



Monetary policy shocks and inflation: The impact of backed vs. unbacked public debt in a policy mix regime

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Abstract

The present study evaluates the role played by backed and unbacked public debt in the propagation of a contractionary monetary policy shock to inflation dynamics under three different policy mix regimes. It shows that a coexistence regime with partially unbacked public debt is able to achieve comparatively lower inflation than Regime F, in which public debt is not backed at all and, at the same time, achieves a relatively well-stabilized public debt level in comparison to Regime M, in which public debt is backed fully. The proposed coexistence regime also performs better, in terms of welfare, than both Regime M and Regime F. Under the coexistence regime, when inflation is mainly fiscal in nature, authorities face higher levels of volatility for both public debt and inflation and a significant trade-off between the respective volatility of public debt and inflation. When prices become more sticky, debt service costs become much higher than those observed in a relatively flexible price scenario, resulting in a more significant increase in public debt following the shock. In order to effectively stabilize both public debt and inflation, policymakers need both to ascertain the extent to which a monetary policy shock influences the unbacked component of public debt and to carefully establish the right mix of monetary and fiscal policy for debt stabilization.

JEL Classification: E31, E52, E62, E63, H63

Keywords: Monetary and fiscal policy coordination; Fiscal limits; Unbacked public debt; Fiscal inflation.

1 Introduction

Existing studies on the fiscal theory of the price level (FTPL) predominantly focus on two standard regimes (Regime M or Regime F) with an implicit or explicit assumption that the fiscal authority either fully stabilizes public debt with fiscal surpluses or does not stabilize it at all (see, e.g., [Davig and Leeper, 2011](#); [Bianchi, 2012](#); [Bianchi and Ilut, 2017](#); [Leeper et al., 2017](#); [Chen et al., 2022](#)). This is an extreme assumption. Although the fiscal authority typically commits to debt stabilization, challenges may arise in stabilizing the entire amount of debt using future fiscal surpluses, especially in the face of economic downturns. For instance, literature on FTPL recognizes that a substantial increase in government deficits during economic recessions often results in an accumulation of public debt that may not be backed in full by future fiscal surpluses (see, e.g., [Jacobson et al., 2019](#); [Bianchi and Melosi, 2019](#); [Bianchi et al., 2020, 2023](#)). Hence, the coexistence regime proposed by [Bianchi et al. \(2023\)](#), which features partially-unbacked public debt, warrants further exploration, as it mirrors the current situation characterized by exceptionally elevated public debt levels amidst constrained fiscal capacity.

The present study explores the role played by backed and unbacked public debt in the effects of monetary policy shocks on the dynamics of inflation and other main macroeconomic aggregates under three policy mix regimes: Regime M; Regime F; and the coexistence regime. The present study focuses on the coexistence regime and compares it with the two standard regimes. Under Regime M (a mix of active monetary policy and passive fiscal policy), the monetary authority controls inflation and public debt is fully backed by future fiscal surpluses.¹ In contrast, under Regime F (a mix of active fiscal policy and passive monetary policy), the fiscal authority does not stabilize public debt with future fiscal surpluses, with the monetary authority primarily stabilizing the said debt through inflation ([Leeper, 1991](#); [Leeper and Leith, 2016](#); [Leeper et al., 2017](#); [Bianchi et al., 2020, 2023](#)). Under the coexistence regime, public debt comprises two components: backed and unbacked. The backed component of public debt is stabilized by future fiscal surpluses, while the unbacked component is stabilized by inflation. Thus, in this novel regime, the stabilization of public debt is achieved jointly through fiscal and monetary policy.

Current high public debt levels, persistent high inflation, and rising interest rates have prompted scholars and policymakers to rethink the nexus between public debt and inflation dynamics. In response to the global financial crisis (GFC) and the subsequent Great Recession, policymakers implemented substantial fiscal stimulus and unconventional monetary policy measures such as quantitative easing ([Coleman et al., 2021](#)). These interventions led to an unprecedented surge in public debt globally. For instance, the US public debt-to-GDP ratio rose from a pre-crisis level of around 60% in 2006 to above 100% prior to the Covid-19 pandemic (the pandemic).² While countries were still grappling with elevated public debt levels, the economic recession triggered by the pandemic prompted another wave of joint fiscal stimulus and the large-scale purchase of government securities by the Federal Reserve ([Dean, 2022](#)). This led to public debt rising to unprecedented levels. The US public debt-to-GDP ratio reached a record high of 134% in 2020 and

¹The present study defines fiscal surpluses as the difference between the tax revenue obtained from consumption and government expenditure. Thus, the backing of public debt with future primary surpluses entails that the fiscal authority commits to either raising the tax rate levied on consumption or cutting future government expenditure.

²Public debt comprises total federal government debt held by both domestic and foreign investors. The figure is based on data obtained from the Federal Reserve Bank of St. Louis (FRED at <https://fred.stlouisfed.org/>).

remained at a historically elevated level of around 120% in 2022.

While public debt has increased more rapidly since the GFC, inflation dynamics are mixed. As shown in Figure 1, the period of a strong expansion in public debt during the GFC coincided with record-low inflation. In contrast, the unprecedentedly high post-pandemic level of public debt was accompanied by a surge in inflation reminiscent of the 1970s Great Inflation. The data clearly illustrates an inconsistent co-movement between public debt and inflation following similar policy interventions in response to prior economic crises.

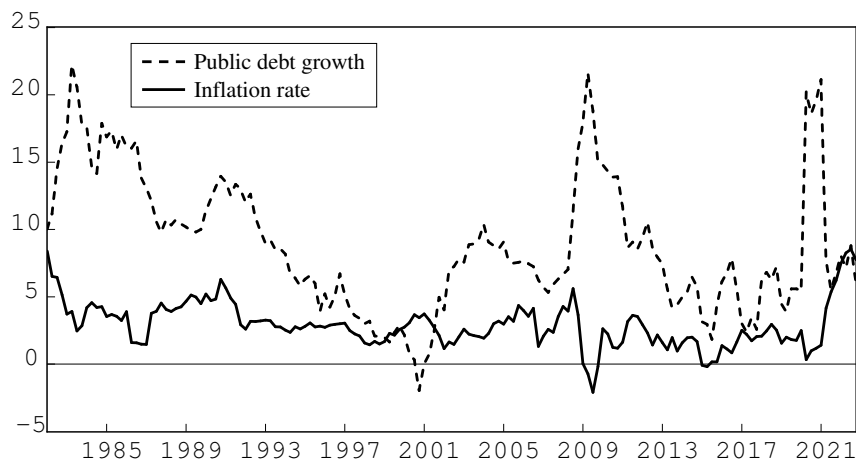


Figure 1: Public debt annual growth rate and inflation rate (%).

The current high interest rate environment further worsens the already high public debt level via the debt service cost channel, a key aspect the present study also seeks to explore. High interest rates raise debt service costs, thus contributing to the further accumulation of public debt and creating additional fiscal pressure (Velasco, 1993; Leeper and Leith, 2016). The rise in debt service costs increases the fiscal deficit, which may be financed through the issuance of additional public debt due to limited fiscal space. This additional debt may not be backed by future fiscal surpluses, thus leading to inflation. Figure 2 shows evidence obtained from the data for the co-movement between interest rates (federal funds rate or FFR) and debt service costs. During periods of zero lower bound, debt service costs were not worrisome because interest rates were extremely low, meaning that the risk of further accumulation of public debt was comparatively low. This is, however, no longer the case since the Fed started hiking interest rates at the beginning of 2022. Periods of rising interest rates are followed by rising interest payments on public debt, a co-movement that was more pronounced in the period following the Covid-19 pandemic.

The present study contributes to the literature by developing a novel model featuring different policy mix regimes and which uses the broader literature on the interaction between monetary and fiscal policy in several ways. Firstly, this is the first paper to analyze the effects of a contractionary monetary policy shock on the dynamics of inflation and other main macroeconomic variables when both backed and unbacked public debt coexist. The effects of monetary policy shock on the dynamics of inflation and other main macroeconomic aggregates in the presence of both backed and unbacked public debt remain distinct and are

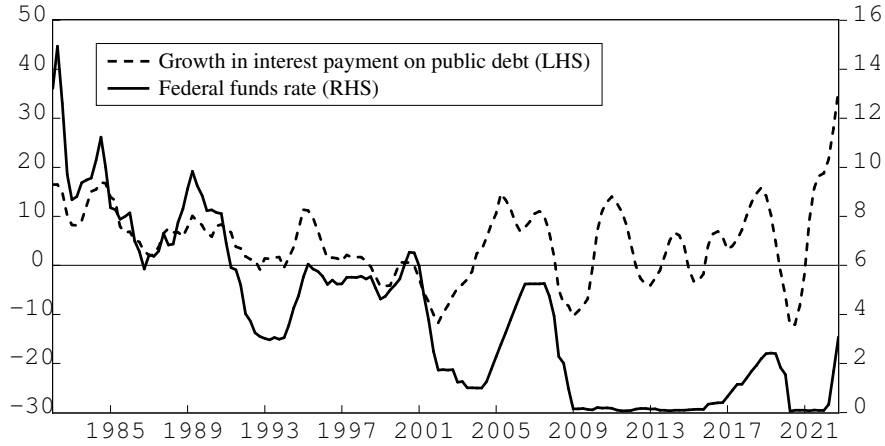


Figure 2: Federal funds rate and growth in interest payment on public debt (%).

yet to be thoroughly examined.³ Secondly, the study focuses on this novel coexistence regime to evaluate its effectiveness in promoting the stability of both public debt and inflation. Thirdly, the present study explores the debt service cost channel for monetary policy, addressing an important policy question on the effects of a contractionary monetary policy shock on inflation dynamics when debt service costs are high. Lastly, the paper contributes to the literature on welfare analysis by evaluating the welfare implications of different policy mix regimes following a contractionary monetary policy shock. To the best of our knowledge, no prior research has delved into these analyses within the context of the coexistence regime.

