THE IMPACT OF MONETARY POLICY SHOCK ON PUBLIC DEBT: A DSGE APPROACH

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1. Introduction

In the actual context, increase in public debt and in inflation represents the main concern among economists and policymakers. Expansionary fiscal policies implemented by governments to face the more recent crisis caused by the Covid-19 Pandemic have entailed public debt raises at global level (de Soyres *et al*, 2021). At the same time, the war in Ukraine has contributed to an increase in inflation reaching a high value of 8.6% in May 2022 in the United States (Rockeman, 2022).

In that context, two questions have sparked a lively debate among economists: first, is inflation increases a transitory or permanent phenomenon? Second, could high inflation act as a deflator of public debt?

As for the first question, most economists seem concerned inflation keeps at high levels for a long time (Beckmann *et al*., 2021; Blanchard, 2021; Summers, 2021; Tepper, 2022). As for the second debate, it is very difficult to predict if high inflation may reduce public debt-to-GDP ratio in the medium and long term. This depends on whether higher inflation can or not be anticipated by financial markets and on its expected persistence. However, at first glance, inflation erodes the real value of debt.

This is what we demonstrate here. Specifically, this paper addresses two questions: what are the effects of inflation increases in a model with fiscal sector and price distortion? What are different impacts on agents? To answer these questions, we simulate a positive monetary policy shock in a New Keynesian Dynamic Stochastic General Equilibrium (NK-DSGE) model à la Leeper *et al*., (2017) with monopolistic competition in goods, sticky-price, and distortionary taxation. Savers and hand-to-mouth households populate the economy: the former have access to financial and capital markets while hand-to-mouth households consume all their disposable income.

Results show that an increase in inflation positively affects savers' disposable income in the short term. As consequence, they increase their consumption and bond investments by entailing public debt raises. On the opposite, hand-to-mouth households face losses in terms of income. Overall, aggregate demand growth up following an increase in investments, savers' consumption, and public spending.

However, the positive effect on output caused by higher inflation prevails with respect to the negative effect on government's budget constraint in terms of public debt raises. As result, the debt-to-GDP ratio reduces. This implies that an increase in inflation improves public debt sustainability in short-term.

This paper contributes to the theoretical literature on monetary and fiscal policy interaction (Krause and Moyen (2016), Cardani *et al* (2020), Bhattarai *et al* (2014), Leeper *et al* (2017), Kliem *et al* (2016), Bianchi and Melosi (2019), Bianchi *et al* (2020)). Moreover, it contributes to empirical literature analyzing the link between inflation and public debt (Taghavi (2000), Reinhart and Rogoff (2010), Lopes da Veiga *et al* (2016), Akitoby *et al* (2017), Hilscher *et al* (2022)).

The paper is structured as follows. Section 2 summarizes the model. Section 3 reports the calibration of parameters. Impulse response functions are shown in Section 4. Section 5 concludes.

2. Model

This section shows the main model's equation. A fraction μ of households are hand-to-mouth (H) while the remaining fraction 1-μ are savers (S) à la Leeper *et al*., 2017. The economy includes firms, the government and the central bank as well. Monetary authority follows a Taylor rule in setting the nominal interest rate.

2.1. Savers

Savers consume private and public goods and supply labor services. Their utility function is the following:

$$maxE^0 \sum_{\{t=0\}}^{\{\infty\}} \quad \beta_{\{S\}}^{\{t\}} \left[logC_{\{S,t\}} - \left(\frac{\left(N_{\{S,t\}}\right)^{\{1+\eta\}}}{1+\eta} \right) \right], \tag{1}$$

where $\beta_{\{S\}}^{\{t\}}$ is the discount factor; $C_{\{S,t\}}$ denotes a composite consumption for savers given by the sum of private and public consumption; finally, $N_{\{S,t\}}$ represents the working hours and η denotes labor elasticity. Their budget constraint is:

$$P_{\{t\}}C_{\{S,t\}}(1+\tau^C) + P_{\{t\}}^{\{B\}}B_{\{t\}} + \left(\frac{B_{\{S,t\}}}{R_{\{S,t\}}}\right) =$$
$$\left(1+\rho P_{\{t\}}^{\{B\}}\right)B_{\{t-1\}} + B_{\{S,t-1\}} + (1-\tau^N)w_{\{S,t\}}N_{\{S,t\}} + (1-\tau^K)r_{\{t\}}^K K_{\{S,t\}} \tag{2}$$

where $P_{\{t\}}$ denotes prices; $B_{\{S,t\}}$ are one-period bonds that can be purchased at the present discounted value $R_{\{S,t\}}^{-1}B_{\{S,t\}}$; $B_{\{t\}}$ are long-term government bond that can

be purchased at price $P_{\{t\}}^{\{B\}}$; ρ ∈[0,1] represents a maturity and $(1\text{-}\beta\rho)^{-1}$ denotes duration. τ^C is tax rate on nominal consumption; τ^K and τ^N are capital and labor incomes taxes, respectively. Wages are represented by $w_{\{S,t\}}$ and rental rate of regular capital is represented by $r_{\{t\}}^K$.

