# Monetary Policy with Partial Fiscal Backing*

Roberto M. Billi
Sveriges Riksbank

Frank Smets
BIS and CEPR

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**Abstract**

We study how the degree of fiscal backing, the share of government debt funded by future primary surpluses, affects macroeconomic stability and welfare in a New Keynesian model with price and wage rigidities. Under a Taylor-type rule, partially unfunded debt improves welfare when the economy is hit by demand or technology shocks; the welfare-optimal unfunded share is about one-third and rises when the zero lower bound (ZLB) binds. A fiscal rule with an automatic stabilizer reinforces these gains when monetary policy is constrained. Under a first-difference rule, the gains from unfunding shrink and can vanish, shifting the optimum toward full funding. The results are shock-dependent: with price-markup disturbances, fully unfunded debt is welfare-optimal, whereas with wage-markup disturbances, fully funded debt is preferred, reflecting differences in the comovement of price and wage inflation across markup shocks. Overall, the welfare-optimal degree of fiscal backing varies with the choice of monetary policy rule, the relevance of the ZLB, and the source of the disturbances.

Keywords: Automatic stabilizer, monetary–fiscal policy interaction, partially unfunded government debt, welfare analysis.

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# 1 Introduction

The recent surge in inflation across advanced economies has renewed interest in the interplay between monetary and fiscal policy. This contrasts with the preceding decade, when many central banks faced persistently low inflation and the re-emergence of the zero lower bound (ZLB) on nominal interest rates. Meanwhile, fiscal authorities faced increasing pressure to support economic stabilization, often resulting in elevated government debt and making future stabilization more challenging.

Against this backdrop, we ask how the degree of fiscal backing, the share of government debt funded by future primary surpluses, shapes macroeconomic stability and welfare. The Fiscal Theory of the Price Level (FTPL) offers a useful perspective on the joint determination of prices and government debt. However, the welfare implications of partial unfunding remain less well understood, particularly across different shock scenarios and policy regimes, including environments where the ZLB binds.

Our goal is to characterize the welfare-optimal degree of fiscal backing—the share of government debt ultimately financed by future primary surpluses—as a function of (i) the monetary policy rule, (ii) the relevance of the ZLB, and (iii) the source of the disturbance. To do so, we vary the unfunded share while holding policy-rule coefficients fixed. This isolates how changes in rule form and fiscal backing reallocate stabilization across inflation and real activity, rather than changes that would arise from re-tuning those coefficients. The key mechanism is that varying the unfunded share shifts the allocation of shock absorption between (i) expected future primary surpluses and (ii) inflation-driven debt revaluation, thereby changing the inflation–output stabilization trade-off under a given monetary-policy rule.

We study this issue in a New Keynesian model with price and wage rigidities, calibrated to standard values and featuring demand, technology, price-markup, and wage-markup shocks; monetary policy may be constrained by the ZLB. The model includes long-term government debt, and the fiscal rule features an automatic stabilizer calibrated to enhance stabilization. We evaluate alternative monetary and fiscal policy rules using the model-implied welfare loss function while varying the share of unfunded debt.

This framework provides a transparent mapping from policy rules to inflation, the output gap, and welfare, which we use to quantify how the degree of fiscal backing should adjust across regimes and shock environments. Our main contribution is normative: we characterize the welfare-optimal degree of fiscal backing as a function of the monetary policy rule, the relevance of the ZLB, and the source of disturbances. Our welfare evaluation complements recent positive and empirical work on partial backing by identifying when partial backing improves welfare and when it does not.

Our analysis yields several key results. Under a Taylor-type rule, allowing a share of government debt to remain unfunded improves welfare when the economy is hit by demand or

technology shocks; the welfare-optimal unfunded share is about one-third and rises when the policy rate is constrained by the ZLB. These gains reflect a better balance between inflation and output stabilization when fiscal and monetary policies share the adjustment burden, particularly when the ZLB binds. They also motivate us to examine a more history-dependent monetary policy rule. As we show, under a first-difference rule, where the policy rate adjusts more gradually over time, the gains from unfunding shrink and can vanish, shifting the optimum toward full funding.

The welfare ranking also depends on the source of inflationary pressure. With price-markup disturbances, policymakers can "look through" inflation more effectively when part of the fiscal adjustment occurs through unfunded debt, making fully unfunded debt optimal. With wage-markup disturbances, the look-through logic is less relevant and fully funded debt is preferred, reflecting differences in the comovement of price and wage inflation across markup shocks. Overall, the welfare-optimal degree of fiscal backing varies with the choice of monetary policy rule, the relevance of the ZLB, and the type of shock hitting the economy. These findings connect to and extend several strands of the existing literature, to which we now turn.

Related literature. This paper contributes to research on monetary–fiscal interactions, building on the FTPL as developed by Leeper (1991), Sims (1994), Woodford (2001), and Cochrane (2001). These foundational works show how regime coordination shapes equilibrium outcomes and anchors the price level. More recently, Leeper and Leith (2016) and Cochrane (2023) offer comprehensive overviews and further theoretical development.

Our modeling approach builds on Galí (2015), providing a standard New Keynesian benchmark for our experiments that ensures transparency and comparability with the literature. We also draw on Billi and Galí (2020) and Billi (2020), which emphasize wage flexibility and the ZLB, and we use these insights to guide how we evaluate monetary policy performance in our framework.

Our work is closely related to recent advances by Cochrane (2022), Bianchi, Faccini, and Melosi (2023), and Smets and Wouters (2024). Cochrane (2022) explores policy shocks in a fiscal-led regime with incomplete fiscal backing. Bianchi, Faccini, and Melosi (2023) develop a fiscal theory of persistent inflation driven by funded and unfunded transfers. Smets and Wouters (2024) provide empirical evidence that partial fiscal backing reshapes the transmission of fiscal and non-fiscal shocks, using a partial-backing framework built on the funded–unfunded decomposition introduced in Bianchi, Faccini, and Melosi (2023). Our focus is normative: we take a welfare perspective and quantify the state-contingent degree of fiscal backing across shock types and monetary rules, both with and without the ZLB.

This paper is also related to recent work by Angeletos, Lian, and Wolf (2026), who study an overlapping-generations version of the New Keynesian model without the ZLB. In their framework, a central bank averse to interest-rate volatility may at times prefer no fiscal ad-

justment, since allowing debt to remain unfunded can dampen policy-rate movements. By contrast, we adopt a social-welfare perspective under the ZLB. Consistent with their mechanism, when interest-rate volatility enters the central bank's objective, the preferred share of unfunded debt rises above the social optimum.

Building on these theoretical and empirical foundations, our paper offers a normative analysis of the optimal extent to which central banks should accommodate unfunded government debt. We systematically quantify the welfare effects of partially unfunded debt across different shock scenarios and policy regimes, with particular attention to the ZLB and the presence of demand, technology, and markup shocks. Unlike previous studies, our framework pins down the optimal share of shock absorption through unfunded debt, providing a systematic basis for policy evaluation and new insights for designing stabilization frameworks in fiscally constrained environments. Together, these findings imply that the welfare-optimal degree of fiscal backing is state-contingent: it depends on the policy rule in place, on whether the ZLB binds, and on the source of the disturbances.

Outline. The paper is organized as follows. Section 2 describes the baseline model and its calibration, including demand and technology shocks and the standard Taylor-type rule. Section 3 presents the main findings. Section 4 analyzes the effects of adopting a first-difference monetary policy rule. Section 5 examines the role of price and wage markup shocks. Section 6 concludes with a summary of the key results and policy implications. The appendices provide robustness checks for alternative policy rules, present the equilibrium conditions for the optimal commitment policy, and consider a central bank averse to interest-rate volatility.

# 2 Baseline Model and Calibration

We employ a New Keynesian model with price and wage rigidities, in which the private sector is subject to demand and technology shocks. Government bonds are long-term, risk-free perpetuities with declining coupons. The fiscal authority's budget constraint permits a variable share of debt to remain unfunded—that is, not backed by future primary surpluses. Policy regimes are formalized through distinct monetary and fiscal rules, and we use the optimal commitment policy as a benchmark for welfare maximization. The model is calibrated to standard values to ensure comparability with the literature and to support a robust welfare analysis. The model period is one quarter, and figures report annualized deviations as indicated.

## 2.1 Private Sector

The private sector is modeled as a closed economy with staggered price and wage setting *à la Calvo* in a standard New Keynesian framework. The model incorporates both demand and technology shocks, which drive fluctuations in output and inflation. As in Galí (2015, chapter

6), all equations are log-linearized around an efficient steady state with zero inflation in prices and wages. Hats on variables denote log deviations (unless explicitly defined otherwise below); natural variables are efficient outcomes absent nominal rigidities.

The supply side of the model is described by the price and wage Phillips curves, along with the dynamics of the real wage gap:

$$\pi_t^p = \beta E_t\{\pi_{t+1}^p\} + \varkappa_p \widetilde{y}_t + \lambda_p \widetilde{\omega}_t \tag{1}$$

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} + \varkappa_w \widetilde{y}_t - \lambda_w \widetilde{\omega}_t \tag{2}$$

$$\widetilde{\omega}_t \equiv \widetilde{\omega}_{t-1} + \pi_t^w - \pi_t^p - \Delta\hat{\omega}_t^n, \tag{3}$$

where $\pi_t^p$ and $\pi_t^w$ denote price and wage inflation, respectively, while $\widetilde{y}_t$ and $\widetilde{\omega}_t$ represent the output and real wage gaps; $\Delta$ denotes the first-difference operator. These gaps are defined as deviations from their respective natural levels in the absence of nominal rigidities: $\widetilde{y}_t \equiv \hat{y}_t - \hat{y}_t^n$ and $\widetilde{\omega}_t \equiv \hat{\omega}_t - \hat{\omega}_t^n$. The natural output and wage reflect shifts in technology, with $\hat{y}_t^n \equiv \psi_{ya} a_t$ and $\hat{\omega}_t^n \equiv \psi_{\omega a} a_t$.[1]

On the demand side, the model features a dynamic IS equation:

$$\widetilde{y}_t = E_t\{\widetilde{y}_{t+1}\} - \frac{1}{\sigma}\left(\hat{\imath}_t - E_t\{\pi_{t+1}^p\} - \hat{r}_t^n\right), \tag{4}$$

where $\hat{\imath}_t \equiv i_t - \rho$ is the nominal interest rate deviation from steady state, and $\rho \equiv 1/\beta - 1 > 0$ is the discount rate. The natural rate of interest, $\hat{r}_t^n$, is a function of both demand and technology shocks: $\hat{r}_t^n \equiv (1-\rho_z) z_t - \sigma\,(1-\rho_a)\,\psi_{ya} a_t$. The demand and technology shocks, $z_t$ and $a_t$, are modeled as independent $AR(1)$ processes with autoregressive coefficients $\rho_z$ and $\rho_a$, reflecting persistent fluctuations.

Model parameters include the Calvo indices for price and wage rigidity ($\theta_p$ and $\theta_w$), elasticities of substitution ($\epsilon_p$ and $\epsilon_w$), the degree of decreasing returns to labor ($\alpha$), the discount factor ($\beta$), risk aversion ($\sigma$), and labor disutility ($\varphi$). We calibrate these parameters to standard values in Section 2.6 to ensure comparability with the literature (Billi and Galí, 2020; Billi, 2020).

## 2.2 Government Budget with Long-Term Debt

The fiscal authority issues long-term, risk-free bonds. Following Woodford (2001), these bonds are modeled as perpetuities, with coupon payments that decline at a rate $\eta \in [0,1]$ each period. The government's budget constraint and the bond-arbitrage condition are log-linearized

[1] In addition, the slope coefficients in the Phillips curves are $\varkappa_p \equiv \lambda_p\left(\frac{\alpha}{1-\alpha}\right)$ and $\varkappa_w \equiv \lambda_w\left(\sigma + \frac{\varphi}{1-\alpha}\right)$, where $\lambda_p \equiv \frac{(1-\theta_p)(1-\beta\theta_p)(1-\alpha)}{\theta_p(1-\alpha+\alpha\epsilon_p)}$ and $\lambda_w \equiv \frac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w(1+\epsilon_w\varphi)}$. The coefficients for the natural output and wage are $\psi_{ya} \equiv \frac{1+\varphi}{\sigma(1-\alpha)+\varphi+\alpha}$ and $\psi_{\omega a} \equiv \frac{\sigma+\varphi}{\sigma(1-\alpha)+\varphi+\alpha}$, respectively.

around a steady state with no trend growth and zero inflation, providing a tractable description of fiscal dynamics.[2]

Thus, the fiscal side of the model is described by the flow budget constraint and the arbitrage condition for government debt:

$$\hat{b}_t = \beta^{-1}\hat{b}_{t-1} + b\beta^{-1}\left(\eta\beta\hat{Q}_t - \hat{Q}_{t-1} - \pi_t^p\right) - \hat{\tau}_t \tag{5}$$

$$\hat{\imath}_t = \eta\beta E_t\left\{\hat{Q}_{t+1}\right\} - \hat{Q}_t, \tag{6}$$

where $\hat{b}_t \equiv (B_t - B)/Y$ and $\hat{\tau}_t \equiv (T_t - T)/Y$ are the real market value of government debt and the tax revenue, measured as deviations from steady state and normalized by output. $B_t$ is measured in real terms (deflated by the price level), and $Y$ is steady-state output used for normalization. In this framework, $\hat{\tau}_t$ is equal to the primary surplus, because government spending is omitted. Taxes are assumed to be non-distortionary, meaning they raise revenue without creating inefficiencies in resource allocation.[3]

Regarding the government's liabilities and maturity structure, the debt-to-GDP target is $b \equiv B/Y$. The percent deviation of the ex-dividend bond price is $\hat{Q}_t \equiv (Q_t - Q)/Q$, where $Q \equiv \beta/(1-\eta\beta)$. The average duration of the bond is $1/(1-\eta\beta)$ and rises with $\eta$, reflecting the long-term nature of government debt. The debt target and bond duration are calibrated to recent U.S. data, as described in Section 2.6.

