t) = -a_1 c_t + a_0$ for some parameters a_0 and a_1.

3. we also assume simple form for output, in which the output of the economy is determined by consumption and a stochastic shock.:

$$y_t = c_t + \varepsilon_{gdp} \tag{4.6}$$

Substituting these assumptions into the Euler equation in (4.4), we get:

$$-a_1 c_t + a_0 = \beta(1 + i_t - \pi_{t+1})(-a_1 c_{t+1} + a_0) \tag{4.7}$$

We can rearrange and solve for y_t using the relationship between output and consumption established in (4.6):

$$y_t + \frac{a_1}{\beta}(1 + i_t - \pi_{t+1})y_{t+1} - \frac{a_0}{\beta}(1 + i_t - \pi_{t+1}) = \varepsilon_{y,t} \tag{4.8}$$

Then, from the equation (4.8), we identify the parameters $a_1 = -a_1/\beta(1 + i_t - \pi_{t+1})$ and $a_2 = a_0/\beta$, and after rearranging the terms, obtain the IS curve :

$$y_t = a_1 y_{t+1} - a_2(i_t - \pi_{t+1}) + \varepsilon_{y,t} \tag{4.9}$$

4.1.2 Firms

The New Keynesian Phillips Curve (NKPC) is derived from the optimization problem faced by firms under monopolistic competition and nominal rigidities. Firms set their prices to maximize the expected present value of profits, subject to a staggered price setting à la Calvo (1983).

The objective function for a firm able to reset its price at time t is given by:

$$\max_{P_t^*} E_t \left\{ \sum_{k=0}^{\infty} (\theta\beta)^k \, \frac{(P_t^* - MC_{t+k})\, Y_{t+k}}{P_{t+k}} \right\} \tag{4.10}$$

where P_t^* is the optimal price set by the firm, MC_{t+k} is the marginal cost, Y_{t+k} is the output, θ is the fraction of firms that do not change their prices, and β is the discount factor.
The demand for the firm's product Y_{t+k} is subject to the following constraint:

$$Y_{t+k} = \left(\frac{P_t^*}{P_{t+k}^e} \right)^{-\epsilon} Y_{t+k}^d \tag{4.11}$$

where ϵ is the price elasticity of demand, P_t^e is the expected general price level, and Y_{t+k}^d represents the aggregate demand.

The first-order condition for this optimization yields the standard NKPC in (4.12) after log-linearizing around the steady state, collecting parameters into b_1 and $(1 - b_1)$, and making the necessary the rearrangements.

$$\pi_t = b_1 E_t \pi_{t+1} + (1 - b_1)\pi_{t-1} + \kappa y_t + \varepsilon_{\pi,t} \tag{4.12}$$

Here, π_t represents the rate of inflation, $E_t\pi_{t+1}$ is the expected inflation, y_t is the output gap measured as the log-deviation of output from its natural level, and $\varepsilon_{\pi,t}$ captures various exogenous cost-push shocks.

4.1.3 Central Bank

In this model, the central bank is assumed to minimize a loss function subject to the constraints of a New Keynesian Phillips Curve and an exogenous interest rate shock. The central bank's policy rule adjusts depending on whether inflation is above or below a certain threshold.

The central bank's loss function can be expressed as:

$$L = E_t \left\{ \sum_{k=0}^{\infty} \beta^k \left[\lambda_\pi (\pi_{t+k} - \pi^*)^2 + \lambda_y y_{t+k}^2 + \lambda_i (i_{t+k} - i_{t+k-1})^2 \right] \right\}, \tag{4.13}$$

where λ_π and λ_y, are the weights the central bank places on stabilizing inflation and output, respectively, while while λ_i is a parameter that captures the degree at which the central bank desires to smooth the path of the nominal interest rate.

The Phillips curve constraint is given by:

$$\pi_t = \kappa y_t + \nu_t + \varepsilon_{\pi,t}, \tag{4.14}$$

where κ is the slope of the Phillips curve, ν_t is the expected future inflation, and shock_{π_t} is the inflation shock.

The regime is determined by the deviation of inflation from its target with a tolerance level (tol):

$$\text{Regime}_t = \begin{cases} 1 & \text{if } \pi_{t-1} > \pi^* + \text{tol}, \\ 0 & \text{if } \pi_{t-1} \leq \pi^* + \text{tol}. \end{cases} \tag{4.15}$$

The Lagrangian for the central bank's problem is therefore:

$$\mathcal{L} = L - \lambda_t(\pi_t - \kappa y_t - \nu_t - \varepsilon_{\pi,t}), \tag{4.16}$$

where λ_t is the Lagrange multiplier for the inflation constraint.

The first-order condition for the optimal policy rule is derived by taking the derivative of the Lagrangian with respect to the nominal interest rate:

$$\frac{\partial \mathcal{L}}{\partial i_t} = 0. \tag{4.17}$$

4.1.4 Policy Rules

For the upper regime, the policy rule is:

$$r_t = \phi_{\pi_u}(\pi_{t-1} - \pi^*) + \phi_{y_u} y_t + \phi_{r_u}(r_{t-1} - r_t) + \varepsilon_{r,t}, \tag{4.18}$$

and for the lower regime, it is:

$$r_t = \phi_{\pi_l}(\pi_{t-1} - \pi^*) + \phi_{y_l} y_t + \phi_{r_l}(r_{t-1} - r_t) + \varepsilon_{r,t}, \tag{4.19}$$

Where ϕ_{π_u}, ϕ_{y_u}, ϕ_{r_u}, ϕ_{π_l}, ϕ_{y_l}, and ϕ_{r_l} are the policy parameters for the upper and lower regimes, respectively.

