# Optimal monetary policy under bounded rationality*

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**Abstract**

Unlike the baseline rational expectations New Keynesian model, the behavioral New Keynesian model emphasizes different myopia on macroeconomic variables. By revisiting optimal monetary policy in this framework, we show that the optimality of monetary policy is not independent of agents' behavioral state. The myopia characterizing the representative agent influences the choice of optimal monetary policy. While price level targeting emerges as the optimal policy for some myopia, inflation targeting prevails for others. Instrument rules implementation of this optimal policy is shown to be infeasible, questioning the ability of simple rules to assist monetary policy conduct. Bounded rationality is not necessarily associated with welfare losses.

*Keywords:* bounded rationality, optimal monetary policy, welfare, commitment, discretion, optimal simple rules.

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# 1 Introduction

There is wide agreement that the rational expectations hypothesis falls short in capturing the complex dynamics between monetary policy decisions and agents anticipations. There is less agreement on the appropriate deviation from this hypothesis to investigate monetary policy questions. Overall, the monetary policy conclusions from the rational inattention or learning literature are the same as in the rational model or, at best, slightly deviate without altering the way monetary policy should be conducted. Our new insights about the dependence of optimal monetary policy on the specific myopia[1] characterizing households and firms as well as their practical implications on the monetary policy conduct contribute to this debate.

Optimal monetary policy is widely analyzed in the literature through New Keynesian models (Clarida et al., 1999; Woodford, 2003), emphasizing that agents' expectations about the future are rational and somehow perfect. According to Blanchard (2009, 2018), this assumption is exaggerated and quite far from reality, even when considering aggregated representative agents. Who knows exactly what the inflation rate will be next month? What will the output gap be next quarter? Even perfectly informed people cannot be certain. Despite this caveat, academics, and practitioners widely consider this model to be the workhorse for monetary policy analysis, and it continues to provide conclusions that shape the monetary economics literature.

As Stiglitz (2011) notes, one important underlying assumption of the traditional model is the rational behavior of the economy, but the real-world economy seems inconsistent with any model of rationality. Criticisms of policy prescriptions arising from such models, as well as the dimensions along which they fall short of capturing true economic behavior and their policy implications should be scrutinized.

The agent's knowledge of the future is bounded (Andrade and Le Bihan, 2013; Coibion and Gorodnichenko, 2015; Gennaioli et al., 2016). Economic models should relax the rationality assumption in favor of bounded rationality, whereby agents are assumed to be partially myopic and unable to perfectly anticipate the future. This recommendation, made long ago by Akerlof and Yellen (1987) claiming that theory fitting the real world has to be based on the assumption that economic agents are not fully rational, is the main element characterizing the original Keynesian ideas in particular and monetary economics models in general.

Bringing non-rational elements to New Keynesian models to highlight their impact on optimal monetary policy prescriptions is essential for policymakers. In

[1] The terms myopia, inattention, and bounded rationality are used interchangeably in this paper.

addition to their intensive use of rational expectation-based models for analyzing and forecasting the economy, policymakers have to educate and communicate to real (non-rational) economic agents. Households and firms' bounded rationality lead policymakers to question the optimality of monetary policy under such forms of inattention.[2]

Inspired by the bounded rationality approach of Gabaix (2018), we derive optimal monetary policy results that differ from the latter. We study optimal monetary policy through a welfare-relevant behavioral New Keynesian model[3] with decreasing return to scale allowing a model-consistent welfare criterion. Here, bounded rationality means an agent's myopia to variables of interest in its decision-making.[4]

Optimal monetary policy in a fully microfounded behavioral New Keynesian DSGE framework, using a second-order approximation of the household's utility, is assessed. The first and second best equilibria under commitment and discretion, respectively, are examined. The possibility that an optimal simple rule implements the first best solution is analyzed. All these configurations are explored through variants of the behavioral New Keynesian model emphasizing output gap, interest rate, inflation, revenue, general or full myopia.

This paper is related to several strands of the literature. First, it extends the monetary economics literature (Clarida et al., 1999; Woodford, 2003; Galí, 2015) by relaxing the rational expectation hypothesis. Second, compared to the learning (Evans and Honkapohja, 2012, 2013; Woodford, 2013) or the rational inattention (Sims, 2003; Maćkowiak and Wiederholt, 2009, 2015) literature, it provides an alternative way to deviate from the rational expectation hypothesis while providing more richer policy conclusions. Third, based on Gabaix (2014), it extends the optimal monetary policy literature.

Our finding challenges the existing conclusions about optimal monetary policy in the rational expectation as well as the bounded rationality–including the rational inattention and learning–literature. The policy conclusion from our behavioral framework complements and enriches the existing literature. We show that bounded rationality has important implications for the conduct of monetary policy, as many as bounded rationality extensions previously shown in this literature. The optimal policy resulting from the rational New Keynesian framework recommends a form of price level targeting (PLT) while the rational inattention finds small differences in terms of welfare–compared to the rational case–which

[2]Our framework assumes the central bank behaves rationally. By optimizing behavioral agents, and with respect to our research question, a behavioral central bank is not necessary.

[3]Normative analysis with exogenous myopia parameters is made possible relying on the *local rigidity* property explained in Section 3.1.

[4]The plausibility of this approach finds its roots in the work of Kahneman (1973), who attributes attention to effort and inattention, by deduction, to laziness. Consequently, it is more convenient to model *Homo sapiens* as myopic agents.

does not alter the policy conclusions (Maćkowiak and Wiederholt, 2015). Learning models as surveyed in Eusepi and Preston (2018) convey the conclusion that a form of PLT could be a good proxy to the optimal policy. Yet, Gabaix (2018) finds that PLT is suboptimal with behavioral agents. We show that PLT is optimal when assuming some forms of bounded rationality, while it is suboptimal in other cases.

On the practical side, we find that simple instrument rules, as Taylor (1993), price level or nominal GDP (NGDP) rules, are unable to implement the optimal policy path. This result calls for the adoption of targeting rules in the sense of Woodford (2003, 2010) as a practical guideline for the optimal monetary policy conduct. Such a proposal has been made long ago by Svensson (2003). Our result can be seen as a formal proof of the shortsightedness of mechanical simple rules in the policymaking process, especially in a behavioral world.

Additionally, we found that bounded rationality is not necessarily associated with decreased welfare. Several forms of economic inattention, especially extreme ones, can increase welfare. In contrast, output gap myopia implies significant welfare losses compared to the rational case.

The remainder of the paper is organized as follows. Section 2 describes the behavioral New Keynesian model and Section 3 the methodology used for the study of optimal monetary policy. Section 4 and Section 5 present optimal monetary policy under commitment and discretion, respectively. Section 6 characterizes optimal simple rules and weights within the same model. Section 7 interprets and discusses our findings to draw some policy implications in Section 8. Section 9 presents the concluding remarks and Section 10 presents our derivations and robustness checks.

# 2 The model

Our model is based on the psychological foundations of bounded rationality brought by Gabaix (2014, 2018), among others (De Grauwe, 2012; Evans and Honkapohja, 2013; Woodford, 2013), to macroeconomic analysis. In this framework, agents' representations of the economy are sparse, i.e., when they optimize, agents care only about a few variables that they observe with some myopia.

Departing from Gabaix (2018), our model assumes decreasing returns to scale and different types of myopia–other than general myopia. This framework will serve later on to assess optimal monetary policy under different policy designs: discretion, commitment, and optimal simple rules.

## 2.1 Households

The infinitely lived rational representative household's utility is

$$U(c_t, N_t) = \frac{c_t^{1-\gamma} - 1}{1-\gamma} - \frac{N_t^{1+\phi}}{1+\phi} \tag{1}$$

where $c_t$ is real consumption and $N_t$ labor supply. $\gamma$ is the coefficient of the household's relative risk aversion–the inverse of the intertemporal elasticity of substitution–and $\phi$ is the inverse of the Frisch elasticity of labor supply–the inverse of the elasticity of work effort with respect to the real wage.

The household maximizes

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(c_t, N_t) \tag{2}$$

where $\mathbb{E}$ is the usual expectation operator and $\beta$ is the static discount factor subject to the wealth dynamics

$$k_{t+1} = (1 + r_t)(k_t - c_t + y_t) \tag{3}$$

and the real income as

$$y_t = w_t N_t + y_t^f \tag{4}$$

where $k_t$ is the household's wealth, $r_t$ the real interest rate, $y_t$ the agent's real income, $w_t$ the real hourly wage, $N_t$ the worked hours, and $y_t^f$ the profit income.

The rational household's problem is to maximize its period utility (Eq. 2) subject to its wealth evolution (Eq. 3).

The behavioral household maximizes the same lifetime utility (Eq. 2) but does not pay full attention to all the variables in the budget constraints, as correctly processing information entails a cost. The behavioral agent perceives reality with some myopia, which is associated with this information cost.

Let $\hat{r}_t = r_t - \overline{r}$ and $\hat{y}_t = y_t - \overline{y}$ be the deviations of real interest rate and output, respectively, from their steady state. Following Gabaix (2018), the behavioral agent's inattention is associated with *perceived* deviations from the steady-state real interest rate, $\hat{r}_t^{BR} = \hat{r}^{BR}(S_t)$, function of the current state vector of the economy $S_t$, and real income, $\hat{y}_t^{BR} = \hat{y}^{BR}(N_t, S_t)$.

The behavioral agent's budget constraint becomes

$$k_{t+1} = \left(1 + \bar{r} + \hat{r}^{BR}(S_t)\right)\left(k_t - c_t + \bar{y} + \hat{y}^{BR}(N_t, S_t)\right) \tag{5}$$

where $\hat{r}^{BR}(S_t) = m_r \hat{r}_t(S_t)$ and $\hat{y}^{BR}(N_t, S_t) = \hat{y}^{BR}(S_t) + w_t(N_t - N(S_t))$.

$\hat{y}^{BR}(N_t, S_t)$ is the perceived personal income while $\hat{y}^{BR}(S_t) = m_y \hat{y}_t(S_t)$ is the aggregate income. The equation of the perceived income indicates that the behavioral agent perceives only a fraction of the aggregate income but perfectly perceives his marginal income.

Note that $m_r$ and $m_y$ are myopia parameters[5] in $[0,1]$. For $m_r = m_y = 1$, the rational household's budget constraint is recovered. Separately, $m_r$ is the real interest rate myopia, and $m_y$ is the real income myopia.

The future state vector of the whole economy populated by rational agents evolves as

$$S_{t+1} = f\left(S_t, \epsilon_{t+1}\right) \tag{6}$$

where $f$ is a function of the current state vector of the economy[6] and an innovation process vector in the next period, $\epsilon_{t+1}$.

The future state vector of the whole economy populated by behavioral agents evolves as

$$S_{t+1} = \bar{m} f\left(S_t, \epsilon_{t+1}\right) \tag{7}$$

where $\bar{m} \in [0,1]$ represents the general myopia of the agent regarding the economy's state. When $\bar{m} = 1$, the rational agent's law of motion (Eq. 6) is recovered.

Consequently, the problem of the behavioral household consists of maximizing the period utility (Eq. 2) subject to the behavioral wealth (Eq. 5) and the behavioral state vector of the economy (Eq. 7).

By clearing the goods market, in which output equates consumption $y_t = c_t$, and solving the household's problem with respect to $c_t$, the behavioral IS equation[7] becomes

$$\tilde{y}_t = M\mathbb{E}_t\left[\tilde{y}_{t+1}\right] - \sigma\left(i_t - \mathbb{E}_t\left[\pi_{t+1}\right] - r_t^n\right) \tag{8}$$

where $\tilde{y}_t$ is the output gap expressed as deviations of output from its natural level, $i_t$ is the nominal interest which links to $r_t$ by the Fisher equation, $r_t^n$ is the natural level of the real interest rate, $M = \bar{m}/\left(R - m_Y \bar{r}\right)$, $\sigma = m_r/\left(\gamma R\left(R - m_Y \bar{r}\right)\right)$ where $m_Y = \left(\phi m_y + \gamma\right)/\left(\phi + \gamma\right)$ and $R = 1 + \bar{r} = 1/\beta$ and $\bar{r}$ is the steady state of the real interest rate.

The First-Order Condition (FOC) with respect to $N_t$ is

$$w_t = \gamma c_t + \phi n_t \tag{9}$$

where $n_t$ is the log deviation of employment, $N_t$, from its steady state.

The rational IS curve obtained as a particular case, when $m_r = m_y = \bar{m} = 1$, is

$$\tilde{y}_t = \mathbb{E}_t\left[\tilde{y}_{t+1}\right] - \sigma_{re}\left(i_t - \mathbb{E}_t\left[\pi_{t+1}\right] - r_t^n\right) \tag{10}$$

where $\sigma_{re} = 1/\left(\gamma R\right)$.

[5] See Section 3.1 for more details about these parameters.

[6] The function $f$ may contain technological shocks, fiscal measures, etc.

[7] See Appendix A.1 for a detailed derivation of the IS curve (Eq. 8).

By comparing the behavioral (Eq. 8) and the rational (Eq. 10) IS curves,[8] the future output appears to have less influence on current output in the behavioral equation ($M < 1$). Moreover, the transmission of monetary policy to the real economy is stronger in the rational than in the behavioral case ($\sigma_{re} \geq \sigma$).

## 2.2 Firms

Our economy is populated by a continuum of firms. Each firm $i$ produces differentiated goods using the same technology described by

$$Y_t(i) = A_t N_t(i)^{1-\alpha} \tag{11}$$

where $A_t$ is the technological factor (identical across all firms) that evolves such that $a_t = \rho_a a_{t-1} + \varepsilon_t^a$, where $a_t = \ln A_t$ and $\varepsilon_t^a \sim N(0; \sigma_a)$, *i.i.d.* over time, and $N_t(i)$ are the worked hours at firm $i$ which aggregates as $N_t = \int_0^1 N_t(i)\, di$.

Note that unlike Gabaix (2018), we assume decreasing returns to scale ($\alpha > 0$), allowing our inflation dynamics to depend on the elasticity of substitution between different goods, $\varepsilon$. Assuming constant returns to scale ($\alpha = 0$) in the production function removes the role of this elasticity of substitution in the Phillips curve.[9]

Following Galí (2015), firms face Calvo (1983) pricing frictions and adjust their prices in each period with the probability $1 - \theta$. The optimal price setting of the firm, $P_t^*$, is the price that maximizes the current market value of the profits generated while that price remains effective.

The problem of the behavioral firm is to maximize

$$\sum_{k=0}^{\infty} \theta^k \mathbb{E}_t^{BR} \left[ \Lambda_{t,t+k} \left( P_t^* Y_{t+k|t} - \Psi_{t+k}\left(Y_{t+k|t}\right)\right)\right] \tag{12}$$

subject to the sequence of demand constraints

$$Y_{t+k|t} = \left( \frac{P_t^*}{P_{t+k}} \right)^{-\varepsilon} Y_{t+k} \tag{13}$$

where behavioral agents have a subjective expectation[10] denoted by the operator $\mathbb{E}_t^{BR}[.]$, $\Lambda_{t,t+k} = \beta^k (c_{t+k}/c_t)^{-\gamma} (P_{t+k}/P_t)$ is the stochastic discount factor in nominal terms, $\Psi_{t+k}(.)$ is the cost function, and $Y_{t+k|t}$ is the output in period $t+k$ for

[8] To obtain the rational version of the IS equation (Eq. 10), the reader is invited to expand Eq. 39 in Appendix A.1, as we do for the behavioral case.

[9] As presented below, this elasticity plays an important role in the Phillips curve (Eq. 15). Decreasing return to scale also allows us to provide complete robustness checks (Appendix B.1).

[10] See Appendix A.1 for the definition of this subjective expectation operator.

a firm that last reset its price in period $t$, $P_t^*$ is the optimal price the behavioral firm seeks to determine and $P_t$ is the price level of the overall economy.

Expanding the FOC of the firm's problem around the zero-inflation steady state[11] yields to

$$p_t^* - p_{t-1} = (1-\beta\theta) \sum_{k\geq 0} (\beta\theta)^k \, \mathbb{E}_t^{BR} \left[\widehat{mc}_{t+k|t} + p_{t+k} - p_{t-1}\right] \tag{14}$$

where $\widehat{mc}_{t+k|t}$ is the deviation of the real marginal cost, $mc_{t+k|t} = \ln \frac{\Psi'_{t+k}\left(Y_{t+k|t}\right)}{P_{t+k}}$, in $t+k$ of a firm that last reset its price at $t$, from its steady state value, $mc = -\ln \frac{\varepsilon}{\varepsilon-1}$.

The resulting behavioral Phillips curve is[12]

$$\pi_t = \beta M^f \mathbb{E}_t \left[\pi_{t+1}\right] + \kappa \tilde{y}_t \tag{15}$$

where $M^f = \theta\bar{m}/\left(1-(1-\theta)\, m_\pi^f\right)$ and $\kappa = \frac{(1-\theta)(1-\beta\theta)m_x^f}{1-(1-\theta)m_\pi^f}\Theta\left(\gamma + \frac{\phi+\alpha}{1-\alpha}\right)$, where $\Theta = (1-\alpha)\,/\,(1-\alpha+\alpha\epsilon)$. $m_x^f$ and $m_\pi^f$ represent the perfect foresight fraction by the firm of the future marginal cost[13] and inflation, respectively.