We adopt a novel class of New-Keynesian Dynamic Stochastic General Equilibrium (NK-DSGE) model with one-period government bonds and a fiscal block as in [Leeper and Leith \(2016\)](#). However, we follow [Bianchi et al. \(2023\)](#) on the specification of a fiscal policy rule with two components of public debt: backed and unbacked. Passive fiscal policy responds to backed public debt, while active fiscal policy responds to unbacked public debt. Accordingly, the monetary policy rule responds to two components of inflation, the first of which is corresponding to backed public debt, referred to here as non-fiscal inflation. The monetary authority actively controls non-fiscal inflation by adjusting interest rates more than one-to-one in response to changes in this component of inflation (active monetary policy). The second component corresponds to unbacked public debt, which is the amount of inflation that the monetary authority either controls weakly or does not control (passive monetary policy) when attempting to help stabilize public debt in coordination with the fiscal authority. [Bianchi et al. \(2023\)](#) refer to this as fiscal inflation.

The present study shows that, when a contractionary monetary policy shock influencing both backed and unbacked public debt occurs, the coexistence regime achieves comparatively lower inflation than Regime F and, at the same time, a relatively well-stabilized public debt level than Regime M. Under the coexistence regime, monetary and fiscal authorities coordinate with each other to stabilize public debt, unlike under the standard regimes where either the fiscal authority (Regime M) or the monetary authority (Regime F) is solely responsible for debt stabilization. Subsequently, under the coexistence regime the effects of the

³[Bianchi et al. \(2023\)](#) analyze the effects of government transfer shocks on inflation under this novel regime.

shock on the real economy are moderate and the recovery of consumption, employment, and real wages is well-balanced. Additionally, the results of the present study show that the coexistence regime is the best regime of the three examined here, achieving a level of welfare 1.3% higher than Regime M, whereas Regime F results in a welfare level that is 2.3% lower than that observed for Regime M.

The efficient policy frontier (EPF) analysis results show a significant trade-off between debt stability, measured by the volatility of public debt, and price stability, measured by the volatility of inflation. This trade-off is more or less the same under the coexistence regime with both an equal portion (50%) and a larger portion (75%) of monetary policy shock influencing unbacked public debt. This implies that public debt stability can be achieved at the cost of an increase in price stability and vice versa. This trade-off is, however, eliminated when only a small portion (25%) of monetary policy shock influences unbacked public debt. Furthermore, the results show that, when inflation is mainly fiscal in nature, namely when a larger portion of monetary policy shock influences unbacked public debt, the authorities will face higher levels of volatility for both public debt and inflation. In contrast, when inflation is non-fiscal the authorities will face significantly low levels of volatility for both public debt and inflation.

The sensitivity analysis results further validate the findings of the EPF analysis and underscore the importance of the coexistence regime in the current environment of high public debt as observed from the data, and limited fiscal capacity for stabilizing the entire public debt with future fiscal surpluses. In order to effectively stabilize both public debt and inflation, policymakers need to ascertain the extent to which a monetary policy shock influences the unbacked component of public debt and to carefully establish the right mix of monetary and fiscal policy for debt stabilization. For instance, the larger the portion of monetary policy shock that influences the unbacked component of public debt, the higher the debt service costs. This requires much higher inflation to stabilize both the unbacked public debt and the increased debt service costs. In addition, price stickiness plays a significant role in shaping the dynamics of inflation and the main macroeconomic variables, as well as having notable implications for the mechanism of debt stabilization under the coexistence regime. When prices become more sticky, debt service costs become much higher than in a relatively flexible price scenario which, in turn, results in a more significant increase in public debt following a contractionary monetary policy shock.

The subsequent sections of the paper are organized as follows. Section 2 provides a review of the literature related to the study; Section 3 details the model; Section 4 describes the calibration of the model parameters; Section 5 discusses the main results; Section 6 discusses the results of sensitivity analysis; and Section 7 concludes.

2 Related literature

The present section provides an overview of the literature relevant to the present study, which is closely related to the literature on a new class of NK-DSGE models featuring partially-unbacked public debt (see, e.g., [Jacobson et al., 2019](#); [Bianchi and Melosi, 2019](#); [Bianchi et al., 2020](#); [Cochrane, 2022](#); [Bianchi et al., 2023](#); [Smets and Wouters, 2024](#)). This novel class of NK-DSGE model constitutes a fiscal rule with both

backed and unbacked components of public debt and shocks influencing the specific component of public debt (Bianchi et al., 2023). Accordingly, the monetary and fiscal authorities respond to shocks influencing backed public debt with Regime M, while they respond to shocks influencing unbacked public debt with Regime F, hence the coexistence regime. Cochrane (2022) characterises it as a partial fiscal backing regime, whereas Smets and Wouters (2024) describe it as an intermediate regime. Bianchi et al. (2023) show that unbacked fiscal shocks in the aftermath of the Covid-19 pandemic resulted in a persistent rise in inflation in the US, while also sustaining economic recovery. Additionally, the authors reveal that the rise in government transfers during the 1960s, which were not backed by fiscal surpluses, contributed to the persistent increase in inflation observed during the Great Inflation period. In this regard, Bianchi et al. (2023) suggest that unbacked public debt leads to fiscal inflation. While Bianchi et al. (2023) focus on fiscal transfer shocks, Smets and Wouters (2024) extend the methodology to encompass a broader range of business cycle shocks, decomposing them into components influencing backed and unbacked public debt.

In related work, both Bianchi and Melosi (2019) and Bianchi et al. (2020) introduce a two-component fiscal budget framework comprising regular and emergency components. Public debt ascribed to the regular budget is backed by fiscal surpluses, while the debt associated with an emergency budget is not backed (Bianchi and Melosi, 2019; Bianchi et al., 2020). The unbacked public debt ascribed to the emergency budget is stabilized by inflation. The rise in inflation is due to the positive wealth effect induced by active fiscal policy and the higher inflation expectations of private agents based on passive monetary policy. The foregoing authors suggest that a regime with a two-component fiscal budget produces a moderate increase in inflation along with a corresponding economic recovery, in contrast to a fiscal orthodoxy scenario with an aggregated fiscal budget wherein the entire public debt is not backed by fiscal surpluses (Bianchi et al., 2020). In Bianchi et al. (2023), the concept of a coexistence regime shares similarities with these previous studies, thus emphasizing that the monetary and fiscal policy responses to a shock depend on the nature of the particular shock and, consequently, on the component of the budget that is influenced by the shock.

This approach of modeling two components of fiscal budget in a DSGE model is motivated by the response of the fiscal authority to the Great Depression whereby President Roosevelt distinguished between an ordinary and an emergency budget (Jacobson et al., 2019). The fiscal authority pledged to balance an ordinary budget with future fiscal adjustments, but did not commit to balancing an emergency budget implemented to counter the depression. Woodford (1996) posits that in such a scenario, failing to control the path of public debt poses a significant threat to price stability, thus recommending nominal deficit targeting as an appropriate fiscal policy for supporting a monetary policy that strictly follows the Taylor rule. This strategy is also akin to the coexistence regime. The difference is that Woodford (1996)'s strategy means that fiscal policy would support an active monetary policy by controlling the amount of public debt that the fiscal authority cannot stabilize with future fiscal surpluses. In contrast, the coexistence regime with both backed and unbacked public debt (see, e.g., Bianchi et al., 2020, 2023) entails fiscal policy that also supports an active monetary policy by stabilizing backed public debt with future fiscal surpluses. At the same time, monetary policy would support an active fiscal policy by passively responding to the inflation that stabilizes the unbacked portion of public debt (fiscal inflation).

The present study also relates to the literature on the fiscal limit, which is defined as the threshold at which the fiscal authority is no longer able to sustain a rise in public debt by adjusting future tax rates (Davig et al., 2011). The literature on the fiscal limit highlights challenges faced by the fiscal authority in stabilizing overall public debt using fiscal surpluses, especially given limited fiscal space (see, e.g., Davig et al., 2011; Leeper, 2013; Bianchi and Melosi, 2022). Previous studies on monetary and fiscal policy coordination predominantly concentrate on the two standard regimes, implicitly or explicitly assuming that increases in public debt following a shock are either fully backed by adjusting future fiscal surpluses (Regime M) or not backed at all (Regime F). Other studies explore how the fiscal response to monetary policy shocks influences their transmission to the real economy (see, e.g., Caramp and Silva, 2023; Caramp and Feilich, 2024; Kloosterman et al., 2024). These studies find that a contractionary (expansionary) monetary policy shock causes a decline (an increase) in inflation and output when accompanied by a simultaneous contractionary (expansionary) fiscal policy. Hence, considering the fiscal limit, the coexistence regime becomes more relevant for understanding the prevailing inflation dynamics, given the current high public debt environment.

The present study pertains to an extensive body of literature on the coordination of monetary and fiscal policy and the FTPL.⁴ These prior studies underscore the importance of pairing an appropriate monetary policy with a credible fiscal policy (namely either Regime M or Regime F) to ensure a unique equilibrium price level. For instance, Leeper and Leith (2016) establish that in Regime F, a contractionary monetary policy shock results in higher inflation due to the positive wealth effect, which arises from an expected increase in nominal interest receipts on households' government bond holdings. As there are no expectations of tax rate adjustments in the future, households perceive the increase in nominal interest receipts as an increase in their wealth, which, subsequently, increases aggregate demand and inflation. Other studies have examined the influence of public debt on inflation responses to various shocks, placing specific emphasis on either Regime M or Regime F.⁵ For example, Faraglia et al. (2013) find that a higher level of public debt leads to higher inflation following government spending and negative preference shocks. Similar findings are established by Leeper and Leith (2016) who examine the impact of a government transfer shock on inflation with varying levels of public debt. Bhattarai et al. (2014) find that positive innovation to the outstanding public debt leads to high and persistent inflation.

To our knowledge, no existing study has investigated the effects of monetary policy shocks on inflation via a model comprising both backed and unbacked public debt and with a specific focus on debt service cost channel. The present study is particularly relevant considering the constrained fiscal capacity caused by elevated public debt and the potential additional fiscal burden arising from higher interest rates, which raise debt service costs. The present study aims to address and bridge these notable gaps in the literature.