This model is built in form of the three-equation standard New Keynesian Model where the first equation is the aggregate demand (AD) equation, the second portrays the Phillips Curve equation, however, this inflation dynamics is built in form of a hybrid Phillips Curve with both backward and forward looking terms of inflation. The last equation of the monetary policy reaction is broken down into two parts as referred to in Le Bihan et al. (2023).

$$y_t = a_1 y_{t+1} - (1 - a_1)(i - \pi_{t+1}) + \varepsilon_t^y \tag{4.20}$$

$$\pi_t = b_1 \pi_{t+1} + (1 - b_1)\pi_{t-1} + b_2 y_t + \varepsilon_t^\pi \tag{4.21}$$

$$i_t = c_1 i_{t-1} + (1 - c_1)\{c_\pi[\alpha_0 \pi_t + (\alpha_0 \delta + \alpha_1(\pi_t - \delta))] + c_y y_t\} + \varepsilon_t^i \tag{4.22a}$$

$$i_t = c_1 i_{t-1} + (1 - c_1)\{c_\pi[\alpha_0 \pi_t + (-\alpha_0 \delta + \alpha_1(\pi_t + \delta))] + c_y y_t\} + \varepsilon_t^i \tag{4.22b}$$

Where y is the output gap, i is the central bank policy rate (CBR) or nominal interest rate, π is the inflation rate [9]. Moreover, a_1 is the parameter of reaction of output gap to the forward-looking term, b_1 is the parameter of reaction of inflation to the forward-looking term while b_2 is the parameter of the Phillips Curve. c_1 is the parameter of reaction of the CBR from its past value, α_0 is the switch parameter in the regime where the inflation deviation is below the tolerance range whereas α_1 is switch parameter in the regime where the inflation deviation is below the tolerance range. Moreover, the parameters of c_π and c_y define the reaction of the CBR to the inflation deviation and output gap, respectively. Equations (4.22a) and (4.22b) enable us to capture the inflation that is built up on the ranges not just a point target, this specification gives the model flexibility to choose the inflation ranges based on both position regime (upper boundary or lower boundary) and ranges by adjusting the α_0 and α_1 parameters.

Additionally, this model has an element represented by ε_t^y, ε_t^π, and ε_t^i that shocks for the aggregate demand, inflation and monetary policy, respectively. Just like most of the DSGE models, this model assumes that the shocks follow an autoregressive of order one process (i.e., AR(1)) represented by ϵ_t^y, ϵ_t^π, and ϵ_t^i for the aggregate demand, inflation and monetary policy, respectively. The shocks' equations can be written as follows:

$$\varepsilon_t^y = \rho_y \varepsilon_{t-1}^y + \epsilon_t^y \tag{4.23}$$

$$\varepsilon_t^\pi = \rho_\pi \varepsilon_{t-1}^\pi + \epsilon_t^\pi \tag{4.24}$$

$$\varepsilon_t^i = \rho_i \varepsilon_{t-1}^i + \epsilon_t^i \tag{4.25}$$

The terms ϵ_t^y, ϵ_t^π, and ϵ_t^i are independent and identically distributed with mean μ and constant variance σ^2 [i.e., $\mathcal{N}(\mu, \sigma^2)$]. The level of autoregression (shock persistence) is determined by ρ_y, ρ_π, and ρ_i, respectively. The model is solved using the dynare toolbox (Adjemian et al., 2011).

[9] These variables are deviations (i.e., you can think y as $\hat{y}$ in the standard notations like; Akosah (2020) and Schmidt-Hebbel & Carrasco (2016))

4.2 Data

The paper uses three data sets; the output, represented by the Gross Domestic Product (GDP) of the national accounts; the inflation, represented by the year-on-year change in the consumer price indices (CPI) from the National Institute of Statistics of Rwanda (NISR); and the policy rate. The policy rate is obtained from the National Bank of Rwanda (BNR)[10]. The procedure to obtain the gap variables was to subtract the long-term trend variable from the actual variable (for example, the output gap was the difference between actual output and potential output). The paper uses the Hodrick-Prescott (HP) filter to obtain gap variables.

In the paper, a year-over-year change is expressed as the ratio of the current month's CPI to that of the corresponding month in the previous year, minus one, multiplied by one hundred (100)[11]. The period of analysis was the quarterly data from 2006Q1 – 2023Q1. The quarterly data of the GDP is seasonally adjusted to provide a better understanding of movements in the series. The quarterly data on inflation is the average of three (3) consecutive months, which is the same procedure for the CBR.

No.	Data	Source
1	Gross Domestic Product	National Institute of Statistics of Rwanda
2	Consumer Price Index	National Institute of Statistics of Rwanda*
3	Central Bank Rate	National Bank of Rwanda*

* Denotes monthly data.

Table 1: Data

4.3 Calibration

This research will calibrate a total of ten (10) basic parameters that are related to the equations of the model outlined in equations (4.20, 4.21, 4.22a) [12]. These parameters of the model are calibrated based on estimations through running series of estimations of backward models of counterparts [13] and other previous studies that used similar parameters because it is a fairly common habit to select parameters only on the basis of the fact that other literature has previously employed them. This allowed us to specify the model

[10]To obtain the policy rate for this period, the paper uses the key repo rate as a proxy for the period before the price-based monetary policy regime as well as the central bank rate (CBR) in the period of the price-based monetary policy regime.