Assuming constant return to scale[14] affects the core optimal monetary policy analysis, which depends on the trade-off between inflation and the output gap, $\kappa$. In our Phillips curve (15), the coefficient $\kappa$ depends on $\alpha$, the decreasing return to scale parameter. Interestingly, $\frac{\partial\kappa}{\partial\alpha} = m_x^f \frac{(1-\theta)(1-\theta\beta)}{(\alpha\epsilon-\alpha+1)^2}\left(\phi + 1 - \epsilon\left(\gamma+\phi\right)\right) < 0$, i.e. $\kappa$ is decreasing with $\alpha$.

The rational Phillips curve, obtained by assuming $m_x^f = m_\pi^f = \overline{m} = 1$, is

$$\pi_t = \beta \mathbb{E}_t \left[\pi_{t+1}\right] + \kappa_{re} \tilde{y}_t \tag{16}$$

where $\kappa_{re} = \frac{(1-\theta)(1-\beta\theta)}{\theta}\Theta\left(\gamma + \frac{\phi+\alpha}{1-\alpha}\right)$.

The first contrast between the behavioral (Eq. 15) and the rational (Eq. 16) Phillips curves is the weight of future inflation in the determination of current inflation. This weight is more attenuated in the behavioral than in the rational equation (as $M^f < 1$). Second, the sensitivity of inflation to the output gap in the rational model is bigger than the one in the behavioral model (as $\kappa_{re} > \kappa$).

Note that Gabaix (2018) derived a similar Phillips curve, at least in its functional form: inflation depends on its expectations as well as on the output gap. The only difference is related to the magnitude of the feedback from each variables to inflation. The feedback coefficients from Gabaix (2018) are as follows

$$M_G^f = \overline{m}\left(\theta + \frac{1-\beta\theta}{1-\beta\theta\overline{m}} m_\pi^f \left(1-\theta\right)\right) \tag{17}$$

[11] See Eq. 48 in Appendix A.2 for further details.

[12] See Appendix A.2 for detailed derivations.

[13] By extension, as it proportionally enters $\kappa$, we recall this marginal cost myopia an output-gap myopia.

[14] Or, in other words, $\alpha = 0$ in the production function (Eq. 11).

$$\kappa_G = m_x^f \frac{(1-\theta)(1-\beta\theta)}{\theta}(\gamma+\phi) \tag{18}$$

Eq. 17 and Eq. 18 highlight two substantial differences.

First, the main difference between $M^f$ (Eq. 15) and $M_G^f$ consists of the use of the term structure of expectations. In our formulation, $M^f$, we use the term structure of expectation starting from Eq. 56 while Gabaix (2018) used the same formula starting from Eq. 55. We believe that our formulation is consistent with the term structure of expectations stipulated in the Lemma 2.6 in Gabaix (2018). Unlike from the level, the deviation from the steady-state defines the transition from the subjective to the objective expectations.

Second, the difference between $\kappa$ (Eq. 15) and $\kappa_G$ is related to our assumption of decreasing returns to scale in the production function. Gabaix (2018) assumes constant return to scale, $\alpha = 0$, which simplify $\kappa_G$. Although this assumption may seem to be irrelevant, we noticed that $\kappa$ is a function of $\alpha$ in our formulation and more importantly $\kappa$ is decreasing with $\alpha$ ($\frac{\partial\kappa}{\partial\alpha} < 0$). In other words, the decreasing return to scale assumption might lengthen the feedback from real variables to nominal variables. Considering a decreasing return to scale also allows a role for inflation myopia ($m_\pi^f$) in $\kappa$ nonexistent in $\kappa_G$.

Our microfounded Phillips curve (Eq. 15) reflects the importance of both general myopia ($\overline{m}$) and inflation myopia ($m_\pi^f$) in the weight of inflation expectations in the current inflation determination, which is also the case in Gabaix (2018). Moreover, our Phillips curve gives a role to inflation myopia ($m_\pi^f$) in the weight of the output gap in the determination of current inflation, which is not the case in Gabaix (2018).

## 2.3 Welfare-relevant model

In the presence of nominal rigidities alongside real imperfections, the flexible price equilibrium is inefficient (Galí, 2015). Consequently, it is not optimal for the central bank to target this allocation, but it is optimal to target efficient allocation. Our model has to be expressed in terms of deviations with respect to the efficient aggregates so the resulting variables become *welfare-relevant* ones.

Let us define the welfare-relevant output gap such that $x_t = y_t - y_t^e$, where $y_t$ is the (log) output, $y_t^e$ is the efficient output and $y_t^n$ is the natural output (flexible-price output). Since $\tilde{y}_t = y_t - y_t^n$, linking the output gap and the welfare-relevant output gap gives $\tilde{y}_t = x_t + (y_t^e - y_t^n)$.

By exploiting this relationship, the behavioral IS curve in welfare-relevant output gap terms is

$$x_t = M\mathbb{E}_t x_{t+1} - \sigma\left(i_t - \mathbb{E}_t\left[\pi_{t+1}\right] - r_t^e\right) \tag{19}$$

where $r_t^e = r_t^n + (1/\sigma)\left(M\mathbb{E}_t\left[y_{t+1}^e - y_{t+1}^n\right] - (y_t^e - y_t^n)\right)$ is the efficient interest rate perceived by households.[15]

The behavioral Phillips curve in welfare-relevant output gap terms is

$$\pi_t = M^f \mathbb{E}_t\left[\pi_{t+1}\right] + \kappa x_t + u_t \tag{20}$$

where $M^f = \frac{\beta\theta\overline{m}}{1-(1-\theta)m_\pi^f}$ and $\kappa = \frac{(1-\theta)(1-\beta\theta)\Theta m_x^f}{1-(1-\theta)m_\pi^f}\left(\gamma + \frac{\phi+\alpha}{1-\alpha}\right)$, and $u_t = \kappa\left(y_t^e - y_t^n\right)$ is a cost-push shock evolving according to an $AR(1)$ process such that $u_t = \rho_u u_{t-1} + \varepsilon_t^u$ and $\varepsilon_t^u \sim N(0;\sigma_u)$, *i.i.d.* over time.

Expectations in Eq. 19 and Eq. 20 are augmented by $M$ and $M^f$, respectively, reducing the exaggerated weight given to expectations in the rational New Keynesian model (Blanchard, 2009).

# 3 Methodology

## 3.1 Myopia parameters

As optimal monetary policy is fully microfounded, our research question is independent of the determination of the myopia parameters. They are thereby considered exogenous but in the interval $[0, 1]$ as in Gabaix (2018). The endogenous case may be obtained by specifying cost functions for the agents but we let the myopia endogenization specification for further research.

Gabaix (2014) argues that inattention is derived from information's cost minimization which yields to myopia parameters in the interval $[0, 1]$. By construction, New Keynesian models have to obey to some heuristics, like convergence and stability, implying that the framework may not support all irrationality forms, like over-attention which is behaviorally plausible. Knowing these limitations, this type of model is preferred because of its tractability.

Although our model only focuses on under-reaction, it is also able to generate over-reaction (indirectly). As raised in Gabaix (2014), neglecting mitigating factors (i.e., negatively correlated additional effects) leads to overreaction. In other words, a consumer overreacts to an income shock if he pays too little attention to the fact that this shock is very transitory.

## 3.2 Calibration

Our main experiment uses calibrated values at 15% of myopia, corresponding to a calibration of the myopia parameters at 0.85. The detailed calibration for each model is described in Table 1. The robustness analysis, using higher and extreme

[15] See Appendix A.4 for technical details.

values for myopia parameters to demonstrate our conclusions hold, is available in Appendix B.

| | Models | | | | | | |
|---|---|---|---|---|---|---|---|
| | No myopia | Myopia | | | | | |
| | Rational | Interest rate | Output gap | Inflation | Revenue | General | Full |
| $m_r$ | 1 | 0.85 | 1 | 1 | 1 | 1 | 0.85 |
| $m_x^f$ | 1 | 1 | 0.85 | 1 | 1 | 1 | 0.85 |
| $m_\pi^f$ | 1 | 1 | 1 | 0.85 | 1 | 1 | 0.85 |
| $m_y$ | 1 | 1 | 1 | 1 | 0.85 | 1 | 0.85 |
| $\overline{m}$ | 1 | 1 | 1 | 1 | 1 | 0.85 | 0.85 |

Table 1: Calibration of the myopia parameters used for the simulation of each model.

Table 2 summarizes the values used to simulate our regimes. The standard parameters of our model are calibrated as in Galí (2015). Several robustness checks, using various calibrations from the New Keynesian literature, are presented in Appendix B.

| **Parameter** | **Calibration** | **Description** |
|---|---|---|
| $\beta$ | 0.996 | Static discount factor |
| $\gamma$ | 2 | Household's relative risk aversion |
| $\varepsilon$ | 9 | Elasticity of substitution between goods |
| $\alpha$ | 1/3 | Return to scale |
| $\phi$ | 5 | Frisch elasticity of labor supply |
| $\theta$ | 0.75 | Probability of firms not adjusting prices |
| $\rho_a$ | 0.75 | Technology shock persistence |
| $\rho_u$ | 0.75 | Cost-push shock persistence |

Table 2: Calibration of the other parameters used for the simulation of all the models. Source: Galí (2015).

## 3.3 Optimal policy

The optimal monetary policy question discussed in this paper requires to evaluate the household's utility as the criterion the central bank maximizes subject to the economy's constraints. Cornerstone of our analysis, the microfounded welfare loss measure

$$\mathbb{W} = \frac{1}{2}\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left( \pi_t^2 + \frac{w_x}{w_\pi} x_t^2 \right) \tag{21}$$

where $w_\pi = \frac{\epsilon}{\Theta}\frac{\theta}{(1-\beta\theta)(1-\theta)}$ and $w_x = \gamma + \frac{\phi+\alpha}{1-\alpha}$, is derived from the second order approximation of the behavioral household's utility, as demonstrated in Appendix A.5.

# 4 First best solution

The central bank is assumed to be credible and able to commit to a policy plan. The monetary authority must be able to choose a path for the output gap and inflation over the infinitely lived horizon to minimize a policy objective function, the welfare loss (Eq. 21).

## 4.1 Analytical solution

**Solution 1** *The central bank problem solution under commitment yields to the following FOCs*

$$\pi_t + \varphi_t - \frac{M^f}{\beta}\varphi_{t-1} = 0 \tag{22}$$

$$\frac{w_x}{w_\pi}x_t - \kappa\varphi_t = 0 \tag{23}$$

*where $\varphi_t$ is the Lagrange multiplier associated with the policy problem.*

**Proposition 1** *A form of PLT is optimal when $\overline{m} = 1$ and $m_\pi^f = 1$, a form of inflation targeting (IT) is optimal when this condition is not satisfied.*

**Proof.** The Lagrangian of the central bank's problem is

$$L_t = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{2}\left(\pi_t^2 + \frac{w_x}{w_\pi}x_t^2\right) + \varphi_t\left(\pi_t - \kappa x_t - M^f \pi_{t+1}\right)\right] \tag{24}$$

Deriving the Lagrangian with respect to $\pi_t$ yields the first FOC (Eq. 22). Deriving the latter with respect to $x_t$ yields the second FOC (Eq. 23). Consequently, we can write the first equation (Eq. 22) in terms of the price level

$$p_t + \varphi_t = p_{t-1} + \frac{M^f}{\beta}\varphi_{t-1} \tag{25}$$

Two cases can be distinguished: (i) The case where price level is stationary i.e. $\frac{M^f}{\beta} = 1$. Such a case prevails when $\overline{m} = 1$ and $m_\pi^f = 1$, and a form of PLT is optimal. (ii) Otherwise, a form of IT is optimal. ■

Unlike Gabaix (2018) who concluded that PLT is not optimal with behavioral agents, our result points to the shortsightedness of this conclusion and indicates the optimality of PLT in many behavioral agent cases. Referring to the cases described in 1, the cases of interest rate, output gap, and revenue myopia satisfy the proposition (Section 4.1), all exhibiting a form of PLT.

In response to a cost-push shock, the central bank's commitment to engineering a deflation in the future has implications for the current inflation to the extent that behavioral agents–households and firms–are forward-looking in terms of this specific variable while myopic to other macroeconomic variables. The conclusion that bounded rationality implies suboptimality of PLT is shortsighted. Digging into different forms of bounded rationality shows that this targeting might be optimal in the cases highlighted earlier as well as IT is optimal in the remaining cases.

The takeaway from this analysis, to the contrary of the existing monetary economics literature there is no definitive answer in term of the optimal conduct of monetary policy. Depending on which myopia characterizing households and firms prevails, a central bank has to choose the corresponding targeting.

## 4.2 Simulation and welfare

Fig. 1 presents the responses of the economy to a 1 percent cost-push shock. The cost-push shock implies a trade-off between the output gap and inflation. The intensity of such trade-off differs slightly depending on the form of myopia.

For instance, full myopia entails a large increase in inflation while a big drop in the output. Such deviations require a strong reaction from the central bank. Further, in this (full) myopia case, we notice that the price level never comes back to its steady-state after a cost-push shock which corroborates the analytical result of suboptimality of the PLT in this particular case.

Concerning the output gap myopia, revenue myopia, and interest rate myopia we notice that, following a cost-push shock, inflation rises on impact but decreases to deflation after some periods. It also shows the price level reaching its steady-state value in both cases which makes these myopia entail a form of PLT as an optimal monetary policy.

Regarding the central bank reactions, it is worth noting that the impulse response function amplitudes in the cases of the output gap, inflation, and revenue myopia are very close to the rational case. The only cases where a strong central bank reaction is required are the interest rate, general and full myopia. In these cases, the optimal policy is set in a way to sharply offset the shock and then it does not allow the price level to recover its steady-state value. Instead, it finds a new steady-state value. However, in the remaining cases, the optimal required action is more smooth and the central bank improves the policy trade-off in a way that allows a deflation to operate and then the price level to be stationary.

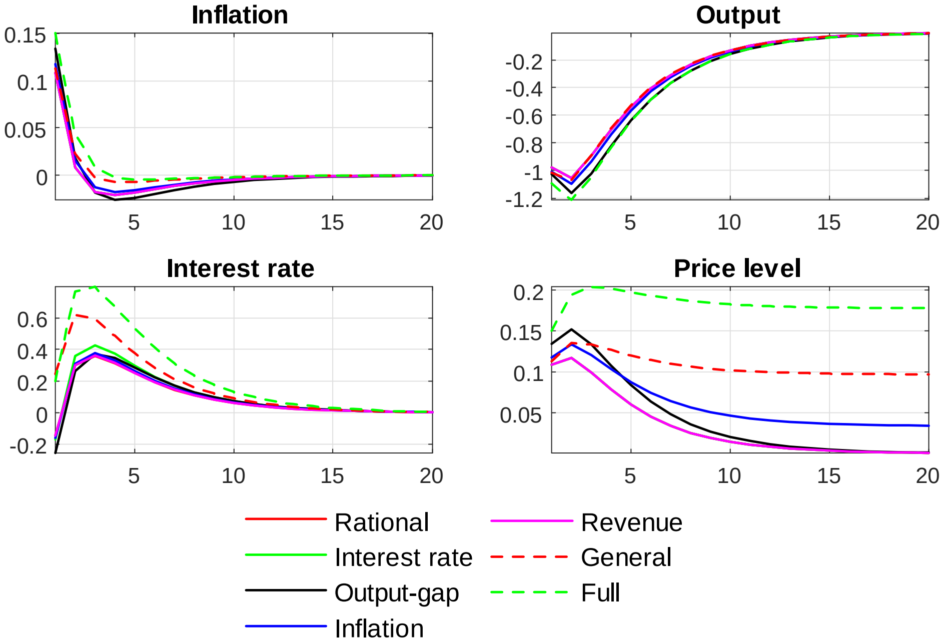


Figure 1: Impulse response functions of inflation, price level, output and interest rate following a 1% cost push shock under commitment for each model.

To sum up, the impulse response results confirm the analytical result derived earlier (Section 4.1) in addition to emphasizing that the optimal responses of the central bank, in the presence of behavioral agents, are not always strong compared to the rational benchmark. These results are robust to different model and myopia calibrations that we use and report in Appendix B.

Table 3 presents the welfare losses for each bounded rationality case.

| **No myopia** | **Myopia** | | | | | |
|---|---|---|---|---|---|---|
| Rational | Interest rate | Output gap | Inflation | Revenue | General | Full |
| 0.174 | 0.174 | 0.227 | 0.190 | 0.174 | 0.176 | 0.248 |

Table 3: Welfare loss values by type of bounded rationality under commitment.