⁴The literature include but are not limited to: Leeper (1991), Sims (1994), Leeper and Yun (2006), Davig and Leeper (2011), Bianchi (2012), Leeper and Leith (2016), Bianchi and Ilut (2017), Chen et al. (2022), and Cochrane (2023).

⁵These studies include Woodford (1996); Adam (2011); Faraglia et al. (2013); Niemann et al. (2013); Bhattarai et al. (2014); Leeper and Leith (2016).

3 The model

The present study adopts a standard NK-DSGE model, as in [Leeper and Leith \(2016\)](#), featuring one-period government bonds and a fiscal block.⁶ Following [Bianchi et al. \(2023\)](#), it incorporates both backed and unbacked public debt in the fiscal policy rule. Similarly, the monetary rule also constitutes two components of inflation, namely inflation corresponding to backed debt (hereafter non-fiscal inflation) and inflation associated with unbacked debt (hereafter fiscal inflation). Under this novel regime featuring both backed and unbacked public debt, Regime M and Regime F coexist. The detailed specifications of fiscal and monetary rules are presented in Subsection [3.2.1](#).

As in [Bianchi et al. \(2023\)](#), the coexistence regime features two distinct economies: the actual economy and a shadow economy. These two economies enable the proper identification of shocks affecting backed and unbacked public debt and their impact on the ensuing inflation. The actual economy keeps track of the portion of shocks influencing backed public debt, whereas the shadow economy serves as a complement to the actual economy, keeping track of the portion of shocks influencing unbacked public debt and the associated fiscal inflation.

3.1 The households

The representative household consumes final goods (c_t) and supplies labor to the firms (N_t). The household maximizes the following expected utility function:⁷

$$E_t \sum_{t=0}^{\infty} \beta^t \left[\frac{c_t^{1-\sigma}}{1-\sigma} - \chi \frac{N_t^{1+\eta}}{1+\eta} \right], \quad (1)$$

and is subject to the budget constraint:

$$(1 + \tau_t)c_t + \frac{B_t}{R_t P_t} = \frac{W_t}{P_t} N_t + \frac{B_{t-1}}{P_t} + \frac{\Psi_t}{P_t}, \quad (2)$$

where $\beta \in (0, 1)$ denotes the household's discount factor, $\sigma > 0$ is the inverse of intertemporal elasticity of substitution, and $\eta > 0$ is the inverse of Frisch elasticity of labor supply.

The household invests in one-period nominal government bonds (B_t), which yield a gross nominal return of R_t , and pays the tax rate levied on consumption to the government (τ_t). The household receives nominal wage (W_t) and nominal profits (Ψ_t) from firms, while P_t denotes the price level.

The household's optimization problem gives the following first order conditions for B_t and N_t , respectively:

⁶Given that the production sector is a standard one in the NK-DSGE model, this section only presents the household sector and a government consisting of fiscal and monetary authorities. The production sector is presented in [Appendix A](#).

⁷The aggregate variables in small letters are in real terms while those in capital letters are in nominal terms, except for the labor supply.

$$\frac{1}{R_t} = \beta E_t \left[\left(\frac{1 + \tau_t}{1 + \tau_{t+1}} \right) \left(\frac{c_t}{c_{t+1}} \right)^\sigma \left(\frac{1}{\Pi_{t+1}} \right) \right], \quad (3)$$

$$\frac{W_t}{P_t} = (1 + \tau_t) \frac{\chi N_t^\eta}{c_t^{-\sigma}}, \quad (4)$$

where $\Pi_{t+1} = P_{t+1}/P_t$ denotes one-period ahead gross inflation.

Equation 3 is the standard Euler equation for consumption. Equation 4 shows that the marginal rate of substitution between consumption and leisure equals the real wage.

3.2 Government

The government's budget constraint is given below:

$$\frac{B_t}{R_t P_t} + \tau_t c_t = \frac{B_{t-1}}{P_t} + \frac{G_t}{P_t}, \quad (5)$$

where G_t is nominal government expenditure.

3.2.1 Coexistence regime

Following [Bianchi et al. \(2023\)](#), the fiscal rule under the coexistence regime constitutes both backed and unbacked public debt:⁸

$$\frac{s_t}{y_t} = \left(\frac{s}{y} \right) \left(\frac{b_{t-1}}{R_{t-1} y_{t-1}} / \frac{b_{t-1}^f}{R_{t-1} y_{t-1}} \right)^{\delta^{PF}} \left(\frac{b_{t-1}^f}{R_{t-1} y_{t-1}} / \frac{b}{R y} \right)^{\delta^{AF}}, \quad (6)$$

where $s_t = \tau_t c_t - g_t$ denotes real primary surpluses and g_t is real government expenditure. b_{t-1}^f denotes unbacked real public debt, and b_{t-1} is the total amount of real public debt, hence, $b_{t-1}^m = b_{t-1} - b_{t-1}^f$ is defined as backed real public debt, which is the difference between total real public debt and unbacked real public debt. y_{t-1} denotes real GDP. Public debt appears in the fiscal policy rule in terms of its market value to GDP ratio, where the price of nominal debt is captured by the inverse of the nominal gross interest rate (see, e.g., [Leeper and Leith, 2016](#); [Bianchi and Melosi, 2019](#); [Bianchi et al., 2023](#)).

The fiscal authority makes the necessary fiscal adjustments in response to changes in backed public debt. As such, backed debt is fully stabilized by fiscal surpluses, i.e. fiscal policy is passive. In contrast, the fiscal authority weakly adjusts fiscal surpluses in response to changes in unbacked public debt,⁹ i.e. fiscal policy is active. Hence, unbacked public debt is stabilized by fiscal inflation. The parameter δ^{PF} measures the

⁸A variable shown without a time subscript represents its steady state value.

⁹In terms of deviations from steady state.

responsiveness of primary surpluses to changes in backed public debt, while the parameter δ^{AF} measures the responsiveness of primary surpluses to changes in unbacked public debt.

The monetary authority follows a Taylor-type interest rate rule. As in [Bianchi et al. \(2023\)](#), the monetary rule has two components of inflation: non-fiscal and fiscal:

$$\frac{1}{R_t} = \left(\frac{1}{R}\right) \left(\frac{1}{\Pi_t} / \frac{1}{\Pi_t^f}\right)^{\alpha_\pi^{AM}} \left(\frac{1}{\Pi_t^f} / \frac{1}{\Pi}\right)^{\alpha_\pi^{PM}} e^{\xi_t^R}, \quad (7)$$

where Π_t^f denotes gross fiscal inflation, i.e. the level of inflation due to unbacked public debt, while Π_t denotes gross aggregate inflation, hence gross non-fiscal inflation which corresponds to backed public debt is defined as $\Pi_t^m = \Pi_t - \Pi_t^f$, i.e. the difference between gross aggregate inflation and gross fiscal inflation.¹⁰ The monetary policy shock has two portions corresponding to non-fiscal and fiscal inflation. The portion of monetary policy shock corresponding to non-fiscal inflation influences backed public debt, while the portion of monetary policy shock corresponding to fiscal inflation influences unbacked public debt. As such, the monetary authority adjusts the nominal policy rate by more than one-to-one in response to changes in non-fiscal inflation, i.e. monetary policy is active in controlling non-fiscal inflation. On the other hand, the authority weakly adjusts the nominal policy rate in response to changes in fiscal inflation, i.e. monetary policy is passive. The parameter α_π^{AM} measures the response of monetary policy to changes in non-fiscal inflation, while the parameter α_π^{PM} measures the response of monetary policy to changes in fiscal inflation, wherein ξ_t^R is the monetary policy shock which evolves as follows:

$$\xi_t^R = \rho_R(\xi_{t-1}^R) + \epsilon_t^R, \quad (8)$$

where $0 < \rho_R < 1$ measures the persistence of the monetary policy shock and ϵ_t^R measures the size of the monetary policy shock (see, e.g., [Gali, 2015](#)).

Following [Leeper and Leith \(2016\)](#), the present study assigns the values of the policy parameters to meet the conditions that guarantee the existence of a unique equilibrium solution with the coexistence of Regime M and Regime F. For backed public debt and the corresponding non-fiscal inflation, fiscal policy is passive when $\beta^{-1} - \delta^{PF} < 1$, while monetary policy is active when $\frac{\alpha_\pi^{AM}}{\beta} > 1$, hence Regime M. For unbacked public debt and the corresponding fiscal inflation, fiscal policy is active when $\beta^{-1} - \delta^{AF} > 1$, while monetary policy is passive when $\frac{\alpha_\pi^{PM}}{\beta} < 1$, thus Regime F.¹¹

3.2.2 Standard regimes M and F

For comparison analysis purposes, the present study also considers the standard fiscal rule, as in [Leeper and Leith \(2016\)](#), with public debt either fully backed by fiscal surpluses (Regime M) or not backed at all (Regime

¹⁰Linearizing the monetary rule in Equation 7 we obtain $\hat{r}_t = \alpha_\pi^{AM}(\hat{\pi}_t - \hat{\pi}_t^f) + \alpha_\pi^{PM}\hat{\pi}_t^f + \xi_t^R$, where π_t denotes inflation rate. Variables marked with hats denote variables expressed as a log-deviation from their steady state values.

¹¹For details, see Appendix B.

F). Under the standard regimes, the fiscal authority adjusts primary surpluses in response to changes in the market value of total public debt, as follows:

$$\frac{s_t}{y_t} = \left(\frac{s}{y}\right) \left(\frac{b_{t-1}}{R_{t-1}y_{t-1}} / \frac{b}{Ry}\right)^\delta, \quad (9)$$

where the parameter δ measures the extent to which the fiscal authority adjusts future primary surpluses in response to changes in the market value of total public debt.