[11]The formula is $\left(\frac{X_t}{X_{t-12}} - 1\right) \times 100$ where t is monthly CPI.

[12]Theory provides sufficient literature on this practice (Cooley, 1997; Gomme et al., 2013; Cooley & Prescott, 1982; Kydland & Prescott, 1982).

[13]For example, fitting a model of the form $\hat{y}_{t-1} = \alpha_1 \hat{y}_t + \beta_1 (r_{t-1} - \hat{\pi}_t) + \varepsilon_t$ is a backward iterative way of calibrating the model.

with the best possible estimates to represent the macroeconomic behavior.

Parameter	Description	Calibration	Source
a_1	Reaction output gap to the forward-looking term	0.70	Charry et al. (2014)
b_1	Reaction of inflation to the forward-looking term	0.91	Authors' Calculations
b_2	Slope of the Phillips Curve	0.60	Authors' Calculations
c_1	Reaction of the CBR to past value	0.80	Karangwa & Mwenese (2015); Vlček et al. (2020)
c_y	Reaction of the CBR to output gap	0.20	Karangwa & Mwenese (2015); Vlček et al. (2020)
c_π	Reaction of the CBR to inflation deviation	1.50	Karangwa & Mwenese (2015); Vlček et al. (2020)
ρ_y	Output gap shock persistence	0.07	Authors' Calculations
ρ_π	Inflation shock persistence	0.44	Authors' Calculations
ρ_i	CBR shock persistence	0.20	Authors' Calculations
δ	Parameter of tolerance	1 (2)	Authors' Calculations

Table 2: Calibration

4.4 Discussions

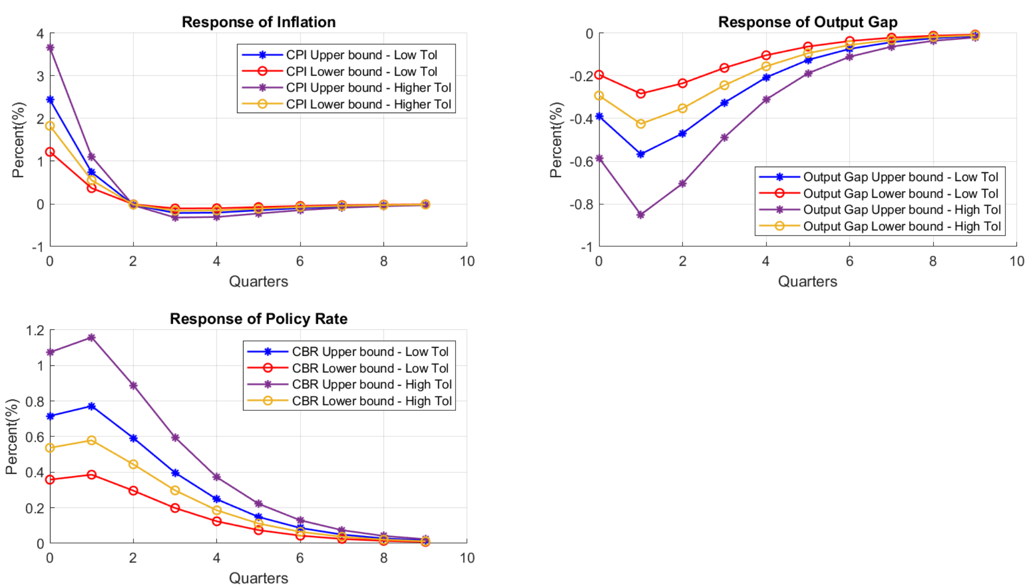
This section outlines results on the response of endogenous variables to a one standard deviation inflation shock. The endogenous variables are the central bank rate, the output gap, and inflation. Through probability distribution functions, the section also describes how variables are distributed across the lower and upper inflation regimes. Specifically, the distributions illustrate the range of values that a given variable (inflation and the central bank rate) can take given that it is in a specific regime (upper or lower).

4.4.1 Impulse Responses: Tolerance and the asymmetric response of monetary policy

In general, the impulse responses show that monetary policy becomes more aggressive in the upper-boundary inflation regime. In other words, monetary policy will be more reactive when inflation exceeds the upper threshold than when inflation falls below the lower boundary. Naturally, this will result in a larger output loss.

To empirically display these results, a 0.2% shock of inflation will drive the inflation levels upwards by around 3% in the upper bound regime when the shock happens and reduces immediately and slightly undershoots and becomes smooth from the second quarter and onward where it stabilizes after 9 quarters. This will lead to an increase in the monetary policy rate by roughly 1.1%; the monetary policy reaction will continue to where the rate increases further to around 1.2% in the next quarter and start to decrease gradually and onward. This aggressiveness in the upper boundary regime is also costly to the output where the output gap drops by 0.6% and continues to drop a quarter ahead and then starts to recover until the 8th period before it is stabilized to its steady state level. These findings in the IRFs are in ranges found within the study of Uwilingiye et al. (2021). The results show aggressiveness in the policy reaction where the monetary policy reduces gradually despite an immediate decline in inflation.