Although the rational case generates the lowest welfare loss, which is intuitive given the perfect foresight assumption, in this case, interest rate and revenue myopia provide both the same welfare losses as the rational benchmark. The reason is simple, the central bank loss does not penalize deviations of interest rate or revenue while in these two myopia cases agents are well informed about output and inflation. Moreover, the general myopia is very close to these cases. As a result, bounded rationality is not necessarily welfare decreasing.

# 5 Second best solution

According to Plosser (2007), when the central bank is "not bound by previous actions or plans and thus is free to make an independent decision every period", monetary policy is called *discretionary.* In such a case, the central bank makes whatever decision is optimal in each period without committing itself to any future actions.

In this section, we characterize the second-best solutions of the central bank's optimization problem following a cost-push shock.

## 5.1 Analytical solution

In this regime, the central bank minimizes the welfare loss related to the decision period, taken into account that expectations are given, which yield to the following proposition.

**Proposition 2** *Discretionary central bank has to obey to the following targeting criterion when setting its optimal policy*

$$\pi_t = -\frac{w_x}{\kappa w_\pi} x_t \tag{26}$$

**Proof.** It is sufficient to write the Lagrangian and derive with respect to both endogenous variables to get FOCs. Once combined we end up with the targeting rule for the central bank in this case. ■

After a cost push shock, a discretionary central bank has to keep this proposition satisfied to minimize the welfare loss. When inflationary pressures arise, the policymaker has an incentive to drive output below its efficient level to accommodate the cost-push shock. While this proposition is silent about the influence of bounded rationality on a discretionary policy, the size of deviations of both output and inflation due to the cost-push shock are dependent on myopia. To make this clear, let us replace the Eq. 26 in the Phillips curve and solve forward, which yield to the following expression for inflation

$$\pi_t = \frac{\frac{w_x}{w\pi}}{\frac{w_x}{w\pi} + \kappa^2 - \frac{w_x}{w\pi} M^f \rho_u} u_t \tag{27}$$

and for output gap

$$x_t = \frac{-\kappa}{\frac{w_x}{w\pi} + \kappa^2 - \frac{w_x}{w\pi} M^f \rho_u} u_t \tag{28}$$

These expressions state that the central bank has to let the output gap and inflation deviate proportionally to the cost-push shock ($u_t$). Bounded rationality impacts the magnitudes of these deviations. Optimal policy response entails that the price level is indeterminate but inflation is, which suggests a form of IT as the preferred regime for a central bank under discretion.

Although the type of myopia considered could impact the magnitudes of the reactions to a particular shock, bounded rationality under discretion does not impact the choice of the policy regime. The rationale under such a proposition is that, in this case, monetary policy takes expectations as exogenous and seek to stabilize only the shock in the current period. Yet, bounded rationality has an impact on the expected outcome of macroeconomic variables.

### 5.2 Simulation and welfare

Fig. 2 presents the impulse response functions to a 1 percent cost-push shock under an optimal discretionary monetary policy. As discussed previously (Section 5.1), we can assess the deviation of both output-gap and inflation reacting to a cost push-shock. Differences arising in each type of myopia reflect the way myopia interact with the proposed solution for inflation and output-gap (Eq. 27 and Eq. 28).

Two remarks are worth noting here. First, optimal monetary policy reaction seeks to increase the policy rate to accommodate the inflation increase, but in an aggressive way compared to the rational benchmark–except for the case of revenue myopia. Second, as mentioned previously, the price level is not stationary in any case which suggests an IT regime as the desirable monetary policy.

As reported in Table 4, the evaluation of welfare losses reveals the optimal policy is better under general myopia than under the rational benchmark.

| **No myopia** | **Myopia** | | | | | |
|---|---|---|---|---|---|---|
| Rational | Interest rate | Output gap | Inflation | Revenue | General | Full |
| 0.270 | 0.270 | 0.386 | 0.287 | 0.270 | 0.236 | 0.341 |

Table 4: Welfare loss values by type of bounded rationality under discretion.

Although this result could seem counterintuitive, one should remember this form of myopia (general myopia) impacts the level of expectations of all the macroeconomic variables or the model. In this case, people expectations are distorted, which is consistent with a discretionary policymaker.

## 6 Optimal simple rules

In this section, we postulate various simple rules and numerically determine the optimal values of the associated coefficients which minimize the central bank loss

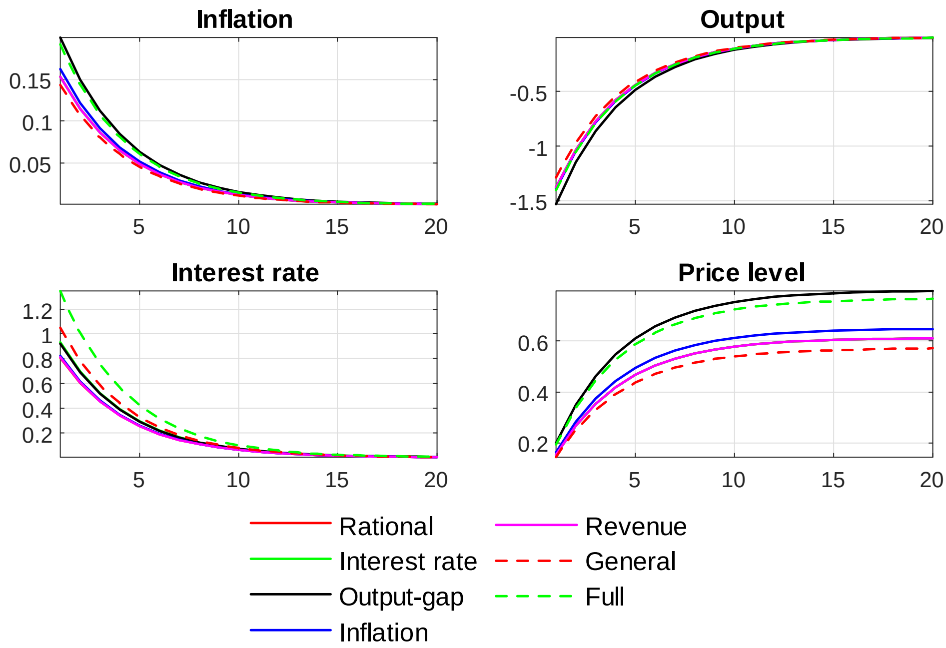


Figure 2: Impulse response functions of inflation, price level, output and interest rate following a 1% cost push shock under discretion for each model.

function. We consider eight rules, as described in Table 5.

The instrument rules described in Table 5 reproduce the central bank's instrument rules when reacting only to the targeted variable, in a strict targeting sense (rules S1 to S4), and when reacting to real fluctuations in addition to its primary target, in a flexible sense (rules F1 to F4). Note that, in some cases, the central bank does not restrict its attention only to endogenous variables, which is why the monetary policy shock ($\varepsilon_t^{mp}$) is added to reflect the deviations of the central bank from its rule.

Hereafter, we provide the optimal coefficient values (Section 6.1) and welfare losses (Section 6.2).

## 6.1 Optimal coefficient values

Table 6 reports the optimal values[16] of $\phi_\pi$, the weight on inflation; $\phi_y$, the weight on the output gap; $\phi_p$, the weight on the price level; $\phi_g$ the weight on NGDP growth; and $\phi_n$ the weight on the NGDP level for different monetary policy rules.

As shown in Table 6, the inflation coefficients under the flexible and strict IT regimes (F1 and S1) are strictly greater than one in all myopia cases which is in line with the stability condition (Galí, 2008, 2015). As the results show, myopia

[16] Optimizations are based on the calibration presented in Section 3.2.

| Name | Targeting regime | Instrument-rule |
|---|---|---|
| F1 | Flexible inflation | $i_t = \phi_\pi \pi_t + \phi_y \tilde{y}_t + \varepsilon_t^{mp}$ |
| F2 | Flexible price level | $i_t = \phi_p p_t + \phi_y \tilde{y}_t + \varepsilon_t^{mp}$ |
| F3 | Flexible NGDP growth | $i_t = \phi_g \left(\pi_t + \Delta\tilde{y}_t\right) + \phi_y \tilde{y}_t + \varepsilon_t^{mp}$ |
| F4 | Flexible NGDP level | $i_t = \phi_n \left(p_t + \tilde{y}_t\right) + \phi_y \tilde{y}_t + \varepsilon_t^{mp}$ |
| S1 | Strict inflation | $i_t = \phi_\pi \pi_t + \varepsilon_t^{mp}$ |
| S2 | Strict price level | $i_t = \phi_p p_t + \varepsilon_t^{mp}$ |
| S3 | Strict NGDP growth | $i_t = \phi_g \left(\pi_t + \Delta\tilde{y}_t\right) + \varepsilon_t^{mp}$ |
| S4 | Strict NGDP level | $i_t = \phi_n \left(p_t + \tilde{y}_t\right) + \varepsilon_t^{mp}$ |

Table 5: Regime names, descriptions and simple rules

| | **F1** | | **F2** | | **F3** | | **F4** | | **S1** | **S2** | **S3** | **S4** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $\phi_\pi$ | $\phi_y$ | $\phi_p$ | $\phi_y$ | $\phi_g$ | $\phi_y$ | $\phi_n$ | $\phi_y$ | $\phi_\pi$ | $\phi_p$ | $\phi_g$ | $\phi_n$ |
| No (rational) | 1.96 | 0.25 | 0.33 | 0.0 | 2.62 | 0.5 | 0.17 | 0.0 | 2.37 | 0.34 | 3.90 | 0.17 |
| Interest rate | 2.44 | 0.20 | 0.39 | 0.0 | 3.32 | 0.5 | 0.20 | 0.0 | 3.11 | 0.40 | 4.00 | 0.20 |
| Output gap | 1.39 | 0.32 | 0.26 | 0.0 | 1.81 | 0.5 | 0.13 | 0.0 | 2.02 | 0.27 | 3.43 | 0.13 |
| Inflation | 1.43 | 0.27 | 0.30 | 0.0 | 1.55 | 0.5 | 0.15 | 0.0 | 1.99 | 0.31 | 3.26 | 0.15 |
| Revenue | 2.03 | 0.21 | 0.33 | 0.0 | 2.63 | 0.5 | 0.17 | 0.0 | 2.37 | 0.34 | 3.91 | 0.17 |
| General | 2.05 | 0.14 | 0.56 | 0.0 | 1.61 | 0.5 | 0.25 | 0.0 | 2.38 | 0.58 | 3.34 | 0.25 |
| Full | 1.54 | 0.18 | 0.49 | 0.0 | 1.10 | 0.5 | 0.21 | 0.0 | 2.10 | 0.50 | 2.82 | 0.21 |

Table 6: Coefficients of the optimal simple rules (F1 to S4) under different myopia.

does impact the coefficients of the optimal simple rules. Consequently, people perception of the futures macroeconomic dynamics leads the central bank to react differently under each regime for each myopia.

Compared to the rational case, interest rate myopia appears to increase the sensitivity of the policy instrument to the central bank target. The way monetary policy transmits to output gap and inflation is performed through the IS and Phillips Curve equations, conditional on the model coefficients influenced by behavioral myopia parameters. Agents' myopia to the future interest rate weakens the transmission of monetary policy to the output gap. To control its target, the central bank has to react aggressively in order to send the appropriate signal. Intuitively, the policymaker needs to strongly signal its control over its target when people misperceive interest rate for each targeting cases.

For all the considered rules, the output gap myopia decreases the sensitivity of interest rate to the central bank's target compared to the rational case. However, the reaction to the output gap becomes stronger compared to the rational case in the flexible IT rule. The reason for this shift is related to the fact the output gap myopia implies that the transmission from output gap to inflation becomes week, while the other channel from interest rate to output gap is kept unaffected by this myopia. For instance, to have the desired impact on inflation, the central bank reacts strongly to output gap while softly to inflation in F1. By misperceiving the output gap dynamics, this economy lacks the pass-through from the output gap to the nominal variables which are the targeted variables for the central bank. Then, the central bank reaction function is less sensitive to its nominal target compared to the rational case.

Regarding inflation myopia, the sensitivity to targeted variables is smaller than the rational case due to the higher transmission from inflation expectations and output gap to inflation. The case for revenue myopia is quite similar, given that this myopia increases the feedback from output gap expectations and interest rate to output gap which feeds to inflation while the transmission from output gap to inflation is kept constant. That's why we see such similar coefficients in reaction to the targeted variable compared to the rational case.

The central bank should react aggressively in order to curb down the expectations and impact the desired variables under general and full myopia.

Another set of results is derived when comparing among the considered targeting regimes. Optimal rules display different characteristics as to their sensitivity to different myopia cases. The central bank appears to be more sensitive to its target when operating under strict targeting compared to flexible targeting.

The nominal income coefficients associated with the strict NGDP growth targeting (S3) are higher than the flexible NGDP growth targeting coefficients (F3), across all types of myopia, a result in line with the literature (Rudebusch, 2002;

Benchimol and Fourçans, 2019). As these coefficients are also larger than one, they respect the necessary stability conditions (Taylor principle). Table 6 reveals that when the central bank targets the NGDP level (F4 and S4) or the price level (F2 and S2), both in the strict and flexible senses, the coefficients are positive but lower than one, a result in line with Rudebusch (2002).

If we compare between PLT in the flexible and strict senses, we find equivalent results. The same result is found when comparing NGDP level targeting in flexible and strict forms. When the central bank targets a form of price level or NGDP objective, the output gap objective becomes not desirable. This result consists of a *divine coincidence* between stabilizing the price level and the output gap. Indeed, a form of PLT leads to self-stabilizing dynamics for the output gap. If the price level deviation from its target increases, let's say a decrease (increase) from its target, the central bank takes correcting measures to increase (decrease) inflation in the future to restore the targeted price level, inducing a lower real interest rate that contributes to boosting the output gap.

All the optimal coefficients depend more or less on agent myopia, and it is clear that interest rate myopia delivers the most substantial amplitude compared to other types of myopia under IT and NGDP growth targeting. Under price level and NGDP level targeting regimes, it is general myopia that delivers the highest coefficients.

For the optimal values of $\phi_p$ in rules F2 and S2, regardless of whether the central bank targets the price level in a flexible or strict way, the sensitivity of the policymaker's instrument to the price level does not vary significantly between flexible and strict regimes. This is also the case between rules F4 and S4.

The coefficient of the output gap varies across the different types of myopia and rules considered. First, the rules reflecting flexible PLT (F2) and NGDP level targeting (F4) show null optimal values for the output gap, which suggests that the central bank does not have to care about real fluctuations under these regimes. Second, the coefficient on the output gap in the flexible IT rule (F1) displays a slight sensitivity to myopia.

## 6.2 Which rule does best describe the first best solution?

The performance of policy rules is compared using the same microfounded welfare criterion as in Section 5 and Section 4. The welfare losses for each rule are reported in Table 3.

Flexible targeting rules do not necessarily induce welfare losses compared to strict rules. Most flexible targeting rules generate similar welfare losses compared to their corresponding strict targeting rules. For instance, welfare losses are identical between F1 and S1.

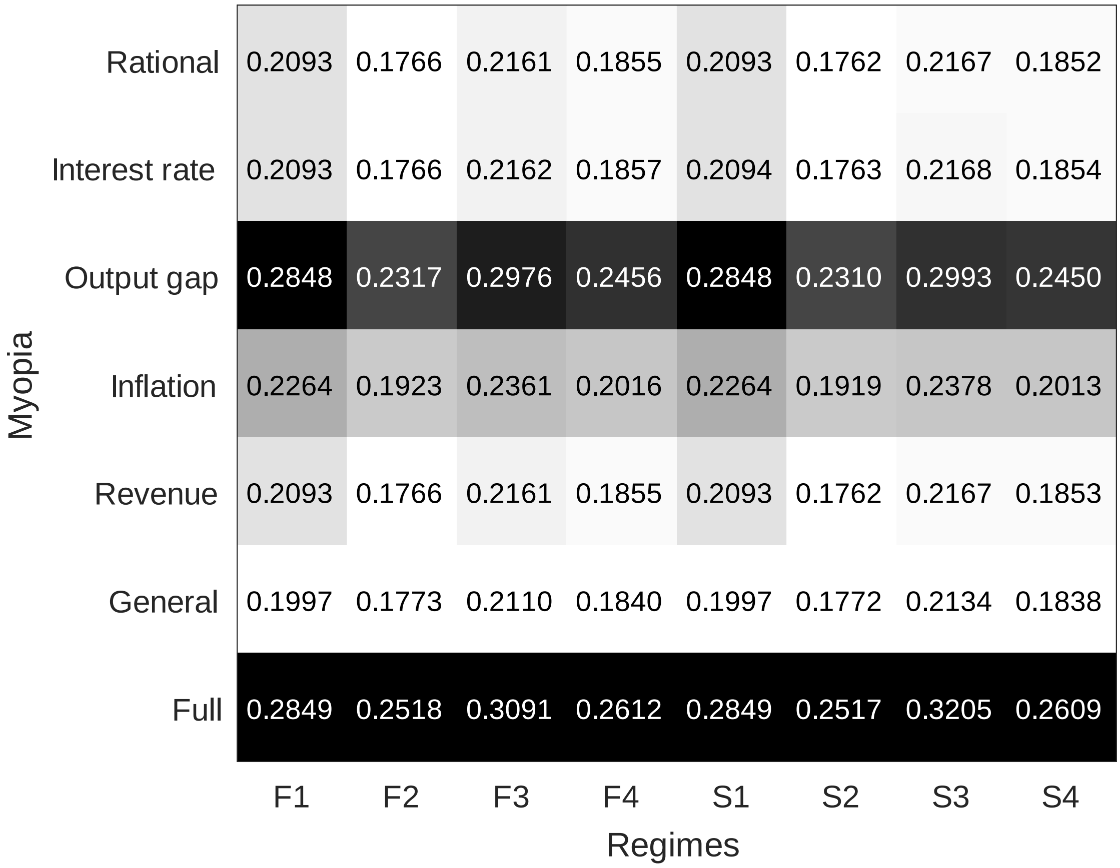


Figure 3: Welfare loss values by regime and bounded rationality for different optimal simple rules. Gray cells highlight welfare-improving myopias for each regime.

