Unconventional Policies in State-Dependent Liquidity Traps

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Abstract

We characterize optimal unconventional monetary and fiscal-financial policies against supply- and demand-driven liquidity traps within a tractable New Keynesian model featuring a cash-in-advance constraint and a monetary policy cost channel. Deposit *subsidies* circumvent the inflation-output trade-off arising from stagflationary shocks and supply-driven liquidity traps by enabling *negative* nominal interest rates. Additionally, deposit *taxes* facilitate modest interest rate *hikes* to escape demand-driven deflationary traps. Notably, discretionary and commitment policies with deposit taxes / subsidies deliver virtually equivalent welfare gains, rendering time-inconsistent forward guidance schedules unnecessary. We also derive robust and implementable optimal policy rules when the sources of shocks are unknown.

Keywords: Deposit Tax-Subsidy; Cost Channel; Optimal Policy; Discretion vs. Commitment; Zero Lower Bound.

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1 Introduction

The zero lower bound (ZLB) constraint on nominal interest rates severely impedes the effectiveness of monetary policy in stimulating economic activity during liquidity trap episodes. With the unprecedented economic response to the COVID-19 crisis, we were once again reminded of the limitations of merely using conventional monetary policy. Such challenges to traditional interest rate strategies call for the implementation of supplementary (un)conventional monetary and fiscal policies aimed at minimizing the social costs of output gap and price fluctuations. Most of the theoretical literature has so far focused on: *i)* optimal monetary commitment – forward guidance schedules (Eggertsson and Woodford 2003; Adam and Billi 2006; Nakov 2008); *ii)* quantitative easing (QE) and a negative interest rate policy (Sims and Wu 2021; Sims, Wu, and Zhang 2023); *iii)* increased government spending (Eggertsson 2011; Christiano, Eichenbaum, and Rebelo 2011; Schmidt 2013); and *iv)* flexible adjustments in consumption and/or labor taxes – 'unconventional fiscal policy' (Eggertsson and Woodford 2006; Correia, Farhi, Nicolini, and Teles 2013; D'Acunto, Hoang, and Weber 2018). Less attention has been given to the *normative* implications of corrective *financial* tax-based policies and their interactions with monetary policy in *state-dependent* liquidity traps. We fill this gap by developing a tractable New Keynesian model that examines the stabilization roles of state-dependent monetary and fiscal-financial interventions – the latter taking the form of term deposit taxes / subsidies – in response to both demand-driven and supply-driven liquidity traps.[1] The present article points to novel unconventional policies that central banks and governments can employ to address the ZLB constraint, a challenge that, as noted by Bernanke (2020), may become increasingly common in advanced economies with a low inflation target.[2]

We analyze the optimal mix of monetary and private asset tax stabilization policies under both discretion and commitment in a stylized New Keynesian model à la Ireland (2004). The core framework is modified for: *i)* a working-capital borrowing constraint faced by firms prior to production, which gives rise to a monetary policy cost channel (Ravenna and Walsh 2006);[3] *ii)* a deposit tax-subsidy; and *iii)* an occasionally-binding lower bound restriction on the *effective tax-augmented* nominal interest rate faced by households-depositors. Our textbook treatment of the research topic simplifies the model into a familiar two-equation forward-looking system consisting

[1] Throughout the text, financial taxes, (private) asset taxes, savings taxes, and (time or term) deposit taxes / subsidies are used interchangeably and denoted by $\tau_t^D \lesseqgtr 0$.

[2] Despite continued efforts to curb the inflation surge through nominal interest rate hikes since early 2022, there is limited evidence indicating an increase in equilibrium real rates (Gopinath 2022; Lemoine and Lindé 2023; Holston, Laubach, and Williams 2023). As a result, a significant lingering risk of a recession persists, where monetary policy alone may prove insufficient to sustain output and inflation at their target levels.

[3] On the empirical significance of the monetary policy cost channel and how the nominal interest rate influences inflation via the New Keynesian Phillips Curve (NKPC), see also Christiano, Eichenbaum, and Evans (2005); Chowdhury, Hoffmann, and Schabert (2006); Tillmann (2008); Abo-Zaid (2022); Beaudry, Hou, and Portier (2024).

of an aggregate demand (AD) schedule (Euler equation) and an aggregate supply (AS) relation (Phillips curve). These equations are influenced by the unique occasionally-binding lower bound floor on the tax-augmented nominal deposit rate, which arises endogenously from a cash-in-advance (CIA) constraint. A key aspect of our model is that the fiscal-financial instrument enters directly into the AD curve, with the nominal interest rate entering both the AD and AS curves.[4]

