Monetary Policy with Partial Fiscal Backing*

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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 welfare ranking is shock-dependent: with price-markup disturbances, fully unfunded debt is optimal, whereas with wage-markup disturbances, fully funded debt is preferred. These opposite rankings reflect differences in the comovement of price and wage inflation across markup shocks. Overall, the welfare-optimal degree of fiscal backing varies with the monetary policy rule, the relevance of the ZLB, and the source of the disturbance.

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

JEL codes: E31, E52, E63.

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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, especially in environments with elevated public debt. This stands in sharp contrast to the preceding decade, when many central banks faced persistently low inflation and repeated encounters with the zero lower bound (ZLB) on nominal interest rates. In such settings, the degree of fiscal backing—the share of government debt funded by future primary surpluses—shapes the joint determination of inflation and debt. The Fiscal Theory of the Price Level (FTPL) provides a useful lens for this interaction. However, the welfare implications of partial fiscal backing remain less well understood, especially across shocks and policy regimes, including when the ZLB binds.

Question and approach. Our goal is to characterize the welfare-optimal degree of fiscal backing as a function of (i) the monetary policy rule, (ii) the relevance of the ZLB, and (iii) the source of the disturbance. We do so by varying the unfunded share (the complement of fiscal backing) while holding the policy-rule coefficients fixed, so that changes in outcomes reflect fiscal backing rather than re-optimized rules. The key mechanism is that changing the unfunded share reallocates shock absorption between expected future primary surpluses and inflation-driven debt revaluation, reshaping 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 driven by demand, technology, price-markup, and wage-markup shocks. The model features long-term government debt and a fiscal rule with an automatic stabilizer, while monetary policy may be constrained by the ZLB. We evaluate alternative monetary and fiscal rules using the model-implied welfare loss function while varying the share of unfunded debt. This setup provides a transparent mapping from policy rules to inflation, the output gap, and welfare, allowing us to quantify how the degree of fiscal backing should adjust across regimes and shocks.

Contribution. Our main contribution is normative: we provide a welfare-based characterization of how much fiscal backing is desirable across monetary policy rules and shock types, including when the ZLB binds. Because we hold policy-rule coefficients fixed, welfare differences reflect changes in the funding mix between future primary surpluses and inflation-driven debt revaluation, rather than differences driven by re-optimizing rule coefficients. This perspective complements recent positive and empirical work by identifying when partial backing improves welfare and when it does not.

Main results. Our analysis yields three main results. First, 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 policy share the adjustment burden, particularly at the ZLB.

Second, we consider a first-difference rule, which makes monetary policy more history dependent by adjusting the policy rate more gradually. Under this rule, the gains from unfunding shrink and can vanish, shifting the optimum toward full funding. This shift reflects the greater ability of such a rule to stabilize inflation and the output gap over time, internalizing part of the stabilization role that unfunded debt played under the Taylor rule.

Third, the welfare ranking depends critically on the source of inflationary pressure. With price-markup disturbances, greater unfunding allows policymakers to "look through" inflation, making fully unfunded debt optimal. With wage-markup disturbances, the look-through logic is less compelling and fully funded debt is preferred. These opposite rankings reflect differences in the comovement of price and wage inflation across markup shocks.

Taken together, these results imply that the welfare-optimal degree of fiscal backing is state-contingent, varying with the monetary policy rule, the relevance of the ZLB, and the source of the disturbance. These findings connect to and extend several strands of literature, to which we now turn.

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

Our modeling framework adopts the New Keynesian benchmark in Galí (2015) with price and wage rigidities. 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 setting.

The paper is most closely related to recent advances by Cochrane (2022), Bianchi, Faccini, and Melosi (2023), and Smets and Wouters (2024). Cochrane studies policy shocks in a fiscal-led regime with incomplete fiscal backing. Bianchi, Faccini, and Melosi develop a fiscal theory of persistent inflation driven by funded and unfunded transfers, and Smets and Wouters provide empirical evidence that partial fiscal backing reshapes the transmission of fiscal and non-fiscal shocks. Building on these contributions, we evaluate partial fiscal backing through the lens of welfare, emphasizing how the desirable policy mix varies across policy rules, shock sources, and the relevance of the ZLB.

Finally, we relate to Angeletos, Lian, and Wolf (2026), who study an overlapping-generations New Keynesian model without the ZLB. In their framework, a central bank that dislikes interest-rate volatility may prefer little or no fiscal adjustment, since allowing debt to remain unfunded can dampen policy-rate movements. By contrast, we adopt a welfare perspective in an environment where monetary policy may be constrained by 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 welfare optimum.

Overall, we complement this literature by providing a welfare-based assessment of partial fiscal backing across monetary policy rules, shock types, and ZLB relevance.

Outline. The remainder of the paper is organized as follows. Section 2 presents the baseline model and calibration, including demand and technology shocks and the standard Taylor-type rule. Section 3 reports the main findings. Section 4 considers a first-difference monetary policy rule. Section 5 examines price and wage markup shocks. Section 6 summarizes 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, driven by demand and technology shocks. Government debt is long-term and risk-free, modeled as a perpetuity with declining coupons. The fiscal authority can leave a share of debt unfunded, so part of debt stabilization occurs through inflation-driven revaluation rather than future primary surpluses. Policy regimes are formalized through distinct monetary and fiscal rules, and the optimal commitment policy serves as the welfare benchmark. The subsections below describe the private sector, the government budget with long-term debt, the partial-backing setup, the policy rules under the ZLB, and the welfare criterion and calibration. The model period is one quarter, and figures report annualized deviations as indicated.

2.1 Private Sector

We model the private sector as a closed economy with staggered price and wage setting *à la Calvo* in a standard New Keynesian framework. The economy is driven by demand and technology shocks, z_t and a_t, which are modeled as independent $AR(1)$ processes with autoregressive coefficients ρ_z and ρ_a, capturing persistence. Following Galí (2015, ch. 6), all equations are log-linearized around an efficient steady state with zero price and wage inflation. Hats on variables denote log deviations (unless explicitly defined otherwise below), and

natural variables correspond to efficient outcomes absent nominal rigidities.

The supply side consists of the price and wage Phillips curves together with the law of motion for 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 π_t^p and π_t^w denote price and wage inflation, $\widetilde{y}_t$ and $\widetilde{\omega}_t$ denote the output and real wage gaps, and Δ is the first-difference operator. These gaps are deviations from their natural (flex-price) levels: $\widetilde{y}_t \equiv \hat{y}_t - \hat{y}_t^n$ and $\widetilde{\omega}_t \equiv \hat{\omega}_t - \hat{\omega}_t^n$. The natural output and wage, in turn, 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]

The demand side is described by 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 is $\hat{r}_t^n \equiv (1-\rho_z) z_t - \sigma\,(1-\rho_a)\,\psi_{ya} a_t$, which depends on z_t and a_t.

Key parameters are the Calvo indices for price and wage rigidity (θ_p and θ_w), elasticities of substitution (ϵ_p and ϵ_w), the degree of decreasing returns to labor (α), the discount factor (β), risk aversion (σ), and labor disutility (φ). We calibrate these parameters to standard values in Section 2.6, following 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), we model government debt as a perpetuity with coupon payments that decay at rate $\eta \in [0,1]$ each period. The government's budget constraint and the bond-pricing condition are log-linearized around a steady state with no trend growth and zero inflation, which delivers a tractable representation of fiscal dynamics.[2]

Accordingly, long-term debt dynamics are characterized by the government's budget constraint and the bond-pricing condition:

[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.

[2] Government debt issuance reflects the 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 bond price to the short-term rate so that expected returns equal the risk-free rate.

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

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

where $\hat{b}_t \equiv (B_t - B)/Y$ and $\hat{\tau}_t \equiv (T_t - T)/Y$ denote, respectively, the real market value of government debt and the tax revenue, measured as deviations from the steady state and normalized by steady-state output Y. Here B_t is measured in real terms (deflated by the price level). With government spending omitted, $\hat{\tau}_t$ coincides with the primary surplus. We assume taxes are non-distortionary, so fiscal adjustments do not introduce additional wedges into private decisions.[3]

To summarize the government's liability structure, let $b \equiv B/Y$ denote the debt-to-GDP target. Let $\hat{Q}_t \equiv (Q_t - Q)/Q$ denote the (ex-dividend) bond price in percent deviation from its steady-state value, $Q \equiv \beta/(1-\eta\beta)$. The average duration is $1/(1-\eta\beta)$, which increases with η and captures the long-term nature of government debt. The debt target and duration are calibrated to match 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. This captures situations in which the fiscal authority cannot credibly commit to fully repaying debt through future primary surpluses; in such cases, part of the adjustment occurs through inflation-driven debt revaluation.

Following Bianchi, Faccini, and Melosi (2023) and Smets and Wouters (2024), we capture partial fiscal backing by decomposing equilibrium dynamics into a funded component (stabilized by future primary surpluses) and an unfunded component (stabilized by inflation via debt revaluation). We implement this decomposition by adding a shadow-economy block that tracks the unfunded component and the associated fiscal-led variables.[4]

Formally, we replicate equations (1)–(6), adding a superscript "F" to all variables in the fiscal-led shadow block. Let $\gamma \in [0,1]$ denote the unfunded share (where the funded share is $1-\gamma$). In the shadow block, shocks (z_t and a_t) are scaled by γ, which governs the fraction of

[3] This assumption abstracts from distortionary financing and prevents fiscal adjustments from affecting inflation through additional wedges. With distortionary taxation (or alternative fiscal instruments), the 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.

[4] Bianchi, Faccini, and Melosi (2023) introduce the shadow-economy accounting device, whose implied fiscal-led variables enter the monetary-led policy rules as time-varying targets. Smets and Wouters (2024) extend the approach to partial fiscal backing and to a broader set of shocks.

each disturbance absorbed by the unfunded component.[5] When $\gamma = 0$, the regime is monetary-led (full fiscal backing); when $\gamma = 1$, it is fiscal-led (no fiscal backing). Intermediate values of γ correspond to partial fiscal backing and thus a flexible mix of fiscal and monetary responses to shocks.

Varying γ shifts shock absorption between surplus adjustment and debt revaluation. In practical terms, higher γ corresponds to weaker perceived fiscal backing—and hence greater reliance on debt revaluation—while lower γ corresponds to stronger backing through expected future primary surpluses.

In sum, the model consists of equations (1)–(6) for the monetary-led observed economy, alongside their counterparts with superscript "F" and shocks scaled by γ in the fiscal-led shadow economy. Next, we specify the policy rules that govern the behavior of both the shadow and observed economies.