Strict PLT delivers the lowest welfare among the considered rules. Note that the welfare losses associated with this rule are similar to the flexible PLT rule through different myopia cases. The reason behind this equivalence lies in the optimal value of the output gap feedback to the interest rate in rule F2, which is null, a case for a divine coincidence when the central bank is pursuing a price level objective.

Moreover, the rational case delivers similar welfare losses to interest rate and revenue myopia cases as in the previous results (Tables 4 and 3).

Regarding other bounded rationality cases, it is clear that across those targeting rules, output gap, and full myopia imply the most important welfare losses compared to the other cases. However, general myopia, combined with the appropriate central bank action, sometimes yield to smaller welfare losses compared to the rational case as in the discretion case (Table 4).

As the welfare analysis shows (Table 3), the best monetary policy rule (which delivers the lowest welfare loss) is the strict PLT rule, whatever he myopia considered. While this result is interesting, it demonstrates the inability of these simple rules to replicate the first best solution, under commitment, that emphasizes the optimal policy depends on the type of myopia characterizing agents.

# 7 Discussion

Optimal monetary policy analyzed through the lens of a behavioral perspective leads to a richer set of results. Some results corroborate the rational expectations literature findings about optimal monetary policy–as in section 4 when setting myopia parameters to 1. Other results contrast the views of the behavioral macroeconomic literature–when myopia parameters are different from 1. Our results shed light on an old debate about the inability of simple rules to constitute a guideline for monetary policy.

Relaxing the rational agent hypothesis contributes, in the case of commitment, to address one of the critiques made against the New Keynesian model, namely, the persistence of macroeconomic variables with respect to monetary policy shocks (Walsh, 2017; Fuhrer and Moore, 1995). In line with Woodford (2010) that uses near-rational expectations, we come to the same conclusion about the history-dependence of the targeting rule under commitment. One can infer that assuming more *realistic* agents in the New Keynesian model would provide a more accurate replication of the impact of monetary policy.

Our result on the optimality of a form of PLT in the cases of interest rate, output gap or revenue myopia, and the optimality of a form of IT in the remaining cases, departs from the existing monetary economics literature but also from Gabaix (2018). Bounded rationality gives reason to both sides, the proponent of PLT and those in favor of IT, by setting the borders between the appropriate use of each targeting regime depending on the agents' myopia. While this departure from rationality complicates expectation management, it offers a rich set of policy regimes–IT and PLT–the policymaker chooses given the state of the world–myopia.

The baseline rational New Keynesian framework recommends a form of PLT as the optimal policy (Galí and Gertler, 1999; Woodford, 2003). This recommendation is nested in our results by shutting down myopia parameters (in section 4). Deviations from this benchmark like in the rational inattention framework (Maćkowiak and Wiederholt, 2009, 2015) find small differences in terms of welfare compared to the rational case which does not alter the policy conclusions of the rational expectations model.

Learning models, as surveyed in Eusepi and Preston (2018), conclude that a form of PLT could be a good proxy to the optimal policy.

By deviating from the rational agent hypothesis and using price setters' information stickiness, Ball et al. (2005) find that flexible PLT is optimal. Honkapohja and Mitra (2018) employs a nonlinear New Keynesian model under learning to show that PLT performs well depending on the credibility of the central bank. Using different deviations from rationality, namely bounded rationality, supports the finding of PLT optimality. Gabaix (2018) completely dismissed the latter result and concludes on the suboptimality of the PLT.

By exploring all the possible forms of bounded rationality, we emphasize the optimality of PLT in some cases, as the existing literature does, while validate Gabaix (2018) result only under some specific bounded rationality configurations. In light of the real experiment led by Amano et al. (2011), where they find that PLT is better suited to *real* agents' beliefs, which are presumably boundedly rational, we cannot ignore that PLT is the prescribed monetary policy.

Robustness analysis (Appendix B) shows that our results are robust to the model's calibration of the structural parameters. It also shows that high general myopia always improves welfare losses under commitment, discretion, and optimal simple rule regimes. Indeed, bounded rationality is not necessarily associated with decreased welfare. Extreme general myopia can increase welfare whatever the monetary policy regime.

Regarding our result under commitment, one could expect that optimal simple rules would allow us to replicate the first best solution emphasizing IT in some cases (small welfare losses) and PLT in the remaining cases. Yet, under these instrument rules, the welfare loss evaluation points to the desirability of strict PLT as a proxy for the optimal monetary policy, regardless of the bounded rationality type. Such a result is in sharp contrast with the policy prescription under commitment.

This result reminds the old debate regarding the instrument rules versus targeting rules, as emphasized in Svensson (2003). Mechanical instrument rules, as a guideline for monetary policy, are likely to be inadequate for optimizing and forward-looking central banks. Svensson (2003) argues that the concept of targeting rules is more appropriate to the forward-looking nature of monetary policy. In the same vein, the inability of simple rules to replicate the commitment solution is a clear case of the shortcomings related to this kind of monetary policy conception. Managing expectations in a behavioral world needs to deviate from a mechanical rule and enlarge the scope to a targeting rule that provides more room for switching policies as people perceptions change.

# 8 Policy implications

Following the Global Financial Crisis, central bank and policy institution members called for a deep revision of the IT framework which shaped the policy decision of major central banks over several decades (Bernanke, 2017; Blanchard and Summers, 2017; Evans, 2018). Some policymakers advocate the appropriateness of PLT as a measure to overcome the challenges brought by the Zero Lower Bound (Bernanke, 2017). Others want to stick with the current IT framework and make some adjustment to its parameters, as raising the inflation target (Blanchard and Summers, 2017) or allowing interest rates to be negative. Even before the crisis, the debate between IT and PLT was an old debate of the modern monetary policy era (Svensson, 1999).

Our result bridges the gap between this two competing views about which kind of monetary policy targeting is optimal. Both forms of targeting, namely PLT and IT, could be optimal but in different circumstances. Our findings show that assessing bounded rationality is a key indicator for the central bank to decide whether it has to pursue an IT or PLT.

The evaluation of the instrument rules indicates the desirability of strict PLT over the other monetary policy targeting regimes, which is in line with the literature surveyed by Hatcher and Minford (2016) in the rational case. However, regarding the bounded rationality cases, this homogeneity of the choice of the targeting rule leaves us with a lot of concern about the inability of these simple instrument rules to replicate the optimal policy as a first best. This result questions the usefulness of these rules to stabilize the economy while taking into account bounded rationality as an essential policymaking ingredient.

The inability of simple rules to replicate the first best solution calls for a reconsideration of their roles in the conduct of monetary policy. Furthermore, their mechanical nature is not adapted to the changing nature of inattention that agents experience in different circumstances. We join Svensson (2003) in calling for including *targeting rules* (as derived in Proposition 1) to the central banking apparatus in setting monetary policy decisions.

Overall, agents' expectations matter for monetary policy conduct. A concrete illustration is the policymakers' desire to educate the public through intensive communication. Central banks have, for several decades, educated agents in economics to increase the public understanding of their monetary policies, among other objectives. Such a program may be perceived as an effort to attenuate myopia, thus guiding agents to rationality. Even if bounded rationality is not a curable disease–even not always a disease, as demonstrated previously, myopia sometimes improves welfare–and is inherent to human functioning, it should motivate central banks to act using the correct tools by taking into account agents' myopia to improve welfare. Convincing central bank staffs to explore, monitor and analyze agents' myopia constitute an important policy recommendation of this paper. Assessing the degree to which economic agents are myopic is one of the areas that central banks should invest in more and more. Borrowing an analogy from Thaler (2016), the central bank should invest in studying the degree to which *Homo sapi-*

*ens* are myopic and act consistently rather than educate people and attempt to transform humans into *Homo economicus*.

# 9 Conclusion

Optimal monetary policy is assessed in a behavioral New Keynesian framework to show the first best solution depends on the type of myopia characterizing agents. While a form of PLT is optimal in some myopia cases, IT is more appropriate in the remaining cases.

No definitive answer about the targeting policy to adopt in a behavioral setting can be drawn. Neither IT nor PLT is consistently optimal under all the state of the world.

Bounded rationality matters for the conduct of monetary policy. In an attempt to implement the commitment result through an instrument rule, we find that optimal simple rules favor strict PLT in all the bounded rationality cases we consider. Such a result leaves us with a puzzling observation about the replication of the first best solution.

The inability of simple rules to replicate the first best solution calls for a reconsideration of their roles in the conduct of monetary policy. This finding opens a new reflection about the instrument rules in an economy with behavioral agents. While these types of rules provided policymakers with a simple monetary policy tool, it is not clear what these rules could play a role in a behavioral world.

Bounded rationality is not necessarily associated with decreased welfare. Several forms of economic inattention, especially extreme ones, can increase welfare. In contrast, output gap myopia implies significant welfare losses compared to the rational case. The central bank has to assess and monitor different myopia to optimally conduct monetary policy.

# References


Akerlof, G. A., Yellen, J. L., 1987. Rational models of irrational behavior. American Economic Review 77 (2), 137–142.

Amano, R., Engle-Warnick, J., Shukayev, M., 2011. Price-level targeting and inflation expectations: experimental evidence. Tech. rep., Bank of Canada.

Andrade, P., Le Bihan, H., 2013. Inattentive professional forecasters. Journal of Monetary Economics 60 (8), 967–982.

Ball, L., Mankiw, N. G., Reis, R., 2005. Monetary policy for inattentive economies. Journal of Monetary Economics 52 (4), 703–725.

Benchimol, J., Fourçans, A., 2019. Central bank losses and monetary policy rules: a DSGE investigation. International Review of Economics and Finance 61 (1), 289–303.

Bernanke, B. S., 2017. Monetary policy in a new era. In: Prepared for conference titled "Rethinking Macroeconomic Policy", Peterson Institute for International Economics, Washington DC, October. pp. 1–49.

Blanchard, O. J., 2009. The state of macro. Annual Review of Economics 1 (1), 209–228.

Blanchard, O. J., 2018. On the future of macroeconomic models. Oxford Review of Economic Policy 34 (1-2), 43–54.

Blanchard, O. J., Summers, L. H., 2017. Rethinking stabilization policy: evolution or revolution? NBER Working Papers 24179, National Bureau of Economic Research, Inc.

Calvo, G., 1983. Staggered prices in a utility-maximizing framework. Journal of Monetary Economics 12 (3), 383–398.

Clarida, R., Galí, J., Gertler, M., 1999. The science of monetary policy: a New Keynesian perspective. Journal of Economic Literature 37 (4), 1661–1707.

Coibion, O., Gorodnichenko, Y., 2015. Information rigidity and the expectations formation process: a simple framework and new facts. American Economic Review 105 (8), 2644–2678.

De Grauwe, P., 2012. Lectures on behavioral macroeconomics. No. 9891 in Economics Books. Princeton, NJ: Princeton University Press.

Eusepi, S., Preston, B., 2018. The science of monetary policy: an imperfect knowledge perspective. Journal of Economic Literature 56 (1), 3–59.

Evans, C. L., 3 2018. Some practical considerations for monetary policy frameworks. Speech at the Shadow Open Market Committee meeting, Manhattan Institute, New York City.

Evans, G. W., Honkapohja, S., 2012. Learning and expectations in macroeconomics. Princeton, NJ: Princeton University Press.

Evans, G. W., Honkapohja, S., 2013. Learning as a rational foundation for macroeconomics and finance. In: Frydman, R., Phelps, E. S. (Eds.), Rethinking Expectations: The Way Forward for Macroeconomics. Princeton University Press, Ch. 2, pp. 68–111.

Fuhrer, J. C., Moore, G., 1995. Inflation persistence. Quarterly Journal of Economics 110 (1), 127–159.

Gabaix, X., 2014. A sparsity-based model of bounded rationality. Quarterly Journal of Economics 129 (4), 1661–1710.

Gabaix, X., 2018. A behavioral New Keynesian model. Mimeo, Harvard University.

Galí, J., 2008. Monetary policy, inflation and the business cycle: an introduction to the New Keynesian framework, 1st Edition. Princeton, NJ: Princeton University Press.

Galí, J., 2015. Monetary policy, inflation and the business cycle: an introduction to the New Keynesian framework, 2nd Edition. Princeton, NJ: Princeton University Press.

Galí, J., Gertler, M., 1999. Inflation dynamics: a structural econometric analysis. Journal of Monetary Economics 44 (2), 195–222.

Gennaioli, N., Ma, Y., Shleifer, A., 2016. Expectations and investment. NBER Macroeconomics Annual 30 (1), 379–431.

Hatcher, M., Minford, P., 2016. Stabilisation policy, rational expectations and price-level versus inflation targeting: a survey. Journal of Economic Surveys 30 (2), 327–355.

Honkapohja, S., Mitra, K., 2018. Price level targeting with evolving credibility. Research Discussion Papers 5/2018, Bank of Finland.

Kahneman, D., 1973. Attention and effort. Vol. 1063. Englewood Cliffs, NJ: Prentice-Hall.

Maćkowiak, B., Wiederholt, M., 2009. Optimal sticky prices under rational inattention. American Economic Review 99 (3), 769–803.

Maćkowiak, B., Wiederholt, M., 2015. Business cycle dynamics under rational inattention. Review of Economic Studies 82 (4), 1502–1532.

Plosser, C. I., 2007. Credibility and commitment: a speech presented to the New York Association for Business Economics, March 6, 2007, and as the Hutchinson Lecture, University of Delaware, April 10, 2007. Speech 4, Federal Reserve Bank of Philadelphia.

Rudebusch, G., 2002. Assessing nominal income rules for monetary policy with model and data uncertainty. Economic Journal 112 (479), 402–432.

Sims, C. A., 2003. Implications of rational inattention. Journal of Monetary Economics 50 (3), 665–690.

Stiglitz, J. E., 2011. Rethinking macroeconomics: what failed, and how to repair it. Journal of the European Economic Association 9 (4), 591–645.

Svensson, L. E. O., 1999. Price-level targeting versus inflation targeting: a free lunch? Journal of Money, Credit and Banking 31 (3), 277–295.

Svensson, L. E. O., 2003. What is wrong with Taylor rules? Using judgment in monetary policy through targeting rules. Journal of Economic Literature 41 (2), 426–477.

Taylor, J. B., 1993. Discretion versus policy rules in practice. Carnegie-Rochester Conference Series on Public Policy 39 (1), 195–214.

Thaler, R. H., 2016. Behavioral economics: past, present, and future. American Economic Review 106 (7), 1577–1600.

Walsh, C., 2017. Monetary theory and policy. Cambridge, MA: MIT Press.

Woodford, M., 2003. Interest and prices: foundations of a theory of monetary policy. Princeton, NJ: Princeton University Press.

Woodford, M., 2010. Robustly optimal monetary policy with near-rational expectations. American Economic Review 100 (1), 274–303.

Woodford, M., 2013. Macroeconomic analysis without the rational expectations hypothesis. Annual Review of Economics 5 (1), 303–346.

# 10 Appendix

# A Derivations

## A.1 IS curve

In this section, we use the Feynman-Kac methodology to derive the Taylor expansion of the consumption deviations.

The Lagrangian of the optimization problem is

$$L = \sum_{t=0}^{\infty} \beta^t u\left(c_t, N_t\right) + \sum_{t=0}^{\infty} \beta^t \lambda_t^k \left(k_t - \left(1 + r_t\right)\left(k_{t-1} - c_{t-1} + y_{t-1}\right)\right) \tag{29}$$

where $r_t = \bar{r} + m_r \hat{r}_t$, $y_t = \bar{y} + m_y \hat{y}_t$, $\lambda_t$ is the Lagrange multiplier, which is equal to $\partial V(k_t)/\partial k_t$, the derivative of the value function with respect to $k$.