The higher jump in inflation, when in the upper bound, reflects that our model is calibrated to represent an economy with mostly forward-looking price setters. In this environment, forward-looking agents with volatile expectations are more susceptible to lose trust in the central bank's ability to bring back inflation to the medium-term target. In turn, this reasoning follows from the counterfactual that with an otherwise credible central bank, agents would have adaptive expectations anchored around the central bank's target (Reis, 2022). Overall, the IRFs therefore convey an asymmetric reaction of monetary policy, characterized by a state-dependent slope of the policy reaction function, the aforementioned being steeper when a shock increases inflation above the upper bound coupled with the levels of tolerance.



Notes: Red line with rings is the lower boundary regime with low tolerance. Blue starred line is the upper boundary regime with low tolerance. Purple line with rings is the lower boundary regime with high tolerance. Blue starred line is the upper boundary regime with high tolerance.
x-axis represents quarters whereas y-axis represents percent(%)

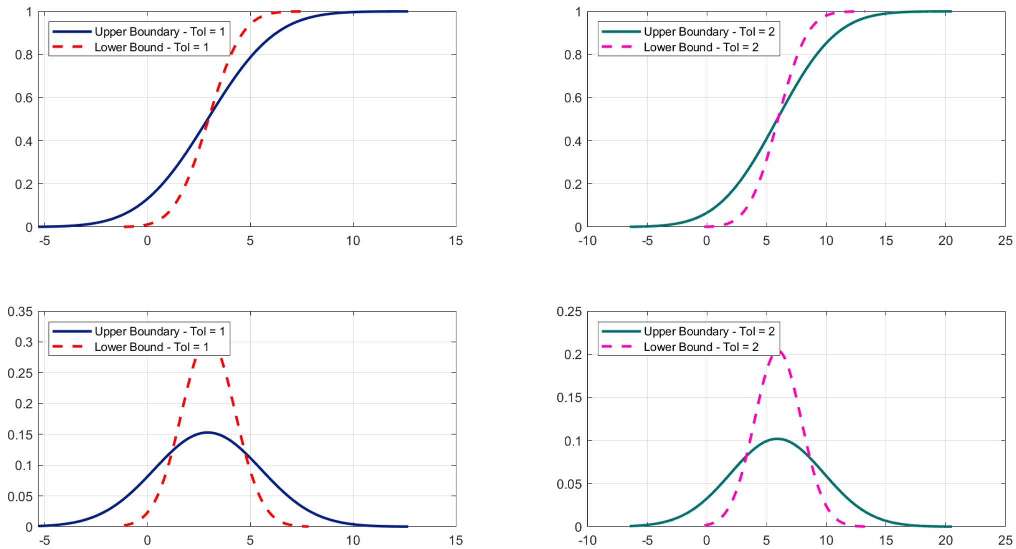
Figure 3: **Impulse Response Functions**

4.4.2 Tolerance, inflation convergence, and policy aggressiveness

This section outlines how inflation, central Bank rate, and output Gap differ between different tolerance values. This experiment considers also those differences among regimes represented by lower boundary, and upper boundary. To understand this phenomenon we use the measurements of the cumulative distribution function (CDF), and probability density function (PDF).

The cumulative distribution function tells us the concentration (percent) of inflation, and central Bank rate among the simulated values of these endogenous variables. On the other hand, the probability density function shows us the positions and likelihood of having a certain value of inflation, and central bank rate in simulated values, respectively. For example, we have long-tailed, and flat PDF for upper boundary regime compared to that of the lower boundary regime (which are tall, condensed with short tails). Moreover, considering the central bank rate, this means that the monetary policy is tolerant into the lower boundary regime compared to upper boundary regime, however, considering inflation rate, the volatility in inflation rate is very high when inflation is above the upper boundary compared to when it is below the lower boundary [14].

[14] The paper is taking basis on the reflections from the policy rate equation (4.4) where the lagged value of the interest rate has 80% of the weight. This is inline with the Quarterly Projection Model of the Central Bank of Rwanda (Vlček et al., 2020)



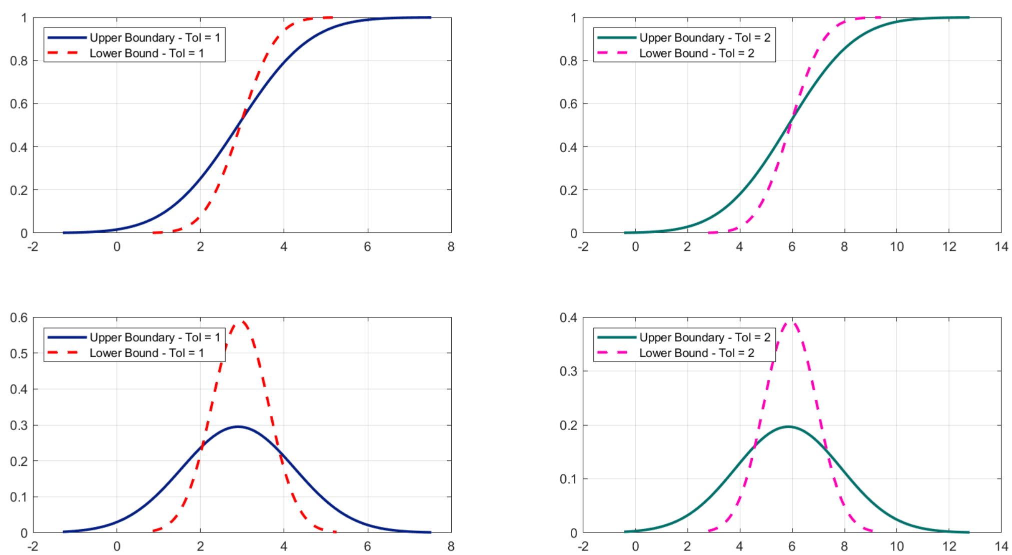
Notes: Blue (Dark Blue) line with represents the Upper boundary regime. Red (magenta) dashed line is the Lower boundary regime. Top panel is the CDF, lower panel is the PDF. x-axis represents simulated values whereas y-axis represents probability [0, 1].