The capital stock $K_{\{S,t\}}$ own by savers, evolves according to the following law of motion:

$$K_{\{S,t+1\}} = I_{\{S,t\}} + (1-\delta)K_{\{S,t\}} \tag{3}$$

where $I_{\{S,t\}}$ denotes investments and δ is the capital depreciation rate.

2.2. Hand-to-mouth

Hand-to-mouth households maximize the same utility function as savers.

They consume their after-tax income, period by period and are subject to the following budget constraint:

$$P_{\{t\}}C_{\{H,t\}}(1+\tau^C) = (1-\tau^N)w_{\{H,t\}}N_{\{H,t\}} \tag{4}$$

where $C_{\{H,t\}}$ indicates consumption of hand-to-mouth households; $w_{\{H,t\}}$ and $N_{\{H,t\}}$ represent wages and working hours of hand-to-mouth' households, respectively.

2.3. Firms

The final goods firms operate under perfect competition and flexible prices. They aggregate intermediate goods $Y(z)_{\{t\}}$ according to the following production function:

$$Y_{\{t\}} = \left[\int_0^1 \quad Y(z)_{\{t\}}^{\left\{\frac{\varepsilon-1}{\varepsilon}\right\}} dz\right]^{\left\{\frac{\varepsilon}{\varepsilon-1}\right\}}, \tag{5}$$

where ε>1 represents the elasticity of substitution between intermediate goods. The final good firm chooses $Y(z)_{\{t\}}$ to minimize its costs, resulting in demand of intermediate good z:

$$Y(z)_{\{t\}} = \left(\frac{P(z)_{\{t\}}}{P_{\{t\}}}\right)^{\{-\varepsilon\}} Y_{\{t\}} \tag{6}$$

where $P(z)_{\{t\}}$ is the price of intermediate goods. The price index is:

$$P_{\{t\}} = \left[\int_0^1 \quad P(z)_{\{t\}}^{\{1-\varepsilon\}} dz\right]^{\left\{\frac{1}{\varepsilon-1}\right\}}. \tag{7}$$

2.4. Intermediate goods producers

We assume that intermediate firms compete monopolistically producing goods according to the following technology:

$$Y(z)_{\{t\}} = \left(K_{\{t\}}\right)^{\{\xi\}} \left(N_{\{S,t\}}^{\{\alpha\}} N_{\{H,t\}}^{\{(1-\alpha)\}}\right)^{\{1-\xi\}} \tag{8}$$

where ξ,α ∈[0,1] denote elasticities in production function.

Intermediate firms choose capital and labor services to maximize their expected profits. They convert household labor and capital into the final good and prices are sticky à la Calvo (1983) with indexation. 1-θ ∈ [0,1] is a constant probability of firms' being able to choose the sale price. The optimal price $P(z)_{\{t\}}^{\{*\}}$ is chosen to maximize the discounted value of expected future profits. The firms' maximization problem is the following:

$$\sum_{\{s=0\}}^{\{\infty\}} \left(\theta\beta_{\{S\}}\right)^{\{s\}} \left(\frac{P_{\{t\}}}{\lambda_{\{t\}}}\right) \left(\frac{\lambda_{\{t+s\}}}{P_{\{t+s\}}}\right) \left[P(z)_{\{t\}}^{\{*\}} \prod_{k=1}^{s} \pi_{\{t+k-1\}}^{\chi} - P_{\{t+s\}} mc_{\{t+s\}}\right] Y(z)_{\{t+s\}}^{\{*\}} \tag{9}$$

where $\pi_{\{t\}}^{\chi}$ represents inflation with price indexation χ; $mc_{\{t\}}$ is the marginal cost, or the inverse of the markup $X_{\{t\}}$. $\left(\frac{\lambda_{\{t+s\}}}{\lambda_{\{t\}}}\right)$ denotes the stochastic discount factor of savers, who own the firms. Eq. (9) is subject to:

$$Y(z)_{\{t+s\}}^{\{*\}} = \left(\left(\frac{P(z)_{\{t\}}^{\{*\}} \prod_{\{k=1\}}^{\{s\}} \pi_{\{t+k-1\}}^{\{\chi\}}}{P_{\{t+s\}}}\right)\right)^{\{-\varepsilon\}} Y_{\{t+s\}}^{\{d\}} \tag{10}$$

where $Y_{\{t\}}^{\{d\}}$ indicates the aggregate demand.