The value function is defined as[17] $V(k_t) = \max_c \{u(c) + \beta V(k_{t+1})\}$

At the optimum, the agent solves the following problem: $V(k) = \max_{c,k}\{L\}$. The envelope theorem implies that

$$\frac{\partial V}{\partial r_t} = \frac{\partial L}{\partial r_t} = \beta^t \left[\frac{\partial u(c_t)}{\partial r_t} + \beta \lambda_t^k (k_t - c_t + y_t)\right] \tag{30}$$

By deriving this expression with respect to $k_0$, we find that

$$\frac{\partial}{\partial k_0}\left(\frac{\partial V}{\partial r_t}\right) = \beta^t \frac{\partial k_t}{\partial k_0}\frac{\partial}{\partial k_t}\left[\frac{\partial u(c_t)}{\partial r_t} + \beta \lambda_t^k (k_t - c_t + y_t)\right] \tag{31}$$

By applying this formula to the problem at hand, and taking into account the derivative of the value function in the default case, $\lambda_t^k = \frac{\partial V}{\partial k_t} = \left(\overline{y} + \frac{r}{R}\frac{\phi}{\phi+\gamma}k\right)^{-\gamma}$, we obtain

$$V_{r,k} = \beta^t \frac{\partial}{\partial k_t}\left[\beta\left(\frac{\bar{r}}{R}\frac{\phi}{\phi+\gamma}k_t + \bar{y}\right)^{-\gamma}\frac{k_t}{R}\right] \tag{32}$$

where $V_{r,k} = \frac{\partial}{\partial k_0}\left(\frac{\partial V}{\partial r_t}\right)$.

By deriving and simplifying the expression above, we obtain

$$V_{r,k} = \frac{1}{R^{t+2}} c_0^{-\gamma-1}\left(-\gamma \frac{\bar{r}}{R}\frac{\phi}{\phi+\gamma}k_0 + c_0\right) \tag{33}$$

Since $u_{c_0} = V_{k_0}$, we have $u_{cc}\partial_{\hat{r}} c_0 = \partial_{\hat{r}} V_{k_0}$, which implies

$$\partial_{\hat{r}} c_0 = \frac{\partial_{\hat{r}}\left(\frac{\partial V}{\partial k_t}\right)}{u_{cc}} = \frac{1}{R^{t+2}}\left(\frac{\bar{r}}{R}\frac{\phi}{\phi+\gamma}k_0 - \frac{1}{\gamma}c_0\right) \tag{34}$$

which gives the expression for $b_r(k_t) = \frac{1}{R^{t+2}}\left(\frac{\bar{r}}{R}\frac{\phi}{\phi+\gamma}k_0 - \frac{1}{\gamma}c_0\right)$.

We take the derivative of the value function with respect to $y_t$. Applying the envelope theorem yields

$$\frac{\partial V}{\partial y_t} = \frac{\partial L}{\partial y_t} = \beta^t\left(\frac{\partial u(c_t)}{\partial y_t} + \beta \lambda_t^k (1 + r_t)\right) \tag{35}$$

[17] In this section, because FOCs with respect to consumption are considered, the labor supply $(N_t)$ is omitted.

By deriving this expression with respect to $k_0$, we find the following expression:

$$\frac{\partial}{\partial k_0}\left(\frac{\partial V}{\partial y_t}\right) = \beta^t \frac{\partial k_t}{\partial k_0}\frac{\partial}{\partial k_t}\left[\frac{\partial u\left(c_t\right)}{\partial y_t} + \beta\lambda_t^k\left(1+r_t\right)\right] \tag{36}$$

Eq. 36 can be simplified as

$$\frac{\partial}{\partial k_0}\left(\frac{\partial V}{\partial y_t}\right) = \frac{1}{R^t}\left(-\gamma\frac{\bar{r}}{R}c_0^{-\gamma-1}\right) \tag{37}$$

Since $u_{c_0} = V_{k_0}$, we have $u_{cc}\partial_{\hat{y}}c_0 = \partial_{\hat{y}}V_{k_0}$, which implies

$$\partial_{\hat{y}}c_0 = \frac{\partial_{\hat{y}}\left(\frac{\partial V}{\partial k_0}\right)}{u_{cc}} = \frac{\bar{r}}{R^{t+1}} \tag{38}$$

Once we obtain Eqs. 34 and 38, the Taylor expansion of $\hat{c}$ can be expressed as

$$\hat{c}_t = \mathbb{E}_t\sum_{\tau\geq t}\frac{b_{r|k=0}\hat{r}_\tau + b_y\hat{y}_\tau}{R^{\tau-t+1}} \tag{39}$$

where $b_r = \frac{1}{R}\left(\frac{\bar{r}}{R}k_0 - \frac{1}{\gamma}c_0\right)$ and $b_y = \bar{r}$.

For the behavioral agent expression, 39 becomes

$$\hat{c}_t = \mathbb{E}_t^{BR}\sum_{\tau\geq t}\frac{b_{r|k=0}\hat{r}_\tau + b_y\hat{y}_\tau}{R^{\tau-t+1}} \tag{40}$$

Recall from Gabaix (2018) the term structure of attention: $\mathbb{E}_t^{BR}\left[\hat{r}_{t+k}\right] = m_r\overline{m}^k\mathbb{E}_t\left[\hat{r}_{t+k}\right]$ and $\mathbb{E}_t^{BR}\left[\hat{y}_{t+k}\right] = m_y\overline{m}^k\mathbb{E}_t\left[\hat{y}_{t+k}\right]$, where $\overline{m}$, $m_r$ and $m_y$ are general, interest rate and revenue myopia, respectively. By replacing those expressions in Eq. 40, we obtain

$$\hat{c}_t = \mathbb{E}_t\sum_{\tau\geq t}\frac{\overline{m}^{\tau-t}}{R^{\tau-t+1}}\left(b_{r|k=0}m_r\hat{r}_\tau + b_y m_y\hat{y}_\tau\right) \tag{41}$$

Dividing Eq. 41 by $\bar{c}$, we find

$$\frac{\hat{c}_t}{\bar{c}} = \mathbb{E}_t\sum_{\tau\geq t}\frac{\overline{m}^{\tau-t}}{R^{\tau-t+1}}\left(\frac{b_{r|k=0}}{\bar{c}}m_r\hat{r}_\tau + b_y m_y\frac{\hat{y}_\tau}{\bar{c}}\right) \tag{42}$$

The market clearing condition is $y_t = c_t$, and thus, $\frac{\hat{c}_t}{\bar{c}} = \frac{\hat{y}_\tau}{\bar{c}} = \tilde{y}_t$ is the output gap. Moreover, $\frac{b_{r|k=0}}{\bar{c}} = \frac{1}{\bar{c}}\frac{1}{R}\left(-\frac{1}{\gamma}c_0\right) = -\frac{1}{\gamma R}$.

Then, Eq. 42 becomes

$$\tilde{y}_t = \mathbb{E}_t\sum_{\tau\geq t}\frac{\overline{m}^{\tau-t}}{R^{\tau-t+1}}\left(-\frac{1}{\gamma R}m_r\hat{r}_\tau + \bar{r}m_y\tilde{y}_\tau\right) \tag{43}$$

Expanding this expression yields

$$\tilde{y}_t = -\frac{1}{\gamma R^2} m_r \hat{r}_t + \frac{\bar{r}}{R} m_y \tilde{y}_t + \frac{\overline{m}}{R} \mathbb{E}_t \tilde{y}_{t+1} \tag{44}$$

which can be simplified to

$$\tilde{y}_t = M \mathbb{E}_t \left[\tilde{y}_{t+1}\right] - \sigma \hat{r}_t \tag{45}$$

where $M = \frac{\bar{m}}{R - \bar{r} m_y}$, $\sigma = \frac{m_r}{\gamma R (R - r m_y)}$ and $R = 1/\beta$.

## A.2 Phillips curve

The problem of the behavioral firm is then to maximize

$$\sum_{k=0}^{\infty} \theta^k \mathbb{E}_t^{BR} \left[\Lambda_{t,t+k} \left(P_t^* Y_{t+k|t} - \Psi_{t+k}\left(Y_{t+k|t}\right)\right)\right] \tag{46}$$

subject to the sequence of demand constraints

$$Y_{t+k|t} = \left(\frac{P_t^*}{P_{t+k}}\right)^{-\varepsilon} Y_{t+k} \tag{47}$$

where $\Lambda_{t,t+k} = \beta^k \left(C_{t+k}/C_t\right)^{-\gamma} \left(P_{t+k}/P_t\right)$ is the stochastic discount factor in nominal terms, $\Psi_{t+k}(.)$ is the cost function, and $Y_{t+k|t}$ denotes output in period $t+k$ for a firm that last reset its price in period $t$.

The FOC of the problem is the following:

$$\sum_{k=0}^{\infty} \theta^k \mathbb{E}_t^{BR} \left[\Lambda_{t,t+k} Y_{t+k|t} \left(P_t^* - \mathcal{M} \psi_{t+k|t}\right)\right] = 0 \tag{48}$$

where $\mathcal{M} = \frac{\varepsilon}{\varepsilon - 1}$ is the desired or frictionless markup.

By dividing Eq. 48 by $P_{t-1}$, and defining $\Pi_{t,t+k} = \frac{P_{t+k}}{P_t}$ and $MC_{t+k/t} = \frac{\psi_{t+k|t}}{P_{t+k}}$ we obtain the following

$$\sum_{k=0}^{\infty} \theta^k \mathbb{E}_t^{BR} \left[\Lambda_{t,t+k} Y_{t+k|t} \left(\frac{P_t^*}{P_{t-1}} - \mathcal{M} MC_{t+k/t} \Pi_{t-1,t+k}\right)\right] = 0 \tag{49}$$

We define the steady state of $\Lambda_{t,t+k}$ as $\beta^k$, $Y_{t+k|t}$ as $Y$, $\frac{P_t^*}{P_{t-1}}$ as 1, $MC_{t+k/t}$ as $\frac{1}{\mathcal{M}}$ and $\Pi_{t-1,t+k}$ as 1. These defined steady states allow us to expand the FOC (Eq. 49) as follows

$$\sum_{k=0}^{\infty} (\beta\theta)^k \mathbb{E}_t^{BR} \left[p_t^* - p_{t-1} - \left(\widehat{mc}_{t+k/t} + p_{t+k} - p_{t-1}\right)\right] = 0 \tag{50}$$

with small letters denoting the logarithm of capital letters $p_t = \ln P_t$ and hat indicates deviation with respect to the steady state $\widehat{mc}_{t+k/t} = mc_{t+k/t} - mc$ where $mc_{t+k/t} = \ln MC_{t+k/t}$ and $mc = -\mu$ where $\mu = \ln \mathcal{M}$.

By simplifying Eq. 50 we obtain

$$p_t^* - p_{t-1} = (1-\beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k \mathbb{E}_t^{BR} \left[\widehat{mc}_{t+k/t} + p_{t+k} - p_{t-1}\right] \tag{51}$$

By rearranging the terms of Eq. 51, we obtain

$$p_t^* = \mu + (1-\beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k \mathbb{E}_t^{BR} \left[mc_{t+k/t} + p_{t+k}\right] \tag{52}$$

The (log) marginal cost can be expressed as

$$mc_{t+k|t} = mc_{t+k} - \frac{\alpha\epsilon}{1-\alpha} (p_t^* - p_{t+k}) \tag{53}$$

We replace Eq. 53 in Eq. 51, we find

$$p_t^* - p_{t-1} = (1-\beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k \mathbb{E}_t^{BR} \left[\widehat{mc}_{t+k} - \frac{\alpha\epsilon}{1-\alpha} (p_t^* - p_{t+k}) + p_{t+k} - p_{t-1}\right] \tag{54}$$

Rearranging terms leads to the following expression

$$p_t^* - p_{t-1} = (1-\beta\theta) \sum_{k=0}^{\infty} (\beta\theta)^k \mathbb{E}_t^{BR} \left[\Theta\widehat{mc}_{t+k} + p_{t+k} - p_{t-1}\right] \tag{55}$$

where $\Theta = \frac{1-\alpha}{1-\alpha+\alpha\epsilon}$.

Eq. 55 can be expressed as

$$p_t^* - p_{t-1} = (1-\beta\theta)\,\Theta \sum_{k=0}^{\infty} (\beta\theta)^k \mathbb{E}_t^{BR} \left[\widehat{mc}_{t+k}\right] + \sum_{k=0}^{\infty} (\beta\theta)^k \mathbb{E}_t^{BR} \left[\pi_{t+k}\right] \tag{56}$$

We recall the term structure of expectations from Gabaix (2018): $\mathbb{E}_t^{BR}\left[\pi_{t+k}\right] = m_\pi^f \overline{m}^k \mathbb{E}_t \left[\pi_{t+k}\right]$ and $\mathbb{E}_t^{BR}\left[\widehat{mc}_{t+k}\right] = m_x^f \overline{m}^k \mathbb{E}_t \left[\widehat{mc}_{t+k}\right]$, where $\overline{m}$ is the general myopia to the evolution of the economy's state, $m_\pi^f$ is the myopia to prices, and $m_x^f$ is the myopia related to output. Hence, Eq. 56 can be rewritten as

$$p_t^* - p_{t-1} = (1-\beta\theta)\,\Theta \sum_{k=0}^{\infty} (\beta\theta)^k m_x^f \overline{m}^k \mathbb{E}_t \left[\widehat{mc}_{t+k}\right] + \sum_{k=0}^{\infty} (\beta\theta)^k m_\pi^f \overline{m}^k \mathbb{E}_t \left[\pi_{t+k}\right] \tag{57}$$

By writing this equation as a difference equation, we find

$$p_t^* - p_{t-1} = \beta\theta\overline{m}\mathbb{E}_t\left[p_{t+1}^* - p_t\right] + (1-\beta\theta)\,\Theta m_x^f \widehat{mc}_t + m_\pi^f \pi_t \tag{58}$$

We combine Eq. 58 with $\pi_t = (1-\theta)(p_t^* - p_{t-1})$, we obtain

$$\pi_t = \frac{\beta\theta\overline{m}}{1-(1-\theta)\,m_\pi^f}\mathbb{E}_t\left[\pi_{t+1}\right] + \frac{(1-\theta)(1-\beta\theta)\,\Theta m_x^f}{1-(1-\theta)\,m_\pi^f}\widehat{mc}_t \tag{59}$$

We express the real marginal cost, $mc_t$, as a function of the output gap, $\tilde{y}_t$. Notice that the real marginal cost is defined in terms of the real wage and marginal productivity of labor:

$$mc_t = w_t - mpn_t \tag{60}$$

Using the facts that the real wage equals the marginal rate of substitution between consumption and labor and marginal productivity can be derived from Eq. 11, expression Eq. 60 can be written as

$$mc_t = (\gamma y_t + \phi n_t) - (y_t - n_t) - \ln(1-\alpha) \tag{61}$$

We use the production function Eq. 11 to eliminate $n_t$ from Eq. 61, and we obtain

$$mc_t = \left(\gamma + \frac{\phi+\alpha}{1-\alpha}\right) y_t - \frac{1+\phi}{1-\alpha}a_t - \ln(1-\alpha) \tag{62}$$

Writing Eq. 62 in the flexible price economy yields

$$mc = \left(\gamma + \frac{\phi+\alpha}{1-\alpha}\right) y_t^n - \frac{1+\phi}{1-\alpha}a_t - \ln(1-\alpha) \tag{63}$$

where $y_t^n$ is the natural output. Finally, by subtracting Eq. 63 from Eq. 62, we obtain

$$\widehat{mc}_t = \left(\gamma + \frac{\phi+\alpha}{1-\alpha}\right)(y_t - y_t^n) = \left(\gamma + \frac{\phi+\alpha}{1-\alpha}\right)\tilde{y}_t \tag{64}$$

Finally, by replacing Eq. 64 in the price setting Eq. 59 we obtain

$$\pi_t = \frac{\beta\theta\overline{m}}{1-(1-\theta)\,m_\pi^f}\mathbb{E}_t\left[\pi_{t+1}\right] + \frac{(1-\theta)(1-\beta\theta)\,\Theta m_x^f}{1-(1-\theta)\,m_\pi^f}\left(\gamma + \frac{\phi+\alpha}{1-\alpha}\right)\tilde{y}_t \tag{65}$$

The resulting behavioral Phillips curve is

$$\pi_t = \beta M^f \mathbb{E}_t\left[\pi_{t+1}\right] + \kappa\tilde{y}_t \tag{66}$$

where $M^f = \frac{\theta\overline{m}}{1-(1-\theta)m_\pi^f}$ and $\kappa = \frac{(1-\theta)(1-\beta\theta)\Theta m_x^f}{1-(1-\theta)m_\pi^f}\left(\gamma + \frac{\phi+\alpha}{1-\alpha}\right)$.

Note that if we consider the rational case, where $m_x^f = m_\pi^f = \overline{m} = 1$, we end up with the usual Phillips curve as in Galí (2015).

## A.3 Natural output

The marginal cost of a firm is defined as

$$\mu_t = -w_t - mpn_t \tag{67}$$

where $mpn_t$ is the marginal productivity of labor. Recall that the marginal rate of substitution between labor and consumption equals the real wage, which can be expressed as

$$-\frac{U_{n,t}}{U_{c,t}} = \frac{W_t}{P_t} \tag{68}$$

Taking logs, we obtain $w_t = \phi n_t + \gamma c_t$.