2.4 Policy Rules under the ZLB

This subsection specifies the policy rules in the fiscal-led shadow economy and the monetary-led observed economy, subject to the zero lower bound (ZLB) on the nominal policy rate. The fiscal rule includes an automatic stabilizer, which strengthens stabilization in regimes where monetary policy must accommodate unfunded debt. We first describe policy in the fiscal-led block and then in the monetary-led block, and we conclude with two brief remarks on special cases and the interest-rate peg.

Fiscal-led shadow economy. In the *fiscal-led* block, monetary policy is passive—the nominal interest rate is pegged at its steady-state value, above the ZLB—while fiscal policy is active in the sense of Leeper (1991), so the primary surplus does not adjust to stabilize government debt. In this regime, debt is effectively unfunded and inflation becomes the main mechanism for returning debt toward its target through debt revaluation rather than through changes in taxes or spending.[6]

Hence policy is given by the nominal interest-rate peg and the fiscal rule:

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

[5] For example, the shadow-economy counterpart to (4) is $\widetilde{y}_t^F = E_t\{\widetilde{y}_{t+1}^F\} - \frac{1}{\sigma}\left(\hat{\imath}_t^F - E_t\{\pi_{t+1}^{pF}\} - \gamma\hat{r}_t^n\right)$, where the term $\gamma\hat{r}_t^n$ reflects scaling (z_t, a_t) by γ. Expectations E_t are taken with respect to the joint system (shadow and observed blocks are solved jointly).

[6] This standard characterization of policy rules in a fiscal-led regime is not essential for our results. Appendix A allows monetary policy to lean against fiscal inflation (so that $\hat{\imath}_t^F$ responds to π_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.

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

where ψ_τ governs the speed at which the primary surplus adjusts over time, and ψ_y measures the strength of the automatic stabilizer by determining how strongly the primary surplus responds to the output gap. We calibrate ψ_y to maximize welfare in the fiscal-led regime (Section 2.6), ensuring that fiscal policy provides effective stabilization when monetary policy must accommodate unfunded debt.

Monetary-led observed economy. In the *monetary-led* block, monetary policy is active—the interest-rate rule satisfies the Taylor principle—while fiscal policy is passive, with the primary surplus adjusting systematically to stabilize government debt. Specifically, monetary policy follows a standard Taylor-type rule for the notional (unconstrained) policy rate, while fiscal actions are subordinated to maintaining debt sustainability.

Thus, policy is described by the following monetary and fiscal rules, subject to the ZLB constraint ($\hat{\imath}_t + \rho \equiv i_t \geq 0$):

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

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

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

where ϕ_i is the smoothing coefficient for the notional (unconstrained) policy rate $\hat{\imath}_t^*$. The coefficients ϕ_p^M and ϕ_y^M govern the monetary response to the funded components of price inflation and the output gap; π_t^{pF} and $\widetilde{y}_t^F$ serve as time-varying targets that capture the unfunded component tracked by the fiscal-led shadow block. Similarly, $\psi_b^M > \rho$ governs the fiscal response to the funded component of debt.[7] We set these policy-rule coefficients to standard values reported in Section 2.6.

Two brief remarks complete the subsection. First, we omit fiscal and monetary policy shocks from the rules because under our assumptions their implications for the welfare-optimal γ are straightforward: with non-distortionary taxes, fiscal shocks would be absorbed by the funded component (so $\gamma = 0$ is optimal); with the nominal interest-rate peg in (7), any monetary policy shocks to (10) would be absorbed by the unfunded component (so $\gamma = 1$ is optimal). Second, under the same peg, the welfare-optimal γ does not depend on debt

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

duration.[8] Robustness checks for alternative rules are provided in the appendices.

To summarize, 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 larger 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. Following Galí (2015), we evaluate policy using a second-order approximation to the representative household's welfare loss from fluctuations around an efficient zero-inflation steady state, expressed as a fraction of steady-state consumption.

The resulting welfare loss function is:

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

where welfare losses arise from fluctuations in the output gap, price inflation, and wage inflation. This decomposition allows a detailed evaluation of how policy regimes shape both the total loss and its individual components.

To quantify the welfare implications of partial fiscal backing, we vary $\gamma \in [0,1]$ while holding the monetary and fiscal rule coefficients fixed, and compute the unconditional welfare loss under the corresponding stationary distribution. Varying γ reallocates shock absorption between future primary surpluses and inflation-driven debt revaluation. In turn, welfare outcomes reflect how changes in γ reshape the equilibrium trade-off between inflation and real activity.

We also report outcomes under the optimal commitment policy as the welfare benchmark. With non-distortionary taxes, the commitment allocation is independent of γ and thus provides a natural upper bound on welfare under the simple rules considered here. This benchmark corresponds to the outcome a benevolent planner could achieve under full commitment.[9]

[8] Under the nominal interest-rate peg, the government budget constraint and the bond-pricing condition, (5) and (6), imply that the bond price remains at its steady state, $\hat{Q}_t^F = \hat{\imath}_t^F = 0$ for all t. Hence $\hat{b}_t^F$ is independent of η, so debt duration is irrelevant in our baseline.

[9] With non-distortionary taxes, the commitment allocation is independent of γ because the government budget constraint and the bond-pricing condition do not bind for the planner. The corresponding equilibrium conditions under the ZLB are given in Appendix C.

2.6 Baseline Calibration

Table 1 reports the baseline calibration used in the stochastic simulations that follow. We discuss the private-sector parameters, the debt target and duration, policy-rule coefficients, shock processes calibrated to match the frequency of ZLB episodes, and the automatic fiscal stabilizer calibrated to ensure effective stabilization.

Private sector. We set the discount factor $\beta = 0.995$, which implies a steady-state real interest rate of about 2 percent per year ($\rho \equiv 1/\beta - 1 \approx 0.005$). Preferences and technology are set to $\sigma = 1$, $\varphi = 5$, and $\alpha = 0.25$, and the elasticities of substitution are $\epsilon_p = 9$ and $\epsilon_w = 4.5$. Nominal rigidities are calibrated to $\theta_p = \theta_w = 0.75$, implying an average duration of price and wage spells of one year (four quarters in the model, $1/(1-\theta_p) = 1/(1-\theta_w) = 4$).

Government debt. The debt target and duration are calibrated to recent U.S. data. We use U.S. values as a convenient benchmark; the qualitative mechanisms do not hinge on any particular jurisdiction. We set $b = 4$, corresponding to a 100 percent annualized debt-to-GDP target in the model's normalization, and $\eta = 0.955$, implying an average debt duration of about five years (twenty quarters in the model, $1/(1-\eta\beta) \approx 20$).

Policy rules. We set the smoothing coefficients to $\phi_i = \psi_\tau = 0.85$. In the monetary-led observed economy, monetary policy responds actively to the funded components of price inflation and the output gap with $\phi_p^M = 1.5$ and $\phi_y^M = 0.125$. Fiscal policy responds passively to the funded component of debt with $\psi_b^M = 0.1$ (satisfying $\psi_b^M > \rho$).[10]

Shocks and ZLB frequency. We calibrate the demand and technology shocks 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 $\rho_z = \rho_a = 0.8$ to generate persistence, and then choose shock standard deviations $\sigma_z = 9.7\%$ and $\sigma_a = 7.4\%$ to match this frequency target. As shown in Figure 1, increasing γ reduces the ZLB frequency—as monetary policy accommodates the unfunded component—but at the cost of reduced monetary-policy flexibility.[12] Accordingly,

[10] With this passive fiscal rule, any increase in debt above target in the observed economy decays by about one-third over four quarters, absent further shocks. Specifically, with $\beta = 0.995$ and $\psi_b^M = 0.1$, equations (5) and (11) together imply $\left(\beta^{-1} - \psi_b^M\right)^4 \approx 0.67$.

[11] We target a non-trivial but not dominant ZLB frequency 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 below, provide a benchmark with zero ZLB frequency; alternative frequency targets can be implemented by rescaling shock volatility and may affect quantitative welfare comparisons.

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

the ZLB frequency varies endogenously with γ in our welfare comparisons rather than being held fixed. Hence welfare differences across γ reflect both the economic effects when the ZLB binds and changes in ZLB frequency.

Fiscal stabilizer and debt target. Finally, we set the automatic stabilizer in the fiscal rule to $\psi_y = 1$ to maximize welfare in the fiscal-led regime ($\gamma = 1$). Figure 2 shows, for each shock on its own, the unconditional welfare loss (and its components) for $\psi_y \in [0, 5]$; this illustrates how the welfare-optimal value of ψ_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 to $b = 4$ is welfare-optimal in the fiscal-led regime by dampening inflation, since inflation is the main channel through which debt returns toward target via revaluation.

Overall, the calibration ensures that fiscal policy provides effective stabilization when monetary policy must accommodate unfunded debt, which helps isolate the mechanisms driving our welfare results. With the baseline calibration in place, we now present the model's stochastic simulation results.

3 Welfare Effects of Partially Unfunded Debt

This section shows that allowing an intermediate share of debt to remain unfunded can improve welfare under demand and technology shocks by reshaping the inflation–output stabilization balance. The idea is that partial unfunding lets fiscal and monetary policy share the adjustment between future surpluses and debt revaluation, which matters most when monetary policy is constrained by the ZLB. We first illustrate this idea using the economy's responses and then quantify the welfare loss and its components as the unfunded share γ varies.

Dynamics. Figures 4 and 5 show the economy's responses to a negative demand shock and a positive technology shock, respectively. Both disturbances reduce inflation, the output gap, and the nominal policy rate. With fully funded debt ($\gamma = 0$), inflation falls the most when the ZLB binds: debt stabilization relies on future surpluses, and monetary policy has limited room to offset the decline once the policy rate hits the lower bound. At the opposite extreme, with fully unfunded debt ($\gamma = 1$), inflation overshoots: monetary policy must accommodate the debt adjustment and inflation becomes the primary mechanism for returning debt toward target through revaluation. These polar cases illustrate that neither full funding nor full unfunding delivers satisfactory inflation stabilization under shocks that put downward pressure on inflation.

A more balanced outcome emerges under partial fiscal backing. With an intermediate unfunded share (e.g., $\gamma = 0.5$), inflation responses lie between the two extremes: inflation falls by less than under full funding but avoids the overshooting observed under full unfunding. This intermediate behavior reflects that fiscal and monetary policy share the adjustment burden. The result is a more stable inflation path and better-supported real activity, suggesting that partial backing can improve stabilization for demand and technology shocks, especially when the ZLB binds. Together, these cases illustrate the basic trade-off: full funding yields stronger disinflation when the ZLB binds, while full unfunding risks inflation overshooting as revaluation does the adjustment. We turn next to welfare.