2.5. Aggregation

The market clearing condition for the goods is:

$$Y_{\{t\}} = Y_{\{t\}}^{\{d\}} * s_{\{t\}} \tag{11}$$

where $s_{\{t\}}$ represents the price dispersion in the Calvo model as follows:

$$s_{\{t\}} = (1-\theta)\left(P(z)_{\{t\}}^{\{*\}}\right)^{(-\varepsilon)} + \theta\left(\frac{\pi_{\{t\}}}{\pi_{\{t-1\}}^{\{\chi\}}}\right)^{\{\varepsilon\}} s_{\{t-1\}}; \tag{12}$$

$P_{\{t\}}^{\{*\}}$ indicates the aggregate price level that satisfies the following equation:

$$1 = \theta \pi_{\{t\}}^{\{(\varepsilon-1)\}} \left(\pi_{\{t-1\}}^{\{\chi\}}\right)^{\{(1-\varepsilon)\}} + (1-\theta)\left(P(z)_{\{t\}}^{\{*\}}\right)^{(1-\varepsilon)}. \quad (13)$$

$Y_{\{t\}}^{\{d\}}$ denotes the aggregate demand:

$$Y_{\{t\}}^{\{d\}} = C_{\{t\}} + I_{\{t\}} + G_{\{t\}}, \quad (14)$$

where $C_{\{t\}}$ is the aggregate consumption and it is given by:

$$C_{\{t\}} = \mu C_{\{H,t\}} + (1-\mu) C_{\{S,t\}}. \quad (15)$$

$K_{\{t\}}$ and $I_{\{t\}}$ indicate aggregate capital and investment:

$$K_{\{t\}} = (1-\mu) K_{\{S,t\}}, \quad (16)$$

$$I_{\{t\}} = (1-\mu) I_{\{S,t\}}. \quad (17)$$

2.6. Fiscal sector and Monetary Policy

Government issues new long-term bonds and collects taxes to finances public expenditures $G_{\{t\}}$ and expiring long-term debt. While assuming that short-term bonds are in zero net supply, government' nominal budget constraint can be described as follows:

$$\left(1 + \rho P_{\{t\}}^{\{B\}}\right) B_{\{t-1\}} + P_{\{t\}} G_{\{t\}} = P_{\{t\}}^{\{B\}} B_{\{t\}} + \tau^{\{N\}} w_{\{S,t\}} N_{\{S,t\}} + \tau^{\{N\}} w_{\{H,t\}} N_{\{H,t\}} + \tau^{\{K\}} r_{\{t\}}^{K} K_{\{S,t\}} + \tau^{\{C\}} P_{\{t\}} C_{\{t\}}. \quad (18)$$

$B_{\{t\}} = b_{\{t\}} Y_{\{t\}}$ where $b_{\{t\}}$ indicates public debt-to-GDP ratio; (19)

$G_{\{t\}} = g_{\{t\}} Y_{\{t\}}$ where $g_{\{t\}}$ denotes real public expenditure. (20)

We assume that the Central Bank sets the nominal interest rate following the standard Taylor rule:

$$\left(\frac{R_{\{t\}}}{R^{\{*\}}}\right) = \left(\frac{\pi_{\{t\}}}{\pi^{\{*\}}}\right)^{\left\{\varphi_{\{\pi\}}^{\{R\}}\right\}} \left(\frac{Y_{\{t\}}}{Y^{\{*\}}}\right)^{\left\{\varphi_{\{y\}}^{\{R\}}\right\}} \varepsilon^{R}, \quad (21)$$

where $R^{\{*\}}$ denotes the target nominal interest rate; $\pi^{\{*\}}$ and $y^{\{*\}}$ denote the steady state inflation rate and output, respectively. Finally, ε^{R} is monetary policy shock. $\varphi_{\{\pi\}}^{\{R\}}$ and $\varphi_{\{y\}}^{\{R\}}$ denote the response of nominal interest rate to inflation and output gap, respectively. Then, we define a Taylor-type rule that relates public debt-to-GDP ratio $b_{\{t\}}$ and the inflation target, as follows:

$$\left(\frac{b_{\{t\}}}{b^{\{*\}}}\right) = \left(\left(\frac{\pi_{\{t\}}}{\pi^{\{*\}}}\right)\right)^{\{-\varphi_{\{b\}}\}} \tag{22}$$

where $\varphi_{\{b\}}$ is a policy' parameter measuring the public debt-to-GDP ratio response to inflation gap.