## 2.3 Fiscal-Led Shadow Economy

We extend the model to allow government debt to be only partially backed by future primary surpluses. Such situations arise when fiscal authorities cannot credibly commit to fully repaying debt through future tax increases or spending cuts. In these cases, monetary policy must accommodate part of the fiscal burden. Following Bianchi, Faccini, and Melosi (2023) and Smets and Wouters (2024), we represent partial fiscal backing by decomposing equilibrium dynamics into a funded component—stabilized through future primary surpluses—and an unfunded component that is stabilized through inflation via debt revaluation.

Accordingly, we introduce a shadow-economy block that serves as an accounting device tracking the unfunded component of debt and the associated fiscal-led variables. The shadow (counterfactual) block represents the fiscal-led regime, while the observed economy represents

[2] Government debt issuance reflects rollover of the existing stock, real interest costs, and the primary surplus (revenues net of non-interest outlays). Under no-arbitrage, the bond-pricing condition links the ex-dividend price to the short-term rate so that expected returns equal the risk-free rate.

[3] This assumption abstracts from distortionary financing and prevents fiscal adjustments from affecting inflation through additional distortions. With distortionary taxation (or alternative fiscal instruments), surplus adjustment becomes welfare-relevant and may alter inflation dynamics. We abstract from these channels to focus on the interaction between monetary policy rules and fiscal backing through debt revaluation.

the monetary-led regime.[4] Formally, we replicate equations (1)–(6), adding a superscript "$F$" to all variables to indicate the fiscal-led regime. We introduce the parameter $\gamma \in [0, 1]$ as the share of unfunded debt; in the fiscal-led regime it multiplies each shock ($z_t$ and $a_t$), thereby determining the fraction of each shock absorbed by unfunded debt.[5] The funded share is $1-\gamma$. When $\gamma = 0$, the regime is monetary-led (full fiscal backing); when $\gamma = 1$, it is fiscal-led (no fiscal backing). Intermediate values of $\gamma$ correspond to partial fiscal backing, enabling a flexible mix of fiscal and monetary responses to shocks.

In our experiments, $\gamma$ is a reduced-form measure of the degree of fiscal backing: it governs how much of each disturbance is absorbed by the unfunded (fiscal-led) component of debt dynamics, with the remainder absorbed by the funded component stabilized through future primary surpluses. Thus, varying $\gamma$ shifts the allocation of shock absorption between debt revaluation and surplus adjustment, holding the policy-rule coefficients fixed, rather than re-estimating or re-optimizing the policy rules.

In practical terms, higher $\gamma$ can be interpreted as reflecting weaker fiscal backing—for example, a lower perceived ability or willingness of fiscal authorities to generate future primary surpluses in response to shocks—so that a larger share of adjustment occurs through debt revaluation. Conversely, lower $\gamma$ corresponds to stronger fiscal backing, with a larger share of adjustment implemented through expected future surpluses under the fiscal rule. More formally, $\gamma$ parameterizes the share of each shock that is accommodated via inflation-driven debt revaluation versus via surplus adjustment, holding the underlying monetary and fiscal rules fixed.

The model thus consists of equations (1)–(6) for the monetary-led observed economy, alongside their counterparts with superscript "$F$" and shocks multiplied by parameter $\gamma$ in the fiscal-led shadow economy. In the analysis that follows, we systematically vary $\gamma$ to investigate the welfare-optimal degree of shock absorption through unfunded debt. Next, we specify the policy rules that govern the behavior of both the shadow and observed economies.

## 2.4 Policy Rules under the ZLB

We now present the policy rules that distinguish the shadow and observed economies within our framework. In particular, we highlight how the fiscal rule incorporates an automatic stabilizer, designed to enhance the economy's response to shocks in regimes where monetary

[4] Building on Bianchi, Faccini, and Melosi (2023), the shadow economy is an accounting device that tracks the unfunded component of debt and its implied fiscal-led variables, which enter the monetary-led policy rules as time-varying targets. Smets and Wouters (2024) extend this approach to intermediate (partial) fiscal backing and apply it more broadly across business cycle shocks beyond transfers.

[5] For example, in the model's shadow-economy block, the counterpart to the dynamic IS equation (4) is $\widetilde{y}_t^F = E_t\{\widetilde{y}_{t+1}^F\} - \frac{1}{\sigma}\left(\hat{\imath}_t^F - E_t\{\pi_{t+1}^{pF}\} - \gamma \hat{r}_t^n\right)$. Hence parameter $\gamma$ scales the transmission of shocks through the natural rate (and other shock-driven natural variables where relevant). Expectations $E_t$ are taken with respect to the joint system; the shadow and observed blocks are solved consistently.

policy must accommodate unfunded government debt.

In the *fiscal-led shadow economy*, we assume a policy configuration in which monetary policy is passive—the nominal interest rate is pegged at its steady-state value—while fiscal policy is active in the sense that the primary surplus does not systematically adjust to stabilize government debt (Leeper, 1991). In this regime, debt is effectively unfunded and inflation provides the main mechanism for returning debt toward its target through inflation-driven revaluation rather than through changes in taxes or spending.[6] The following policy rules formalize these assumptions:

$$\hat{\imath}_t^F = 0 \tag{7}$$

$$\hat{\tau}_t^F = \psi_\tau \hat{\tau}_{t-1}^F + (1-\psi_\tau)\,\psi_y \widetilde{y}_t^F, \tag{8}$$

where $\psi_\tau$ controls how gradually the primary surplus adjusts over time. The parameter $\psi_y$ measures the strength of the automatic stabilizer in the fiscal rule by determining how strongly the primary surplus responds to the output gap. The value of this parameter is calibrated to maximize welfare in the fiscal-led regime, as discussed in Section 2.6, ensuring that fiscal policy provides effective stabilization in regimes where monetary policy must accommodate unfunded debt.

In the *monetary-led observed economy*, we assume a policy configuration in which monetary policy is active—the interest-rate rule satisfies the Taylor principle—while fiscal policy is passive in the sense that the primary surplus adjusts to stabilize government debt. In this regime, monetary policy follows a standard Taylor-type rule subject to the zero lower bound (ZLB) on nominal interest rates, and fiscal actions are subordinated to maintaining debt sustainability. The corresponding policy rules are:

$$\hat{\imath}_t = \max\left[-\rho, \hat{\imath}_t^*\right] \tag{9}$$

$$\hat{\imath}_t^* = \phi_i \hat{\imath}_{t-1}^* + (1-\phi_i)\left[\phi_p^M\left(\pi_t^p - \pi_t^{pF}\right) + \phi_y^M\left(\widetilde{y}_t - \widetilde{y}_t^F\right)\right] \tag{10}$$

$$\hat{\tau}_t = \psi_\tau \hat{\tau}_{t-1} + (1-\psi_\tau)\left[\psi_b^M\left(\hat{b}_{t-1} - \hat{b}_{t-1}^F\right) + \psi_y \widetilde{y}_t\right], \tag{11}$$

where $\phi_i$ is the smoothing coefficient for the unconstrained nominal interest rate ($i_t \equiv \hat{\imath}_t + \rho \geq 0$, so when $\hat{\imath}_t^* \leq -\rho$ the ZLB binds and $\hat{\imath}_t = -\rho$). The parameters $\phi_p^M$ and $\phi_y^M$ govern how monetary policy responds to the funded part of fluctuations in price inflation and the output gap; $\pi_t^{pF}$ and $\widetilde{y}_t^F$ are time-varying targets reflecting the unfunded part of fluctuations, determined

[6] This standard characterization of policy rules in a fiscal-led economy is not essential for our results. Appendix A allows monetary policy to lean against fiscal inflation (so that $\hat{\imath}_t^F$ responds to $\pi_t^{pF}$), which reduces the desirability of unfunded debt relative to the baseline. Appendix B allows fiscal policy to lean against unfunded debt (so that $\hat{\tau}_t^F$ responds to $\hat{b}_{t-1}^F$); with the automatic stabilizer in the fiscal rule, this modification leaves the desirability of unfunded debt essentially unchanged.

endogenously in the fiscal-led shadow economy. Similarly, $\psi_b^M > \rho$ governs the responsiveness of fiscal policy to changes in the funded part of government debt.[7] The calibration of these policy-rule coefficients to standard values is described in Section 2.6.

Two remarks follow. First, we do not include fiscal or monetary policy shocks in the policy rules, because their implications for the welfare-optimal $\gamma$ are straightforward. With non-distortionary taxes, fiscal shocks are fully absorbed by funded debt, so $\gamma = 0$ is optimal when facing fiscal shocks. Under the nominal interest-rate peg in equation (7), monetary shocks are absent in the fiscal-led block, so $\gamma = 1$ is optimal when facing monetary shocks. Second, under the same nominal interest-rate peg in equation (7), the welfare-optimal $\gamma$ does not depend on the duration of government debt.[8] Robustness checks for alternative rules are provided in the appendices.

In sum, partial fiscal backing changes how the economy is stabilized by monetary and fiscal policy by altering how government debt is stabilized over time. With a small share of unfunded debt, future primary surpluses do most of the work in returning debt toward its target. With a large unfunded share, inflation plays a more important role through debt revaluation. This shift in funding affects the balance between inflation stabilization and output-gap stabilization, especially when the ZLB limits monetary policy. We now turn to the welfare criterion used to evaluate these policy regimes.

## 2.5 Welfare Loss Analysis and Optimal Commitment

A central objective of this analysis is to assess the welfare implications of partial fiscal backing for monetary policy. Following Galí (2015), we employ a second-order approximation to the welfare loss experienced by the representative household, calculated as deviations from an efficient steady state with zero inflation and expressed as a fraction of steady-state consumption. This approach allows us to capture the effects of fluctuations in key variables on welfare in a tractable way.

This welfare loss function is defined as:

$$\mathbb{L} = \frac{1}{2}\left[\left(\sigma + \frac{\varphi + \alpha}{1-\alpha}\right) var\left(\widetilde{y}_t\right) + \frac{\epsilon_p}{\lambda_p} var\left(\pi_t^p\right) + \frac{\epsilon_w(1-\alpha)}{\lambda_w} var\left(\pi_t^w\right)\right], \tag{12}$$

where the welfare loss comprises three weighted components, each capturing the unconditional variance under the policy-induced stationary distribution of the output gap, price inflation,

[7] The government budget and the fiscal rule, equations (5) and (11), imply that debt dynamics in the observed economy, $\hat{b}_t$, are governed by $\left(\beta^{-1} - \psi_b^M\right)\hat{b}_{t-1}$. Stability therefore requires $\beta^{-1} - \psi_b^M < 1$, or equivalently, $\psi_b^M > \beta^{-1} - 1 \equiv \rho$.

[8] Specifically, in the fiscal-led regime under the nominal interest-rate peg, the government budget and the bond-arbitrage condition, equations (5) and (6), pin down the ex-dividend bond price at its steady state, $\hat{Q}_t^F = \hat{\imath}_t^F = 0$ for all $t$. Thus, $\hat{b}_t^F$ is independent of $\eta$, which implies that the duration of government debt does not affect the outcomes of our baseline model.

and wage inflation. This structure allows a detailed evaluation of how different policy regimes shape both overall welfare loss and its components.

To evaluate the performance of the proposed monetary and fiscal policy rules, we examine welfare outcomes across different degrees of fiscal backing. In particular, we vary the parameter $\gamma \in [0, 1]$, which determines the share of unfunded government debt, holding the underlying monetary and fiscal rule coefficients fixed. Thus, varying $\gamma$ traces out how welfare changes as the economy shifts the burden of adjustment between future primary surpluses (funded component) and inflation-driven debt revaluation (unfunded component).

We compare these welfare outcomes with those obtained under the optimal commitment policy, which is independent of $\gamma$ because taxes are non-distortionary in our setting.[9] Since financing is non-distortionary, this benchmark abstracts from the welfare costs of raising primary surpluses and should be viewed as an upper bound on attainable welfare under simple policy rules, rather than a directly implementable policy. This serves as a theoretical benchmark for welfare maximization under the model's constraints. For context, the optimal commitment policy represents the best possible outcome achievable if policymakers could fully commit to future actions, without being constrained by the limitations of simple, rule-based policies.

## 2.6 Baseline Calibration

The simulations reported in the next sections use the baseline parameter values summarized in Table 1. For the private sector, we set the discount factor $\beta = 0.995$, implying a steady-state real interest rate of 2 percent per year ($\rho \equiv 1/\beta - 1 \approx 0.005$). We set $\sigma = 1$, $\varphi = 5$, $\alpha = 0.25$, $\epsilon_p = 9$ and $\epsilon_w = 4.5$. Setting $\theta_p = \theta_w = 0.75$ implies an average duration of price and wage spells of one year (four quarters in the model, $1/(1-\theta_p) = 1/(1-\theta_w) = 4$).