Similarly, the monetary policy rule follows the standard Taylor-type interest rate rule as follows:

$$\frac{1}{R_t} = \frac{1}{R} \left(\frac{1}{\Pi_t} / \frac{1}{\Pi}\right)^{\alpha_\Pi} \xi_t^R, \quad (10)$$

where the parameter α_Π measures the response of monetary policy to changes in total inflation. As shown in [Leeper and Leith \(2016\)](#), a unique equilibrium exists under Regime M when $\frac{\alpha_\pi}{\beta} > 1$ and $\beta^{-1} - \delta < 1$, and under Regime F when $\frac{\alpha_\pi}{\beta} < 1$ and $\beta^{-1} - \delta > 1$.

3.3 Shadow economy

The specification of the fiscal and monetary policy rules in previous sections characterizes the dynamics of backed public debt ($b_{t-1} - b_{t-1}^f$) and non-fiscal inflation ($\Pi_t - \Pi_t^f$). Following [Bianchi et al. \(2023\)](#), the present study introduces a shadow economy, which keeps track of unbacked public debt (b_{t-1}^f) and the corresponding fiscal inflation (Π_t^f).¹² A shadow economy is a supplement to the actual economy, with shocks affecting unbacked public debt only. That is, the present study models the portion of monetary policy shock corresponding to fiscal inflation in the shadow economy. The shadow economy's fiscal and monetary rules are given as follows:

$$\frac{s_t^f}{y_t^f} = \left(\frac{s}{y}\right) \left(\frac{b_{t-1}^f}{R_{t-1}^f y_{t-1}^f} / \frac{b}{Ry}\right)^{\delta^{AF}}, \quad (11)$$

$$\frac{1}{R_t^f} = \left(\frac{1}{R}\right) \left(\frac{1}{\Pi_t^f} / \frac{1}{\Pi}\right)^{\alpha_\pi^{PM}} e^{\zeta \xi_t^R}, \quad (12)$$

where the parameter ζ measures the portion of monetary policy shock corresponding to fiscal inflation. Therefore, in the shadow economy, monetary and fiscal authorities opt for Regime F. Except for fiscal and monetary policy rules, the model setup for the shadow economy is identical to that of the actual economy.¹³

¹²[Smets and Wouters \(2024\)](#) also adopt a similar approach.

¹³The complete set of equations for the actual and shadow economy are presented in appendix C.

3.4 Market clearing conditions and aggregation

Given the household and government budget constraints specified, the economy's aggregate resource constraint satisfies the following:

$$y_t = c_t + g_t. \quad (13)$$

The aggregate of real public debt is given as:

$$b_t = b_t^f + b_t^m. \quad (14)$$

Gross aggregate inflation is given as:

$$\Pi_t = \Pi_t^f + \Pi_t^m. \quad (15)$$

4 Calibration

Following the standard approach set out in the literature, the model is calibrated based on the US quarterly data over the sample period of 1982:Q2 to 2022:Q4. Some of the parameters are calibrated to ensure that the steady state conditions match the actual data. Other parameter values are borrowed from the DSGE literature on the interaction between monetary and fiscal policy, and the calibrated values of which are quite standard in the literature.

Table 1 presents the parameter values and Table 2 presents the steady state ratios of the model. The household discount factor (β) is set to 0.99 (Rotemberg and Woodford, 1997), which is the standard value established in the literature. This corresponds to a steady state gross interest rate of 1.01, thus implying an annual interest rate of 4%. This closely matches the average FFR of 3.9% observed over the sample period (1982Q2 to 2022Q4). In steady state, gross aggregate inflation (Π) is set to 1, thus inflation is assumed to be zero ($\pi = 0$) in steady state and in line with the literature. The inverse of intertemporal elasticity of substitution (σ) is set to 2, as in Aruoba et al. (2018). The inverse of Frisch elasticity of labor supply (η) is set to 1 (Davig and Leeper, 2011), while the elasticity of substitution between intermediate goods (ν) is set to 9 (Gali, 2015). The Calvo price adjustment parameter (θ) is set to 0.75, as commonly found in the literature (see, e.g., Gali, 2015; Chen et al., 2022). This implies that, on average, firms re-optimize prices every four quarters. The labor disutility parameter (χ) is derived at 1.04.

The steady state ratios for fiscal variables are calibrated to mimic the average ratios observed in US data over the sample period. To be precise, the public debt-to-GDP ratio (b/y) is set to 0.72, which corresponds to the average of public debt over the sample period. Government expenditure-to-GDP ratio (g/y) is set to 0.15, as in Drautzburg and Uhlig (2015). Therefore, the resulting steady state consumption-to-GDP ratio (c/y) is 0.85. The tax rate (τ) is computed as 0.18 to satisfy the government budget constraint in steady state. This gives a tax-receipt-to-GDP ratio ($\tau c/y$) of 0.157 and a surplus-to-GDP ratio (s/y) of 0.0072.

Table 1: Calibration of model parameters.

Parameter	Notation	Value
Standard parameters		
Household discount factor	β	0.99
Inverse of intertemporal elasticity of substitution	σ	2
Inverse of Frisch elasticity	η	1
Elasticity of substitution between goods	ν	9
Calvo probability	θ	0.75
Labor disutility parameter	χ	1.04
Monetary and fiscal policy parameters		
Coexistence regime		
Monetary policy response to non-fiscal inflation	α_{π}^{AM}	1.5
Monetary policy response to fiscal inflation	α_{π}^{PM}	0.5
Response of surpluses to backed public debt	δ^{PF}	1.2
Response of surpluses to unbacked public debt	δ^{AF}	0
Parameter for unbacked monetary shock	ζ	0.75
Regime M		
Monetary policy response to inflation	α_{π}	1.5
Response of surpluses to public debt	δ^{PF}	1.2
Regime F		
Monetary policy response to inflation	α_{π}	0.5
Response of surpluses to public debt	δ^{PF}	0
Exogenous processes		
Persistence of monetary shock	ρ_R	0.85
Persistence of technology shock	ρ_z	0.9

Table 2: Key steady state ratios.

Parameter	Notation	SS value
Public debt to GDP (calibrated)	b/y	0.72
Government expenditure to GDP (calibrated)	g/y	0.15
Consumption to GDP (obtained)	c/y	0.85
Tax revenue to GDP (obtained)	$\tau c/y$	0.157
Surplus to GDP (obtained)	s/y	0.0072

The policy response parameters in the fiscal and monetary policy rules are calibrated to be consistent with conditions for a unique stationary solution as laid out in Appendix B. For Regime M, the parameter for a monetary policy response to inflation (α_{π}) is set to 1.5 as in [Smets and Wouters \(2007\)](#), and the response of surpluses to public debt (δ) is set to 1.2. For Regime F, α_{π} is set to 0.5 and δ is set to 0, as in [Leeper and Leith \(2016\)](#) and [Bianchi et al. \(2023\)](#). This implies that the policy parameter values in a coexistence regime corresponding to Regime M and Regime F also take the same values, respectively: $\alpha_{\pi}^{AM} = 1.5$ and $\delta^{PF} = 1.2$; and $\alpha_{\pi}^{PM} = 0.5$ and $\delta^{AF} = 0$. Setting $\delta^{AF} = 0$ implies that the fiscal authority does not adjust future fiscal surpluses to stabilize unbacked public debt. The value of the parameter for the monetary policy shock corresponding to fiscal inflation (ζ) is set to 0.75. This means that 75% of the contractionary monetary policy shock influences unbacked public debt. The parameter is set to a higher value in order to reflect the current environment of a limited fiscal capacity for adjusting fiscal surpluses amidst high public debt levels. For robustness check, we also conduct sensitivity analysis with alternative values of ζ in Section 6.1.

Regarding the parameters for exogenous processes, the persistence parameter of monetary policy shock (ρ_R) is set to 0.85 to mimic the persistence of the high interest rates environment observed after the Covid-19 pandemic.

5 Results

This section begins its analysis by examining the effects of a contractionary monetary policy shock on the dynamics of inflation and other key macroeconomic variables, under three policy mix regimes: Regime M; Regime F; and the coexistence regime.¹⁴ The welfare gains or losses associated with the policy mix regimes implemented are then evaluated. Lastly, EPF analysis is used to evaluate the effectiveness of the coexistence regime in achieving price stability and debt stability.

5.1 Monetary policy shock: Coexistence regime versus Regime M and Regime F

Figure 3 presents the impulse responses of the main variables to a 1% contractionary monetary policy shock under the three policy mix regimes. Following the shock, the real interest rate increases, raising the real interest payments on public debt and resulting in an initial increase in public debt for all three regimes.

The effect of public debt increases on inflation is determined by the wealth effect, which also depends on the monetary and fiscal policy mix regime. For Regime M (dotted line), increased public debt is accompanied by a significant increase in future primary surpluses, which eliminates the positive wealth effect derived from higher interest receipts on household bond holdings. As a result, households reduce their consumption, leading to a decline in aggregate demand, which in turn, significantly reduces inflation. Employment and real wages also decline following the decrease in aggregate demand. The monetary policy transmission mechanism observed here is consistent with the literature on the NK-DSGE model (see, e.g., [Gali, 2015](#); [Leeper and Leith, 2016](#)).

Under Regime F (dashed line), however, the higher interest receipts on public debt raise households' future wealth, as they do not expect the fiscal authority to raise primary surpluses in the future to stabilize the debt. Furthermore, households raise inflation expectations, as they do not expect the monetary authority to commit to controlling inflation. Consequently, inflation increases significantly, thereby stabilizing real public debt. Consumption, having undergone a less pronounced initial decrease, subsequently experiences a robust recovery. This is attributed to the positive wealth effect, which partially counteracts the negative effect of the contractionary monetary policy shock on consumption. Similarly, the initial decline in employment and real wages is less pronounced and, thereafter, recovers at a faster pace. These results are also consistent with the findings set out in the literature (see, e.g., [Leeper and Leith, 2016](#)).

Under the coexistence regime (solid line), a good balance between debt stability and price stability is achieved. With partially unbacked public debt, the responses of the key variables to a contractionary

¹⁴For the coexistence regime, the baseline assumption is that 75% of the monetary policy shock influences unbacked public debt.