For the marginal productivity of labor in logs, we have

$$mpn_t = a - \alpha n_t + \ln(1-\alpha) \tag{69}$$

and because the production function takes the form $y_t = a_t + (1-\alpha) n_t$, we can express the marginal cost formula in terms of output and a technological factor as

$$\mu_t = -\left(\gamma + \frac{\phi+\alpha}{1-\alpha}\right) y_t - \frac{1+\phi}{1-\alpha} a_t - \ln(1-\alpha) \tag{70}$$

By expressing this formula in the flexible price economy, we obtain

$$\mu = -\left(\gamma + \frac{\phi+\alpha}{1-\alpha}\right) y_t^n - \frac{1+\phi}{1-\alpha} a_t - \ln(1-\alpha) \tag{71}$$

where $\mu = \ln\left(\frac{\varepsilon}{\varepsilon-1}\right)$ is the marginal cost prevailing under flexible prices, and $y_t^n$ is the natural output.

By solving for $y_t^n$, we obtain the expression for natural output as

$$y_t^n = \frac{1+\phi}{\phi+\alpha+\gamma(1-\alpha)} a_t + \frac{(1-\alpha)(-\mu+\ln(1-\alpha))}{\phi+\alpha+\gamma(1-\alpha)} \tag{72}$$

## A.4 Efficient interest rate

The IS curve Eq. 73 is written as

$$\hat{y}_t = M\mathbb{E}_t[\hat{y}_{t+1}] - \sigma\left(i_t - \mathbb{E}_t[\pi_{t+1}] - r_t^n\right) \tag{73}$$

Note that the definitions of the output gap, $\hat{y}_t$, and the relevant output gap, $x_t$, are

$$\hat{y}_t = y_t - y_t^n \tag{74}$$

$$x_t = y_t - y_t^e \tag{75}$$

where $y_t^n$ is the natural output, and $y_t^e$ is the efficient output.

By employing those definitions, we can write the IS curve Eq. 19 as

$$y_t - y_t^n = M\mathbb{E}_t\left[y_{t+1} - y_{t+1}^n\right] - \sigma\left(i_t - \mathbb{E}_t\left[\pi_{t+1}\right] - r_t^n\right) \tag{76}$$

which is equivalent to

$$y_t - y_t^e + y_t^e - y_t^n = M\mathbb{E}_t\left[y_{t+1} - y_{t+1}^e + y_{t+1}^e - y_{t+1}^n\right] - \sigma\left(i_t - \mathbb{E}_t\left[\pi_{t+1}\right] - r_t^n\right) \tag{77}$$

The welfare-relevant output gap is

$$x_t + y_t^e - y_t^n = M\mathbb{E}_t\left[x_{t+1} + y_{t+1}^e - y_{t+1}^n\right] - \sigma\left(i_t - \mathbb{E}_t\left[\pi_{t+1}\right] - r_t^n\right) \tag{78}$$

which leads us to the following expression

$$x_t = M\mathbb{E}_t\left[x_{t+1}\right] + M\mathbb{E}_t\left[y_{t+1}^e - y_{t+1}^n\right] - \left(y_t^e - y_t^n\right) - \sigma\left(i_t - \mathbb{E}_t\left[\pi_{t+1}\right] - r_t^n\right) \tag{79}$$

Hence, we obtain

$$x_t = M\mathbb{E}_t\left[x_{t+1}\right] - \sigma\left(i_t - \mathbb{E}_t\left[\pi_{t+1}\right] - r_t^e\right) \tag{80}$$

where

$$r_t^e = r_t^n + \frac{1}{\sigma}\left(M\mathbb{E}_t\left[y_{t+1}^e - y_{t+1}^n\right] - \left(y_t^e - y_t^n\right)\right) \tag{81}$$

By taking Eq. 81 in deviation from its flexible price economy counterpart, we obtain an expression for the efficient interest rate in deviation form such as

$$\begin{aligned} r_t^e - r_t^n &= \left[r_t^n + \frac{1}{\sigma}\left(M\mathbb{E}_t\left[y_{t+1}^e - y_{t+1}^n\right] - \left(y_t^e - y_t^n\right)\right)\right] \\ &\quad - \left[r_t^n + \frac{1}{\sigma}\left(M\mathbb{E}_t\left[y_{t+1}^n - y_{t+1}^n\right] - \left(y_t^n - y_t^n\right)\right)\right] \end{aligned} \tag{82}$$

Considering the notation $\hat{v} = v - v^n$, Eq. 82 can be simplified to

$$\hat{r}_t^e = \frac{1}{\sigma}\left(M\mathbb{E}_t\left[\hat{y}_{t+1}^e\right] - \hat{y}_t^e\right) \tag{83}$$

## A.5 Welfare loss

Taylor expansion of the utility function $U_t$ defined in Eq. 1 is the following

$$U_t - U = U_c c\left(\frac{c_t - c}{c}\right) + \frac{1}{2}U_{cc}c^2\left(\frac{c_t - c}{c}\right)^2 + U_n N\left(\frac{N_t - N}{N}\right) + \frac{1}{2}U_{nn}N^2\left(\frac{N_t - N}{N}\right)^2 + \Theta\left(Z^3\right) \tag{84}$$

where $\Theta(Z^3)$ represents the terms up to the power of 3 and null cross variables derivatives due to the separability of our utility function.

To further develop the Eq. 84, we use the fact that $U_{cc} = -\gamma \frac{1}{c} U_c$ and $U_{nn} = -\phi \frac{1}{N} U_n$. Moreover, note that for any variable $z_t$ we have $\frac{z_t - z}{z} = \hat{z}_t + \frac{1}{2}\hat{z}_t^2$.

Taking into account all of this, Eq. 84 becomes

$$U_t - U = U_c c \left( \hat{c}_t + \frac{1-\gamma}{2} \hat{c}_t^2 \right) + U_n N \left( \hat{n}_t + \frac{1+\phi}{2} \hat{n}_t^2 \right) + \Theta\left(Z^3\right) \tag{85}$$

We express $\hat{n}_t$ in terms of $\tilde{y}_t$ (remember that $\tilde{y}_t$ is our notation for the output gap from Section 2.1). Using $Y_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} Y_t$ and $P_t = \left(\int_0^1 P_t(i)^{1-\epsilon} di\right)^{\frac{1}{1-\epsilon}}$, we have

$$\begin{aligned} N_t &= \int_0^1 N_t(i)\, di \\ &= \int_0^1 \left(\frac{Y_t(i)}{A_t}\right)^{\frac{1}{1-\alpha}} di \\ &= \left(\frac{Y_t}{A_t}\right)^{\frac{1}{1-\alpha}} \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\frac{\epsilon}{1-\alpha}} di \end{aligned}$$

In terms of log deviations, this expression can be written as

$$(1-\alpha)\hat{n}_t = \tilde{y}_t - a_t + d_t$$

where $d_t = (1-\alpha)\ln \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\frac{\epsilon}{1-\alpha}} di$. It follows from Lemma 1 (Galí (2015), chapter 4) that

$$d_t = \frac{\epsilon}{2\Theta} var_i\left\{p_t(i)\right\}$$

Going back to our Taylor expansion Eq. 85, and using the fact that $\hat{c}_t = \tilde{y}_t$ we obtain

$$U_t - U = U_c c \left( \tilde{y}_t + \frac{1-\gamma}{2} \tilde{y}_t^2 \right) + \frac{U_n N}{1-\alpha} \left( \tilde{y}_t + \frac{\epsilon}{2\Theta} var_i\left\{p_t(i)\right\} + \frac{1+\phi}{2(1-\alpha)} \left(\tilde{y}_t - a_t\right)^2 \right) \tag{86}$$

The efficiency of the steady state implies

$$-\frac{U_n}{U_c} = MPN = (1-\alpha)\frac{Y}{N}$$

By combining the previous two equations we find

$$\frac{U_t - U}{U_c c} = \tilde{y}_t + \frac{1-\gamma}{2} \tilde{y}_t^2 - \left( \tilde{y}_t + \frac{\epsilon}{2\Theta} var_i\left\{p_t(i)\right\} + \frac{1+\phi}{2(1-\alpha)} \left(\tilde{y}_t - a_t\right)^2 \right) \tag{87}$$

As in Galí (2015), we can consider that the product of $\Phi$ with second order terms is null under the assumption of small distortions. We obtain

$$\begin{aligned}\frac{U_t - U}{U_c c} &= -\frac{1}{2}\left[\frac{\epsilon}{\Theta} var_i\left\{p_t(i)\right\} - (1-\gamma)\tilde{y}_t^2 + \frac{1+\phi}{1-\alpha}(\tilde{y}_t - a_t)^2\right] \\ &= -\frac{1}{2}\left[\frac{\epsilon}{\Theta} var_i\left\{p_t(i)\right\} + \left(\gamma + \frac{\phi+\alpha}{1-\alpha}\right)\tilde{y}_t^2 - 2\left(\frac{1+\phi}{1-\alpha}\right)\tilde{y}_t a_t\right] \quad (88)\end{aligned}$$

Using the fact that $\hat{y}_t^e = \frac{1+\phi}{\gamma(1-\alpha)+\phi+\alpha} a_t$, we obtain

$$\frac{U_t - U}{U_c c} = -\frac{1}{2}\left[\frac{\epsilon}{\Theta} var_i\left\{p_t(i)\right\} + \left(\gamma + \frac{\phi+\alpha}{1-\alpha}\right)(\tilde{y}_t - \hat{y}_t^e)^2\right]$$

The welfare loss is expressed as a fraction of the steady state consumption

$$\begin{aligned}\mathbb{W} &= -\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{U_t - U}{U_c c}\right) \\ &= -\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[-\frac{1}{2}\left(\frac{\epsilon}{\Theta} var_i\left\{p_t(i)\right\} + \left(\gamma + \frac{\phi+\alpha}{1-\alpha}\right)(\tilde{y}_t - \hat{y}_t^e)^2\right)\right] \quad (89)\end{aligned}$$

Assuming that $x_t = y_t - y_t^e = \tilde{y}_t - \hat{y}_t^e$ and by applying the Lemma 2 (Galí (2015), chapter 4) we find the welfare loss expression

$$\mathbb{W} = -\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[-\frac{1}{2}\left(\frac{\epsilon}{\Theta}\frac{\theta}{(1-\beta\theta)(1-\theta)}\pi_t^2 + \left(\gamma + \frac{\phi+\alpha}{1-\alpha}\right)x_t^2\right)\right] \quad (90)$$

# B Robustness check

This section presents our results under the alternative model and myopia calibrations.

## B.1 Model calibrations

Table 7 presents the different model calibrations considered in the following robustness analysis.

Fig. 4 to Fig. 7 present the impulse response of inflation, output, interest rate and price level under commitment, respectively, over the different calibrations presented in Table 7. Fig. 8 to Fig. 11 present the impulse response of inflation, output, interest rate and price level under commitment, respectively, over the different calibrations presented in Table 7.

| **Calibration name** | $\beta$ | $\gamma$ | $\phi$ | $\epsilon$ | $\alpha$ | $\theta$ |
|---|---|---|---|---|---|---|
| Galí (2008) | 0.99 | 1 | 1 | 6 | 1/3 | 0.66 |
| Relative risk aversion | 0.99 | 2 | 1 | 6 | 1/3 | 0.66 |
| Frisch elasticity | 0.99 | 1 | 5 | 6 | 1/3 | 0.66 |
| Constant return to scale | 0.99 | 1 | 1 | 6 | 0 | 0.66 |
| Sticky prices | 0.99 | 1 | 1 | 6 | 1/3 | 3/4 |
| Time preferences | 0.996 | 1 | 1 | 6 | 1/3 | 0.66 |
| Demand elasticity | 0.99 | 1 | 1 | 9 | 1/3 | 0.66 |
| Galí (2015) | 0.996 | 2 | 5 | 9 | 1/3 | 3/4 |

Table 7: Calibration of the model parameters used for the robustness checks.

Impulse responses functions for optimal simple rules under each calibration are available upon request. Welfare heatmaps for commitment and discretion under the different model calibrations (Table 7) are presented in Table 8. Welfare heatmaps of optimal simple rules under different model calibrations are available upon request.

The impulse response functions lead to similar conclusions as in Sections 4.2 and 5.2 whatever the model calibration was chosen.

Table 8 reveals that under different model calibrations, myopia does not necessarily increase welfare losses. Interestingly, our previous results hold. Increasing the Frisch elasticity or decreasing the constant return to scale lead to lower welfare losses whatever the myopia cases. Under discretion and optimal simple rules, the welfare improving abilities of the general myopia are clear and robust. This result is not clear under commitment for such myopia levels (85%) but extreme myopia values demonstrate the robustness of this result (Appendix B.2).

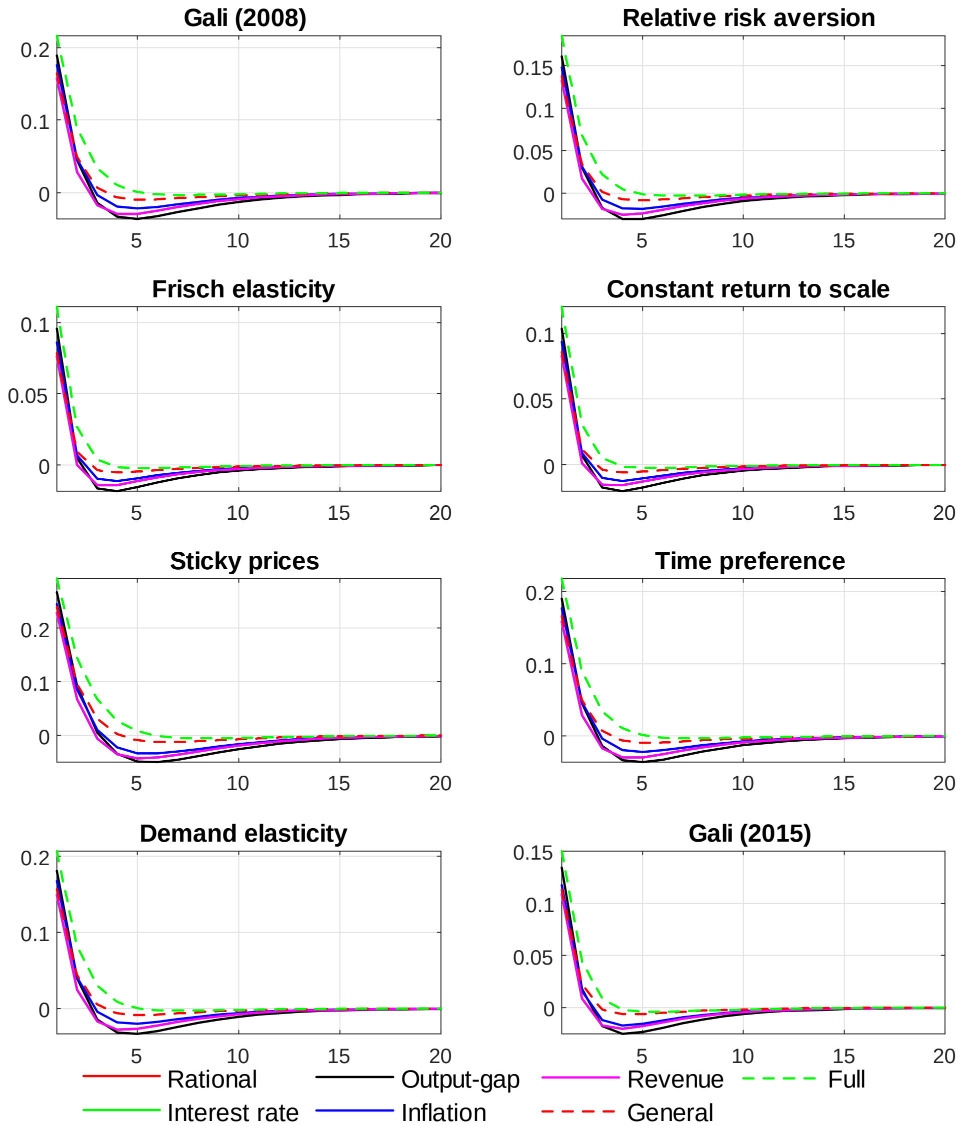


Figure 4: Impulse response functions of inflation following a 1% cost push shock under commitment for each model and myopia calibration.