Welfare. We quantify the welfare implications using the loss function (12). Figure 6 shows the unconditional welfare loss for $\gamma \in [0, 1]$, reported separately for demand shocks (z_t) and technology shocks (a_t), with and without the ZLB. For both shocks, the welfare loss is minimized at an interior value of γ. Without the ZLB, the minimum occurs around $\gamma = 0.3$. With the ZLB, it shifts upward to around $\gamma = 0.4$, reflecting the reduced scope for policy-rate adjustment at the lower bound and the resulting value of shifting part of stabilization toward fiscal policy.[13] This interior optimum reflects an improved inflation–output stabilization balance when fiscal and monetary policy share the adjustment burden.

To see which components of the welfare loss drive this interior optimum, Figure 7 decomposes the total loss into its contributions from the output gap, price inflation, and wage inflation. Partial fiscal backing reduces inflation volatility relative to full funding, with larger gains when the ZLB binds. By contrast, it reduces output-gap volatility primarily in the ZLB environment; without the lower bound, this channel is weaker. Together, these patterns imply that intermediate values of γ strike the best balance: they temper the deflationary pressure associated with fully funded adjustment at the ZLB, while avoiding the excessive inflation volatility associated with fully unfunded adjustment.

Mechanism. The key mechanism is a reallocation of shock absorption. Varying γ reallocates adjustment between (i) expected future primary surpluses that stabilize the funded component of debt and (ii) inflation-driven debt revaluation that stabilizes the unfunded component. With $\gamma = 0$, adverse demand-type shocks translate into larger declines in inflation and the output gap when monetary policy is constrained. With $\gamma = 1$, adjustment relies heavily on revaluation, which supports real activity but makes inflation the main margin of adjustment and can generate overshooting. Intermediate values of γ reduce the need for large policy-rate

[13] As a related comparison, Appendix D shows that when the central bank objective penalizes policy-rate volatility—with the same weight as price-inflation volatility—the preferred share of unfunded debt rises above the welfare optimum. For example, under the Taylor rule without the ZLB, the preferred γ shifts from about 0.3 to about 0.7. Intuitively, a higher γ dampens policy-rate volatility by shifting part of the adjustment away from the policy rate and toward inflation-driven debt revaluation.

cuts after adverse demand-type shocks—thereby lowering the ZLB frequency—while avoiding excessive inflation volatility from revaluation-driven adjustment.

Taken together, the results show that allowing a share of debt to remain unfunded can improve macroeconomic stability and raise welfare, especially when monetary policy is constrained by the ZLB. Figures 6 and 7 also report welfare under the optimal commitment policy (Appendix C), which serves as the benchmark and delivers lower welfare losses than the simple rules considered here. This motivates the next step: examining how sensitive these welfare gains are to the form of the monetary policy rule, especially when policy is more history-dependent.

4 First-Difference Monetary Policy Rule

The previous section showed that partial unfunding can improve welfare under a standard Taylor-type rule by letting fiscal and monetary policy share the adjustment when the ZLB constrains interest-rate cuts. This section asks how much of that benefit depends on the form of the monetary policy rule. A more history-dependent rule can stabilize inflation and the output gap more effectively on its own, potentially leaving less for debt revaluation to accomplish—especially when the ZLB becomes relevant. We therefore turn to a first-difference rule and re-evaluate stabilization and welfare (with and without the ZLB).

Setup. 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 rule for the change in the notional (unconstrained) policy rate:

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

where the response coefficients ϕ_p^M and ϕ_y^M are kept at their baseline values so that the comparison isolates rule form (levels versus differences) rather than re-optimizing coefficients. We implement this rule by updating the notional rate each period as $\hat{\imath}_t^* = \hat{\imath}_{t-1}^* + \Delta\hat{\imath}_t^*$, and then applying the ZLB as in (10). 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 notional 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.

Welfare. We quantify the welfare implications under this rule. Figure 8 shows the unconditional welfare loss for $\gamma \in [0, 1]$, comparing the first-difference rule with the Taylor-rule

benchmark. To facilitate a direct comparison, it reproduces the Taylor-rule outcomes for demand shocks (z_t) and technology shocks (a_t) reported in Figure 6. Because the response coefficients are held fixed across the two rules, the differences reflect the change in rule form rather than changes in coefficients. Under the first-difference rule, the welfare-optimal share of unfunded debt shifts toward zero ($\gamma = 0$), so full funding delivers the highest welfare in this setting, with and without the ZLB.

Interpretation. The more history-dependent rule stabilizes inflation and the output gap more effectively over time, delivering much of the inflation–output balance that partial unfunding helped achieve under the Taylor rule when interest-rate cuts were constrained. Put differently, as monetary policy becomes more effective on its own, there is less for debt revaluation to accomplish. In effect, the first-difference rule internalizes part of the stabilization role that partially unfunded debt played in that setting. Consequently, the welfare gains from moving away from full funding shrink and can vanish, shifting the welfare-optimal degree of fiscal backing toward full funding under this rule.

These results underscore how monetary policy performance shapes the welfare-optimal degree of fiscal backing. The next section shows how this result changes when inflation is driven by markup disturbances.

5 Effects of Price and Wage Markup Shocks

Having examined demand and technology shocks, we next turn to price and wage markup disturbances. These shocks provide a sharper test of the inflation–output trade-off because they move inflation directly, even when real activity is weak. This setting therefore highlights when unfunded debt helps monetary policy "look through" inflation and when it does not, depending on the comovement of price and wage inflation. We first characterize how the welfare ranking of funded versus unfunded debt changes under markup shocks, and then use the economy's responses under the Taylor and first-difference rules to clarify the mechanism.

Setup. 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 (highlighted 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 (unlike the demand and technology experiments in Sections 3 and 4). 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 frequency.

Welfare. With markup disturbances in place, we revisit the desirability of unfunded debt under different monetary policy rules. Figure 9 shows the unconditional welfare loss for $\gamma \in [0, 1]$, comparing the first-difference rule with the Taylor-rule benchmark. The left panel reports outcomes for price-markup shocks (u_t), while the right panel reports 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 penalty by tightening the stabilization trade-off. 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 fluctuations in real activity. The key distinction is whether stabilizing price inflation would require sharp swings in the output gap and wage inflation. Here, "looking through" means allowing markup-driven inflation to pass through temporarily when fully offsetting it would entail those swings, which together receive substantial weight in the loss function. Thus, unfunded debt can improve welfare by allowing monetary policy to accommodate temporary price-markup pressures without inducing excessive fluctuations in real activity.

Dynamics. To illustrate the mechanism behind the welfare rankings, Figure 10 shows the economy's responses to a negative price- or wage-markup shock (which calls for a policy-rate cut) under the Taylor and first-difference rules. 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

[14] In the fiscal-led shadow block, markup shocks are scaled by γ, analogously to demand and technology shocks. Hence γ governs the share of each markup disturbance absorbed by the unfunded component (and thus by debt revaluation), and it determines the strength of markup-shock transmission in that block.

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, markup shocks make clear that the desirability of unfunded debt is shock-dependent. While Sections 3 and 4 showed that partial unfunding can improve outcomes under demand and technology shocks—especially when monetary policy is constrained—markup disturbances shift the question to whether policymakers should accommodate cost-push inflation. Unfunded debt can be welfare-improving under price-markup shocks by allowing monetary policy to "look through" inflation, but this logic is weaker under wage-markup shocks, where full fiscal backing is preferred. These differences underscore the importance of tailoring the monetary–fiscal policy mix to the source of inflationary pressure.

6 Conclusion

TBA

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Parameter	Description	Value
β	Discount factor	0.995
σ	Curvature of consumption utility	1
φ	Curvature of labor disutility	5
α	Index of decreasing returns to labor	0.25
ϵ_p	Elasticity of substitution of goods	9
ϵ_w	Elasticity of substitution of labor	4.5
θ_p	Calvo index of price rigidities	0.75
θ_w	Calvo index of wage rigidities	0.75
γ	Share of unfunded debt (baseline fully funded)	0
b	Debt-to-GDP target (100% of annualized GDP)	4
η	Bond coupon decay rate (duration 5 years)	0.955
ϕ_i	Smoothing coefficient in Taylor rule	0.85
ϕ_p^M	Monetary response to price inflation	1.5
ϕ_y^M	Monetary response to output gap	0.125
ψ_τ	Smoothing coefficient in fiscal rule	0.85
ψ_b^M	Fiscal response to debt	0.1
ψ_y	Fiscal response to output gap	1
$\rho_{z,a}$	Persistence of shocks	0.8
σ_z	Std. deviation of demand shock (%)	9.7
σ_a	Std. deviation of technology shock (%)	7.4

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

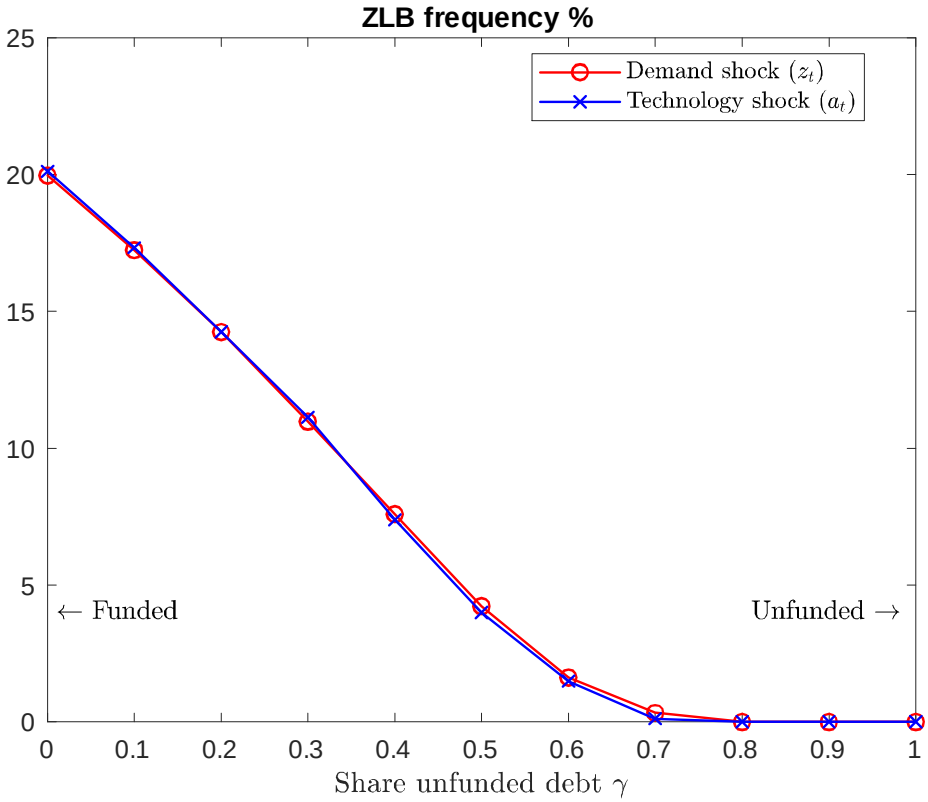


Figure 1: Partially unfunded debt reduces the frequency of zero-lower-bound (ZLB) episodes, but at the cost of reduced monetary-policy flexibility, as monetary policy must accommodate the unfunded part of government debt.