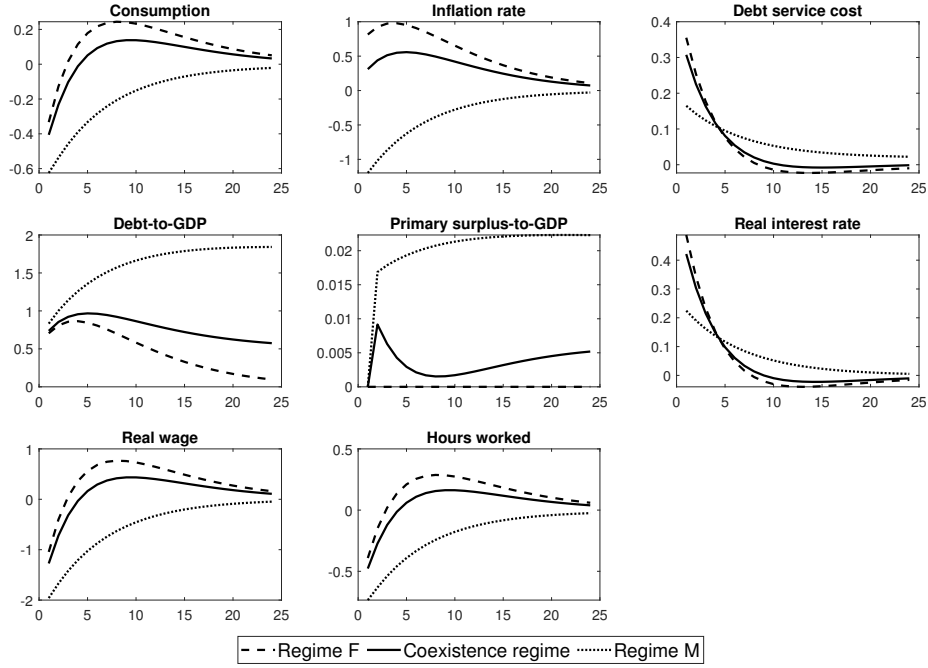


Figure 3: Responses of the main variables to a 1% contractionary monetary policy shock under three policy mix regimes: coexistence regime (solid line); Regime F (dashed line); and Regime M (dotted line). The variables are expressed as % deviations from steady states, except for the fiscal variables, which are expressed as linear deviations from steady state.

monetary policy shock are more contained than those seen for Regime F. This is because public debt is stabilized through a balance of future primary surpluses and inflation. Primary surpluses increase moderately under the coexistence regime, thereby stabilizing part of the debt (backed component). Consequently, the positive wealth effect is subdued compared to that observed for Regime F. At the same time, inflation expectations are relatively lower under the coexistence regime, as private agents are aware that the monetary authority will coordinate with the fiscal authority to stabilize the unbacked component of public debt through inflation. The subdued positive wealth effect and comparatively lower inflation expectations lead to a moderate inflation increase under the coexistence regime. The recovery of consumption, employment, and real wages is well-balanced.

Under the coexistence regime, the authorities coordinate with each other and achieve lower inflation and a well-stabilized public debt level. Under Regime M, however, the significantly lower level of inflation is achieved with a high cost in terms of a significant increase in public debt. This coexistence regime is desirable in times of limited fiscal space as it contributes to well-balanced public debt and price stability. This idea of well-balanced policy coordination is underscored by [Woodford \(2001\)](#), who proposes that monetary policy that strictly follows a Taylor-type rule must be accompanied by a fiscal policy that sets a target for the fiscal deficit or public debt to ensure long-term price stability. Since the second half of 2023, inflation has been eased markedly in most economies, which is primarily attributed to prolonged tight monetary policy. Despite this rapid disinflation in most economies, public debt remains persistently high and poses a substantial threat to price stability, given the constrained fiscal space and rising debt service costs arising from elevated interest rates. Meanwhile, central banks are cautiously reducing interest rates following the rapid disinflation. While

the interest rate cuts may reduce debt service costs, a balanced coordination between monetary policy and fiscal policy, such as that observed for the coexistence policy mix regime studied here, remains imperative for maintaining both debt stability and price stability.

5.2 Welfare analysis

This section evaluates the welfare gains or losses resulting from monetary and fiscal authorities' responses to a contractionary monetary policy shock under the coexistence regime and Regime F, as compared to those seen for Regime M. Regime M is assigned as the benchmark, because it corresponds to the standard interaction of monetary and fiscal policies in NK-DSGE models, wherein the monetary authority actively manages inflation, while the fiscal authority stabilizes public debt by adjusting fiscal surpluses.

To conduct welfare analysis, the present study adopts the second-order approximation approach (see e.g., [Schmitt-Grohé and Uribe, 2004](#); [Benigno and Woodford, 2005, 2012](#)), which involves taking the second-order approximation of the representative household's utility function to derive the welfare function. Based on the utility function (Equation 1), the inter-temporal welfare is given by:

$$W_t = \left(\frac{c_t^{1-\sigma}}{1-\sigma} - \chi \frac{N_t^{1+\eta}}{1+\eta} \right) + \beta W_{t+1}. \quad (16)$$

To derive a comparable welfare measure, the present study follows [Rubio and Carrasco-Gallego \(2014\)](#) and calculates the potential welfare gains or losses in consumption equivalent (CE) terms:

$$CE^i = \exp [(1 - \beta)(W^i - W^M)] - 1, \quad (17)$$

where $CE^i (i \in F, C)$ denotes consumption equivalent welfare under Regime F and the coexistence regime, respectively. Similarly, W^i is the unconditional welfare evaluated under Regime F and the coexistence regime, whereas W^M is the unconditional welfare under Regime M. A positive CE value reflects a welfare gain relative to the benchmark case and vice-versa.

The CE welfare measure quantifies the level of consumption the representative household would be willing to sacrifice to gain the benefits of implementing an optimal combination of monetary and fiscal policies under the two alternative policy mix regimes (a coexistence regime and Regime F) in response to the shock, as compared to the benchmark conditions of Regime M.

Table 3 presents the results of the welfare analysis conducted, indicating that the coexistence regime is a desirable policy mix regime in terms of welfare. The results obtained show that the coexistence regime achieves a welfare level 1.3% higher than that obtained with the benchmark Regime M. In the coexistence regime, the monetary and fiscal authorities coordinate to stabilize a portion of public debt through inflation, while the remaining debt is stabilized through fiscal surpluses. In contrast, the welfare level observed for Regime F is 2.3% lower than that found for Regime M. These findings indicate that the coexistence regime

yields greater welfare gains than Regime F and are consistent with the findings presented in the literature (see e.g. [Bianchi and Melosi, 2019](#)). The authors also find that welfare losses are minimized when the authorities coordinate with each other to stabilize the debt corresponding to the emergency budget.

Table 3: Welfare analysis.

	Regime F	Coexistence regime
Consumption Equivalent (%)	-2.3030	1.3112

5.3 Debt stabilization versus price stability

This section assesses the effectiveness of the coexistence regime in enhancing the stability of both public debt and inflation using EPF analysis. The present study considers the following loss function, which the monetary and fiscal authorities aim to minimize by coordinating their policies:

$$L = \lambda\sigma_{b_t}^2 + (1 - \lambda)\sigma_{\pi_t}^2, \quad (18)$$

where $\sigma_{b_t}^2$ denotes the volatility of public debt and $\sigma_{\pi_t}^2$ denotes the volatility of inflation. The parameter $\lambda \in [0, 1]$ denotes the weight on the volatility of public debt, which varies inversely with the weight on the volatility of inflation. The EPF, presented as a two-dimensional figure, plots the minimum variability in public debt and inflation obtained at different optimal combinations of the policy parameters. These optimal combinations are determined by adjusting the weights assigned to the volatility of public debt and the volatility of inflation in the loss function.

The results presented in Figure 4 show that there is a significant trade-off between price stability and public debt stability under the coexistence regime. This implies that achieving public debt stability comes at the cost of an increase in inflation volatility and vice versa. This can be seen in cases where a larger portion (75%, solid line) and an equal portion (50%, dotted line) of monetary policy shock influence unbacked public debt. The trade-off under the two scenarios is similar, as the slopes of the two frontiers are more or less the same. However, when only a small portion (25%) of monetary policy shock influences unbacked public debt, the costs of reducing the volatility of public debt become minimal and, indeed, almost indifferent, thus eliminating the trade-off between the volatility of public debt and the volatility of inflation. This is reflected as a very short and flat EPF as shown in the figure. Lastly, it is worth noting that the larger the portion of monetary policy shock influencing unbacked public debt, the higher the levels of volatility for both public debt and inflation faced by the authorities. This is seen as the EPF for the scenario involving a 75% monetary policy shock influencing unbacked public debt, which lies further away from the origin in the figure.

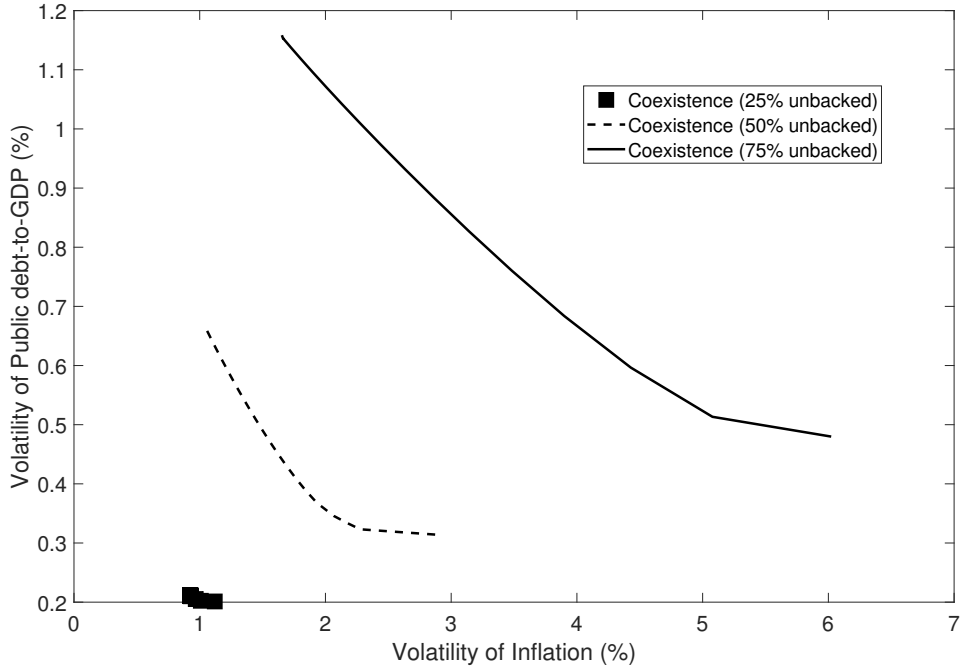


Figure 4: The EPF under the coexistence regime with different portions of monetary policy shock influencing unbacked public debt.