The present paper provides novel positive and normative insights into the ongoing debate on unconventional policies and the advantages of coordinating fiscal-financial and monetary policies in response to business cycle fluctuations arising from *both* supply and demand shocks. As recently emphasized by Ghassibe and Zanetti (2022) and Jo and Zubairy (2024), policy effectiveness is contingent on the source of economic fluctuations. Our contribution to this expanding literature lies in our focus on optimal policies in response to liquidity traps driven by different fundamentals.[5]

We argue that a tax-subsidy on less liquid household deposits – think term deposits or bank bonds used as loanable funds – should be activated in a state-dependent fashion based on the underlying structural shock driving the economy to a liquidity trap.[6] Access to a private asset tax-subsidy system substantially alters the transmission of discretionary (time-consistent) and commitment (Ramsey) monetary policies, and significantly alleviates the severity of liquidity trap episodes that are also influenced by the cost channel. Introducing otherwise distortionary deposit taxes / subsidies – financed through non-distortionary bank dividend tax adjustments – yields non-trivial stabilization and welfare benefits relative to an optimal monetary policy plan alone.[7]

Importantly, a deposit subsidy allows overcoming the inflation-output trade-off arising from stagflationary shocks by enabling the policymaker to set the nominal interest rate deep in negative territory. Buiter and Panigirtzoglou (2003), Rogoff (2017), Agarwal and Kimball (2019), and Lilley and Rogoff (2020) also claim that readily available stabilization tools, or alternatively some corrective legal, regulatory, and tax changes aimed at increasing the cost of hoarding cash, could

[4] In Wu and Xie (2024), for example, unconventional measures such as QE and tax-financed fiscal policies impact both the AD and AS curves, with the nominal policy rate entering only the AD curve. Thus, the interest rate policy in our model, which affects both curves, may be viewed as also embedding unconventional features.

[5] Our model does not consider more conventional Keynesian fiscal policies that are spending-based and that may have an adverse impact on existing and longer-term public debt levels. For a comparison between the macroeconomic effects of conventional policies such as public investment infrastructure spending and unconventional measures taking the form of sales and labor income tax adjustments, see Lemoine and Lindé (2023).

[6] Chari and Kehoe (1999) also advocate for optimal state-contingent and sizeable variations in private asset taxes against adverse shocks. Within the class of frictionless models presented in their paper, private assets may encompass either physical capital or government bonds.

[7] Focused on examining the interactions between financial asset taxes and interest rate policies, we intentionally overlook the prospect of financing asset subsidies through alternative distortionary taxes like consumption and labor income taxes. The macroeconomic ramifications of such taxes at the ZLB have been extensively studied in the literature since the seminal contribution of Correia, Farhi, Nicolini, and Teles (2013) – see also D'Acunto, Hoang, and Weber (2018, 2022) and references therein. Funding unconventional policies through non-distortionary bank dividend tax changes is more in line with Correia, De Fiore, Teles, and Tristani (2021).

enable deep negative interest rates when necessary. We show that fiscal-financial subsidies effectively rationalize such unconventional monetary policy in the short-run, quickly ending a stagflationary recession or even preventing it when the policy toolkit is optimally deployed. In the steady-state, we propose a modified Friedman (1969) rule through which a policy mix combining a deposit subsidy and a negative interest rate policy removes long-run inefficiencies induced by the cost channel and monopolistic competition. This unique policy plan is feasible and does not violate the ZLB constraint on the effective tax-augmented savings rate.

Our main state-dependent results can be further explained as follows. In the face of stagflationary supply shocks, unrestricted optimal policy necessitates an equal reduction in both the financial tax and the nominal risk-free policy-deposit rate. This policy configuration *stabilizes* the effective tax-augmented nominal deposit rate faced by households at its long-run positive level. Therefore, the lower bound constraint on the effective nominal interest rate is entirely removed with the first-best allocation attained at all times. Such bliss outcome holds regardless of whether the economy is in a liquidity trap or not, and does not require any policy commitments. Interestingly, despite the inflationary nature of the supply shock, restricted optimal monetary policy under *commitment* following a sizeable disturbance can trigger the ZLB due to the large inefficient and persistent slump in output.[8] Under unrestricted optimal policy with deposit subsidies, the policymaker can freely set a negative nominal interest rate without breaching the effective ZLB constraint stemming from the household's indifference between saving illiquid time deposits and cash-financed consumption. The expansionary policy mix limits cost-push inflationary pressures as well as demand-pull inflation that would transpire in the absence of deposit subsidies. Negative nominal interest rates and implicit financial income subsidies resemble non-standard policy measures undertaken by policymakers in advanced economies during the COVID-19 pandemic. From a conceptual standpoint, these measures represent an optimal policy plan against a supply-driven liquidity trap and, more broadly, stagflationary shocks.