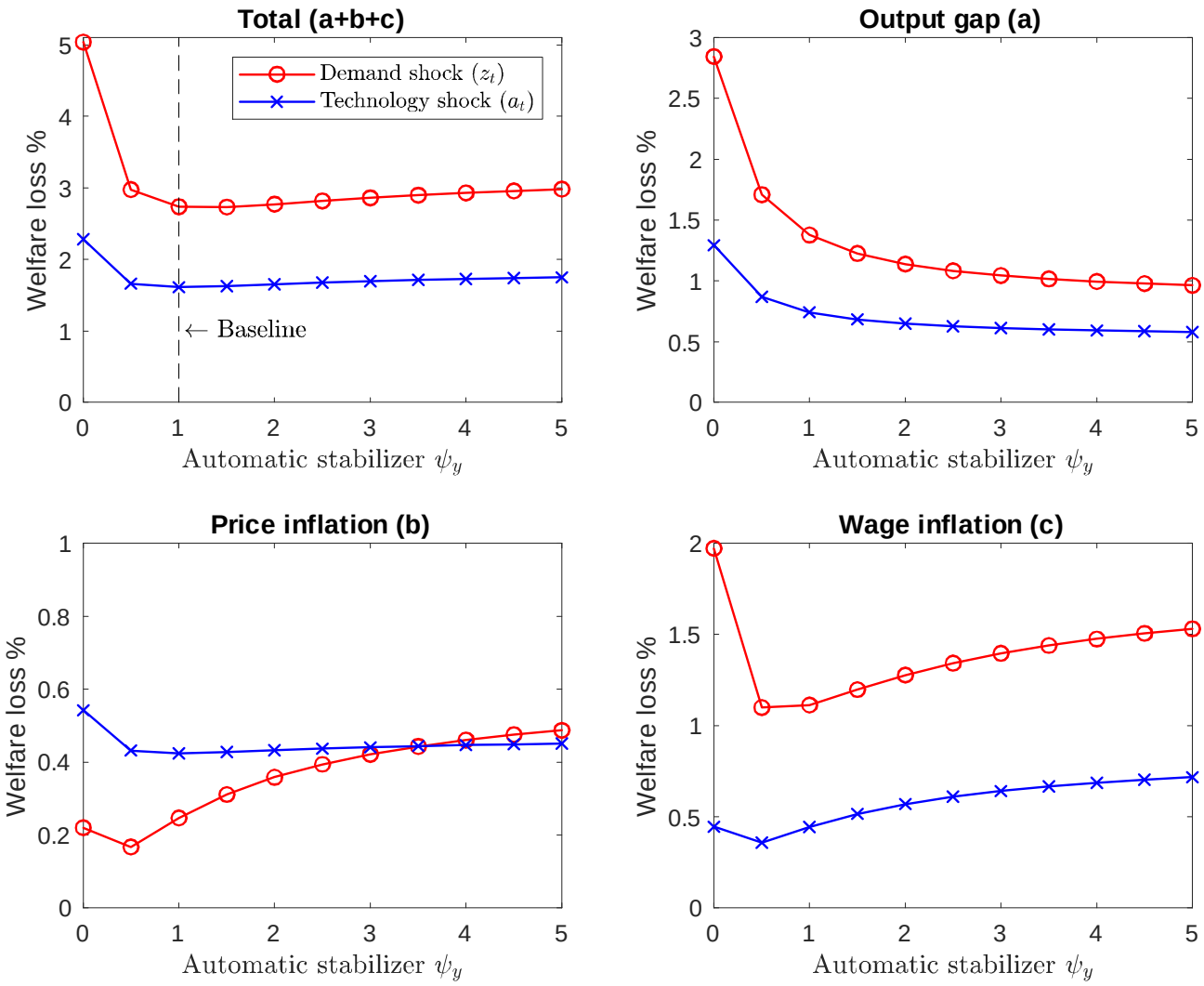


Figure 2: With fully unfunded debt ($\gamma = 1$), the welfare-optimal value of the automatic stabilizer in the fiscal rule ψ_y is close to 1.

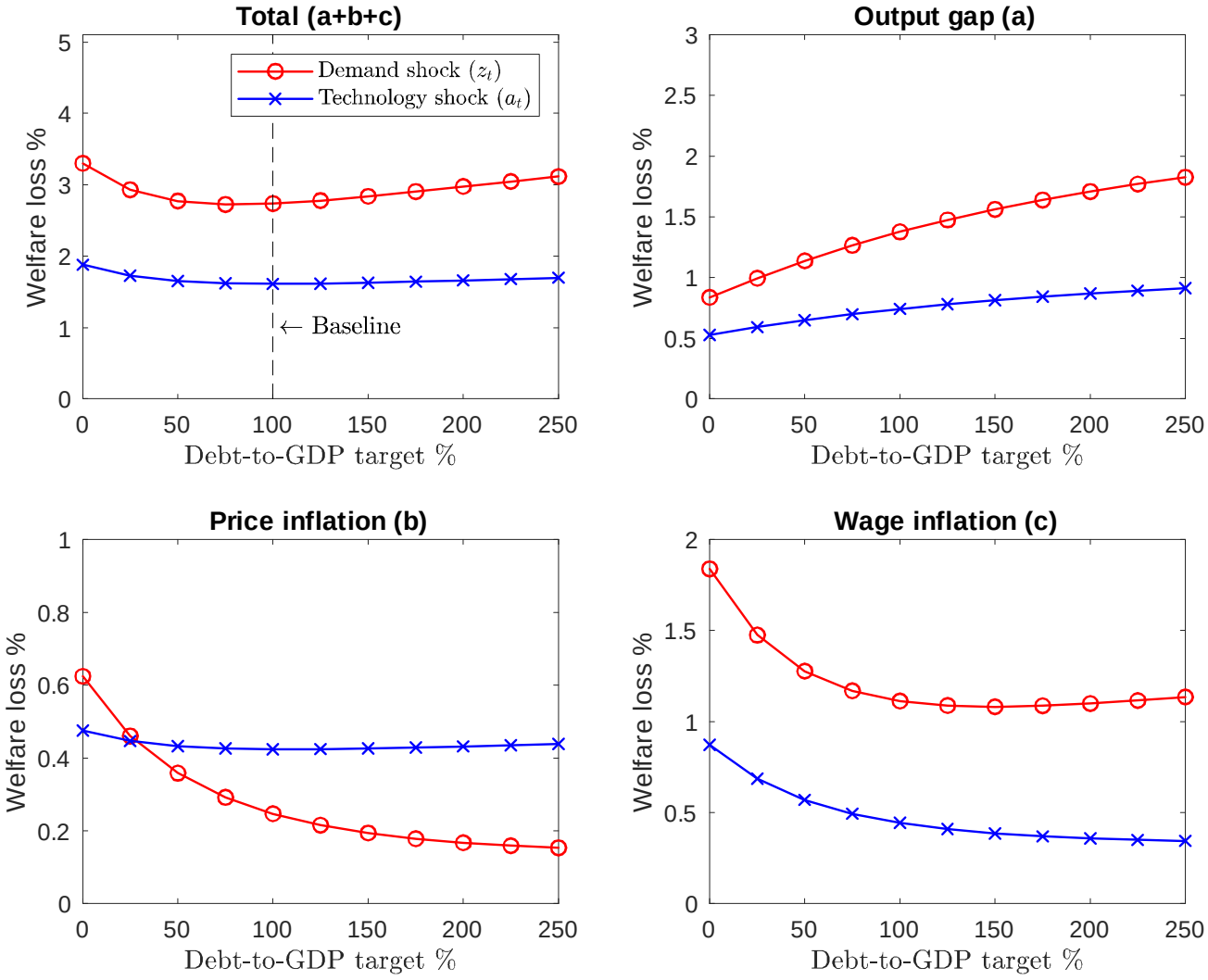


Figure 3: With fully unfunded debt ($\gamma = 1$), setting the annualized debt-to-GDP target at 100% ($b = 4$) is welfare-optimal.