6 Sensitivity analysis: The coexistence regime

This section presents the sensitivity analysis results via the comparison of the dynamics of the main variables following a 1% contractionary monetary policy shock under the coexistence regime.¹⁵ Section 6.1 compares the responses of the main variables, considering different sizes of monetary policy shock influencing unbacked public debt, while Section 6.2 compares the responses of the main variables under flexible versus sticky prices.

6.1 Different sizes of unbacked public debt

Figure 5 shows the impulse responses of the main variables following a 1% contractionary monetary policy shock under the coexistence regime, considering different sizes of the shock influencing unbacked public debt, namely different values for the parameter ζ . The higher the value of ζ , the larger the component of monetary policy shock influencing unbacked public debt and the higher the associated fiscal inflation. This comparison analysis helps to determine the appropriate balance between fiscal and monetary policy, a balance which stabilizes debt without compromising price stability, especially during periods of a larger fiscal burden with limited fiscal space.

Based on the results obtained, it can be observed that while, following the shock, the debt service costs increase in all three scenarios, the initial increase in debt service costs is relatively higher when a larger portion of monetary policy shock influences unbacked public debt (75%, solid line). As a result, public debt also rises in all three scenarios following the increase in debt service costs, although the subsequent path of debt is largely influenced by the debt stabilization mechanism. The larger the portion of monetary policy

¹⁵The benchmark calibration is that 75% of monetary policy shock influences unbacked public debt.

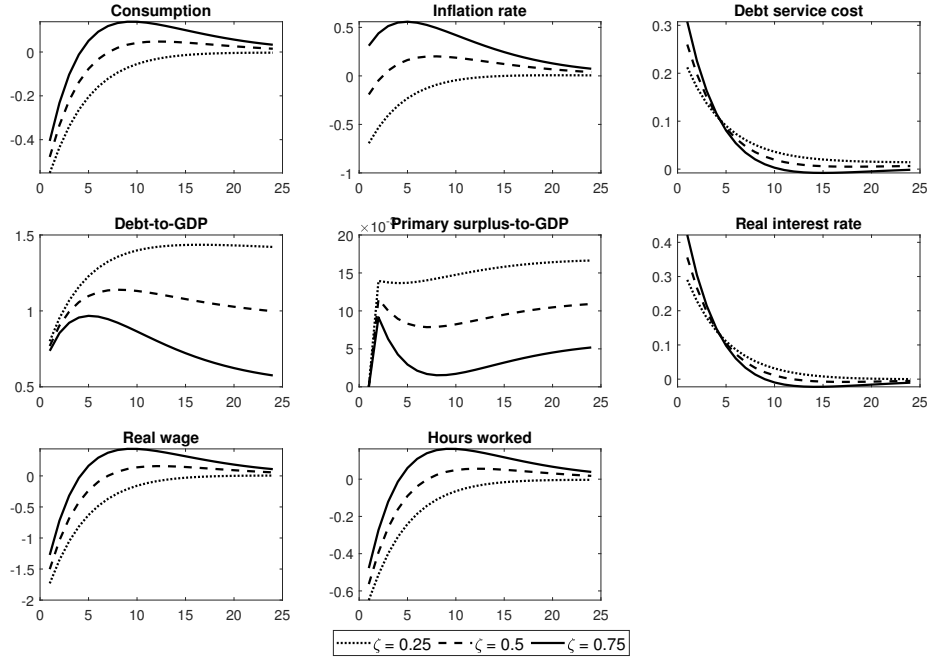


Figure 5: Responses of the main variables to a 1% contractionary monetary policy shock under a coexistence regime with different sizes of monetary policy shock influencing unbacked public debt i.e. different parameter ζ values. $\zeta = 0.25$: dotted line; $\zeta = 0.5$: dashed line; and $\zeta = 0.75$: solid line. Variables are expressed as % deviations from steady states, except for the fiscal variables, which are expressed as linear deviations from steady state.

shock influencing unbacked public debt, the higher the increase in unbacked public debt. In this case, public debt is largely stabilized through inflation rather than primary surpluses, which is due to the reinforcement of the positive wealth effect, as private agents anticipate a minimal rise in future taxes. Additionally, private agents' inflation expectations are higher, as they expect the monetary authority to weakly control inflation. As a result, public debt is stabilized more quickly, due to a more pronounced increase in inflation. In contrast, public debt remains at an elevated level when only a small portion of monetary policy shock influences unbacked public debt (dotted line). This is because there is a larger increase in backed public debt, hence primary surpluses are subject to greater increases to stabilize the debt. Accordingly, inflation is lower due to the reduced positive wealth effect and the lower inflation expectations of private agents.

The initial jump in real interest rates is relatively higher in the case of a larger portion of monetary policy shock influencing unbacked public debt, although, thereafter, it converges back to its steady state faster than in the case of only a small portion of monetary policy shock influencing unbacked public debt. The initial decline in consumption, employment, and real wages are, however, relatively lower and recover faster and stronger when a larger portion of monetary policy shock influences unbacked public debt than the levels of decline found for the alternative scenarios. This is because the negative effect of higher real interest rates on consumption is partially offset by the higher positive wealth effect of higher expected interest receipts for households.

The EPF and sensitivity analysis findings presented here underscore the importance of the coexistence regime in the current environment of high public debt as observed from the data with limited fiscal capacity

in stabilizing the entire public debt with future fiscal surpluses. In order to effectively stabilize both public debt and inflation, policymakers need first to ascertain the extent to which a contractionary monetary policy shock influences the unbacked component of public debt and then to carefully establish the right mix of monetary and fiscal policy for debt stabilization.

6.2 Flexible versus sticky prices

This section investigates the impact of price stickiness on the dynamics of the main variables following a contractionary monetary policy shock under the coexistence regime. In the coexistence regime, stabilizing debt through a balance of monetary and fiscal policy is important for shaping the dynamic responses of public debt and inflation.

One of the key factors that influences this policy balance for debt stabilization is the degree of price flexibility, a key assumption in the NK-DSGE model in terms of the transmission of monetary policy shocks. When prices are flexible, an immediate and more pronounced response in inflation is observed following a contractionary monetary policy shock, whereas the real variables are not affected (Leeper and Leith, 2016; Bianchi et al., 2023). Conversely, when prices are sticky, the adjustment of prices occurs gradually, resulting in a comparatively less pronounced effect on inflation following a shock. These divergent inflation responses under flexible and sticky price scenarios have notable implications for the mechanism of debt stabilization under the coexistence regime. Additionally, the literature posits that the effects of monetary and fiscal policy coordination on the macroeconomic variables depend on the degree of price stickiness (see, e.g., Caramp and Silva, 2023).

Figure 6 presents the impulse responses of the main variables following a 1% contractionary monetary policy shock. The results show that the increase in debt service costs is higher when prices are more sticky due to a larger increase in real interest rates (solid versus dashed lines). The public debt-to-GDP ratio also increases more sharply when prices are sticky than they do in the flexible prices scenario. As private agents are aware that the response of inflation is slow and less pronounced when prices are sticky, they expect the fiscal authority to stabilize a larger portion of public debt with future primary surpluses. Thus, private agents' expectations about a rise in future taxes eliminate the positive wealth effect of higher interest receipts on their government bond holdings. Furthermore, the higher the increase in real interest rates, as seen in the case of more sticky prices, the greater the decline in consumption. This leads to a decrease in aggregate demand, which in turn reduces inflation pressure. In contrast, in the case of flexible prices, as private agents are aware that the response of inflation to the shock is immediate and greater, they expect a larger portion of public debt to be stabilized by inflation than by primary surpluses. Accordingly, the positive wealth effect is induced as agents anticipate a smaller adjustment in future taxes. Caramp and Silva (2023) also find that the wealth effect is amplified with more flexible prices, driven by the fiscal response to shocks in monetary policy. The findings indicate that price stickiness plays a significant role in shaping the dynamics of inflation and key macroeconomic variables under the coexistence regime.