Table 1 – *Parameters Values.*

Parameter	***Value***	***Description***
Households		
$\beta_{\{S\}} = \beta_{\{H\}}$	0.99	Discount factor
H	1.77	Parameter associated with labor elasticity
Δ	0.025	Capital depreciation rate
P	0.959	Maturity of long-term bonds
$\alpha_{\{G\}}$	-0.240	Sustainability of public consumption
M	0.11	Share of hand-to-mouth households
Firms		
Ξ	0.33	Elasticity in production function
A	0.25	Elasticity in production function
E	6	Price elasticity of demand
Θ	0.920	Calvo price
X	0.66	Price indexation
Monetary Policy		
$\varphi_{\{\pi\}}^{\{R\}}$	1.5	Inflation stabilization
$\varphi_{\{y\}}^{\{R\}}$	0.5	Output stabilization
$\varepsilon_{\{R\}}$	0.66	Shock' persistence
Fiscal sector		
$\tau^{\{C\}}$	0.023	Tax rate on consumption
$\tau^{\{N\}}$	0.186	Tax rate on labor
$\tau^{\{K\}}$	0.218	Tax rate on capital
G	0.11	Public spending to GDP ratio
$\varphi_{\{b\}}$	1.5	Policy parameter for inflation response

3. Calibration

This Section summarizes parameter values. Table 1 shows their description and details. For structural parameters' calibration, we follow Leeper *et al.* (2017) consistent with the US data. Hand-to-mouth households' share is set at 0.11 as in Kaplan *et al* (2014) while the decay rate of the maturity of long-term government bonds is calibrated at 0.9593, following Bianchi *et al* (2020).

As for the firms, parameters representing elasticity of production function with respect to capital and working hours are set to 0.33 and 0.25, respectively. The price elasticity of demand ε, is calibrated at 6 as in Cantore and Freund (2021) while the price indexation χ to 0.66, as in Smets and Wouters (2007).

As for monetary policy, we set parameters denoting the response of nominal interest rate to inflation $\varphi_{\{\pi\}}^{\{R\}}$ and output $\varphi_{\{y\}}^{\{R\}}$ to 1.5 and 0.5 respectively, in line with the classical Taylor rule specification. Moreover, we set the parameter representing the persistence of monetary policy shock to 0.66. Eventually, with respect to fiscal sector, we calibrate parameter governing the response of public debt-to-GDP ratio to inflation rate $\varphi_{\{b\}}$, at 1.3.

4. Results

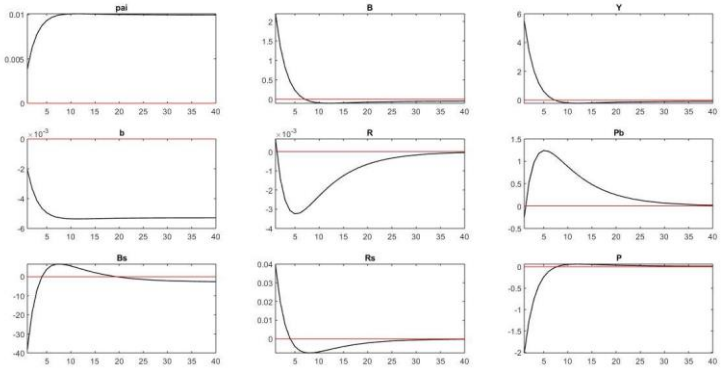
Figures 1 and 2 show impulse response functions of main macroeconomic variables, following a positive monetary policy shock.

The increase in the nominal interest rate causes inflation growth up.

As a result, bond prices ($P_{\{t\}}^{\{B\}}$) decrease since they move inversely with the nominal interest rate. At the same time short-term bonds' nominal interest rate increases as well. However, since savers are forward-looking agents, they expect that in the future short-term bond prices will increase less than those of long-term bonds.