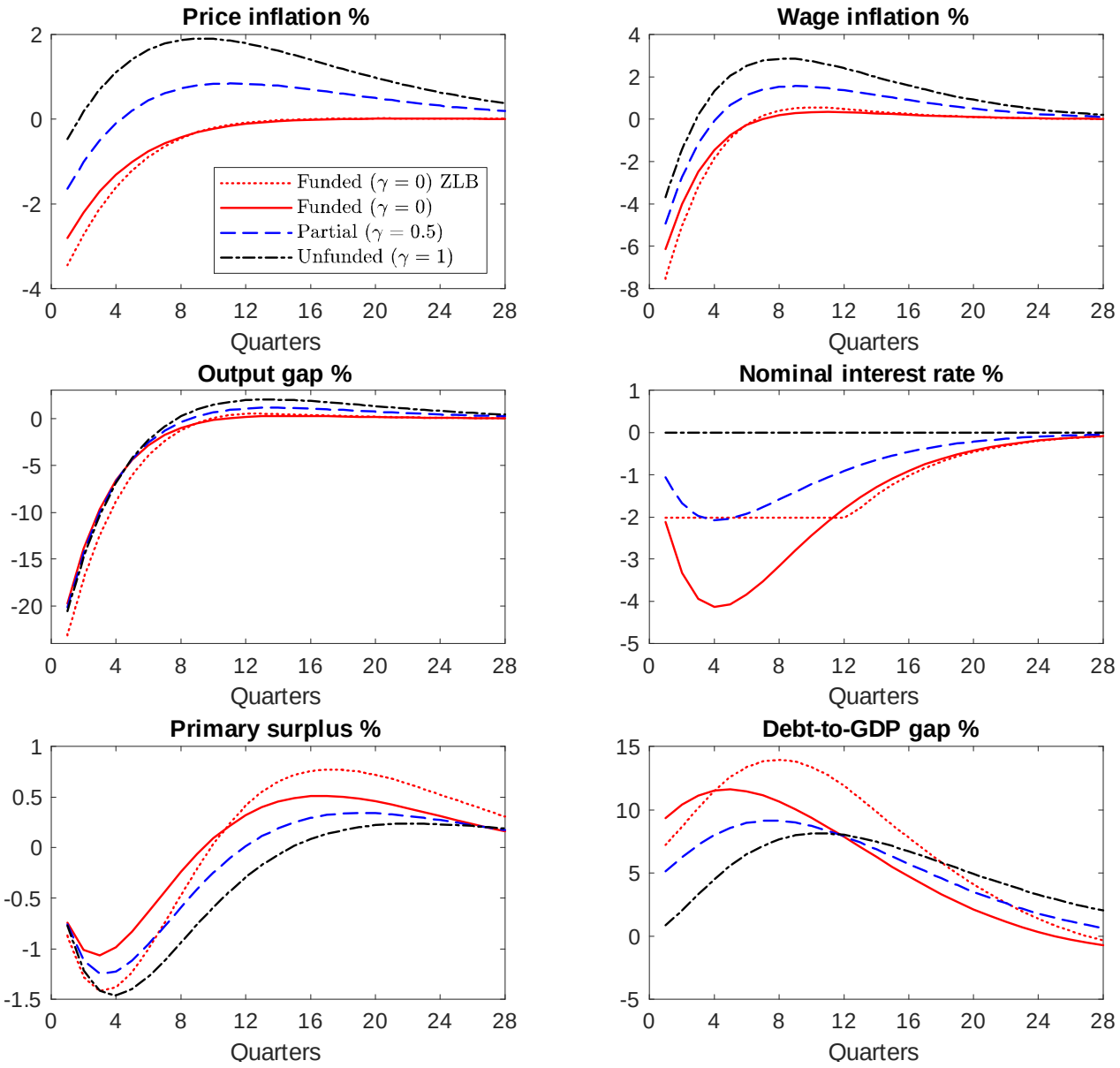


Figure 4: Partially unfunded debt stabilizes inflation in the face of demand shocks, both with and without the ZLB. Responses to a -3σ demand shock. Annualized deviations from steady state.

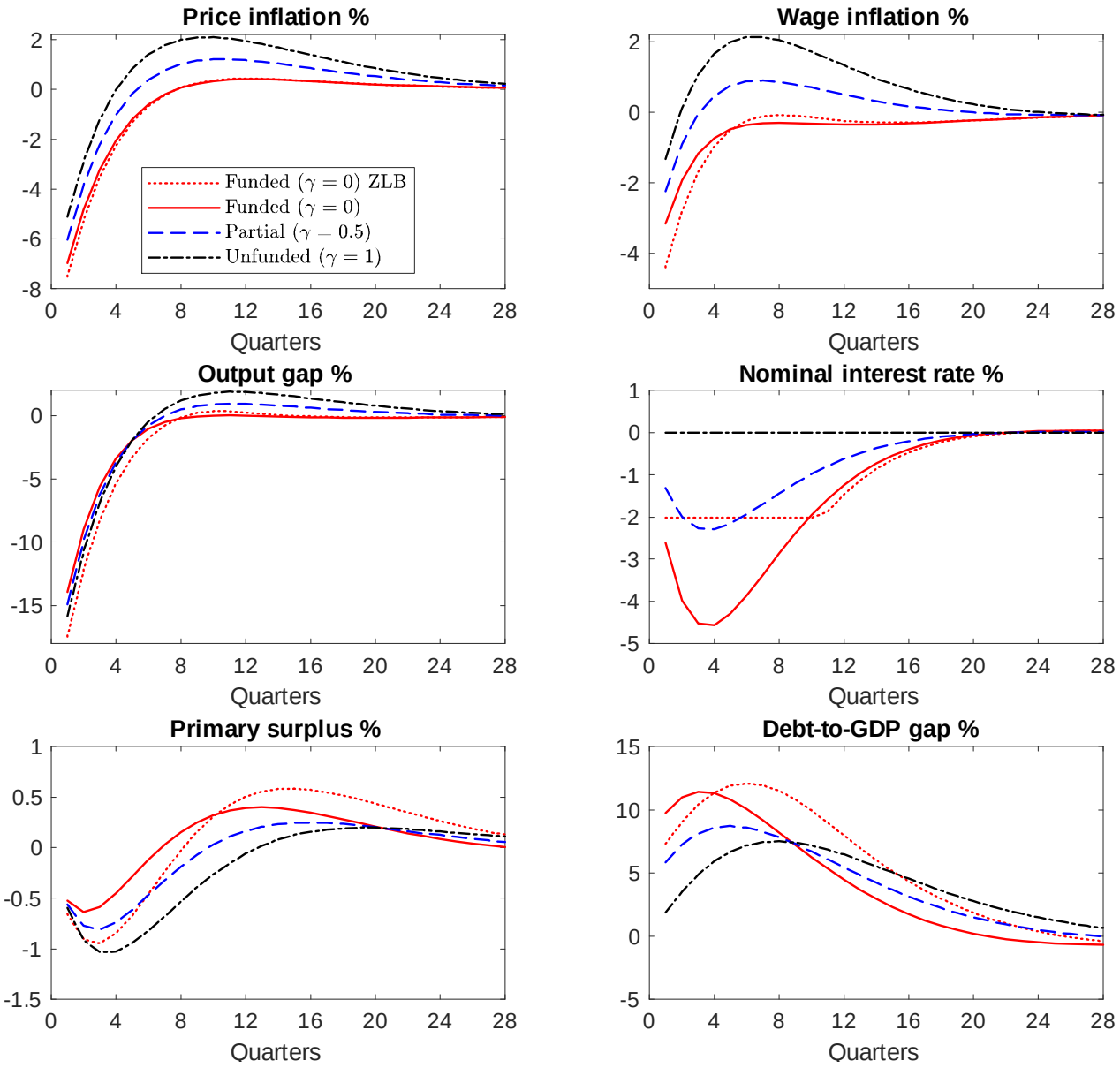


Figure 5: Partially unfunded debt stabilizes inflation in the face of technology shocks, both with and without the ZLB. Responses to a $+3\sigma$ technology shock. Annualized deviations from steady state.

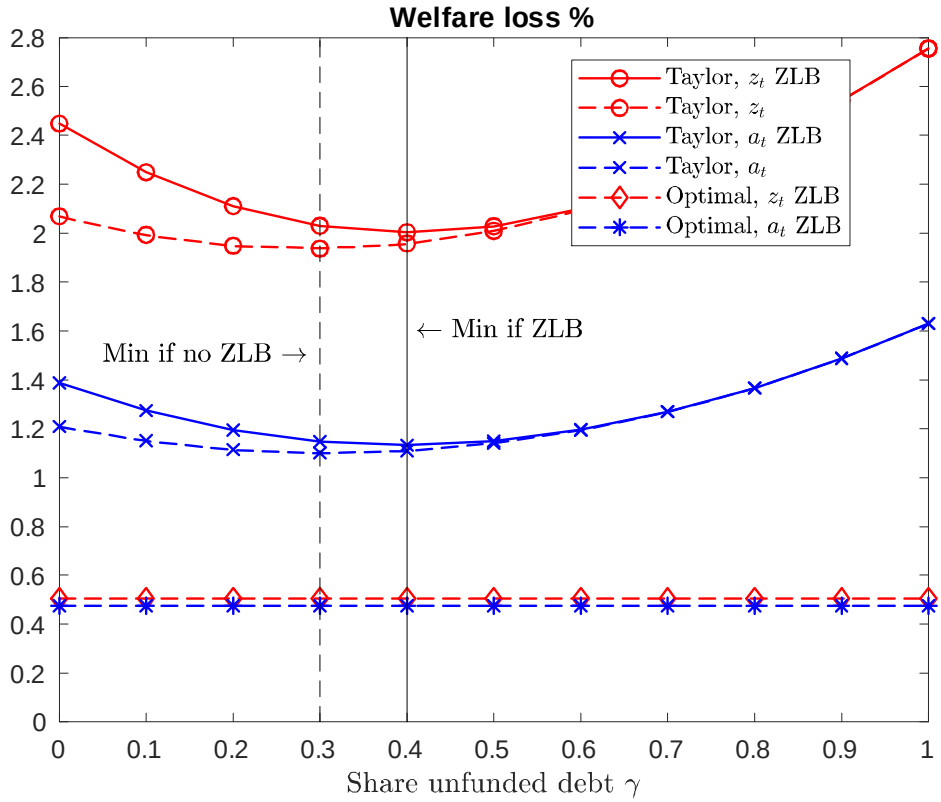


Figure 6: Partially unfunded debt improves welfare, both with and without the ZLB, by balancing inflation and output stabilization.