Turning to the government budget with long-term debt, the debt target and bond duration are calibrated to recent U.S. data. We use U.S. values as a convenient benchmark; the qualitative mechanisms we highlight do not hinge on any particular jurisdiction. We set $b = 4$ so the annualized debt-to-GDP target is 100 percent ($b/4 = B/(4Y) = 1$ in the model). Setting $\eta = 0.955$ implies an average duration of government debt of five years (twenty quarters in the model, $1/(1-\eta\beta) \approx 20$).

For the monetary and fiscal rules, we set the smoothing coefficients $\phi_i = \psi_\tau = 0.85$. We adopt $\phi_p^M = 1.5$ and $\phi_y^M = 0.125$ for the active monetary-policy response to the funded part of fluctuations in price inflation and the output gap. We set $\psi_b^M = 0.1$ (which satisfies $\psi_b^M > \rho$)

[9] Because taxes are assumed to be non-distortionary, the government budget and bond-pricing conditions do not constrain the optimal allocation. The commitment policy is therefore independent of $\gamma$, and fiscal policy can fully stabilize government debt. The corresponding equilibrium conditions under the ZLB are given in Appendix C.

for the passive fiscal-policy response to changes in the funded part of debt.[10]

We calibrate the demand and technology shocks ($z_t$ and $a_t$) so that, in the baseline with fully funded debt ($\gamma = 0$), each shock on its own makes the ZLB bind about 20 percent of the time.[11] We set the autoregressive coefficients $\rho_z = \rho_a = 0.8$ to generate persistence. This calibration implies quarterly standard deviations of the shocks $\sigma_z = 9.7\%$ and $\sigma_a = 7.4\%$. As Figure 1 shows, increasing the share of unfunded debt $\gamma$ reduces the frequency of ZLB episodes—as monetary policy accommodates the unfunded component—but at the cost of reduced monetary-policy flexibility.[12] Accordingly, in our welfare comparisons across $\gamma$, the ZLB frequency varies endogenously rather than being held fixed. Hence welfare differences across $\gamma$ reflect both the economic effects when the ZLB binds and changes in the incidence of ZLB episodes.

Lastly, we set the automatic stabilizer in the fiscal rule $\psi_y = 1$ to maximize welfare in the fiscal-led regime ($\gamma = 1$). Figure 2 displays, for each shock on its own, the welfare loss and its components over a range of values for $\psi_y$ and shows how the welfare-optimal value of $\psi_y$ balances the gains from stabilizing the output gap against the costs of amplifying inflation. In addition, Figure 3 shows that setting the debt-to-GDP target $b = 4$ maximizes welfare by dampening inflation in the fiscal-led regime, where inflation serves as the main channel for returning debt toward its target through revaluation.

Overall, our calibration is chosen to ensure that fiscal policy provides effective stabilization in the fiscal-led regime, namely when monetary policy must accommodate unfunded debt. By anchoring key fiscal parameters in the fiscal-led regime, this calibration helps us isolate the underlying stabilization mechanisms and supports a robust welfare analysis. With the baseline calibration in place, we now present the model's stochastic-simulation results.

# 3 Welfare Effects of Partially Unfunded Debt

This section examines the macroeconomic effects of partially unfunded debt. We first analyze dynamic responses to demand and technology shocks under different fiscal-backing scenarios, highlighting how the unfunded share influences inflation, output, and other key variables. We

[10] With this passive fiscal rule, any increase in debt above target in the observed economy decays by about one-third over one year (four quarters), absent further deficits. Specifically, with $\beta = 0.995$ and $\psi_b^M = 0.1$, the government budget (5) implies $\left(\beta^{-1} - \psi_b^M\right)^4 \approx 0.67$.

[11] We target a non-trivial but not dominant ZLB incidence so that the lower bound is quantitatively relevant in the simulations. For reference, the U.S. policy rate was at the ZLB from December 2008 to December 2015. The results for the case without the ZLB constraint, reported later, provide a zero-incidence benchmark; alternative incidence targets can be implemented by rescaling shock volatility and may affect quantitative welfare comparisons.

[12] Intuitively, accommodating the unfunded component of debt ($\gamma$) shifts part of the adjustment into inflation and debt revaluation, reducing the policy-rate cut needed after adverse demand-type shocks and thereby lowering the incidence of ZLB episodes.

then turn to welfare, showing how varying the unfunded share affects overall social welfare and its components, both with and without the ZLB. Together, these results clarify the stabilization role of unfunded debt across regimes and shock environments. Varying the unfunded share changes how shocks are absorbed—more through future primary surpluses when backing is high, and more through inflation via debt revaluation when backing is low.

To highlight the mechanism, we first examine how the economy responds to shocks under different fiscal-backing scenarios. Figures 4 and 5 show the economy's responses to a negative demand shock and a positive technology shock, respectively, both of which reduce inflation, the output gap, and the nominal interest rate. With fully funded debt ($\gamma = 0$) and the ZLB in place, inflation declines the most, reflecting the strong downward pressure on the economy in a regime where fiscal policy adjusts the primary surplus to stabilize debt. At the other extreme, when debt is fully unfunded ($\gamma = 1$), inflation overshoots because monetary policy accommodates the debt adjustment, so inflation becomes the primary mechanism for returning debt toward its target. These two limiting cases illustrate that neither extreme delivers satisfactory inflation stabilization in the face of shocks that exert downward pressure on inflation.

A more balanced outcome arises under partial fiscal backing. With partially unfunded debt (for example $\gamma = 0.5$), the responses of inflation in Figures 4 and 5 lie between the two extremes. Inflation falls by less than in the fully funded case but avoids the overshooting observed when debt is fully unfunded. This intermediate response reflects that, with partial fiscal backing, fiscal and monetary policy share the adjustment burden. As a result, inflation is more stable and the output gap is better supported. This improved balance between stabilizing inflation and supporting economic activity implies that partial fiscal backing can be welfare-enhancing when the economy is hit by demand or technology shocks. These dynamics suggest that partial fiscal backing can improve stabilization performance; we quantify this trade-off in welfare terms.

We examine how the share of unfunded debt affects social welfare. Figure 6 summarizes the welfare loss from fluctuations in the economy, computed using the loss function (12), for different values of $\gamma$ ranging from zero to one, both with and without the ZLB. The figure reports welfare outcomes for demand shocks ($z_t$) and technology shocks ($a_t$), and in both cases an intermediate share of unfunded debt minimizes the welfare loss. Without the ZLB, the welfare-optimal value of $\gamma$ is about 0.3. With the ZLB, the optimal $\gamma$ rises to about 0.4, because the ZLB constrains policy-rate adjustment and creates more room for fiscal policy to help stabilize both inflation and economic activity.[13]

[13] Appendix D shows that when the central bank's objective penalizes policy-rate volatility—with the same weight as price-inflation volatility—the preferred share of unfunded debt rises above the social optimum. Under the Taylor rule without the ZLB, the preferred value of $\gamma$ shifts from 0.3 (under the welfare loss function) to about 0.7. Allowing some debt to remain unfunded therefore limits policy-rate volatility, which the objective penalizes.

To understand the sources of these welfare improvements in more detail, Figure 7 decomposes the welfare loss into its three components (reflecting the volatility of the output gap, price inflation, and wage inflation) and helps explain why an intermediate share of unfunded debt performs best. Partial fiscal backing reduces inflation volatility relative to the fully funded case, and this improvement is more pronounced with the ZLB. By contrast, partial fiscal backing reduces output-gap volatility only when monetary policy is constrained by the ZLB; without the ZLB, this reduction does not occur. This combination of effects explains why welfare is highest at an intermediate value of $\gamma$ in both model environments.

Varying $\gamma$ shifts how the economy absorbs shocks between (i) future primary surpluses that stabilize the funded component of debt and (ii) inflation-driven debt revaluation that stabilizes the unfunded component. With fully funded debt ($\gamma = 0$), fiscal adjustment relies more on surpluses, so adverse demand-type shocks translate into larger declines in inflation and the output gap when monetary policy is constrained by the ZLB. With fully unfunded debt ($\gamma = 1$), adjustment occurs largely through debt revaluation, which stabilizes activity but makes inflation the primary margin of adjustment and can generate overshooting and higher inflation volatility.

Mechanism. An intermediate degree of unfunding allows fiscal and monetary policy to share the adjustment burden. It reduces the need for large policy-rate cuts, lowering the likelihood that the ZLB binds, and thus muting the fall in inflation following these shocks. At the same time, it prevents inflation-driven debt revaluation from becoming the sole adjustment margin for returning debt toward its target, curbing excessive inflation volatility. This is why the welfare loss is minimized at an interior $\gamma$ in Figure 6 and why the decomposition in Figure 7 points to a balance between inflation and output-gap stabilization.

Overall, the welfare results show that allowing some part of debt to remain unfunded improves macroeconomic stability and raises welfare, particularly when monetary policy is constrained by the ZLB. Figures 6 and 7 also display welfare under the optimal commitment policy (Appendix C), which serves as a theoretical benchmark and delivers lower welfare losses than the simple policy rules considered here. This naturally motivates the next step: assessing how these findings change when monetary policy becomes more history-dependent.

# 4 First-Difference Monetary Policy Rule

When monetary policy follows a more history-dependent rule, the role and desirability of unfunded debt can change significantly. We now replace the standard Taylor-type rule with a first-difference rule and study how this alternative policy rule affects macroeconomic stability and welfare, both with and without the ZLB. This approach allows us to assess how the history-dependence of monetary policy interacts with fiscal backing and to identify under

what conditions unfunded debt remains a useful stabilization tool.

The first-difference rule changes the way monetary policy responds to economic fluctuations. It is more inertial in the short run, smoothing policy adjustments, while over time it can become more persistent because it sets the change in the policy rate in response to inflation and output growth rather than to their levels. This implies that the central bank responds differently to shocks, potentially altering the welfare benefits of unfunded debt identified in the previous section. Because the first-difference rule makes monetary policy more history-dependent, the gains from sharing the adjustment burden through unfunded debt can shrink, especially when the ZLB binds.

To carry out this analysis, we replace the Taylor rule (10) with the first-difference rule in the monetary-led observed economy, while keeping the policy rules of the fiscal-led shadow economy unchanged. We adopt the following first-difference monetary policy rule:

$$\Delta\hat{\imath}_t^* = \phi_p^M \left(\pi_t^p - \pi_t^{pF}\right) + \phi_y^M \left(\Delta\hat{y}_t - \Delta\hat{y}_t^F\right), \tag{13}$$

where the response parameters $\phi_p^M$ and $\phi_y^M$ are kept at their baseline values. We keep these response coefficients fixed so that the comparison isolates rule form (levels versus differences) rather than a re-optimized parameterization. Unlike the Taylor rule, which sets the level of the policy rate based on inflation and the output gap, the first-difference rule sets the change in the policy rate in response to inflation and output growth (each measured relative to their fiscal-led counterparts). This alternative policy rule can change the welfare-optimal degree of fiscal backing.

We now examine how adopting this first-difference rule affects the welfare benefits of unfunded debt. Figure 8 illustrates the welfare implications of using the first-difference rule in place of the Taylor rule. For direct comparison, it replicates the Taylor-rule outcomes for demand shocks ($z_t$) and technology shocks ($a_t$), as previously reported in Figure 6. Because the response coefficients are held fixed across the two rules, the differences in Figure 8 reflect the change in rule form rather than a re-optimized monetary-policy parameterization. Under the first-difference rule, the welfare benefits of unfunded debt diminish substantially, both with and without the ZLB. The welfare-optimal share of unfunded debt shifts toward zero ($\gamma = 0$), namely toward full funding, so a regime with fully funded debt delivers the highest welfare in this setting.

The *mechanism* is straightforward. This shift toward full funding under the first-difference rule reflects the increased ability of monetary policy to stabilize inflation and the output gap when it responds more persistently over time to changes in economic conditions. In effect, a more history-dependent monetary policy internalizes part of the stabilization role that partially unfunded debt played under the Taylor rule, shifting the adjustment burden back toward monetary policy and away from inflation-driven debt revaluation. As a result,

there is less to be gained from sharing the adjustment burden through unfunded debt—and it can even be undesirable—when monetary policy is sufficiently strong under this rule.

Overall, these results underscore how monetary policy performance shapes the optimal degree of fiscal backing. These insights help clarify how the interaction between monetary and fiscal policy changes in the presence of markup disturbances, which we examine in the next section.

# 5 Effects of Price and Wage Markup Shocks

Having examined how partially unfunded debt affects welfare when the economy is driven by demand and technology shocks, we next study markup disturbances, which sharpen the inflation–output trade-off underlying the welfare results. We first evaluate how unfunded debt affects welfare when inflation is shaped by price- or wage-markup shocks, and then assess how the economy responds to these shocks under different monetary policy rules. This analysis clarifies how unfunded debt serves as a stabilization tool when inflationary pressures arise from shifts in pricing and wage-setting behavior rather than from fluctuations in aggregate demand or technology.