Figure 4: **Inflation Outcomes Under Different Tolerance Ranges**

Looking at inflation simulation in figure (4), when the central bank opts for lower tolerance value of 1, inflation rate under the upper boundary regime will be ranging between -10 percentage points to 15 percentage points. On the other hand, when the central bank is less aggressive (by increasing tolerance value to 2), the inflation rate will range between -10 percentage points to roughly 20 percentage points. On the other hand, in the lower boundary regime, when the tolerance is set to 1, inflation rates will range between roughly -2 percentages points to roughly 7 percentage points, whereas the tolerance level of 2 is associated with inflation levels of 0 and 10 percentage points.

Looking at the interest rate simulation in figure (5) in the upper boundary regime, when tolerance is set to 1, the interest rate will range between roughly -6 percentage points to 11 percentage points, whereas in case the tolerance parameter is set to 2, nominal interest rate will range from roughly -4 percentage points to 14 percentage points. On the other hand, in the lower boundary regime, the policy rate rate varies between 0 percent to 5 percent when the tolerance is 1 and ranges between around 2 to 8 percent , for a tolerance level of 2.

The above findings show that the central bank aggressiveness levels impact the inflation outcomes. If the central bank is more tolerant, the potential inflation outcomes will extend compared to a less tolerant/ aggressive monetary policy. These findings are in line with Kryvtsov & Petersen (2019) who argued that the aggressiveness of monetary policy will enable macroeconomic stability as it is provided by the distribution of nominal interest rate values. Another observation is the burden of tolerance, which shows that the central bank tolerance will have to be corrected for in the future. For example, looking back on the figures (4) and (5) of the density function graphs we have, the higher the tolerance, the higher the inflation intervals, and consequently, the higher the interest rate intervals.Furthermore, the literature argues that the intensity of shock effects on inflation for highly inflation-tolerant environment will be different from that of the less inflation-tolerant (See for example, (Dixon et al., 2020; G. C. Montes & Nicolay, 2016))[15,16].



Notes: Blue (Dark Blue) line with represents the Upper boundary regime. Red (magenta) dashed line is the Lower boundary regime. Top panel is the CDF, lower panel is the PDF. x-axis represents simulated values whereas y-axis represents probability [0, 1].

Figure 5: **Policy Rate Outcomes Under Different Tolerance Range**

Despite this generic structure of distribution, there are differences among tolerance. This implies that

[15] Dixon et al. (2020) and Chan et al. (2018) show how low tolerance to inflation deviations from the target affect the forecasters' perceived inflation (i.e., The forecasters use deviations of inflation from the target as a sign of tolerance levels of monetary policy).

[16] G. C. Montes & Nicolay (2016) provide an evidence that if the central banks feels that shocks pose a risk of pushing inflation above the target, it can be less tolerant.

the distributions may look similar but the ranges may differ. To say that, we experimented the tolerance variations and its effects on inflation and CBR by setting it to 1 compared to a 2. It is shown that higher tolerance is costly to the monetary policy because it should pay the price of that tolerance later by being aggressive in the long-run [17]. Based on this experiment, the distribution functions indicate that with a lower tolerance level for inflation deviations, there is a higher probability (over 75%) that inflation values will fall within the target range boundaries compared to when there is a high tolerance level (about 63% probability). As shown in the appendix (4), the probability that the policy interest rate will exceed 4% when inflation breaches the upper target boundary is markedly higher when the tolerance for above-target inflation is higher versus when tolerance is low. These figures confirm the observation that the likelihood of inflation lying outside the target ranges rises along with the probability of increased policy interest rates at a given level of tolerance level.

	Low Tolerance	**High Tolerance**
Inflation Rate	Low	High
Interest Rate	Low	High

Figure 6: **Matrix of inflation tolerance**

The matrix above illustrates how inflation and interest rate are related to the tolerance levels, where a low

[17] See for example the calibration of lagged interest rate in policy rule equation (4.22b) in table (2).

tolerance of inflation will result into lower interest rate and consequently lower inflation rate, same as the higher levels of tolerance, they are related to the higher levels of inflation as well as higher levels of interest rate. This is mostly observed in the upper boundary regime because when the monetary policy becomes tolerant to an inflation that is moving towards beyond the upper boundary, it will require aggressiveness to bring it back into the target range.