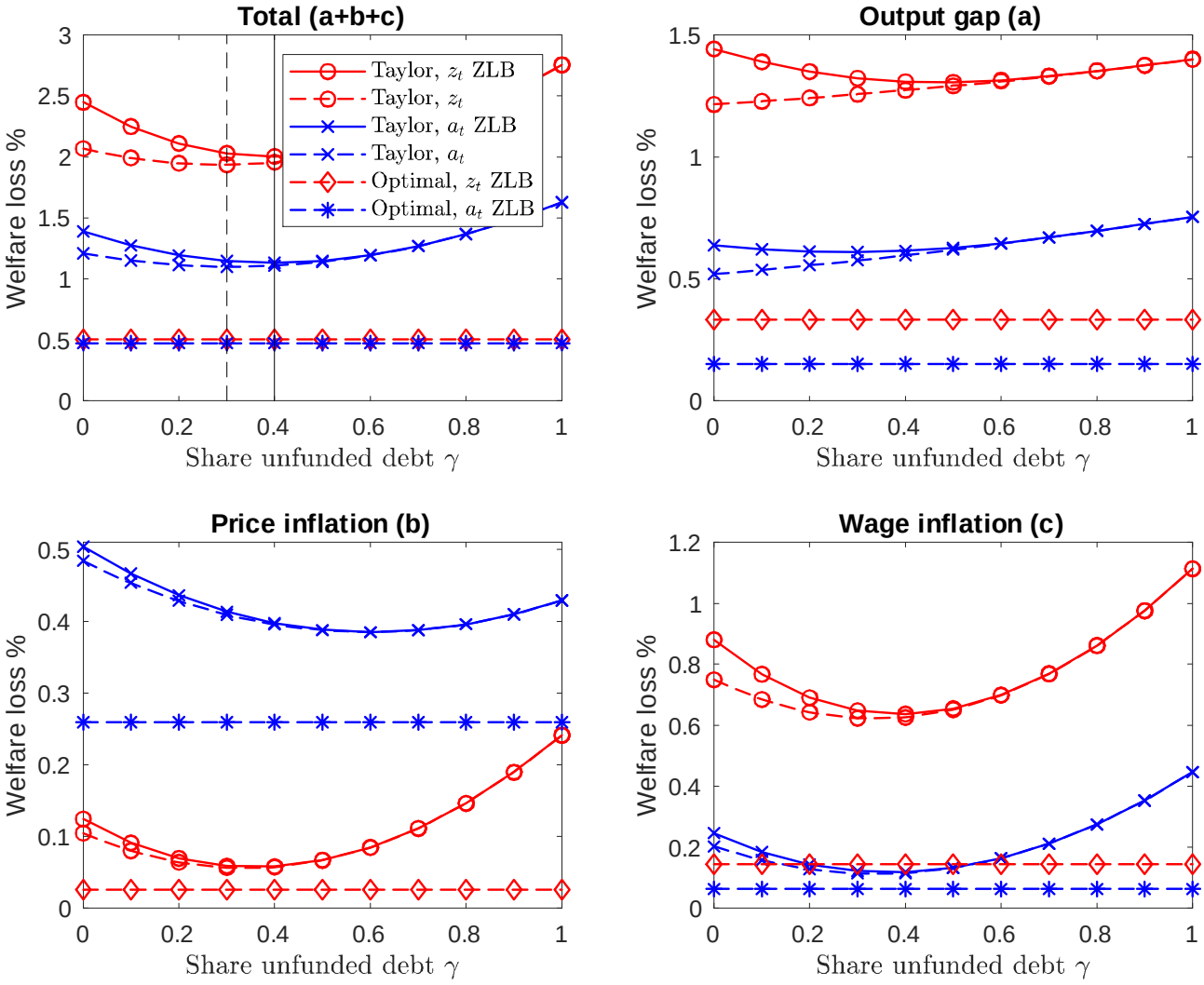


Figure 7: Welfare loss components under partially unfunded debt, both with and without the ZLB. The top left panel replicates Figure 6 for a closer look at the decomposition.

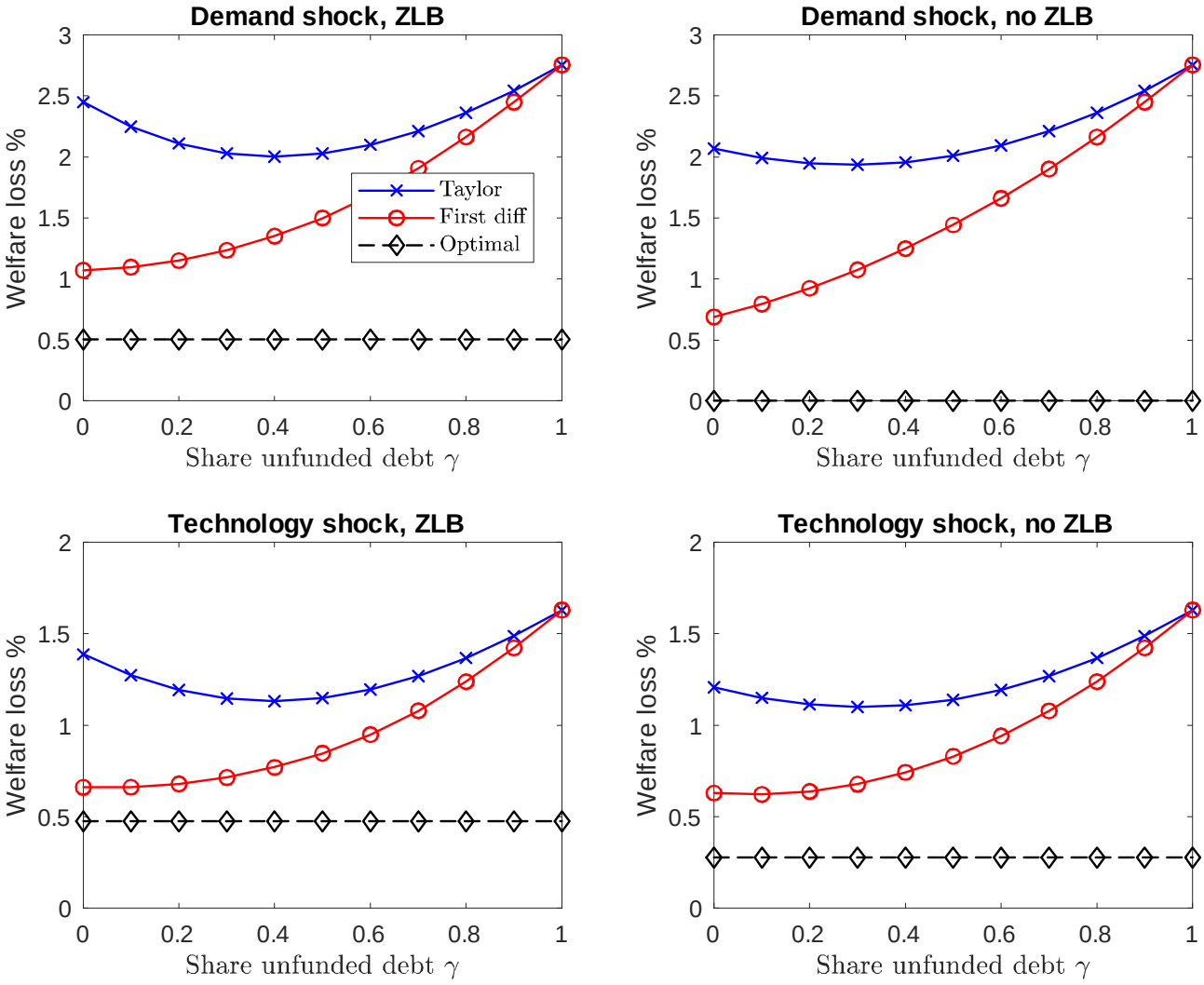


Figure 8: A more history-dependent monetary policy, such as a first-difference rule, can improve welfare and make fully funded debt preferable, both with and without the ZLB. This figure replicates all the outcomes shown in Figure 6, allowing for a direct comparison.

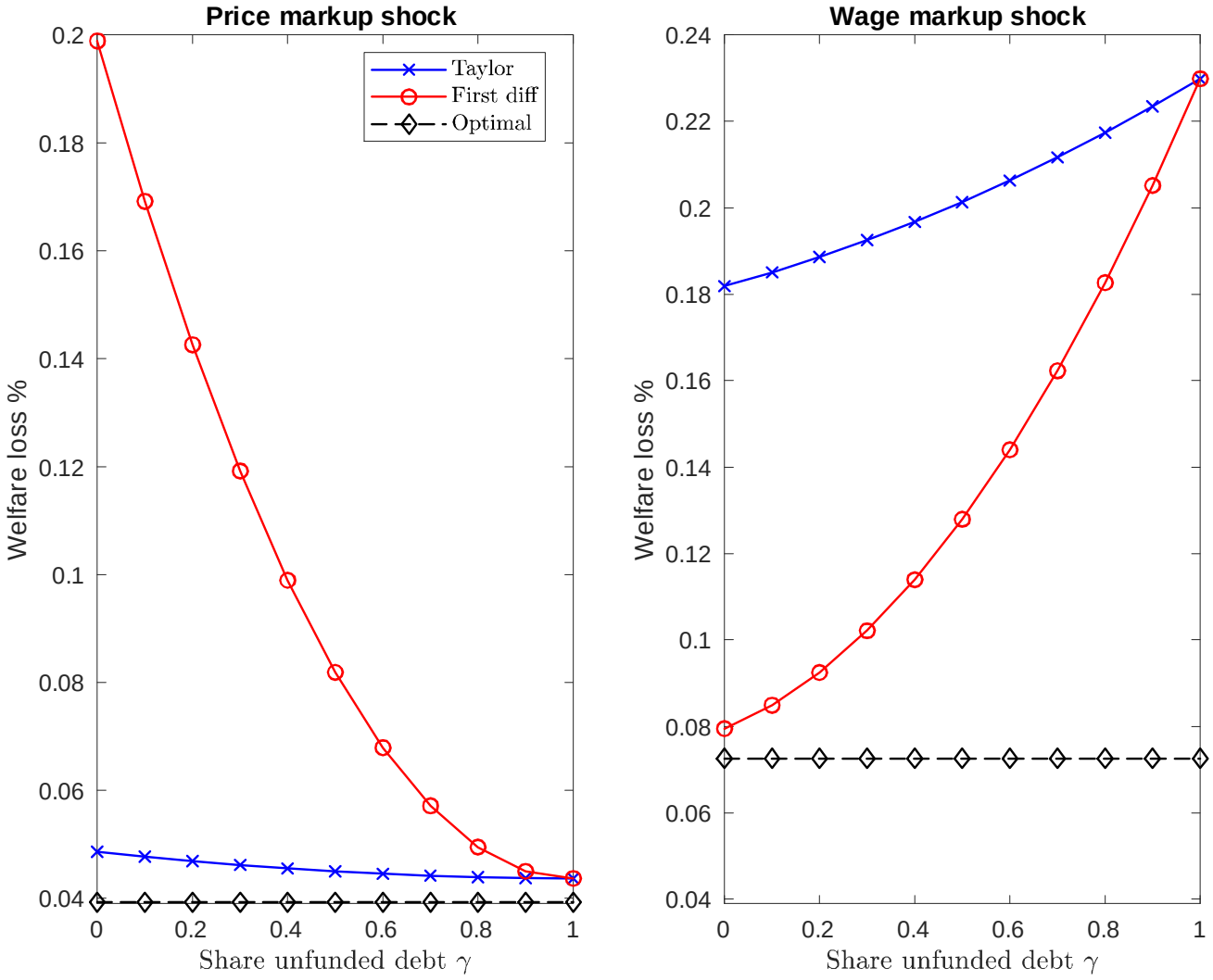


Figure 9: Unfunded debt can improve welfare by allowing the Taylor and first-difference rules to accommodate price-markup shocks, whereas fully funded debt is preferred under wage-markup shocks. Results shown for shock volatility small enough that the ZLB does not bind.