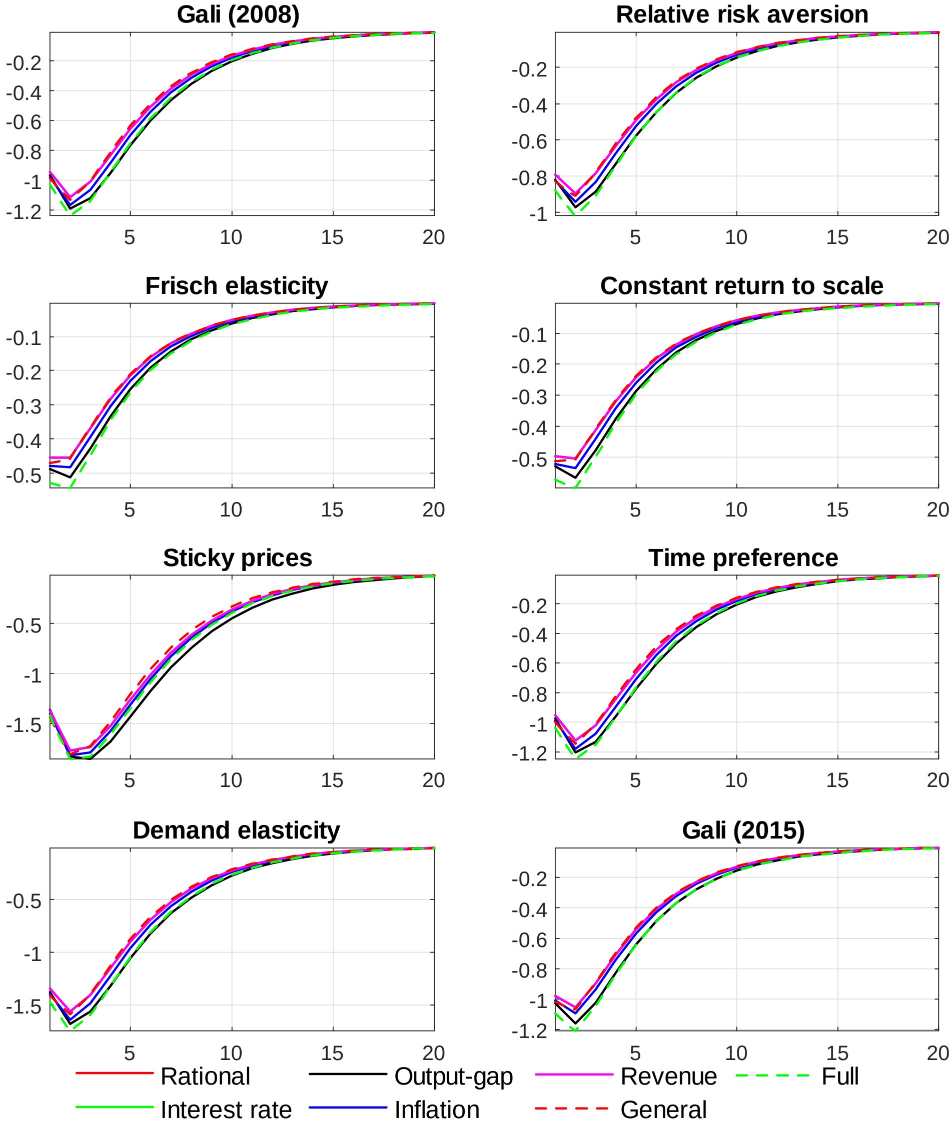


Figure 5: Impulse response functions of output following a 1% cost push shock under commitment for each model and myopia calibration.

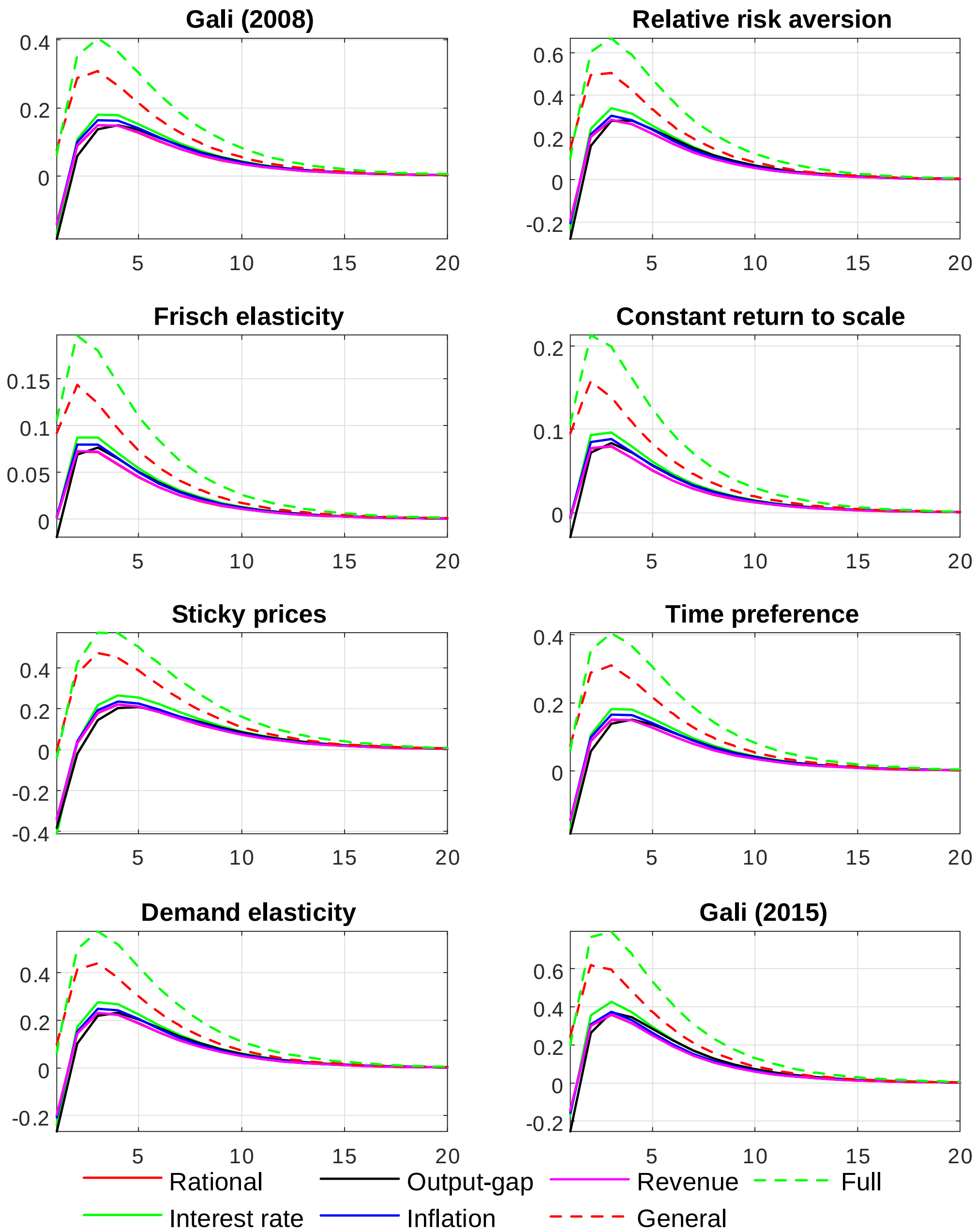


Figure 6: Impulse response functions of interest rate following a 1% cost push shock under commitment for each model and myopia calibration.

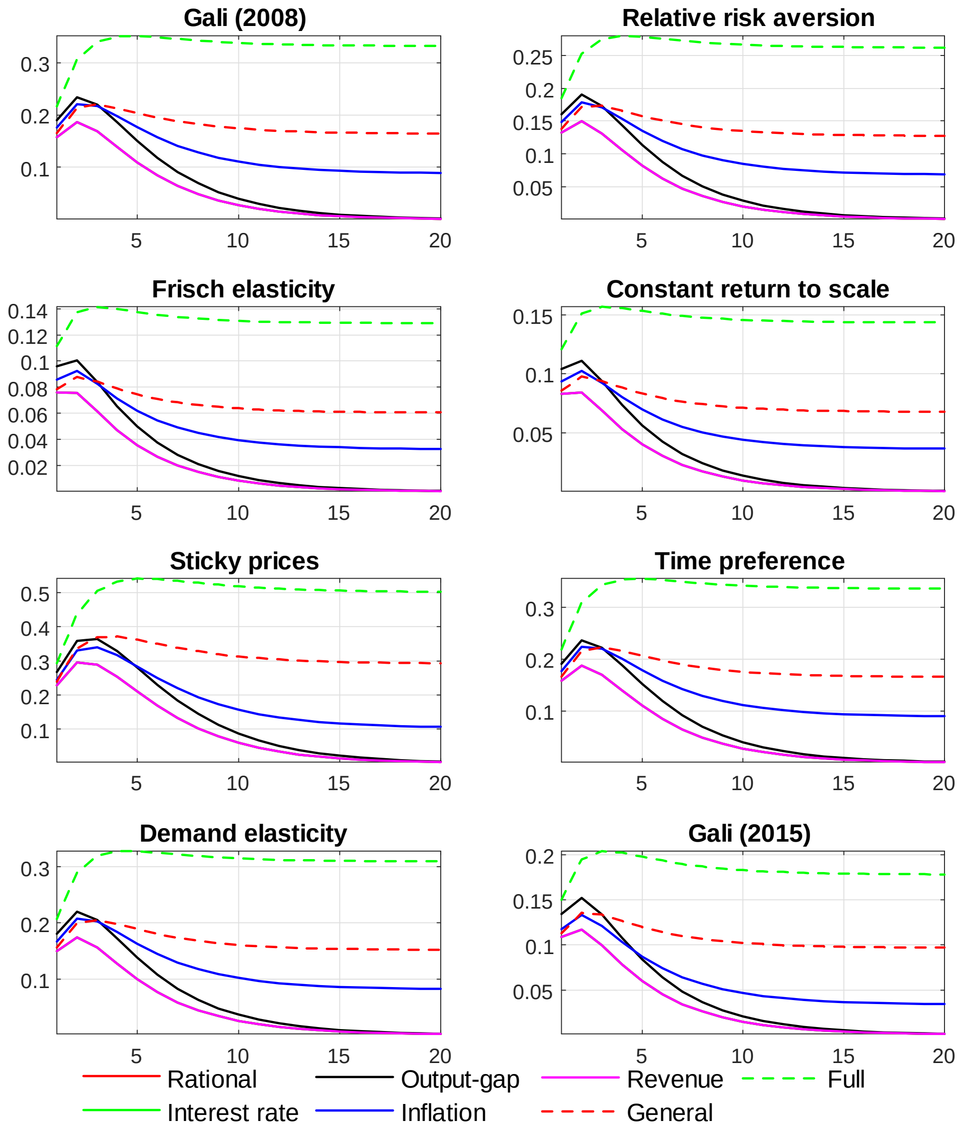


Figure 7: Impulse response functions of price level following a 1% cost push shock under commitment for each model and myopia calibration.

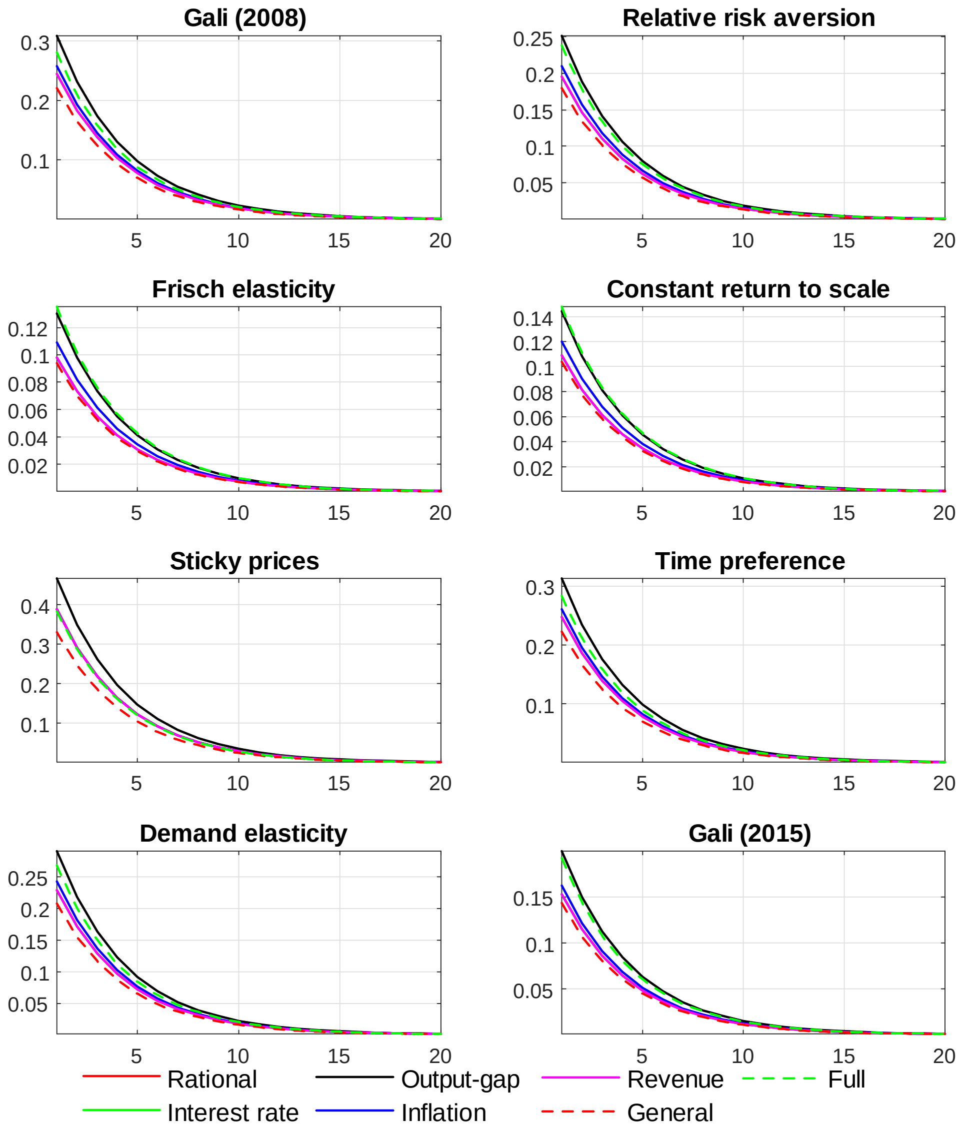


Figure 8: Impulse response functions of inflation following a 1% cost push shock under discretion for each model and myopia calibration.

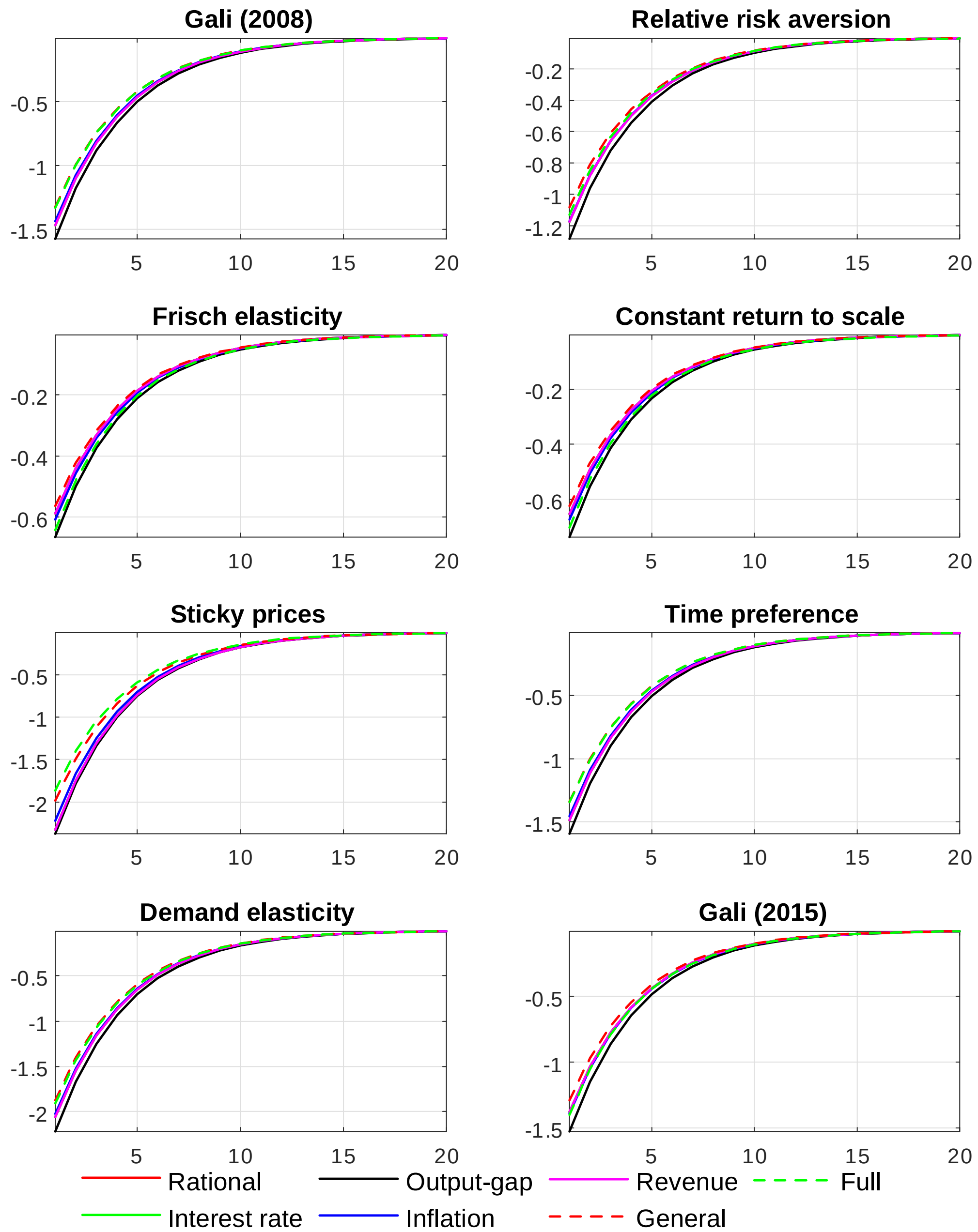


Figure 9: Impulse response functions of output following a 1% cost push shock under discretion for each model and myopia calibration.