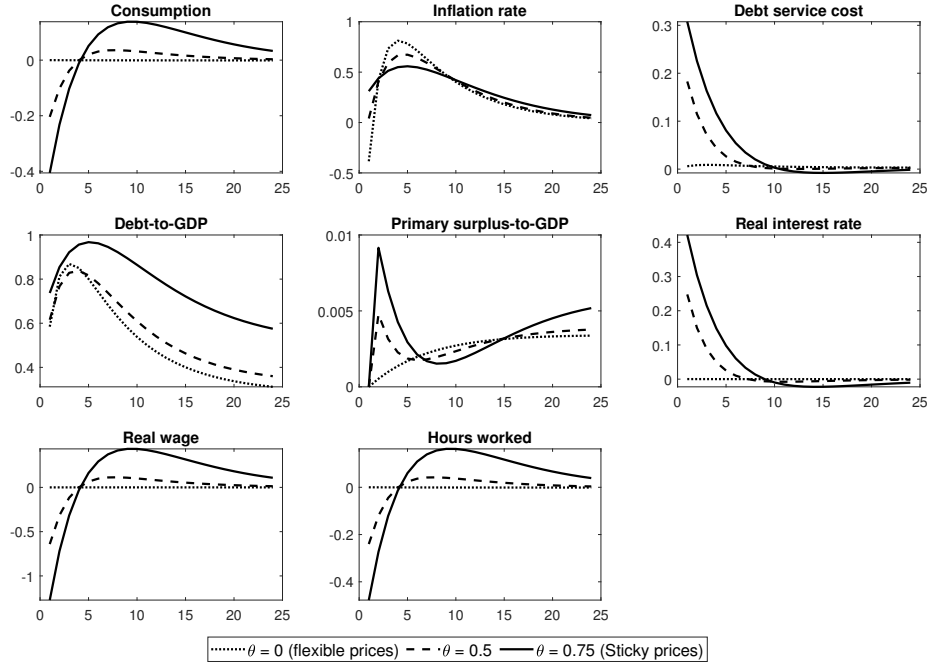


Figure 6: Responses of the main variables to a 1% contractionary monetary policy shock under a coexistence regime with varying Calvo parameter values. $\theta = 0$: dotted line (flexible prices); $\theta = 0.5$: dashed line and $\theta = 0.75$: solid line (sticky prices). The variables are expressed as % deviations from steady states, except for the fiscal variables, which are expressed as linear deviations from steady state.

7 Conclusion

The present study explores the role of backed and unbacked public debt in transmitting monetary policy shocks to inflation dynamics under different policy mix regimes, focusing on a coexistence regime in which two standard regimes, Regime M and Regime F coexist. The findings obtained show that policy coordination under the standard regimes may not be adequate in achieving both public debt stability and price stability, especially in the current environment of elevated public debt with limited fiscal space, persistently high inflation, and high interest rates. Thus, a balanced coordination of monetary and fiscal policies under the coexistence regime studied here is desirable, as it contributes to well-balanced public debt and price stability, thereby improving welfare. These findings underscore the importance of the coexistence regime and the need for the authorities to strike the appropriate balance between monetary and fiscal policy in response to the shocks influencing the fiscal burden, in order to thus enhance the effectiveness of the policy intervention. That being said, there is no one-size-fits-all policy mix as it depends on the situation that the monetary and fiscal authorities are facing and the portion of monetary policy shock that influences unbacked public debt and its corresponding fiscal inflation. This is, therefore a potential area for future research.

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A The production sector

A.1 The final-goods producing firm

The representative final-goods firm aggregates differentiated intermediate goods into a final good. Considering that intermediate goods are indexed by $j \in (0, 1)$, the aggregation is given as:

$$Y_t = \left(\int_0^1 Y_t(j)^{\frac{v-1}{v}} dj \right)^{\frac{v}{v-1}}, \quad (19)$$

where $v > 1$ denotes the elasticity of demand and $Y_t(j)$ denotes differentiated intermediate goods. The final-good firm's profit maximization problem is below:

$$\max_{Y_t(j)} \left[P_t \left(\int_0^1 Y_t(j)^{\frac{v-1}{v}} dj \right)^{\frac{v}{v-1}} - \left(\int_0^1 P_t(j) Y_t(j) dj \right) \right], \quad (20)$$

where $P_t(j)$ is the price of differentiated intermediate goods and P_t the price of final goods.

The following market demand function for the intermediate goods is obtained from the firm's optimization problem:

$$Y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-v} Y_t. \quad (21)$$

The price of final good is aggregated as follows:

$$P_t = \left(\int_0^1 P_t(j)^{\frac{v-1}{v}} dj \right)^{\frac{v}{v-1}}. \quad (22)$$

A.2 The intermediate-goods producing firms

The representative intermediate-goods firm uses labor ($N_t(j)$) and linear technology (Z_t) to produce differentiated intermediate goods, based on the following production function:

$$Y_t(j) = Z_t N_t(j), \quad (23)$$

where technology (Z_t) is an exogenous shock that evolves as:

$$Z_t = \bar{Z}^{1-\rho_Z} Z_{t-1}^{\rho_Z} \xi_t^Z, \quad (24)$$

where $\rho_z \in (0, 1)$ is the persistent parameter of the technology shock, wherein $\xi_t^z \sim N(0, \sigma_z^2)$ is normally distributed with zero mean and variance σ_z^2 .

The representative intermediate-goods producing firm seeks to minimize the costs:

$$\frac{W_t}{P_t} N_t(j), \quad (25)$$

and is subject to the constraint:

$$Z_t N_t(j) \geq (P_t(j)/P_t)^{-v} Y_t. \quad (26)$$

Using Lagrangian multiplier λ_t , the firm's minimization problem can be written as:

$$L = -\frac{W_t}{P_t} N_t(j) + \lambda_t \left[Z_t N_t(j) - (P_t(j)/P_t)^{-v} Y_t \right]. \quad (27)$$

The following first order condition for N_t is obtained from the firm's minimization problem:

$$\frac{W_t}{P_t} = \lambda_t Z_t. \quad (28)$$

The intermediate-goods producing firms face Calvo (1983) type price stickiness when setting the prices. Each period, only $(1 - \theta)$ fraction of firms change the price, while θ fraction of firms maintain previous period price $(P_{t-1}(j))$. The aggregate price index is below:

$$P_t(j)^{1-v} = \theta (P_{t-1}(j))^{1-v} + (1 - \theta) (P_t^*(j))^{1-v}. \quad (29)$$

The fraction of intermediate-goods producing firms that change the price each period choose $P_t^*(j)$ by maximizing:

$$E_t \sum_{i=0}^{\infty} \theta^i \Delta_{t,t+i} \left[\frac{P_t^*(j)}{P_{t+i}} Y_{t,t+i}(j) - \left(\frac{MC_{t+i}}{P_{t+i}} \right) Y_{t,t+i}(j) \right], \quad (30)$$

and is subject to the demand function of intermediate goods as derived in Equation 21. MC is the firms' real marginal cost derived as $\lambda_t = \frac{W_t/P_t}{Z_t}$ and Δ_t is the stochastic discount factor given as: $\beta^i (c_{t+1}/c_t)^{-\sigma}$.

The following equation for optimal $P_t(j)$ is obtained from the firms' profit maximization problem:

$$\frac{P_t^*}{P_t} = \left(\frac{v}{v-1} \right) \frac{E_t \sum_{i=0}^{\infty} \theta^i \beta^i Y_{t+i} MC_{t+i} \left(\frac{P_{t+i}}{P_t} \right)^v}{E_t \sum_{i=0}^{\infty} \theta^i \beta^i Y_{t+i} \left(\frac{P_{t+i}}{P_t} \right)^{v-1}}. \quad (31)$$

B Conditions for bounded solutions

Following [Leeper \(1991\)](#) and [Leeper and Leith \(2016\)](#), the present study sets out the conditions for the policy parameter values, which determine the existence and uniqueness of the model solution. For simplicity, a simple endowment economy is assumed where $y_t = y$ in every period and $g_t = 0$ (see, e.g., [Leeper and Leith, 2016](#); [Bianchi et al., 2023](#)). Combining the Fisher equation $\left(\frac{1}{R_t} = \beta E_t \left(\frac{1}{\Pi_{t+1}}\right)\right)$ with the monetary rule [Equation 10](#), the following monetary block is obtained, which determines inflation dynamics:

$$E_t \left(\frac{1}{\Pi_{t+1}} / \frac{1}{\Pi} \right) = \left(\frac{1}{\Pi_t} / \frac{1}{\Pi} \right)^{\frac{\alpha_{\Pi}}{\beta}} e^{(\xi_t^R)^{\frac{1}{\beta}}}, \quad (32)$$

where the exponential term $\left(\frac{\alpha_{\Pi}}{\beta}\right)$ determines the bounded solution for inflation.

Similarly, the fiscal block for debt dynamics is obtained by combining the government flow budget and the fiscal rule. From the government budget constraint in [Equation 5](#), the flow budget identity in real terms is follows:

$$\frac{b_t}{R_t} + s_t = \frac{b_{t-1}}{\pi_t}. \quad (33)$$

Combining the flow budget identity in [Equation 33](#) and the steady state fisher equation, the following steady state real primary surpluses is obtained ([Leeper and Leith, 2016](#)):

$$\bar{s} = (\beta^{-1} - 1) \frac{b}{R}. \quad (34)$$

Substituting the fiscal rule in [Equation 9](#) into the flow budget identity, the law of motion of real market value of public debt-to-GDP ratio is derived as:

$$E_t \left(\frac{b_{t+1}}{R_{t+1}y_{t+1}} / \frac{b}{Ry} \right) = \left(\frac{b_t}{R_t y_t} / \frac{b}{Ry} \right)^{(\beta^{-1} - \delta)}, \quad (35)$$

where the exponential term $(\beta^{-1} - \delta)$ determines debt stability for the bounded solution for inflation.

Based on the above and in line with [Leeper and Leith \(2016\)](#), the following conditions apply to the policy parameters under Regime M; Regime F; and the coexistence regime:

1. **Regime M:** active monetary policy when $\frac{\alpha_{\pi}}{\beta} > 1$ and passive fiscal policy when $\beta^{-1} - \delta < 1$, respectively.
2. **Regime F:** passive monetary policy when $\frac{\alpha_{\pi}}{\beta} < 1$ and active fiscal policy when $\beta^{-1} - \delta > 1$, respectively.
3. **Coexistence regime:** For unbacked public debt and the corresponding fiscal inflation, active fiscal policy, namely $\beta^{-1} - \delta^{AF} > 1$ and passive monetary policy, namely $\frac{\alpha_{\pi}^{PM}}{\beta} < 1$. For backed public

debt and the corresponding non-fiscal inflation, passive fiscal policy, namely $\beta^{-1} - \delta^{PF} < 1$ and active monetary policy, namely $\frac{\alpha^{AM}}{\beta} > 1$.