We extend the model to include shocks to desired price and wage markups. In particular, the price and wage Phillips curves in equations (1) and (2) are replaced by the modified expressions (magenta terms indicate the introduced markup shocks):

$$\pi_t^p = \beta E_t\{\pi_{t+1}^p\} + \varkappa_p \widetilde{y}_t + \lambda_p \widetilde{\omega}_t + u_t \tag{14}$$

$$\pi_t^w = \beta E_t\{\pi_{t+1}^w\} + \varkappa_w \widetilde{y}_t - \lambda_w \widetilde{\omega}_t + v_t, \tag{15}$$

where $u_t$ and $v_t$ denote price and wage markup shocks, respectively, which are modeled as independent $AR(1)$ processes.[14] We calibrate these shocks by setting the autoregressive coefficients $\rho_u = \rho_v = 0.8$ to generate persistence. The standard deviations are set to $\sigma_u = \sigma_v = 0.06\%$ so that markup shocks produce meaningful movements in inflation and the output gap while remaining small enough that the ZLB does not bind. Accordingly, the results in this section isolate how partial fiscal backing affects the inflation–output trade-off under markup shocks, without conflating that mechanism with changes in ZLB incidence.

With these markup disturbances introduced into the model, we revisit the desirability of unfunded debt under different monetary policy rules. Figure 9 illustrates the welfare implications of using the first-difference rule in place of the Taylor rule, with the left panel showing

[14] In the fiscal-led block, the parameter $\gamma$ scales the markup shocks $u_t$ and $v_t$ in the counterparts to the Phillips curves (14) and (15). Thus, $\gamma$ determines the fraction of each markup shock absorbed by unfunded debt and scales the transmission of markup disturbances in that block.

outcomes for price-markup shocks ($u_t$) and the right panel presenting the corresponding outcomes for wage-markup shocks ($v_t$). When facing price-markup shocks, funded debt raises the welfare loss relative to unfunded debt, and the first-difference rule amplifies this increase. By contrast, wage-markup shocks reverse this ranking. As a result, under both monetary policy rules, fully unfunded debt ($\gamma = 1$) is welfare-optimal for price-markup shocks, whereas fully funded debt ($\gamma = 0$) is optimal for wage-markup shocks.

These opposite welfare rankings reflect differences in the comovement of price and wage inflation across markup shocks, which helps determine when policymakers can "look through" inflation without inducing large real fluctuations. Here, "looking through" means allowing markup-driven movements in inflation to pass through temporarily when stabilizing them aggressively would require large output-gap fluctuations (and associated movements in wage inflation) that are costly in the welfare loss. Thus, unfunded debt can improve welfare by allowing monetary policy to accommodate temporary price-markup pressures without inducing excessive real fluctuations.

To illustrate the *mechanism* behind the welfare rankings, Figure 10 plots the economy's responses to a negative price- or wage-markup shock under the Taylor rule and the first-difference rule. With fully funded debt ($\gamma = 0$), both shocks create a trade-off between stabilizing price inflation and the output gap. When facing either type of markup shock, the stronger reaction of the first-difference rule dampens price-inflation volatility but increases output-gap volatility. Because raising the output gap puts upward pressure on wage inflation, the first-difference rule also makes wage inflation more volatile under price-markup shocks but less volatile under wage-markup shocks. These differences in the comovement of price and wage inflation across markup shocks help explain the opposite welfare rankings in Figure 9.

In summary, the desirability of unfunded debt depends critically on the source of the disturbances. While the earlier sections showed that unfunded debt can be beneficial in the presence of demand and technology shocks, its role is much more nuanced when inflation is driven by markup disturbances. In particular, unfunded debt can help monetary policy accommodate price-markup shocks, but it is generally less desirable when inflation arises from wage-markup pressures. These differences underscore the importance of tailoring the monetary–fiscal policy mix to the source of the disturbances. We conclude by summarizing the main welfare lessons across policy rules and shock environments and discussing their implications for the design of stabilization frameworks.

# 6 Conclusion

TBA

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| Parameter | Description | Value |
|---|---|---|
| $\beta$ | Discount factor | 0.995 |
| $\sigma$ | Curvature of consumption utility | 1 |
| $\varphi$ | Curvature of labor disutility | 5 |
| $\alpha$ | Index of decreasing returns to labor | 0.25 |
| $\epsilon_p$ | Elasticity of substitution of goods | 9 |
| $\epsilon_w$ | Elasticity of substitution of labor | 4.5 |
| $\theta_p$ | Calvo index of price rigidities | 0.75 |
| $\theta_w$ | Calvo index of wage rigidities | 0.75 |
| | | |
| $\gamma$ | Share unfunded debt (baseline fully funded) | 0 |
| $b$ | Debt-to-GDP target (100% of annualized GDP) | 4 |
| $\eta$ | Bond coupon decay rate (duration 5 years) | 0.955 |
| | | |
| $\phi_i$ | Smoothing coefficient in Taylor rule | 0.85 |
| $\phi_p^M$ | Monetary response to price inflation | 1.5 |
| $\phi_y^M$ | Monetary response to output gap | 0.125 |
| $\psi_\tau$ | Smoothing coefficient in fiscal rule | 0.85 |
| $\psi_b^M$ | Fiscal response to debt | 0.1 |
| $\psi_y$ | Fiscal response to output gap | 1 |
| | | |
| $\rho_{z,a}$ | Persistence of shocks | 0.8 |
| $\sigma_z$ | Std. deviation of demand shock (%) | 9.7 |
| $\sigma_a$ | Std. deviation of technology shock (%) | 7.4 |

Table 1: Baseline calibration of model parameters. All values are quarterly rates.

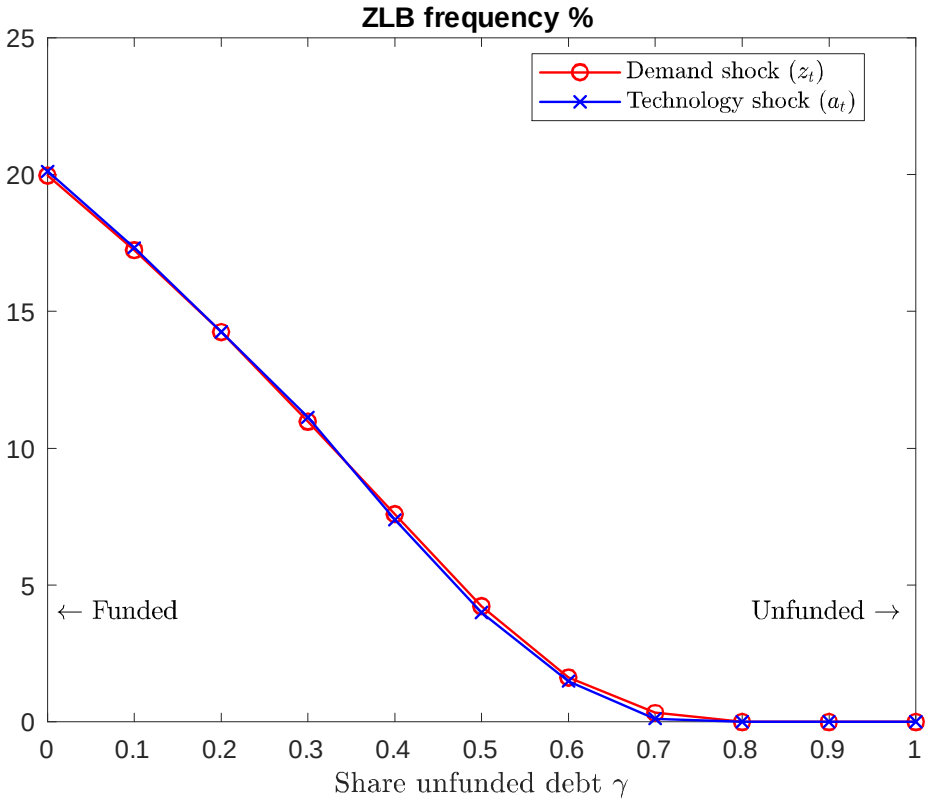



Figure 1: Partially unfunded debt reduces the frequency of zero-lower-bound (ZLB) episodes, but at the cost of reduced monetary-policy flexibility, as monetary policy must accommodate the unfunded part of government debt.

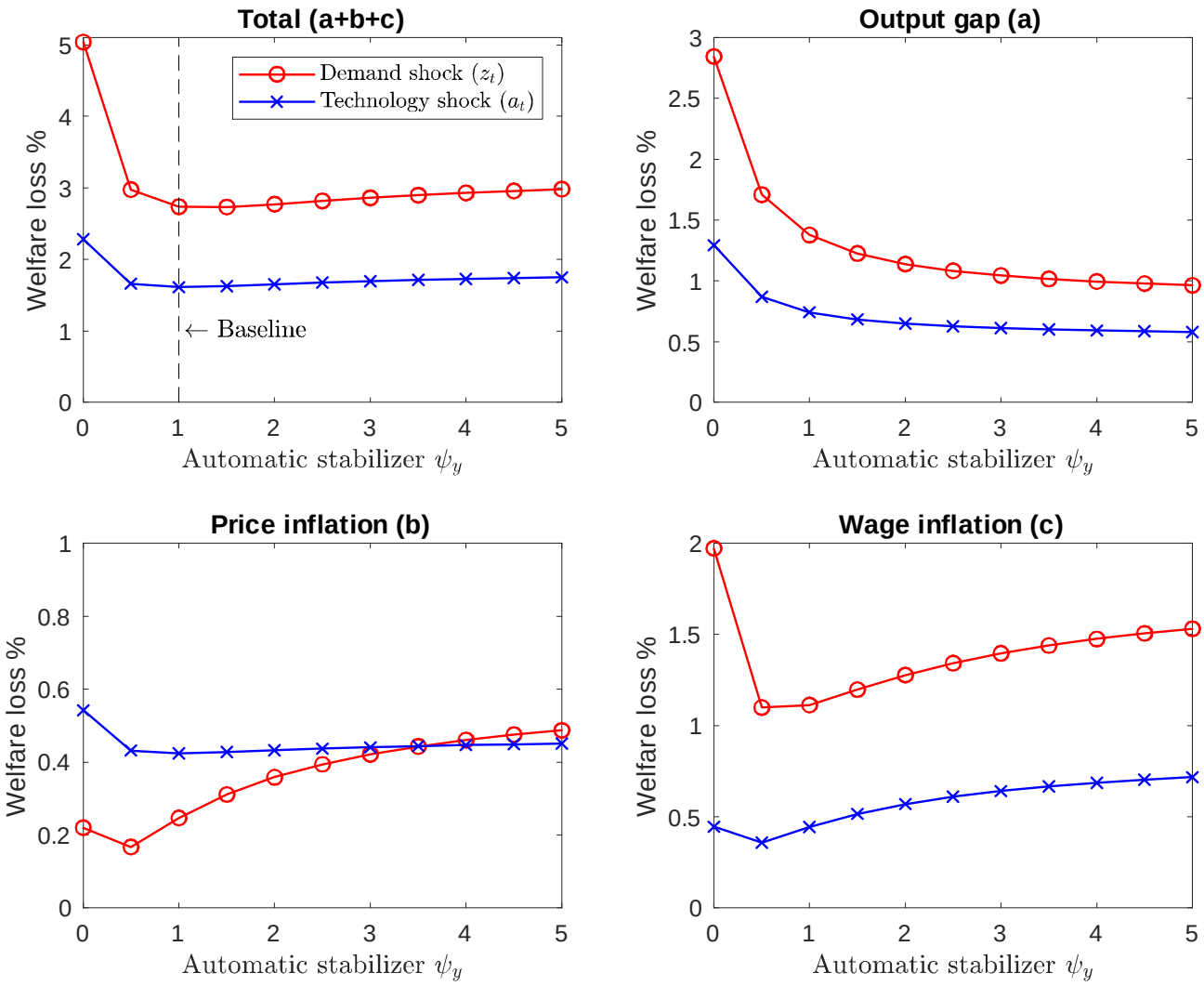



Figure 2: With fully unfunded debt ($\gamma = 1$), the welfare-optimal value of the automatic stabilizer in the fiscal rule $\psi_y$ is close to 1.