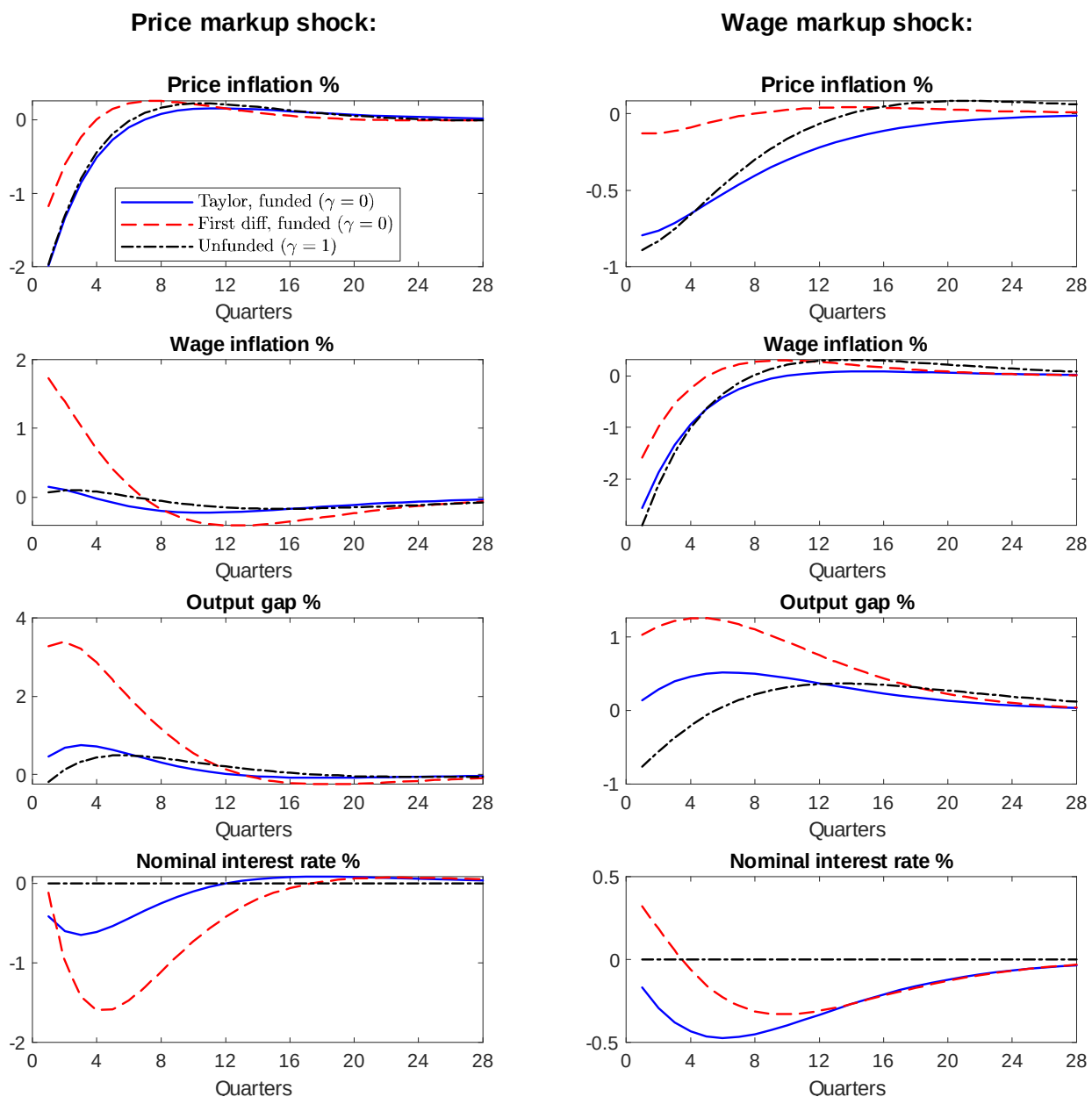


Figure 10: A first-difference monetary policy rule makes wage inflation more volatile facing price-markup shocks, but less volatile facing wage-markup shocks. Responses to a -3σ markup shock, with the ZLB not binding. Annualized deviations from steady state.

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 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 the welfare benchmark. Appendix D considers central bank aversion to interest-rate volatility.

A Monetary Policy Leaning Against Fiscal Inflation

This appendix examines how sensitive the desirability of unfunded debt is to the assumption that monetary policy does not respond to fiscal inflation in the fiscal-led block (Section 2.4). We relax that assumption by allowing monetary policy to lean against fiscal inflation, while keeping all other parameters unchanged. This is a natural check because the baseline rules insulate monetary policy from directly affecting the interest burden on government debt.

Specifically, in the fiscal-led shadow economy, the nominal interest-rate peg (7) is replaced by a rule less accommodative toward fiscal inflation (highlighted terms indicate deviations from the baseline rules):

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

where $\phi_p^F \in [0, 1)$. Raising ϕ_p^F makes monetary policy lean more strongly against fiscal inflation, reflecting a less accommodative but still passive stance. This keeps monetary policy passive so the shadow-economy block remains a fiscal-led regime.

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

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

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 shows the economy's responses to demand and technology shocks under fully unfunded debt ($\gamma = 1$), with inflation overshooting. It compares 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. Intuitively, this leaning weakens the debt revaluation channel—by increasing the interest burden on debt when the policy rate rises—and inflation has more to accomplish to return debt toward its target.

Overall, allowing monetary policy to lean against fiscal inflation weakens the debt revaluation channel and raises macroeconomic volatility, weakening the welfare case for unfunded debt relative to the baseline.

B Fiscal Policy Leaning Against Unfunded Debt

This appendix asks how sensitive the desirability of unfunded debt is to the assumption that fiscal policy does not react to it in the fiscal-led block (Section 2.4). We relax that assumption by allowing fiscal policy to lean against unfunded debt, while keeping all other parameters unchanged. This offers a useful check because the baseline rules include an automatic stabilizer—designed to maximize welfare in the fiscal-led regime—that may leave limited scope for debt leaning.

Within the fiscal-led shadow economy, the fiscal rule (8) is modified to be less accommodative toward unfunded debt (highlighted terms indicate deviations from the baseline rules):

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

where $\psi_b^F \in [0, \rho)$. Increasing ψ_b^F makes fiscal policy lean more forcefully against unfunded debt, reflecting a less accommodative but still active stance. This keeps fiscal policy active so the shadow-economy block remains a fiscal-led regime.

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

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

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 shows the economy's responses to demand and technology shocks under fully unfunded debt ($\gamma = 1$), with inflation overshooting. It compares results without leaning (red solid lines, $\psi_b^F = 0$) and with leaning (blue dashed lines, $\psi_b^F = 0.004$). The responses are nearly identical, owing to the strong automatic stabilizer. The stabilizer's output-gap response ψ_y largely offsets the debt deviations that the leaning ψ_b^F term would otherwise address. For contrast, the figure also shows results for a scenario without the 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.

Hence, with a strong automatic stabilizer, allowing fiscal policy to lean against unfunded debt has negligible additional effects on macroeconomic volatility and does not materially change the desirability of unfunded debt relative to the baseline.

C Optimal Commitment Policy with the ZLB

This appendix derives the equilibrium conditions for the optimal commitment allocation with an explicit zero lower bound (ZLB) on the nominal policy rate, which we use as the welfare benchmark. Because taxes are non-distortionary, debt management does not create a trade-off for the planner and fiscal policy adjusts as needed to satisfy the budget.

With the welfare loss function (12), 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 equilibrium conditions (1)–(4), and the ZLB, $\hat{\imath}_t + \rho \equiv i_t \geq 0$ for all t. With non-distortionary taxes, the government budget constraint and the bond-pricing condition, (5) and (6), are not binding for the planner; hence fiscal policy can fully stabilize government debt. We set $\hat{b}_t = 0$ for all t, with $\hat{\tau}_t$ adjusting as needed.

Let m_{1t}, m_{2t}, m_{3t}, and m_{4t} denote the multipliers on the IS equation, the price Phillips curve, the wage Phillips curve, and the real wage gap identity, respectively. 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 (including complementary slackness for the ZLB) 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 for $\widetilde{\omega}_t$ implies:

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

Thus, the optimal commitment allocation under the ZLB is characterized by the private-sector equilibrium conditions (1)–(4) and the Kuhn–Tucker conditions (20)–(24); the government budget constraint and the bond-pricing condition (5)–(6) are 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

This appendix asks how sensitive the desirability of unfunded debt is to replacing the welfare criterion with a central bank objective that penalizes interest-rate volatility, in addition to the usual stabilization terms. This is a useful check because central bankers often value a smooth policy rate.

We keep the model and policy rules unchanged, while we modify the welfare loss function (12) to represent a central bank loss function (highlighted term indicates modification):

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

where the third component reflects volatility of the nominal interest rate, which receives the same weight as price-inflation volatility for a transparent comparison.

With this central bank loss function in place, we revisit the desirability of unfunded debt. Figure A.3 shows the unconditional loss for $\gamma \in [0, 1]$ under the Taylor rule without the ZLB, reported for demand shocks (z_t) and technology shocks (a_t). For both shocks, the preferred share of unfunded debt rises to around 0.7. This share is more than double the optimum around 0.3 implied by the welfare loss function (12) without the ZLB (Figures 6 and 7). Intuitively, a higher γ dampens policy-rate volatility—that the central bank penalizes—by shifting part of the adjustment away from the policy rate and toward inflation-driven debt revaluation.

This comparison highlights how a preference for policy-rate smoothing can push the preferred degree of unfunding above the welfare optimum. Policymakers and academics may wish to distinguish between these objectives when setting policy goals and evaluating trade-offs. More generally, aligning central bank objectives with welfare criteria helps keep policy evaluation transparent and internally consistent.