This is the reason why savers prefer to invest all their savings in long-term bonds. As result, short-term bonds reduce while long-term bonds raise, namely public debt increases. Overall, an increase in inflation positively affects the output in the short-run. However, as it grows up more than public debt, the debt-to-GDP ratio falls down.

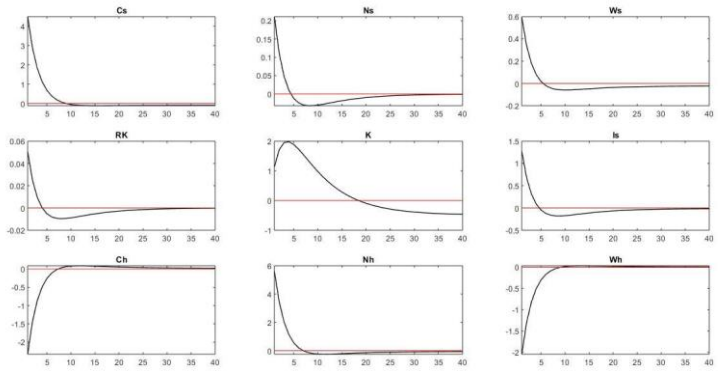
Figure 1 – *Impulse response functions: Monetary policy shock.*



Let's now assess the effects of a positive monetary policy shock on households. Savers benefit from the increase in inflation in the short run. Indeed their wages increase entailing a gain in terms of income. As consequence, savers work and

consume more. After, when effects of higher inflation materialize (namely in medium term), the opposite occurs. The reason lies in the fact that savers as firms' owners, concerned about the sticky-price distortion, prefer situations with low inflation rates.

Figure 2 – *Impulse response functions: Monetary policy shock*



Hand-to-mouth households - who do not have access to financial and capital markets - suffer a loss of income. Indeed, wage reduction induces them to consume less and work more. As for the production sector, the increase in the regular rental rate of capital causes firms to invest more and demand more capital.

However, positive effects on savers' and the government's consumption and in investment more than compensate for negative effects on hand-to-mouth households' consumption. As result, a positive monetary shock initially entails a positive variation in aggregate demand.

Eventually, once inflation stabilizes at higher values, some main macroeconomic variables move inversely undershooting their steady state.

5. Conclusion

This paper investigates the effects of a positive monetary policy shock in a model with fiscal sector and price distortion. The aim is to study what transmission mechanisms that entail in public debt-to-GDP reduction. Moreover, we ask what the redistributive effects on the agents are.

Consistently to the literature, results show that a positive monetary policy shock entails inflation increases. This, in turn, causes different effects on savers and hand-to-mouth households. As for the former, they initially benefit from inflation raises in terms of income. As result, they consume more and invest more in long-term

bonds. On the opposite, hand-to-mouth households - who do not have access to the financial and capital market - work more and consume less. Overall, a positive monetary policy shock causes output grows up in short term.

While analyzing effects of high inflation, we find that the increase in output is larger than in public debt. As a result, debt-to-GDP ratio falls down.

This paper contributes to the literature focusing on monetary policy. Different from the existing studies, we focus on the effects of inflation increases on public debt. However, this work neglects some important features including the wage-setting mechanism. Moreover, it would be interesting to investigate the effects of permanent inflation target increases and carry out a welfare analysis. Eventually, it would be useful to consider in the analysis of fiscal policy shock as well. We leave these extensions for future research.

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SUMMARY

Nowadays, the increase in public debt and inflation are key concerns of the political debate among policymakers. In this regard, some economists have argued that the reason why inflation is higher lies in a transitory rise of commodity prices; others, instead, have asserted that permanent changes in the labor market caused by the Covid-19 pandemic, may also contribute to keeping inflation high for a long time.

This paper aims to investigate the effects of a positive monetary policy shock on the public debt-to-GDP ratio. Moreover, it assesses its different impacts on households. For these purposes, the paper employs an extended version of the New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model à la Leeper *et al.*, (2017) considering an economy populated by savers and hand-to-mouth households, with distortionary taxation.

Our analysis confirms that an increase in inflation contributes to public debt-to-GDP ratio reduction, thanks to the positive impact on output in the short term. Moreover, results highlight a trade-off between agents: savers as forward-looking agents invest their savings in the short term by increasing their income; on the opposite, hand-to-mouth households suffer a loss of income.

This paper contributes to the literature on monetary and fiscal policy, which focuses on the relationship between public debt and inflation.

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