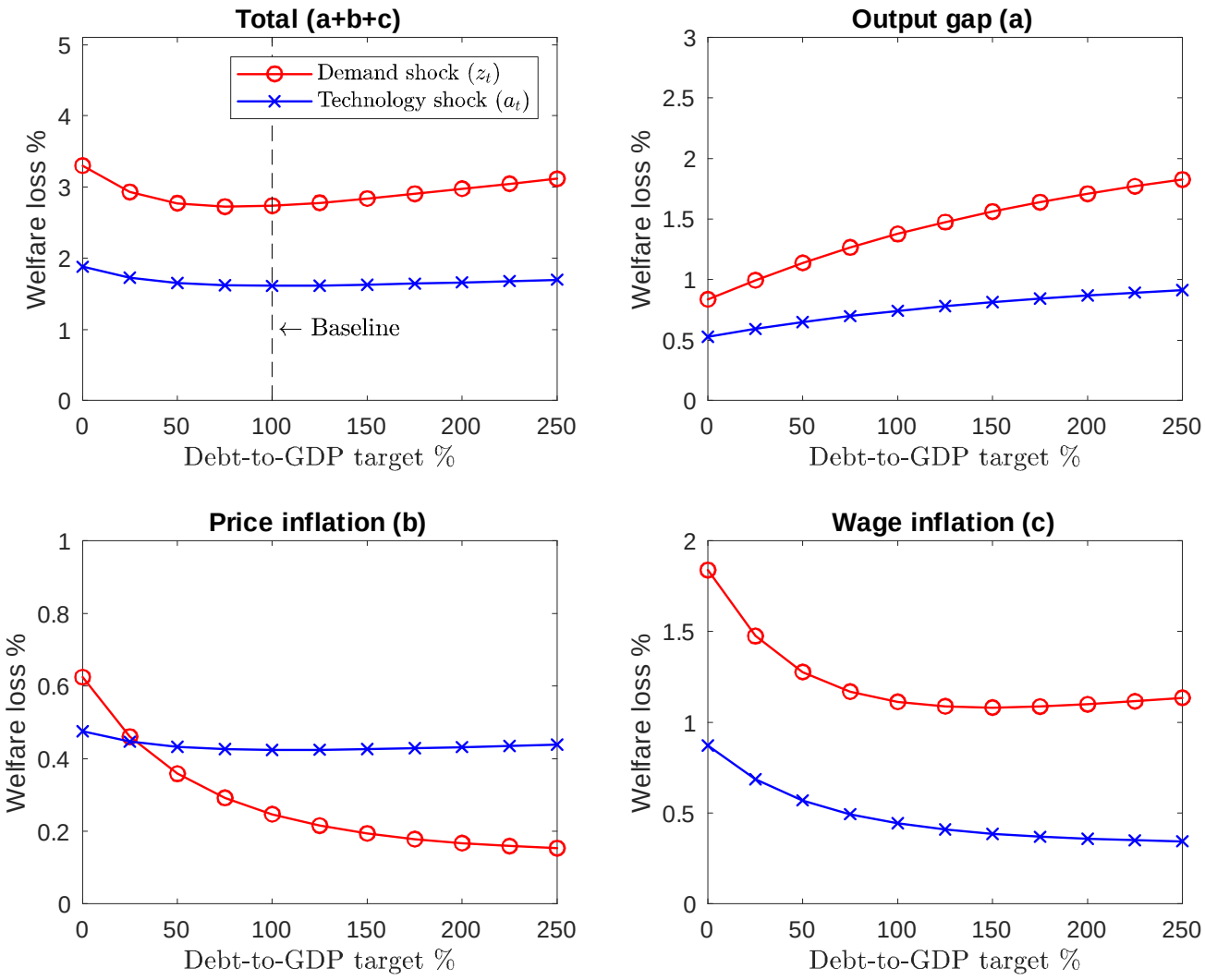



Figure 3: With fully unfunded debt ($\gamma = 1$), setting the annualized debt-to-GDP target at 100% ($b = 4$) is welfare optimal.

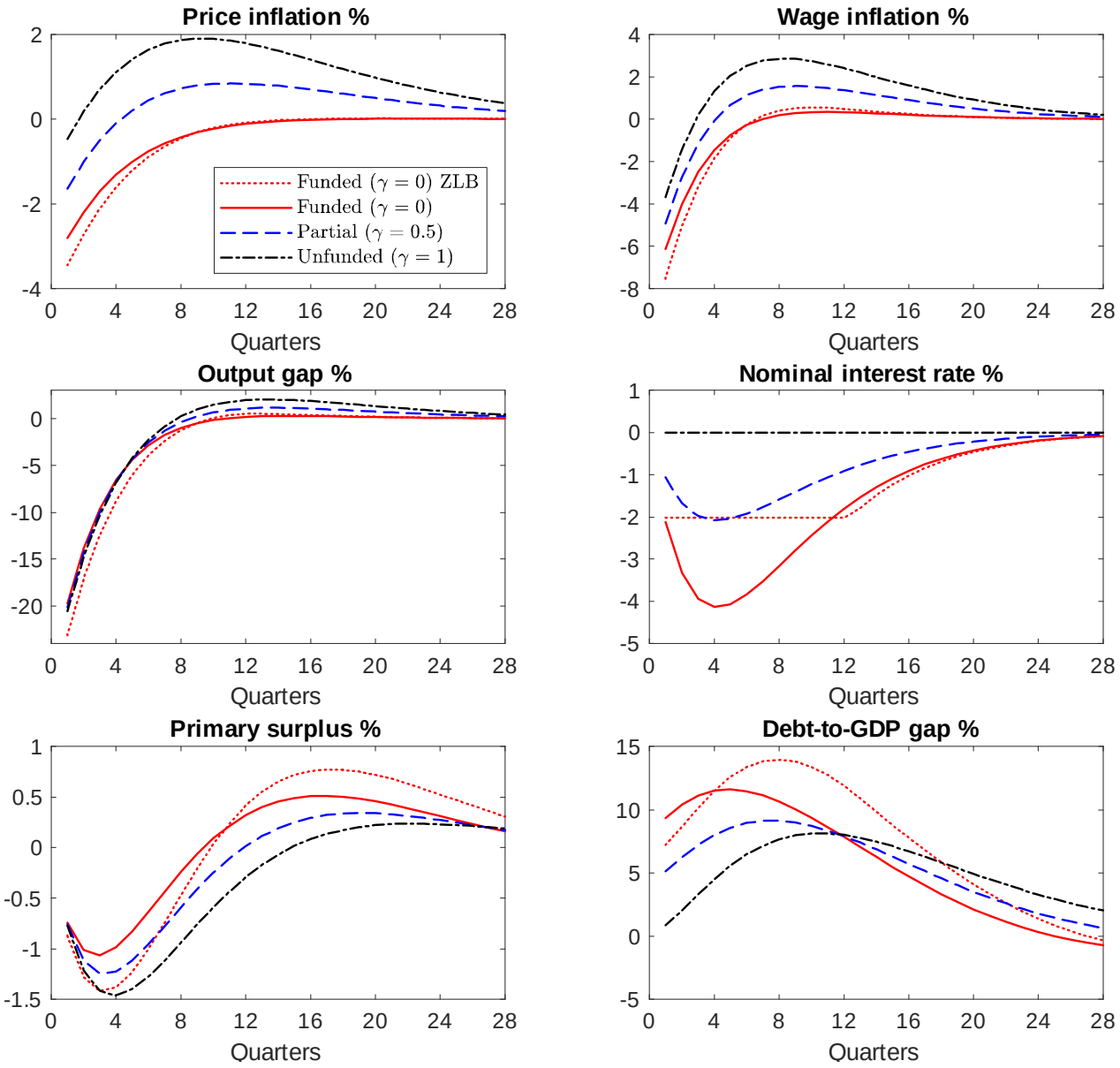



Figure 4: Partially unfunded debt stabilizes inflation in the face of demand shocks, both with and without the ZLB. Responses to a $-3\sigma$ demand shock. Annualized deviations from steady state.

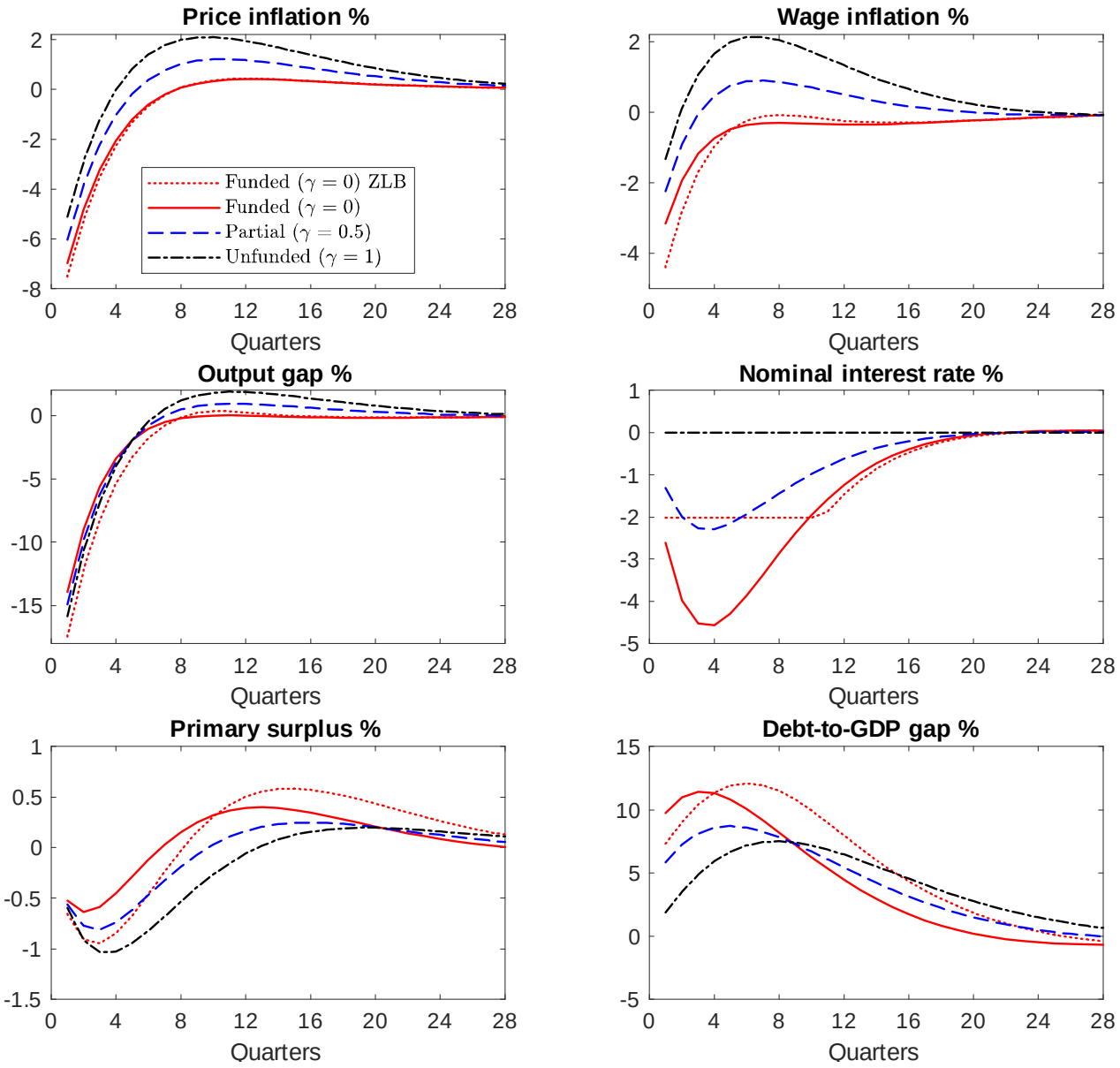



Figure 5: Partially unfunded debt stabilizes inflation in the face of technology shocks, both with and without the ZLB. Responses to a $+3\sigma$ technology shock. Annualized deviations from steady state.

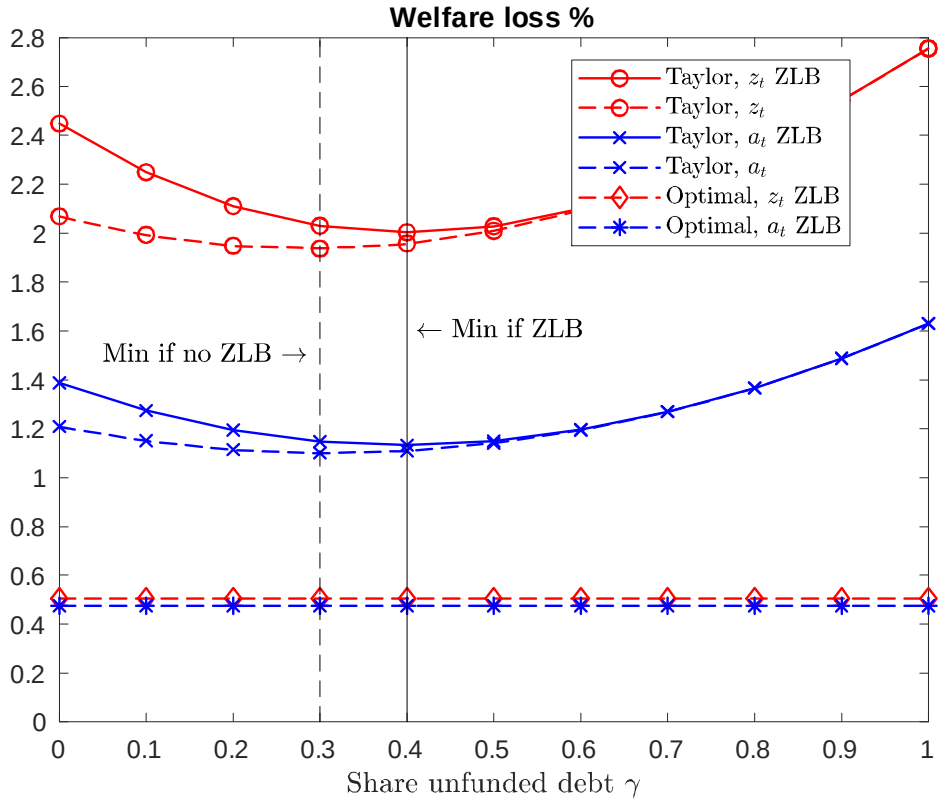



Figure 6: Partially unfunded debt improves social welfare, both with and without the ZLB, by balancing inflation and output stabilization.