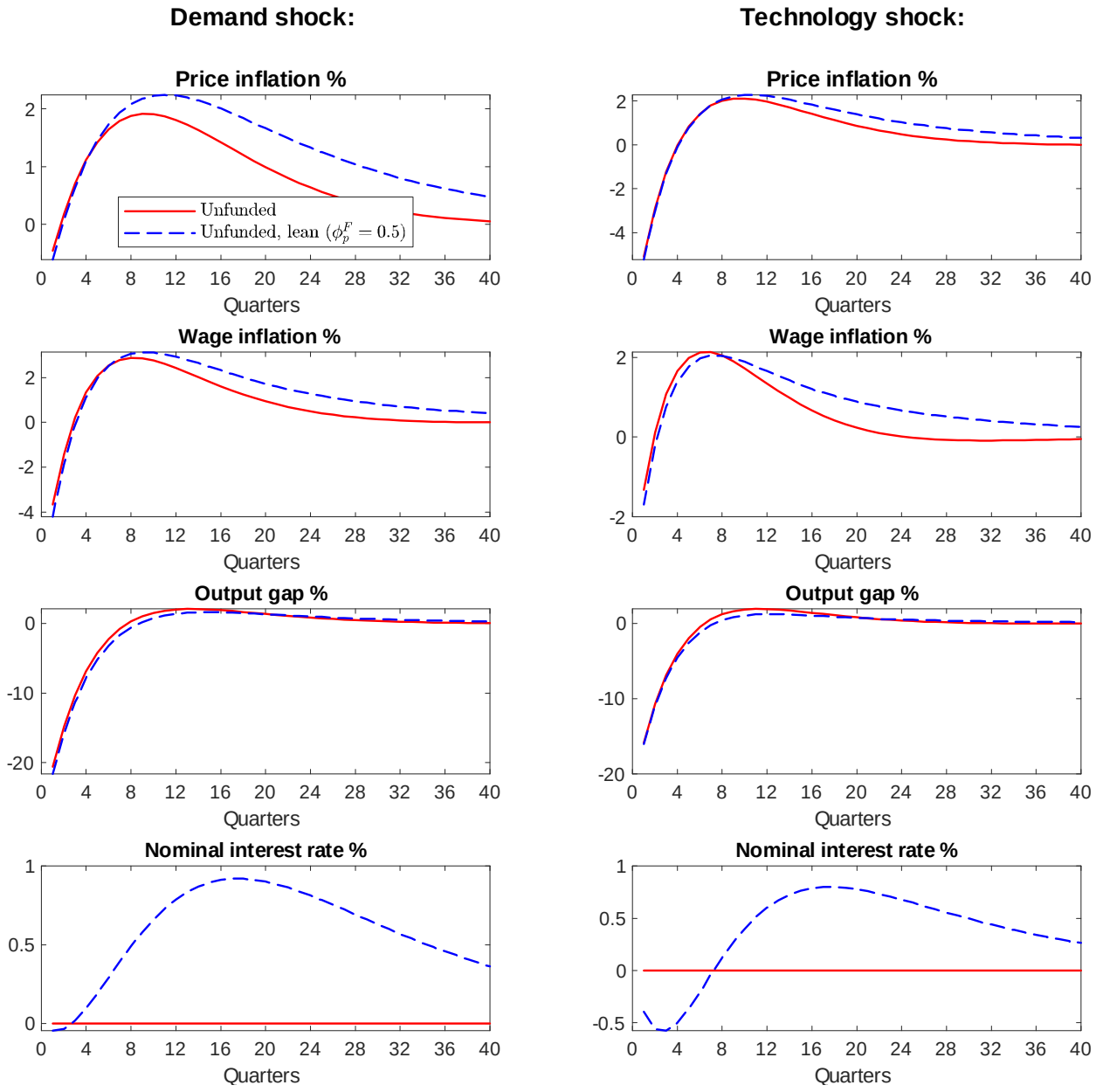


Figure A.1: With fully unfunded debt ($\gamma = 1$), monetary policy leaning against fiscal inflation increases the volatility of inflation and the output gap. Responses to a -3σ demand shock or a $+3\sigma$ technology shock. Annualized deviations from steady state.

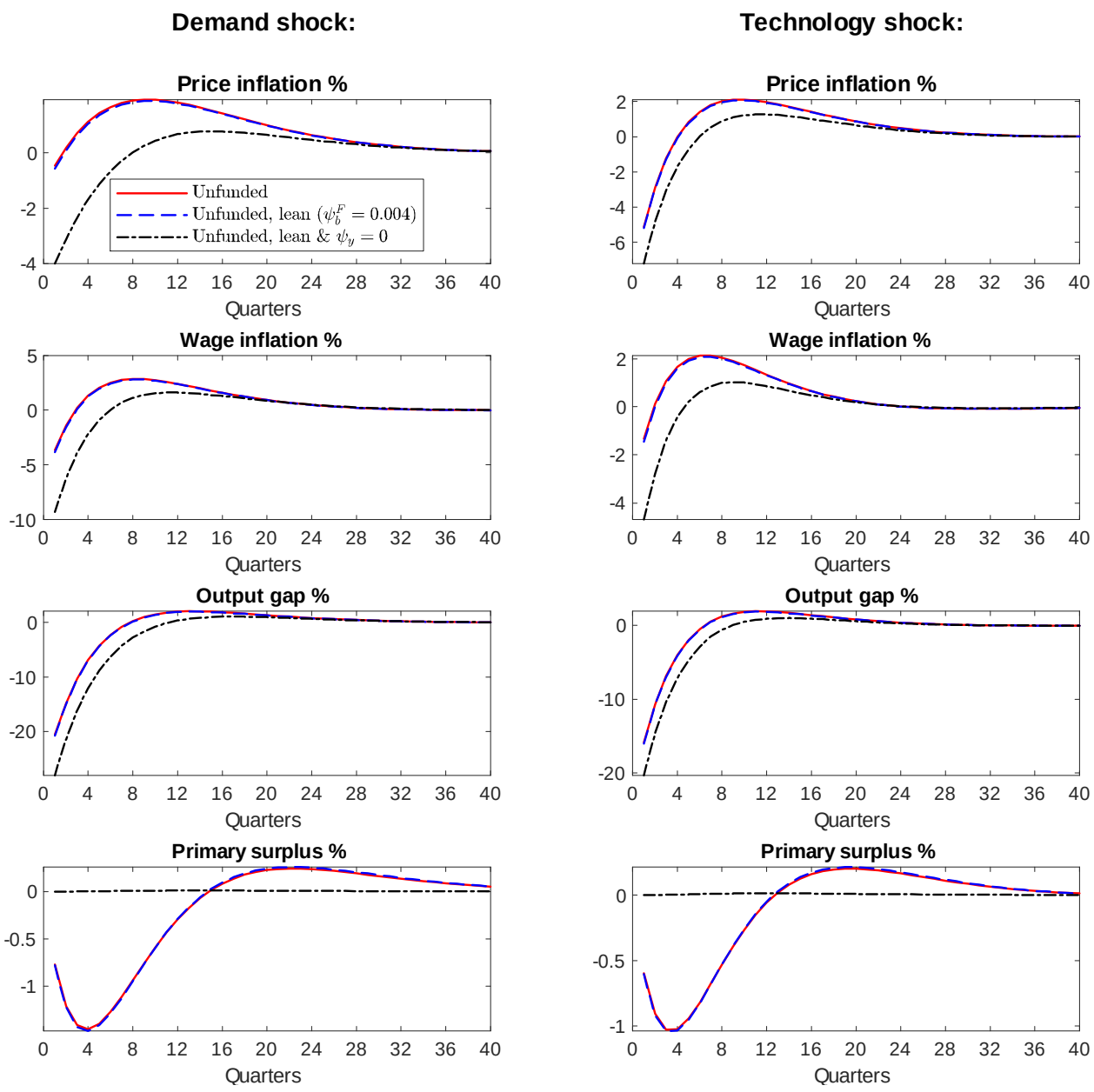


Figure A.2: With fully unfunded debt ($\gamma = 1$), a strong automatic fiscal stabilizer neutralizes the effect of leaning against unfunded debt on macroeconomic volatility. Responses to a -3σ demand shock or a $+3\sigma$ technology shock. Annualized deviations from steady state.

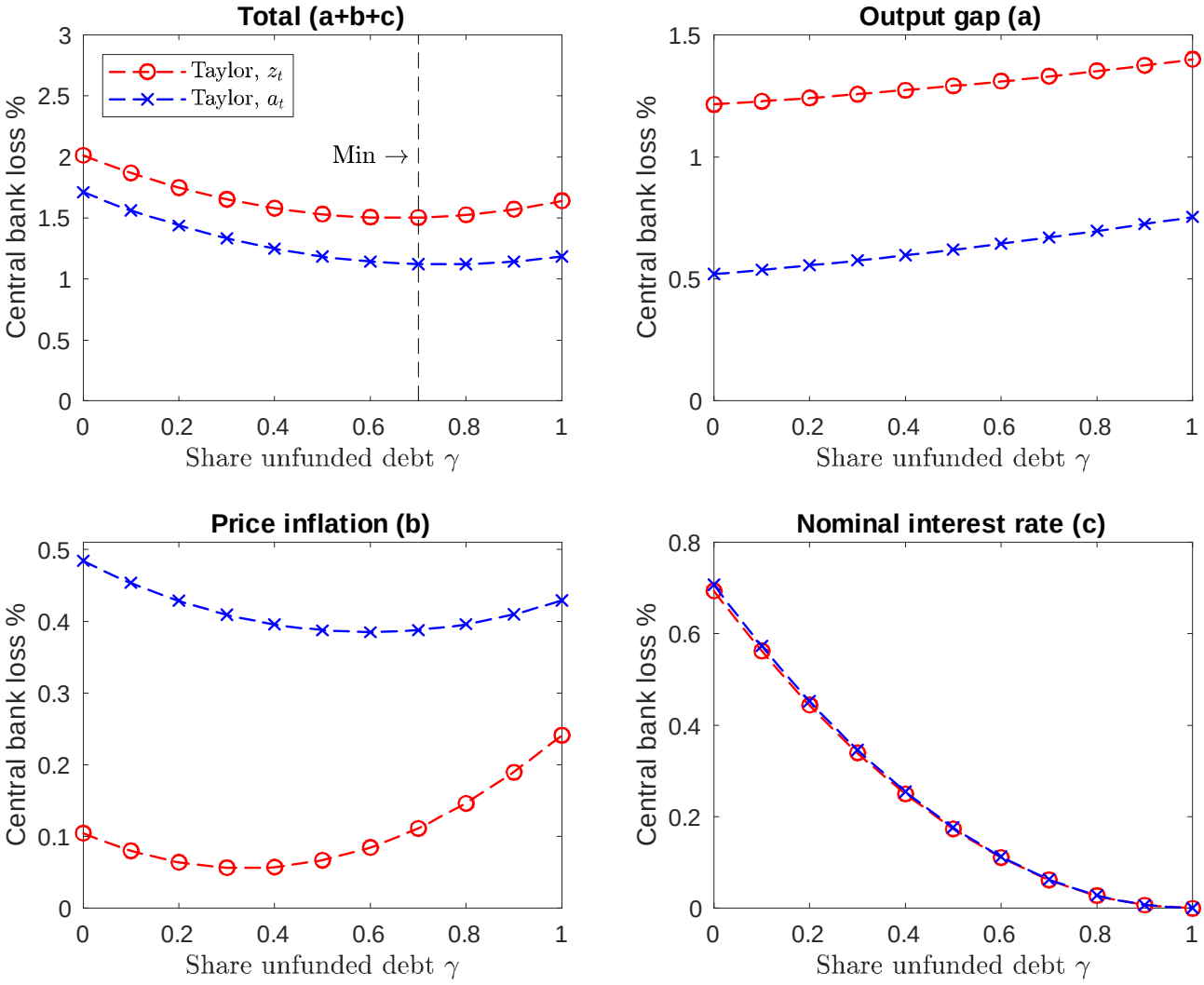


Figure A.3: Central bank aversion to nominal interest-rate volatility raises the preferred share of unfunded debt above the welfare optimum. Results shown without the ZLB. The output gap and price inflation panels (top right and bottom left) correspond to Figure 7, which displays the welfare optimum.