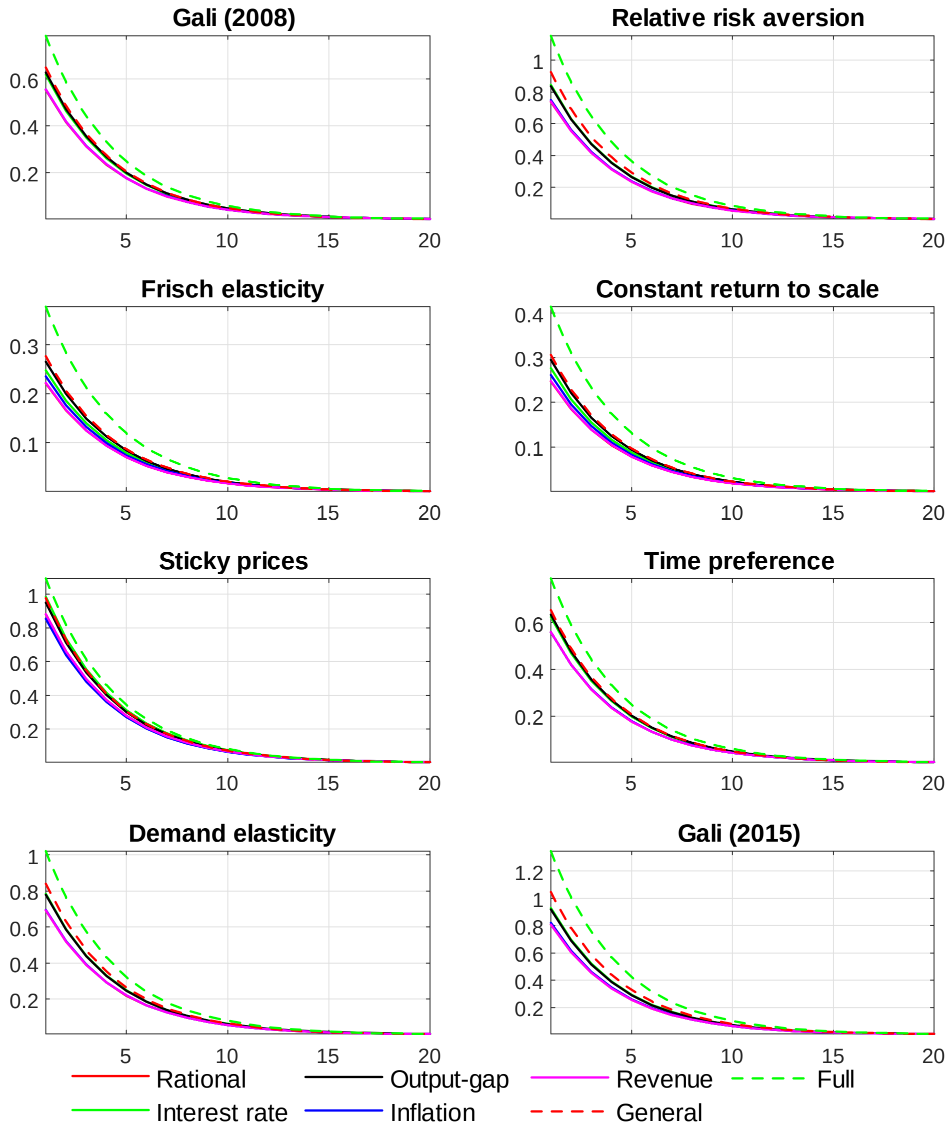


Figure 10: Impulse response functions of interest rate following a 1% cost push shock under discretion for each model and myopia calibration.

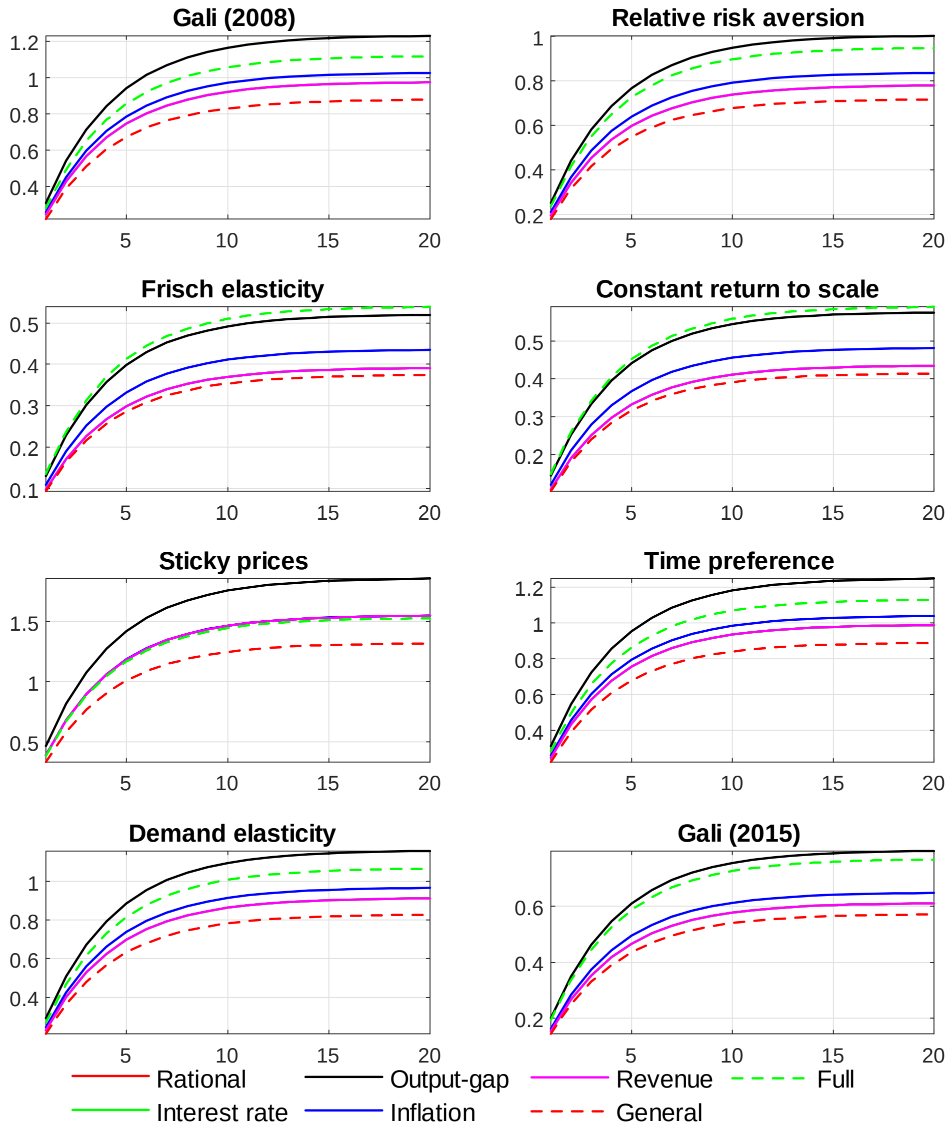


Figure 11: Impulse response functions of price level following a 1% cost push shock under discretion for each model and myopia calibration.

**Commitment**

| Myopia | Gali (2008) | Relative risk aversion | Frisch elasticity | Constant return to scale | Sticky prices | Time preference | Demand elasticity | Gali (2015) |
|---|---|---|---|---|---|---|---|---|
| Rational | 0.2809 | 0.2235 | 0.1126 | 0.1248 | 0.4667 | 0.2832 | 0.2624 | 0.1741 |
| Interest rate | 0.2809 | 0.2235 | 0.1126 | 0.1248 | 0.4667 | 0.2832 | 0.2624 | 0.1741 |
| Output-gap | 0.3599 | 0.2892 | 0.1492 | 0.1649 | 0.5830 | 0.3627 | 0.3372 | 0.2274 |
| Inflation | 0.3171 | 0.2533 | 0.1286 | 0.1424 | 0.5039 | 0.3199 | 0.2966 | 0.1901 |
| Revenue | 0.2809 | 0.2235 | 0.1126 | 0.1248 | 0.4667 | 0.2832 | 0.2624 | 0.1741 |
| General | 0.2834 | 0.2257 | 0.1136 | 0.1260 | 0.4672 | 0.2861 | 0.2648 | 0.1760 |
| Full | 0.3962 | 0.3223 | 0.1699 | 0.1873 | 0.6043 | 0.4001 | 0.3727 | 0.2478 |

**Discretion**

| Myopia | Gali (2008) | Relative risk aversion | Frisch elasticity | Constant return to scale | Sticky prices | Time preference | Demand elasticity | Gali (2015) |
|---|---|---|---|---|---|---|---|---|
| Rational | 0.5102 | 0.3740 | 0.1528 | 0.1740 | 1.0109 | 0.5212 | 0.4649 | 0.2697 |
| Interest rate | 0.5102 | 0.3740 | 0.1528 | 0.1740 | 1.0109 | 0.5212 | 0.4649 | 0.2697 |
| Output-gap | 0.7148 | 0.5308 | 0.2189 | 0.2494 | 1.3426 | 0.7315 | 0.6543 | 0.3862 |
| Inflation | 0.5324 | 0.4005 | 0.1713 | 0.1942 | 0.9864 | 0.5432 | 0.4892 | 0.2868 |
| Revenue | 0.5102 | 0.3740 | 0.1528 | 0.1740 | 1.0109 | 0.5212 | 0.4649 | 0.2697 |
| General | 0.4149 | 0.3165 | 0.1403 | 0.1583 | 0.7347 | 0.4222 | 0.3828 | 0.2362 |
| Full | 0.5625 | 0.4484 | 0.2155 | 0.2412 | 0.8907 | 0.5721 | 0.5264 | 0.3407 |

Table 8: Welfare loss values under commitment (top) and discretion (bottom) for each model and myopia calibration.

## B.2 Myopia calibrations

The different myopia cases considered in this section are presented in Table 9.

| | Models | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | No myopia | Myopia | | | | | | |
| | Rational | Interest rate | Output gap | Inflation | Revenue | General | Full | Extreme |
| $m_r$ | 1 | 0.2 | 1 | 1 | 1 | 1 | 0.2 | 0.01 |
| $m_x^f$ | 1 | 1 | 0.2 | 1 | 1 | 1 | 0.2 | 0.01 |
| $m_\pi^f$ | 1 | 1 | 1 | 0.2 | 1 | 1 | 0.2 | 0.01 |
| $m_y$ | 1 | 1 | 1 | 1 | 0.2 | 1 | 0.2 | 0.01 |
| $\overline{m}$ | 1 | 1 | 1 | 1 | 1 | 0.2 | 0.2 | 0.01 |

Table 9: Calibration of the myopia parameters used for the simulation of each model.

Table 9 presents more pronounced myopic agents with around 80% of myopia and an extreme case with an almost fully myopic agent (99%). Impulse response functions resulting from the calibration presented in Table 9 are presented in the case of commitment (Fig. 12) and discretion (Fig. 13). The optimal simple rule cases are available upon request.

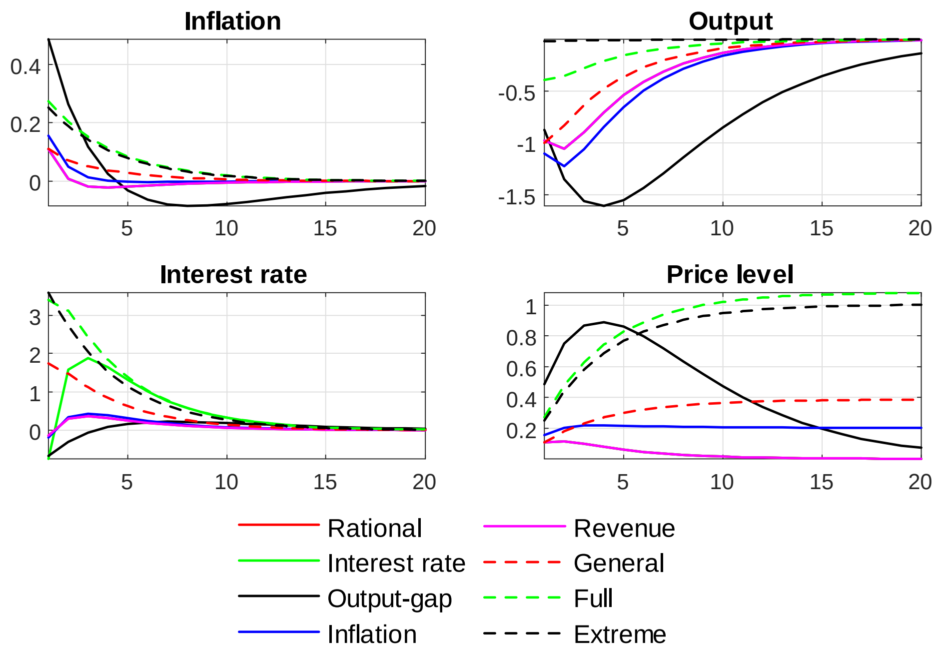


Figure 12: Impulse response functions of inflation, price level, output and interest rate following a 1% cost push shock under commitment for each model calibration (Table 9).

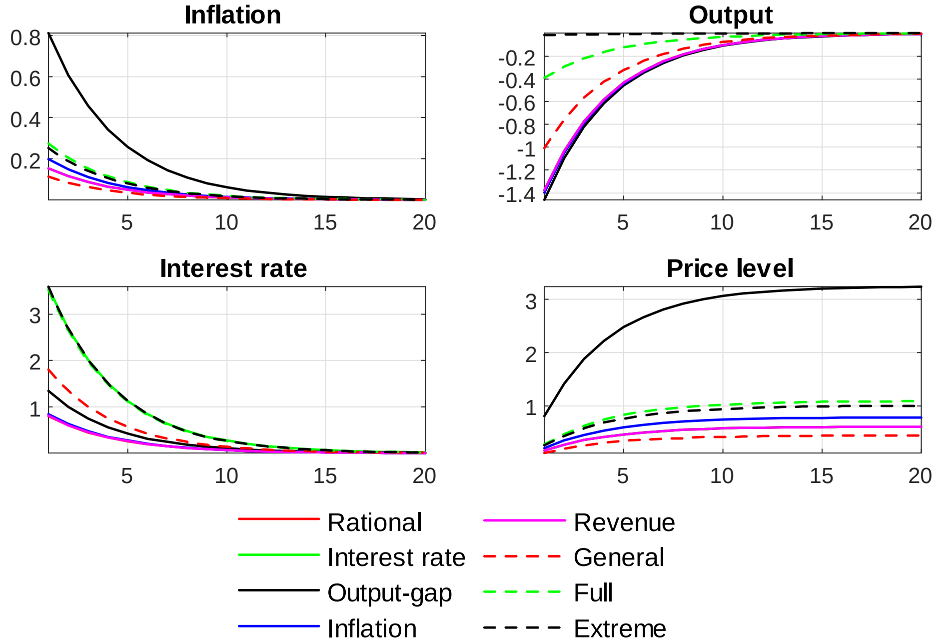


Figure 13: Impulse response functions of inflation, price level, output and interest rate following a 1% cost push shock under commitment for each model calibration (Table 9).

Table 10 presents the welfare losses under the standard calibration Galí (2015) for commitment and discretion. Here again the results for the optimal simple rule cases are available upon request. The results under the different calibrations presented in Table 9 are also available upon request.

| | Myopia | | | | | | |
|---|---|---|---|---|---|---|---|
| | Interest rate | Output gap | Inflation | Revenue | General | Full | Extreme |
| Commitment | 0.174 | 1.446 | 0.257 | 0.174 | 0.143 | 0.372 | 0.302 |
| Discretion | 0.270 | 3.357 | 0.348 | 0.270 | 0.145 | 0.372 | 0.302 |

Table 10: Welfare loss values by type of bounded rationality under commitment and discretion for each myopia calibration under extreme calibration.

Table 10 shows that the welfare losses under discretion are always higher than under commitment, except under full and extreme myopia. Interestingly, the general myopia case leads to the best welfare losses under commitment and discretion, confirming our result that myopia can also improve welfare losses.

From these robustness analyses, one can conclude that it exists a general myopia level that improves the welfare losses whatever the chosen commitment, discretion or optimal simple rule regime.