Inflation						
Regime		**Lower Boundary (%)**			**Upper Boundary (%)**	
Tail	Left	Right	**Diff.**	Left	Right	**Diff.**
Tolerance (1)	-1	7	**8**	-5	12	**17**
Tolerance (2)	0	13	**13**	-6	20	**26**
Interest Rate						
Regime		**Lower Boundary (%)**			**Upper Boundary (%)**	
Tail	Left	Right	**Diff.**	Left	Right	**Diff.**
Tolerance (1)	1	5	**4**	3	9	**6**
Tolerance (2)	-2	7	**9**	0	13	**13**

Table 3: Values of Inflation and Interest Rate under Different Tolerance Values

The table above shows that the ranges of inflation and nominal interest levels as discussed above. It also summarizes the idea by computing the differences in values of simulation in the two variables where for both of them, the higher tolerance has higher differences **(Diff.)** which show extended ranges of values compared to the values that are observed when the tolerance is low. For example, the computations of table (3) show that if the monetary policy is tolerant to 1, the fluctuations in lower boundary will span to levels of 8% considering the distance from the left extreme value of the left tail to the extreme value of the right tail compared to a tolerance level of 2 whose differences among the tails is 13%.

These findings briefly show that the tolerance levels matter for the central bank to ensure closer monitoring of inflation dynamics. Moreover, these findings communicate the importance of central bank/ monetary policy to monitor the tolerances in inflation because it will reflect in later more aggressive and costly decisions of large trade-off between output and inflation consequently higher welfare losses as a consequence of higher levels of tolerance. The paper is defending the inflation bands; the boundaries of 2% and 8% work like a signal for the central bank which allows monetary policy a flexibility to observe the movements of inflation and avoidance of under/overshooting the target which can jeopardize its credibility as it is propounded by Ehrmann (2021) in what they call ***"credibility enhancement hypothesis"***[18]. In this case, monetary policy

[18] Claeys et al. (2018) go on to elaborate on some advantages of using tolerance bands and why the use of ranges in commu-

benefits from implementing decisions through a flexible tolerance range rather than having a point target. However, an increase in the degree of tolerance may weaken the monetary policy's complete autonomy from the policy rule. If the tolerance level to inflation is higher when the inflation is beyond the target ranges, monetary policy reaction may substantially become highly endogenous due to the consequences of that tolerance, forcing it to be aggressive in order to bring inflation towards the range.

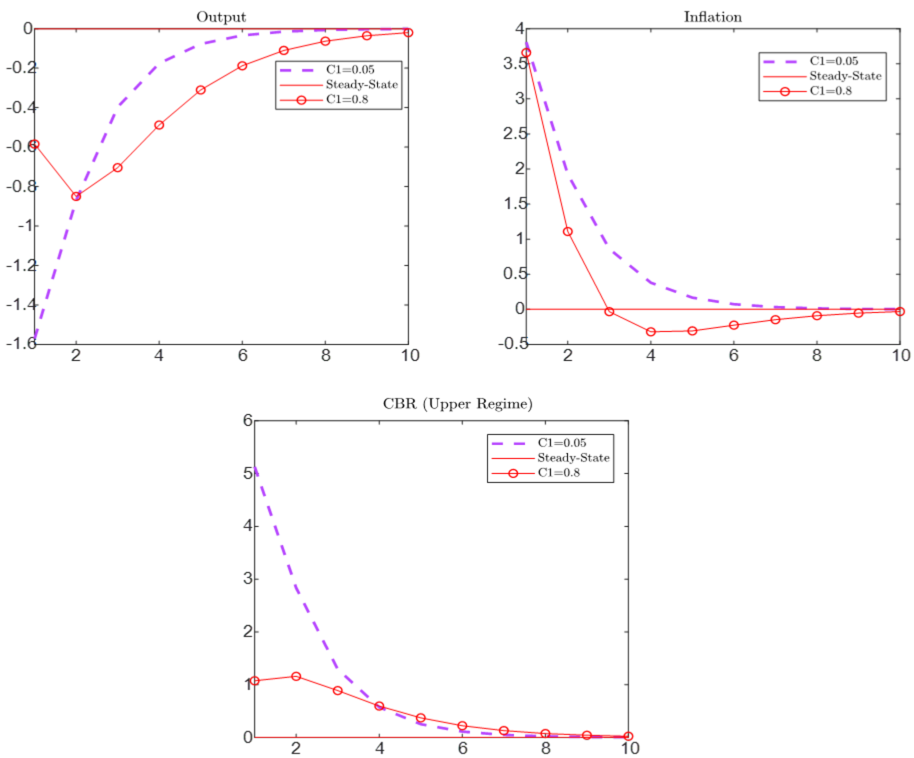
4.4.3 Tolerance and the strength of monetary policy transmission

This paper also tried to understand if weak monetary transmission worsens the effects of high inflation tolerance. We do this by changing the parameters of central bank rate persistence rate- i.e., c_1 in equations (4.22a) and (4.22b), the inertia coefficient in the policy reaction function. We iterate across various levels of the inertia coefficient, for a positive level of tolerance, specifically we set $tol = 1$. This way, we are able to analyze the implications of increasing the tolerance range for an economy with weak monetary policy transmission such as Rwanda. A seminal work in the monetary policy rules literature suggests that a high inertia of the policy rate leads to a smoother adjustment of the policy rate path (Williams, 1999), because gradualism reduces uncertainty when monetary policy has long and variable lags. Given this literature, we can represent an environment of low monetary policy transmission through a high inertia coefficient. Such an environment of low monetary policy transmission is documented in several studies conducted on the case of Rwanda, evidencing the existence of long lags (Kigabo, 2021) and advancing a number of structural challenges that still impede the pass-through of monetary policy in Rwanda (Musekera et al., 2023; Nyalihama et al., 2023). Therefore, in the iteration represented in figure (7), the impulse response corresponding to $c1 = 0.8$ reflects a monetary environment similar to Rwanda's. The alternative calibration, $c1 = 0.05$, is used as benchmark to represent an economy with a high degree of monetary transmission.