C System of Non-linear model equations - Coexistence regime

The actual economy in the present paper consists of a complete set of non-linear equations for 16 variables, $y_t, N_t, c_t, R_t, w_t, b_t, \Psi_t, s_t, \tau_t, g_t, \Pi_t, P_t^*, d_t, g_{1,t}, g_{2,t}, mc_t$, and 2 stochastic shocks, ξ_t^R, ξ_t^z :

$$y_t = c_t + g_t, \quad (36)$$

$$y_t = \frac{\xi_t^z N_t}{d_t}, \quad (37)$$

$$\Psi_t = y_t - w_t N_t, \quad (38)$$

$$\frac{1}{R_t} = \beta E_t \left[\left(\frac{1 + \tau_t}{1 + \tau_{t+1}} \right) \left(\frac{c_t}{c_{t+1}} \right)^\sigma \left(\frac{1}{\Pi_{t+1}} \right) \right], \quad (39)$$

$$w_t = (1 + \tau_t) \frac{\chi N_t^\eta}{c_t^{-\sigma}}, \quad (40)$$

$$\frac{b_t}{R_t} + \tau_t c_t = \frac{b_{t-1}}{\Pi_t} + g_t, \quad (41)$$

$$g_t = g_{ss} * y_t, \quad (42)$$

$$\frac{s_t}{y_t} = \left(\frac{s}{y} \right) \left(\frac{b_{t-1}}{R_{t-1} y_{t-1}} / \frac{b_{t-1}^f}{R_{t-1} y_{t-1}} \right)^{\delta^{PF}} \left(\frac{b_{t-1}^f}{R_{t-1} y_{t-1}} / \frac{b}{Ry} \right)^{\delta^{AF}}, \quad (43)$$

$$s_t = \tau_t c_t - g_t, \quad (44)$$

$$\frac{1}{R_t} = \left(\frac{1}{R} \right) \left(\frac{1}{\Pi_t} / \frac{1}{\Pi_t^f} \right)^{\alpha^{AM}} \left(\frac{1}{\Pi_t^f} / \frac{1}{\Pi} \right)^{\alpha^{PM}} e^{\xi_t^R}, \quad (45)$$

$$mc_t = \frac{w_t}{\xi_t^z}, \quad (46)$$

$$1 = \theta \Pi_t^{v-1} + (1 - \theta) (P_t^*)^{1-v}, \quad (47)$$

$$d_t = (1 - \theta) (P_t^*)^{-v} + (\theta \Pi_t^v) d_{t-1}, \quad (48)$$

$$P_t^* = \frac{v}{v-1} \frac{g_{1,t}}{g_{2,t}}, \quad (49)$$

$$g_{1,t} = y_t mc_t c_t^{-\sigma} + \theta \beta E_t (\Pi_{t+1})^v g_{1,t+1}, \quad (50)$$

$$g_{2,t} = y_t c_t^{-\sigma} + \theta \beta E_t (\Pi_{t+1})^{v-1} g_{2,t+1}. \quad (51)$$

The exogenous shocks:

$$\log(\xi_t^z) = \rho_z \log(\xi_{t-1}^z) + \epsilon_t^z, \quad (52)$$

$$\xi_t^R = \rho_R \xi_{t-1}^R + \epsilon_t^R. \quad (53)$$

The actual economy is supplemented by a shadow economy that pins down unbacked public debt and

fiscal inflation. The shadow economy consists of a set of non-linear equations for 16 variables, y_t^f , N_t^f , c_t^f , R_t^f , w_t^f , b_t^f , Ψ_t^f , s_t^f , τ_t^f , g_t^f , Π_t^f , P_t^{*f} , d_t^f , $g_{1,t}^f$, $g_{2,t}^f$, mc_t^f , as below:

$$y_t^f = c_t^f + g_t^f, \quad (54)$$

$$y_t^f = \frac{\xi_t^z N_t^f}{d_t^f}, \quad (55)$$

$$\Psi_t^f = y_t^f - w_t^f N_t^f, \quad (56)$$

$$\frac{1}{R_t^f} = \beta E_t \left[\left(\frac{1 + \tau_t^f}{1 + \tau_{t+1}^f} \right) \left(\frac{c_t^f}{c_{t+1}^f} \right)^\sigma \left(\frac{1}{\Pi_{t+1}^f} \right) \right], \quad (57)$$

$$w_t^f = (1 + \tau_t^f) \frac{\chi (N_t^f)^\eta}{(c_t^f)^{-\sigma}}, \quad (58)$$

$$\frac{b_t^f}{R_t^f} + \tau_t^f c_t^f = \frac{b_{t-1}^f}{\Pi_t^f} + g_t^f, \quad (59)$$

$$g_t^f = g_{ss} * y_t^f, \quad (60)$$

$$\frac{s_t^f}{y_t^f} = \left(\frac{s}{y} \right) \left(\frac{b_{t-1}^f}{R_{t-1}^f y_{t-1}^f} / \frac{b}{Ry} \right)^{\delta^{AF}}, \quad (61)$$

$$s_t^f = \tau_t^f c_t^f - g_t^f, \quad (62)$$

$$\frac{1}{R_t^f} = \left(\frac{1}{R} \right) \left(\frac{1}{\Pi_t^f} / \frac{1}{\Pi} \right)^{\alpha^{PM}} e^{\zeta \xi_t^R}, \quad (63)$$

$$mc_t^f = \frac{w_t^f}{\xi_t^z}, \quad (64)$$

$$1 = \theta (\Pi_t^f)^{v-1} + (1 - \theta) (P_t^{*f})^{1-v}, \quad (65)$$

$$d_t^f = (1 - \theta) (P_t^{*f})^{-v} + (\theta (\Pi_t^f)^v) d_{t-1}^f, \quad (66)$$

$$P_t^{*f} = \frac{v}{v-1} \frac{g_{1,t}^f}{g_{2,t}^f}, \quad (67)$$

$$g_{1,t}^f = y_t^f mc_t^f (c_t^f)^{-\sigma} + \theta \beta E_t \left(\Pi_{t+1}^f \right)^v g_{1,t+1}^f, \quad (68)$$

$$g_{2,t}^f = y_t^f (c_t^f)^{-\sigma} + \theta \beta E_t \left(\Pi_{t+1}^f \right)^{v-1} g_{2,t+1}^f. \quad (69)$$

D System of Non-linear Benchmark model equations- standard regimes

Under the two standard regimes, the model economy consists of a set of non-linear equations for 16 variables, $y_t, N_t, c_t, R_t, w_t, b_t, \Psi_t, s_t, \tau_t, g_t, \Pi_t, P_t^*, d_t, g_{1,t}, g_{2,t}, mc_t$, and 2 stochastic shocks, ξ_t^R, ξ_t^z :

$$y_t = c_t + g_t, \quad (70)$$

$$y_t = \frac{\xi_t^z N_t}{d_t}, \quad (71)$$

$$\Psi_t = y_t - w_t N_t, \quad (72)$$

$$\frac{1}{R_t} = \beta E_t \left[\left(\frac{1 + \tau_t}{1 + \tau_{t+1}} \right) \left(\frac{c_t}{c_{t+1}} \right)^\sigma \left(\frac{1}{\Pi_{t+1}} \right) \right], \quad (73)$$

$$w_t = (1 + \tau_t) \frac{\chi N_t^\eta}{c_t^{-\sigma}}, \quad (74)$$

$$\frac{b_t}{R_t} + \tau_t c_t = \frac{b_{t-1}}{\Pi_t} + g_t, \quad (75)$$

$$g_t = g_{ss} * y_t, \quad (76)$$

$$\frac{s_t}{y_t} = \left(\frac{s}{y} \right) \left(\frac{b_{t-1}}{R_{t-1} y_{t-1}} / \frac{b}{R y} \right)^\delta, \quad (77)$$

$$s_t = \tau_t c_t - g_t, \quad (78)$$

$$\frac{1}{R_t} = \frac{1}{R} \left(\frac{1}{\Pi_t} / \frac{1}{\bar{\Pi}} \right)^{\alpha \Pi} e^{(1-\zeta)\xi_t^R}, \quad (79)$$

$$mc_t = \frac{w_t}{\xi_t^z}, \quad (80)$$

$$1 = \theta \Pi_t^{v-1} + (1 - \theta)(P_t^*)^{1-v}, \quad (81)$$

$$d_t = (1 - \theta)(P_t^*)^{-v} + (\theta \Pi_t^v) d_{t-1}, \quad (82)$$

$$P_t^* = \frac{v}{v-1} \frac{g_{1,t}}{g_{2,t}}, \quad (83)$$

$$g_{1,t} = y_t mc_t c_t^{-\sigma} + \theta \beta E_t (\Pi_{t+1})^v g_{1,t+1}, \quad (84)$$

$$g_{2,t} = y_t c_t^{-\sigma} + \theta \beta E_t (\Pi_{t+1})^{v-1} g_{2,t+1}. \quad (85)$$

The exogenous shocks:

$$\log(\xi_t^z) = \rho_z \log(\xi_{t-1}^z) + \epsilon_t^z, \quad (86)$$

$$\xi_t^R = \rho_R \xi_{t-1}^R + \epsilon_t^R. \quad (87)$$

E Data and sources

The following data are obtained from the Federal Reserve Bank of St. Louis (FRED) for the sample period of 1982Q2 to 2022Q4:

Output (y_t): Real GDP: Billions of US dollars, quarterly, seasonally adjusted at annual rate.

Public debt (b_t): Total Federal government debt as a percent of GDP: quarterly, seasonally adjusted.

Federal funds rate (R_t): Effective Federal Funds Rate: percent, quarterly, not seasonally adjusted.

Inflation rate (π_t): Consumer price index all items, annual percent change, quarterly, not seasonally adjusted.

Consumption (c_t): Private final consumption expenditure: Billions of US dollars, quarterly, seasonally adjusted.

The following data are generated:

Government expenditure (g_t): Generated as a percentage of real GDP.

Primary surpluses (s_t): Generated as the difference between tax revenue on consumption and government expenditure.