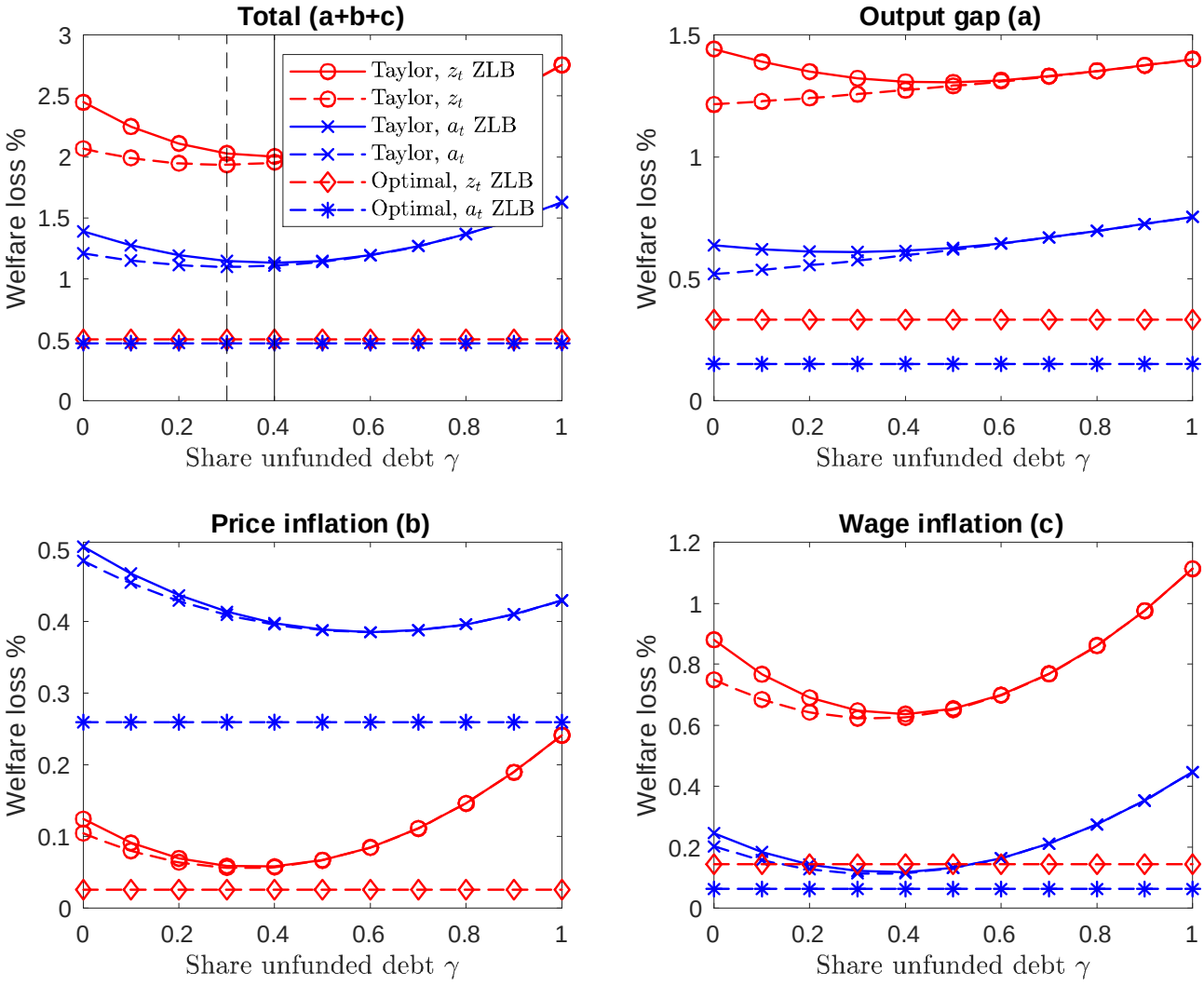



Figure 7: Welfare loss components under partially unfunded debt, both with and without the ZLB. The top left panel replicates Figure 6 for a closer look at the decomposition.

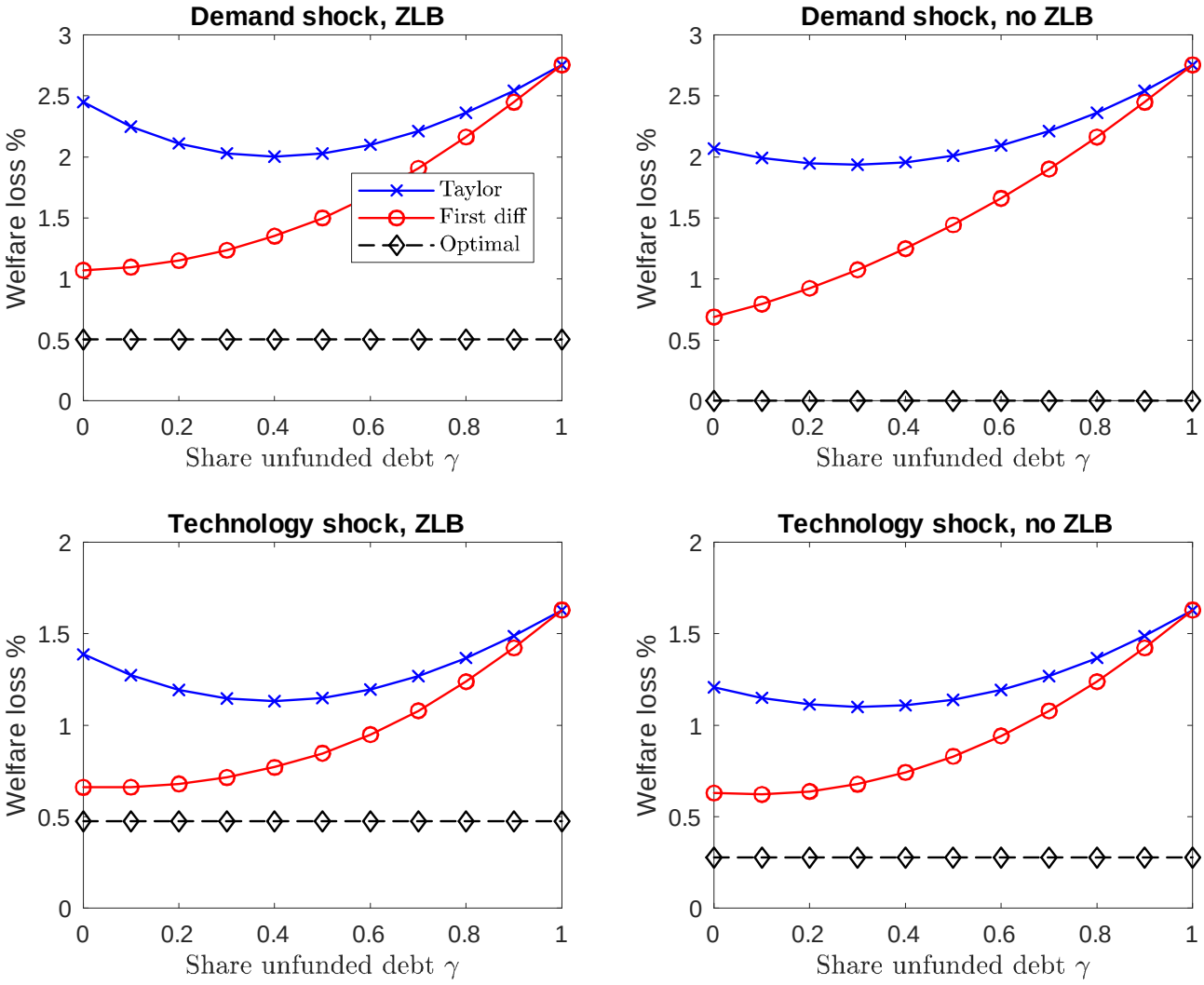



Figure 8: A more history-dependent monetary policy, such as a first-difference rule, can improve welfare and make fully funded debt preferable, both with and without the ZLB. This figure replicates all the outcomes shown in Figure 6, allowing for a direct comparison.

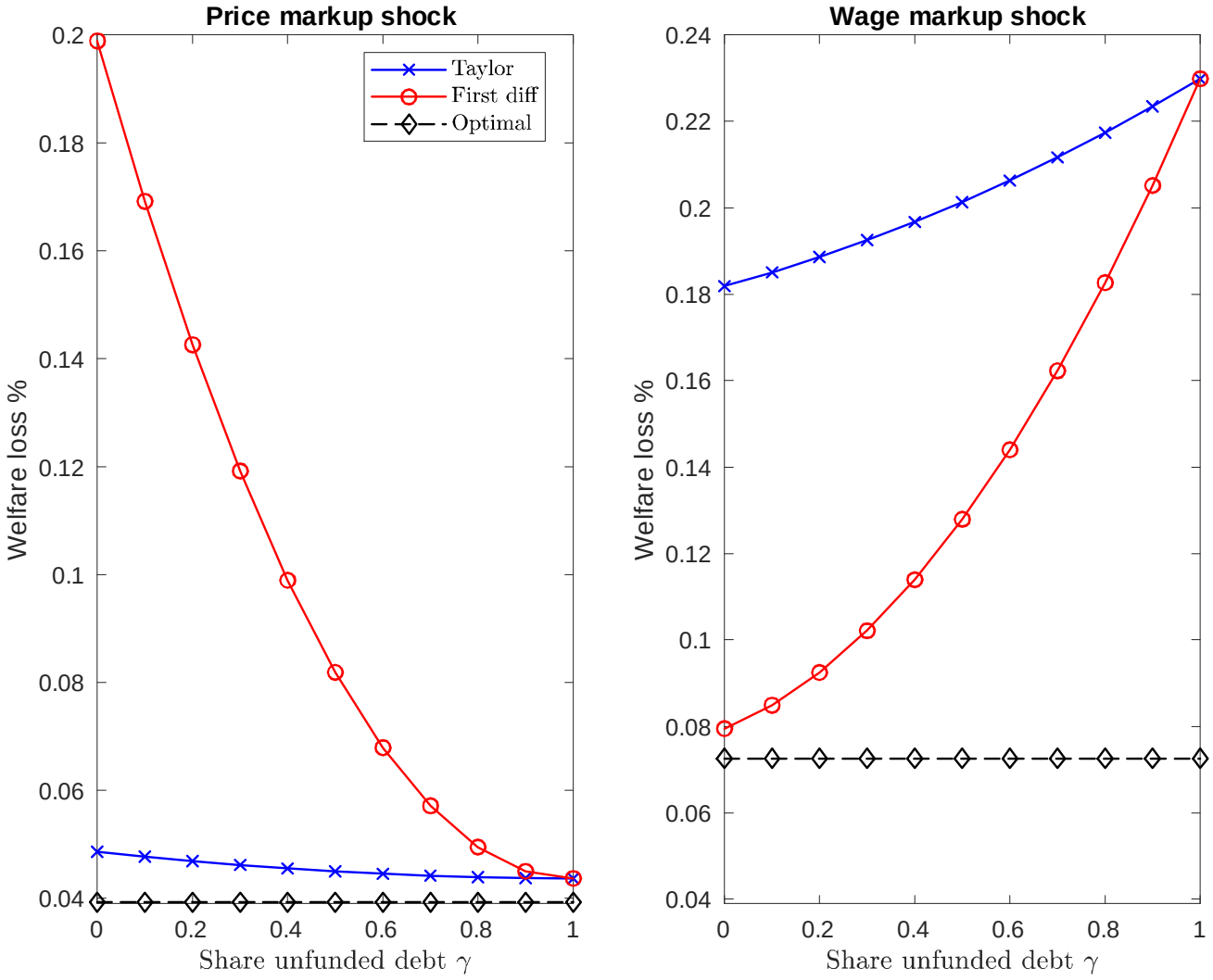



Figure 9: Unfunded debt can improve welfare by allowing monetary policy to accommodate price-markup shocks, whereas fully funded debt is preferred under wage-markup shocks. Results shown for shock volatility small enough that the ZLB does not bind.