The results of the first iteration in figure (7) indicate that in response to a positive inflation shock, weak transmission dampens the loss in output when interest rates are hiked by the central bank. Also interesting is that as suggested by the literature, the central bank rate's path is smoother, as reflected by a flatter slope of the policy reaction curve, indicating passiveness from the central bank. This suggests that the central bank, being cognizant of the lags associated with the transmission of its policy decisions, is more reluctant to tighten aggressively in response to the inflation shock, and as a result, the loss in output is mitigated. Both under weak and strong transmission, inflation increases rapidly following the stochastic shock. However, under strong transmission, inflation eventually converges back to its steady-state level faster , while under weak transmission inflation takes longer to converge. In fact, it undershoots for a considerable period, only converging back to its equilibrium level much later. A host of literature links the lack of inflation convergence and the undershooting to a loss in central bank credibility (Woodford & Walsh (2005b); Galí (2015);

nication mitigates skewed expectations.

Blinder (1999)). Therefore, for an economy with relatively weak monetary policy transmission like Rwanda, these findings warn against abruptly raising inflation tolerance ranges. The results on the impact of higher tolerance with weak transmission back up the lack of convergence (at high tolerance) uncovered by the CDF and PDF analysis explained in 4.4.2 and table 4



Notes: In the upper boundary regime (When inflation exceeds 8 percent), weak transmission is represented by the Red lines (with the circular markers). The tolerance level is set to 1 (*Tol=1*) in this iteration.

Figure 7: **Response to a positive inflation shock under different levels of transmission**

Now we turn to results from the lower boundary regime to analyze the influence of the strength of monetary policy transmission. In figure (8), the IRFs suggest that just as in the upper boundary regime, weak transmission in the lower boundary mitigates the loss in output, with a slight scale difference (see black dotted line and solid red line with markers). In turn, this scale difference is explained by the asymmetric reaction of monetary policy in both inflation regimes (documented in 4.4.1), where monetary policy is less aggressive in the lower boundary regime. Further with weak transmission, the policy rate or CBR increases less in the lower boundary, specifically by less than 20 basis points, compared to a 100 basis points increase in the upper boundary regime, in response to an inflation shock of similar magnitude. These reactions are of lower magnitude when compared to an environment of stronger transmission (see green and magenta dotted lines). Similarly, subsequent to the shock, the strength of transmission affects the level of inflation in both the upper and lower boundary regimes, with the latter regime recording lower inflation for any level of transmission.

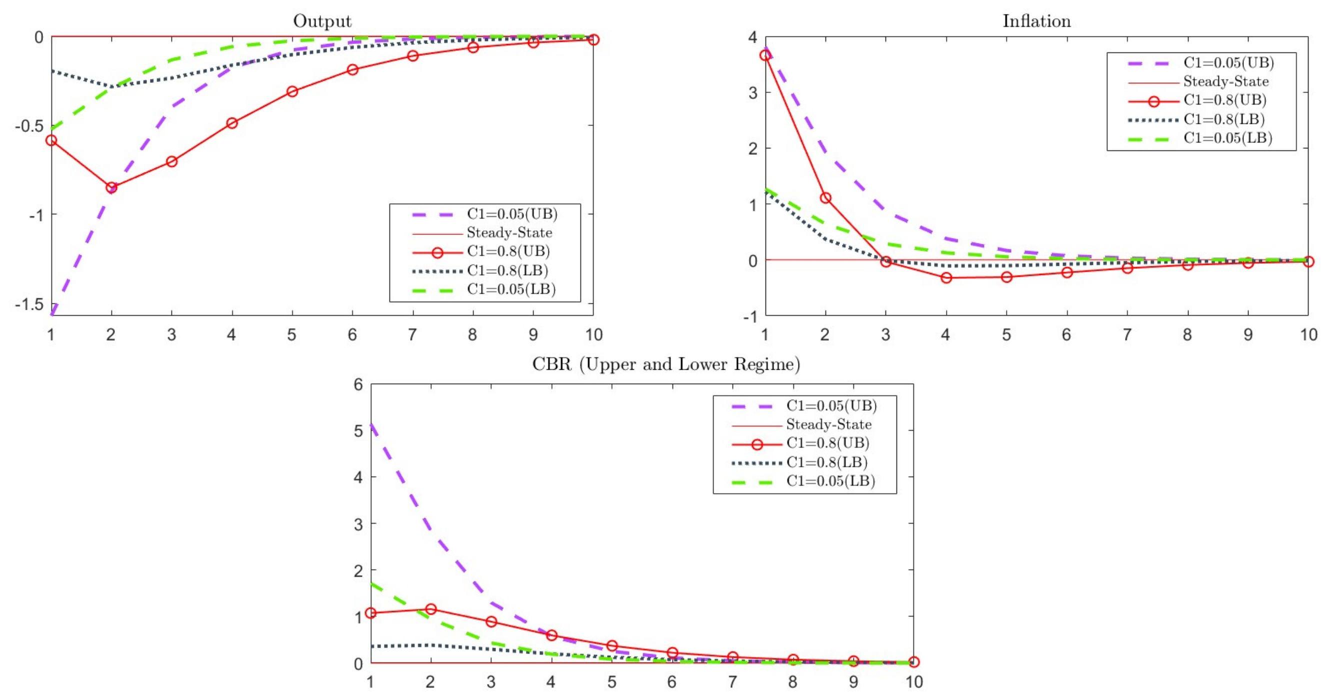


Figure 8: **The impact of increasing tolerance across different levels of transmission**

5 Conclusions

This paper aimed to analyze the implications of inflation tolerance ranges on monetary policy. In so doing, the analysis positions the study to judge the appropriateness of BNR's official tolerance range (target band). By employing a stylized three-equation New Keynesian model with alternative policy rules, the paper examined the central bank's response to deviations from the inflation benchmark target (5%) within specified tolerance ranges. The paper uses series of experimental analysis to try to understand if the tolerance of monetary policy can have effects on its decisions.