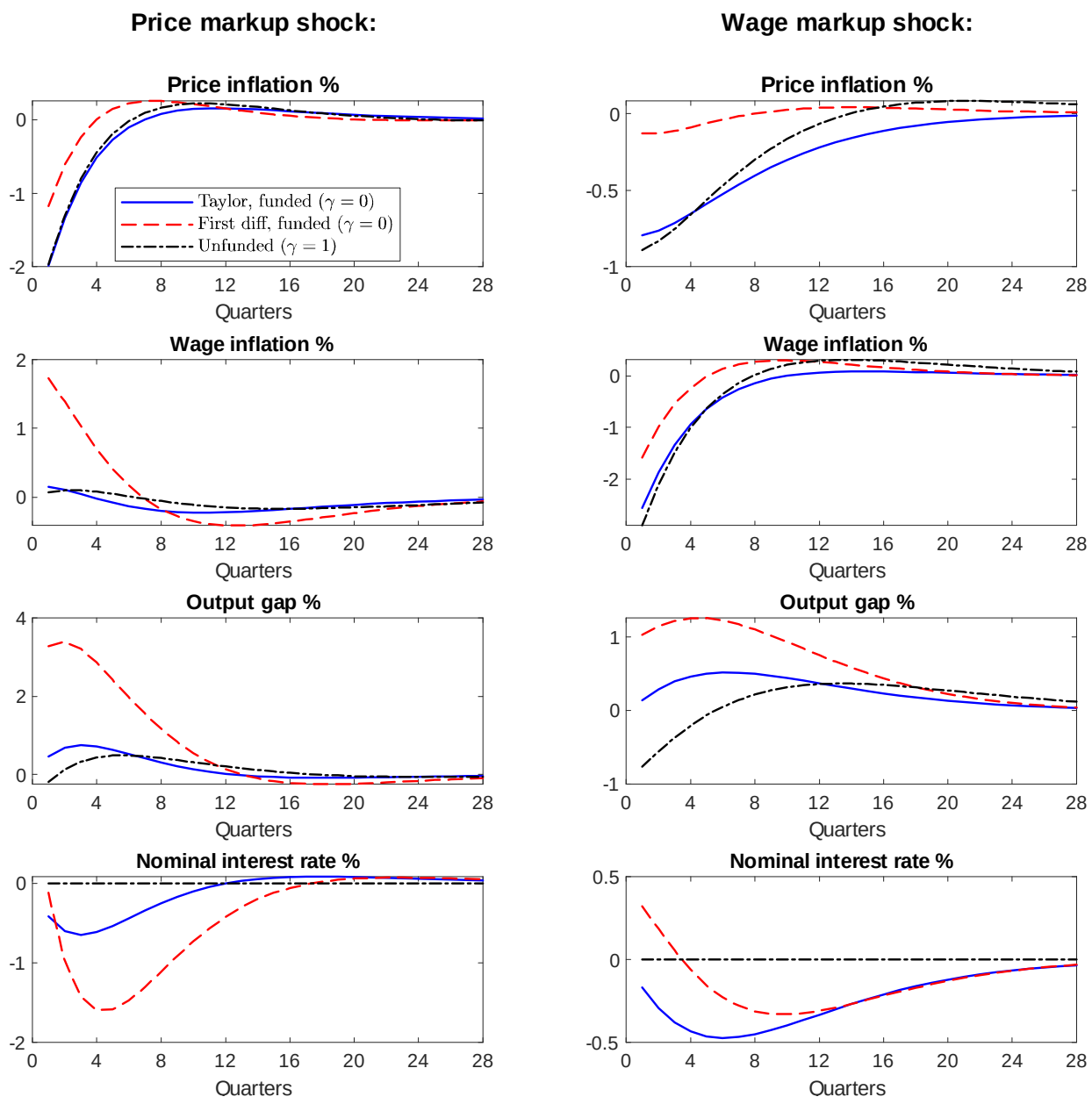



Figure 10: A first-difference monetary policy rule makes wage inflation more volatile facing price-markup shocks, but less volatile facing wage-markup shocks. Responses to a $-3\sigma$ markup shock, with the ZLB not binding. Annualized deviations from steady state.

# Appendices

We extend the baseline analysis in several directions, evaluating the robustness of our results to alternative policy assumptions and providing additional insights. Appendix A analyzes the implications of monetary policy leaning against fiscal inflation. Appendix B explores fiscal policy leaning against unfunded debt. Appendix C presents the equilibrium conditions for the optimal commitment policy with the ZLB, which we use as a benchmark for welfare maximization. Appendix D considers central bank aversion to interest-rate volatility.

## A Monetary Policy Leaning Against Fiscal Inflation

In the baseline analysis, monetary policy does not respond to fiscal inflation (see Section 2.4). This appendix relaxes that assumption by allowing monetary policy in the fiscal-led block to lean against fiscal inflation.

Specifically, in the fiscal-led shadow economy, the nominal interest-rate peg (7) is replaced by a rule less accommodative toward fiscal inflation (magenta terms indicate modifications relative to the baseline rules in the main text):

$$\hat{\imath}_t^F = \phi_i \hat{\imath}_{t-1}^F + (1-\phi_i)\,\phi_p^F \pi_t^{pF}, \tag{16}$$

where $\phi_p^F \in [0,1)$ ensures that monetary policy remains "passive" in the fiscal-led block. Higher values of $\phi_p^F$ imply that monetary policy leans more strongly against fiscal inflation, reflecting a less accommodative but still passive stance.

In the monetary-led observed economy, the Taylor rule (10) is modified accordingly as follows:

$$\hat{\imath}_t^* = \phi_i \hat{\imath}_{t-1}^* + (1-\phi_i)\left[\phi_p^M\left(\pi_t^p - \pi_t^{pF}\right) + \phi_p^F \pi_t^{pF} + \phi_y^M\left(\widetilde{y}_t - \widetilde{y}_t^F\right)\right], \tag{17}$$

where the additional term $\phi_p^F \pi_t^{pF}$ reflects that the fiscal-led component of inflation contributes to total inflation; setting $\phi_p^F = 0$ recovers the baseline policy rules. For illustration, we consider $\phi_p^F = 0.5$, a moderate degree of leaning. Figure A.1 compares the responses of the economy to demand and technology shocks under fully unfunded debt ($\gamma = 1$). The figure shows results without leaning (red solid lines, $\phi_p^F = 0$) and with leaning (blue dashed lines, $\phi_p^F = 0.5$). Leaning against fiscal inflation increases the volatility of inflation and the output gap, thereby raising the welfare loss from demand and technology shocks.

Taken together, these findings indicate that monetary policy leaning against fiscal inflation can be counterproductive, as it amplifies macroeconomic volatility and reduces the desirability of unfunded debt relative to the baseline model. These results reinforce the main finding that unfunded debt is most desirable when monetary policy does not lean against fiscal inflation.

# B Fiscal Policy Leaning Against Unfunded Debt

In the baseline model, fiscal policy does not react to unfunded debt (see Section 2.4). Here, we instead permit fiscal policy in the fiscal-led block to respond to deviations of unfunded debt from its target.

Within the fiscal-led shadow economy, the fiscal rule (8) is modified to be less accommodative toward unfunded debt (magenta terms indicate modifications relative to the baseline rules in the main text):

$$\hat{\tau}_t^F = \psi_\tau \hat{\tau}_{t-1}^F + (1-\psi_\tau)\left(\psi_b^F \hat{b}_{t-1}^F + \psi_y \widetilde{y}_t^F\right), \tag{18}$$

where $\psi_b^F \in [0, \rho)$ ensures that fiscal policy remains "active" in the fiscal-led block. A higher value of $\psi_b^F$ implies that fiscal policy leans more forcefully against unfunded debt, representing a less accommodative but still active stance.

In the monetary-led observed economy, the fiscal rule (11) is modified accordingly as follows:

$$\hat{\tau}_t = \psi_\tau \hat{\tau}_{t-1} + (1-\psi_\tau)\left[\psi_b^M\left(\hat{b}_{t-1} - \hat{b}_{t-1}^F\right) + \psi_b^F \hat{b}_{t-1}^F + \psi_y \widetilde{y}_t\right], \tag{19}$$

where the additional term $\psi_b^F \hat{b}_{t-1}^F$ reflects that the fiscal-led component of debt contributes to total debt; setting $\psi_b^F = 0$ recovers the baseline policy rules. For reference, we set $\psi_b^F = 0.004$, a value just below $\rho \approx 0.005$. Figure A.2 displays the economy's responses to demand and technology shocks under fully unfunded debt ($\gamma = 1$), comparing the case without leaning (red solid lines, $\psi_b^F = 0$) to that with leaning (blue dashed lines, $\psi_b^F = 0.004$). The responses are nearly identical, owing to the presence of an automatic stabilizer in the fiscal rule ($\psi_y = 1$), which is calibrated to maximize welfare in the fiscal-led regime.

The automatic stabilizer ensures that the primary surplus adjusts strongly to output fluctuations, thereby largely neutralizing the effect of leaning against unfunded debt and supporting macroeconomic stability. For contrast, the figure also shows outcomes for a scenario without the automatic stabilizer (black dash-dotted lines, $\psi_b^F = 0.004$ and $\psi_y = 0$), which leads to noticeably greater volatility of inflation and the output gap, highlighting the stabilizer's crucial role in dampening economic fluctuations.

In summary, the automatic stabilizer in the fiscal rule is strong enough to counteract the effect of leaning against unfunded debt, ensuring that such leaning has a negligible impact on macroeconomic volatility. As a result, the desirability of unfunded debt remains unchanged relative to the baseline model, with a strong automatic stabilizer. This finding supports the robustness of the main results regarding the desirability of unfunded debt.

# C Optimal Commitment Policy with the ZLB

Our main analysis evaluates policy from a social-welfare perspective (see Section 2.5), which serves as a benchmark for optimal policy design. Using the welfare loss function (12), this appendix derives the equilibrium conditions that characterize the optimal commitment allocation with an explicit zero lower bound (ZLB) on the nominal policy rate.

The planner's problem is:

$$\min \frac{1}{2} E_0 \sum_{t=0}^{\infty} \beta^t \left[ \left( \sigma + \frac{\varphi + \alpha}{1-\alpha} \right) (\widetilde{y}_t)^2 + \frac{\epsilon_p}{\lambda_p} (\pi_t^p)^2 + \frac{\epsilon_w (1-\alpha)}{\lambda_w} (\pi_t^w)^2 \right]$$

subject to the private-sector equations (1)–(4), and the ZLB, $\hat{\imath}_t + \rho \equiv i_t \geq 0$ for all $t$. Because taxes are non-distortionary in our setting, the government budget and bond-arbitrage conditions (5) and (6) do not bind the commitment allocation; hence fiscal policy can fully stabilize government debt. We set $\hat{b}_t = 0$ for all $t$, with $\hat{\tau}_t$ adjusting as needed.

We now write the period Lagrangian:

$$\begin{aligned}
\mathbb{L}_t = & \frac{1}{2} \left[ \left( \sigma + \frac{\varphi + \alpha}{1-\alpha} \right) (\widetilde{y}_t)^2 + \frac{\epsilon_p}{\lambda_p} (\pi_t^p)^2 + \frac{\epsilon_w (1-\alpha)}{\lambda_w} (\pi_t^w)^2 \right] \\
& + m_{1t} \left[ \widetilde{y}_t + \frac{1}{\sigma} (\hat{\imath}_t - \hat{r}_t^n) \right] - \beta^{-1} m_{1t-1} \left( \widetilde{y}_t + \frac{1}{\sigma} \pi_t^p \right) \\
& + m_{2t} (\pi_t^p - \varkappa_p \widetilde{y}_t - \lambda_p \widetilde{\omega}_t) - m_{2t-1} \pi_t^p \\
& + m_{3t} (\pi_t^w - \varkappa_w \widetilde{y}_t + \lambda_w \widetilde{\omega}_t) - m_{3t-1} \pi_t^w \\
& + m_{4t} (\widetilde{\omega}_t - \widetilde{\omega}_{t-1} - \pi_t^w + \pi_t^p + \Delta \hat{\omega}_t^n) \\
& + \beta E_t \mathbb{L}_{t+1}.
\end{aligned}$$

The Kuhn-Tucker conditions are:

$$0 = \frac{\partial \mathbb{L}_t}{\partial \widetilde{y}_t} = \left( \sigma + \frac{\varphi + \alpha}{1-\alpha} \right) \widetilde{y}_t + m_{1t} - \beta^{-1} m_{1t-1} - \varkappa_p m_{2t} - \varkappa_w m_{3t} \tag{20}$$

$$0 = \frac{\partial \mathbb{L}_t}{\partial \pi_t^p} = \frac{\epsilon_p}{\lambda_p} \pi_t^p - \frac{1}{\beta \sigma} m_{1t-1} + m_{2t} - m_{2t-1} + m_{4t} \tag{21}$$

$$0 = \frac{\partial \mathbb{L}_t}{\partial \pi_t^w} = \frac{\epsilon_w (1-\alpha)}{\lambda_w} \pi_t^w + m_{3t} - m_{3t-1} - m_{4t} \tag{22}$$

$$0 = \frac{\partial \mathbb{L}_t}{\partial \widetilde{\omega}_t} = \frac{\partial \beta E_t \mathbb{L}_{t+1}}{\partial \widetilde{\omega}_t} - \lambda_p m_{2t} + \lambda_w m_{3t} + m_{4t} \tag{23}$$

$$0 = \frac{\partial \mathbb{L}_t}{\partial \hat{\imath}_t} (\hat{\imath}_t + \rho) = \frac{1}{\sigma} m_{1t} (\hat{\imath}_t + \rho), \quad m_{1t} \geq 0 \text{ and } \hat{\imath}_t + \rho \geq 0. \tag{24}$$

The envelope condition gives:

$$\frac{\partial \beta E_t \mathbb{L}_{t+1}}{\partial \widetilde{\omega}_t} = -\beta E_t m_{4t+1}.$$

Thus, the optimal commitment allocation under the ZLB is characterized by equations (1)–(6) and (20)–(24), with (5)–(6) implied but not binding given non-distortionary taxes. Accordingly, this allocation serves as the welfare benchmark for our analysis of the optimal degree of fiscal backing.

# D Central Bank Aversion to Interest-Rate Volatility

Central banks often value a smooth policy rate. To examine how that preference shapes outcomes in our model, we evaluate a central bank objective that penalizes policy-rate volatility alongside the standard stabilization terms. The new penalty is assigned the same weight as price-inflation volatility, ensuring a transparent comparison with the social-welfare criterion.