After specifying state-dependent policy rules in two different inflation regimes - the upper and lower boundary regimes - the paper uses some iterative processes to analyze the impact of increasing inflation tolerance ranges. The results are as follow; on the asymmetry, monetary policy will be more reactive when inflation exceeds the upper threshold than when inflation falls below the lower boundary. On tolerance, higher tolerance is costly to the monetary policy because it should pay the price of that tolerance later by being aggressive in the long-run, while the loss of credibility reduces the likelihood of inflation convergence. Moreover, an environment of weak monetary policy transmission exacerbates the lack of convergence when monetary policy increases inflation tolerance.

Therefore, this paper provides evidence on the importance of tolerance ranges and how they can provide monetary policy with efficiency by acting as signals for measuring the inflation threat. Although monetary policy might be tempted to operate within higher inflation tolerance ranges, especially due to the added flexibility it grants in periods of high inflation as recently observed in Rwanda, the paper suggests that high tolerance levels present potential threats themselves. Consequently, any decisions to alter inflation tolerance ranges requires scrutinizing the trade-offs involved in terms of credibility of the central bank, the aggressiveness of monetary policy, and the associated welfare/output losses. A focused quantitative assessment of these trade-offs for the case of Rwanda could be taken up by future studies.

Finally, future research could also expand on these conclusions to explore additional implications of inflation tolerance ranges on monetary policy using larger macroeconomic models that can capture more features of the Rwandan economy. One way to do this research could be to explicitly include inflation tolerance ranges in a broader DSGE model of the Rwandan economy.

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Appendices

Appendix A Probabilities Values of Inflation Convergence and Policy Rate Levels

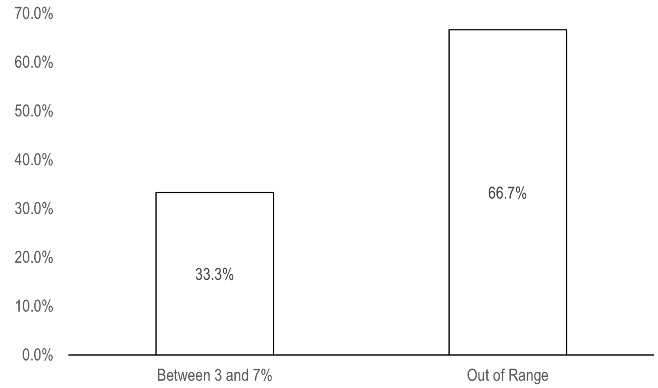
	Inflation Rate (2-8%)	*Policy Rate (> 4%)*
Higher Tolerance	63%	82%
Lower Tolerance	76%	21%

Table 4: Probability of Inflation Converges and Policy Rate Levels

The values presented in the table can be interpreted as follows: Increasing the inflation tolerance range reduces the probability that inflation will converge back to the new range from 76 percent to 63 percent. Moreover, when the inflation tolerance range is increased, the likelihood that the policy rate will exceed 4 percent sharply increases from 21 percent to 82 percent.

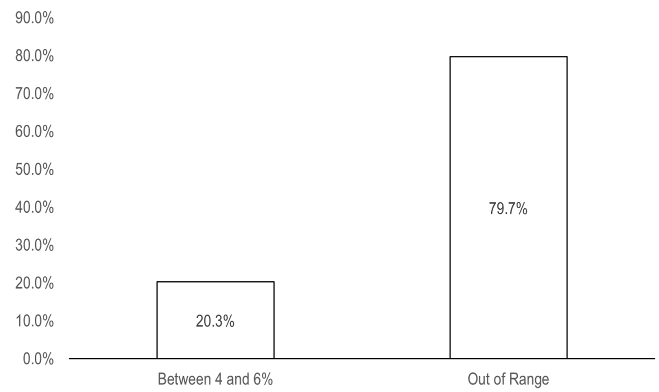
Appendix B Unanchored Inflation in Narrow Tolerance Ranges

This appendix presents empirical data to justify the exclusion of narrower tolerance ranges from the iterative analyses conducted in the paper. The data suggests that on average, Rwandan headline inflation is substantially not anchored within smaller tolerance ranges such as 3 to 7 percent or 4 to 6 percent.



Notes: The methodology used is simple tallying and percentage counts to identify the percentage of quarters in which inflation lied in the specific tolerance range

Figure 9: **Frequency of Headline Inflation in a band of 3 to 7 percent (2007Q1-2023Q4)**



Notes: The methodology used is simple tallying and percentage counts to identify the percentage of quarters in which inflation lied in the specific tolerance range

Figure 10: **Frequency of Headline Inflation in a band of 4 to 6 percent (2007Q1-2023Q4)**