Specifically, we replace the welfare loss function (12) with the following central bank objective (the magenta term indicates the modification relative to the welfare loss function):

$$\mathbb{L} = \frac{1}{2}\left[\left(\sigma + \frac{\varphi + \alpha}{1-\alpha}\right) var\left(\widetilde{y}_t\right) + \frac{\epsilon_p}{\lambda_p} var\left(\pi_t^p\right) + \frac{\epsilon_p}{\lambda_p} var\left(\hat{\imath}_t\right)\right], \tag{25}$$

where the third component is now the volatility of the nominal interest rate, which receives the same weight as price-inflation volatility. Figure A.3 shows that, under the Taylor rule without the ZLB, applying the central bank objective raises the preferred share of unfunded debt to about 0.7 for demand shocks ($z_t$) and technology shocks ($a_t$). This share is more than double the social optimum of 0.3 under the welfare loss function (12) without the ZLB (see Figures 6 and 7). The mechanism is that allowing part of the fiscal adjustment to occur through unfunded debt dampens policy-rate volatility, which this objective penalizes.

This result illustrates how institutional preferences can shift the preferred policy mix from the social optimum toward regimes that stabilize the policy rate more aggressively. Policymakers and academics should remain mindful of these differences when setting objectives and evaluating trade-offs. Ultimately, ensuring that central bank objectives align with social-welfare goals is crucial for effective and balanced policy outcomes.

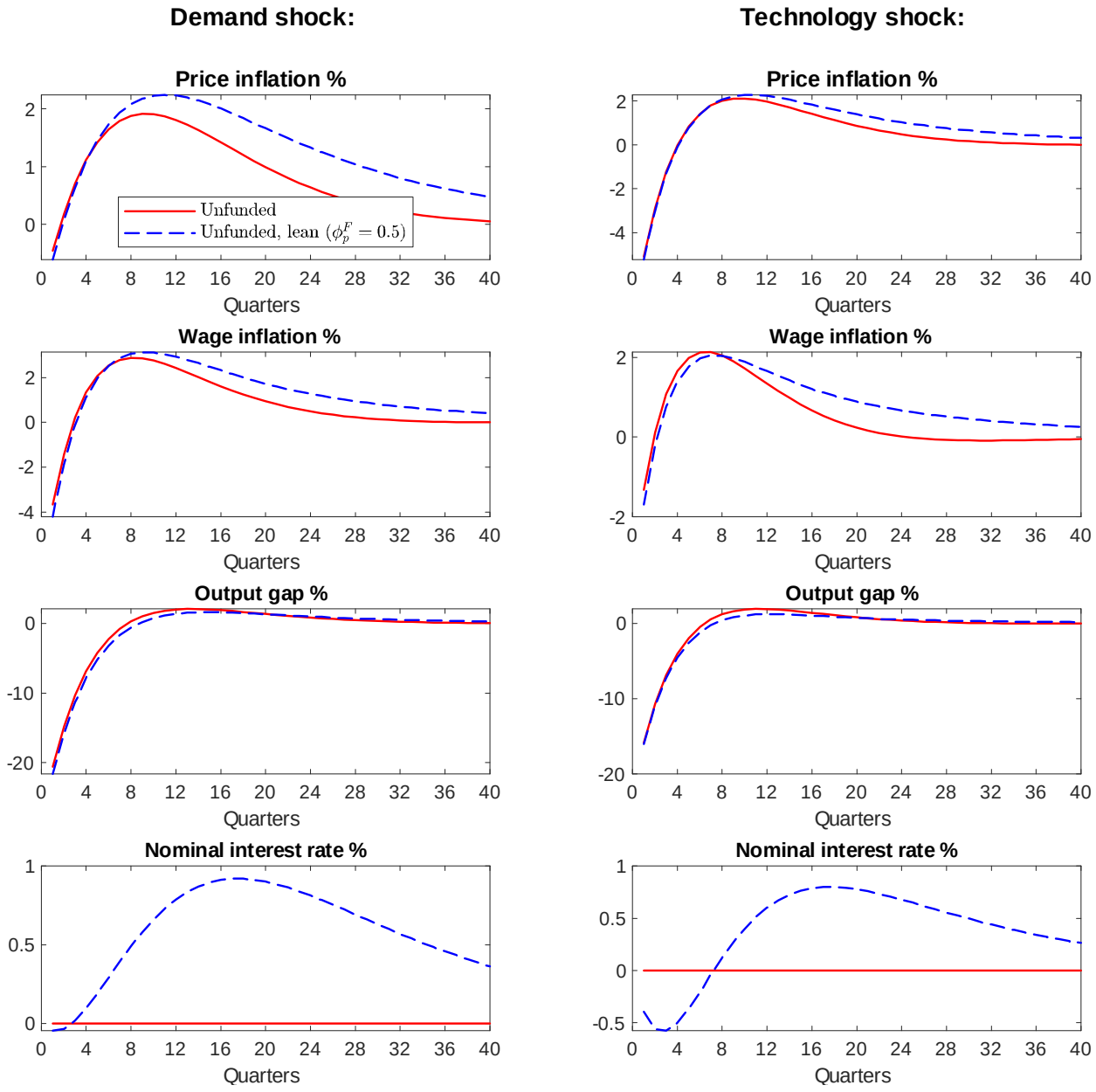



Figure A.1: With fully unfunded debt ($\gamma = 1$), monetary policy leaning against fiscal inflation increases the volatility of inflation and the output gap. Responses to a $-3\sigma$ demand shock or a $+3\sigma$ technology shock. Annualized deviations from steady state.

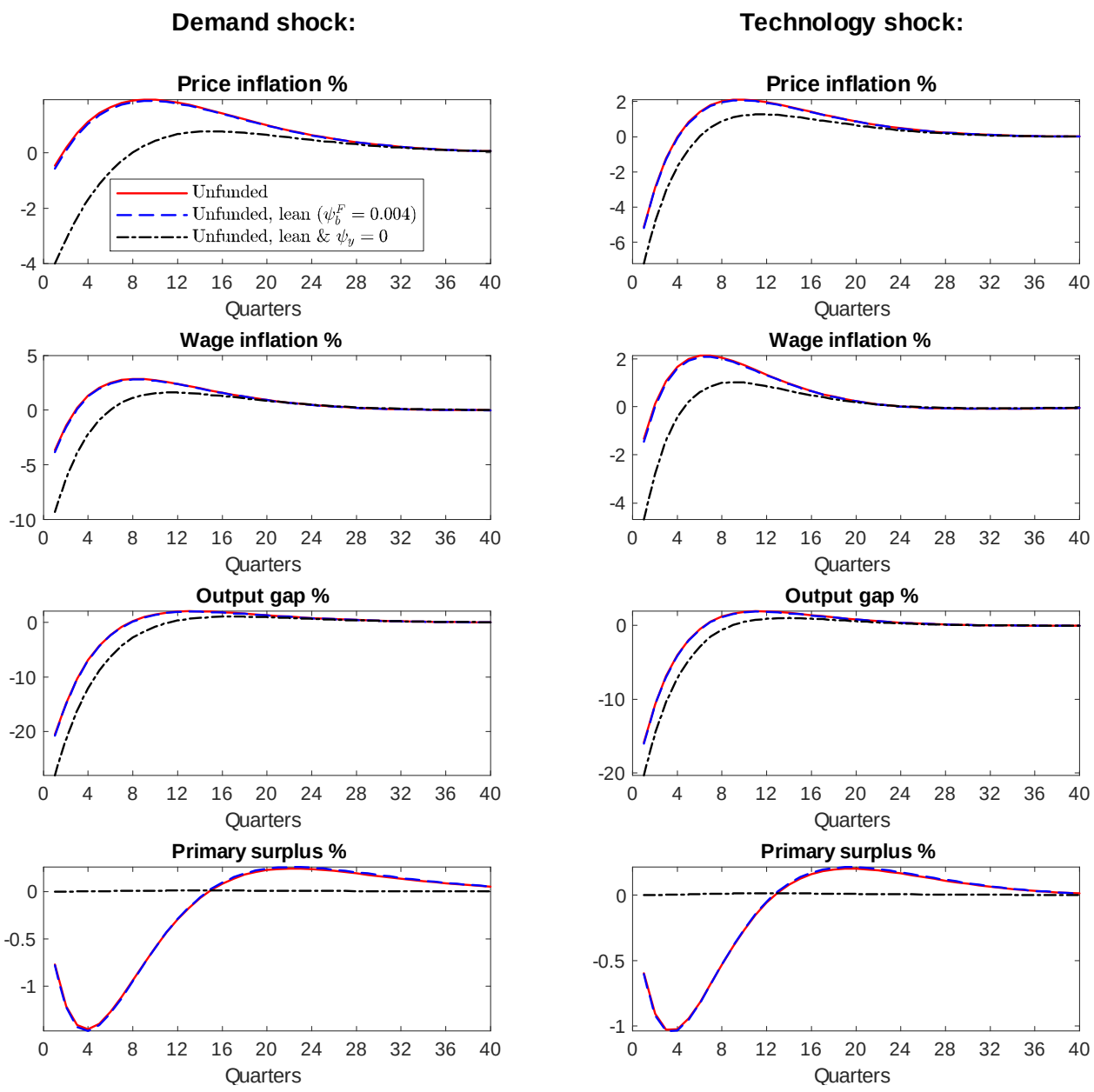



Figure A.2: With fully unfunded debt ($\gamma = 1$), a strong automatic fiscal stabilizer neutralizes the effect of leaning against unfunded debt on macroeconomic volatility. Responses to a $-3\sigma$ demand shock or a $+3\sigma$ technology shock. Annualized deviations from steady state.

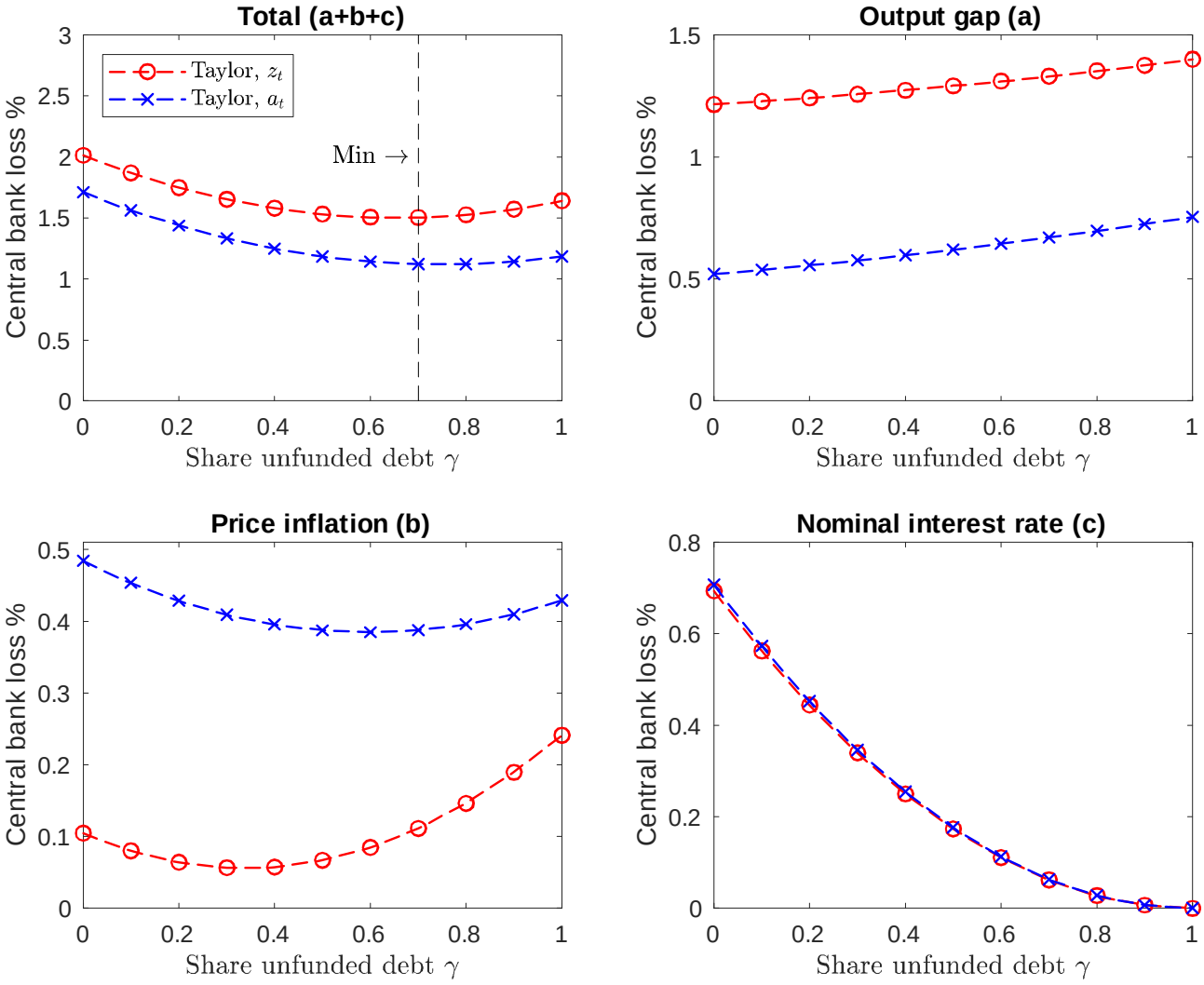



Figure A.3: Central bank aversion to nominal interest-rate volatility raises the preferred share of unfunded debt above the social optimum. Results shown without the ZLB. The output gap and price inflation panels (top right and bottom left) correspond to Figure 7, which displays the social optimum.