When the economy enters a liquidity trap triggered by large adverse demand shocks, optimal policy warrants a hike in the deposit tax rate and a relatively more modest increase in the nominal policy-deposit rate. Such counterfactual policy combination *lowers* the effective tax-augmented nominal and real deposit rates, which, in turn, limit the shrinkage in output through intertemporal substitution emanating from the AD curve. Simultaneously, the nominal interest rate rise generates a sufficient cost-push inflationary force that fosters price stability through the AS schedule. These qualitative results hold under both discretion and commitment, and represent a Neo-Fisherian

[8] Following stagflationary shocks, we find that the cost channel always triggers an interest rate cut under optimal monetary policy commitment, regardless of parameter values. The supply-induced ZLB constraint depends on the shock size only in this case.

approach to escape a deflationary trap (e.g., Garín, Lester, and Sims 2018; Bilbiie 2022). The attempts by the European Central Bank (ECB) between 2014 and 2020 to lower deposit rates by paying negative rates on bank reserves are conceptually consistent with the implications of a higher and inflationary tax on fixed-term deposits that our economy advocates for when the liquidity trap is demand-driven.

In comparing welfare benefits relative to the restricted optimal monetary commitment policy, we find that both unconstrained optimal time-consistent and Ramsey policies, equipped with a flexible dynamic deposit tax-subsidy system, yield identical welfare gains in response to supply shocks. Following demand shocks, the gains are near-equivalent – albeit small – when the ZLB constraint is occasionally-binding. In other words, time-inconsistent commitment policies that involve optimal forward guidance are of secondary importance as long as the policymaker can optimally alter the tax rate on loanable capital-type assets.

Finally, drawing on the analysis of Giannoni and Woodford (2003) and Woodford (2003), we derive robust optimal policy rules for the nominal interest rate and the asset tax that are independent of the statistical properties of the exogenous disturbances. Motivated by the idea that central banks seek to avoid hitting the effective lower bound, we introduce a penalty to the variance of policy changes in the welfare function. The tractable feedback rules reveal a close interaction between the two instruments, policy inertia, and, importantly, responsiveness to observable macroeconomic variables. Such robust optimal rules may offer a more practical guide for policymakers when the origin of shocks cannot be identified.

We share the view of Farhi and Werning (2016) and Korinek and Simsek (2016) regarding the importance of financial asset taxes in alleviating credit market inefficiencies and liquidity traps. However, the source of distortion in our framework is of a supply-side nature rather than merely an aggregate demand externality. The cost channel leads to a distorted long-run allocation, and to inefficient exacerbated economic dynamics, both of which justify corrective fiscal-financial interventions in the form of a deposit income tax-subsidy. Our main contribution relative to the aforementioned papers is to illuminate the private asset tax policy transmission at play across different states of the economy.

Despite abstracting from more complex unconventional instruments used in the world of policymaking, the generic specification of the private asset tax in our theoretical model preserves the transmission channels of credit market interventions and enhances analytical tractability (Farhi and Werning 2016; Korinek and Simsek 2016; De Paoli and Paustian 2017).[9] Arguably, a deposit

[9] These papers also label private asset taxes as 'macroprudential policies'. Nevertheless, since our model centers on inflation and output stabilization – deliberately excluding considerations of financial crises, credit shocks, and banking sector stability – we find it more fitting to designate financial taxes / subsidies as part of the 'unconventional

tax-subsidy may not be the first tool to spring to mind of policymakers, but its relative simplicity, effectiveness, and conceptual resemblance to other more intricate instruments, could and should encourage additional consideration of this distinctive unconventional policy affecting household financial income. While our contribution to the New Keynesian optimal policy literature is primarily theoretical, we believe our results hold practical significance, especially considering the arguably mixed inflationary and deflationary nature of the most recent liquidity trap that resulted from the pandemic recession.

Our generalized framework with deposit taxes / subsidies and a microfounded CIA-induced ZLB constraint benefits from nesting the simple cost channel setup of Ravenna and Walsh (2006). As in their paper, we ignore physical capital and habit persistence in consumption that are introduced in the more elaborate cost channel setup of Christiano, Eichenbaum, and Evans (2005). We opt for the simplified approach to keep our model stylized and particularly to enable the derivation of analytical optimal target rules using the linear-quadratic approach (e.g., Woodford 2003).

In spite of its simplicity, the basic cost channel setup is also rather instructive as it shows that the nominal interest rate becomes a constrained policy tool when firms' marginal costs are directly affected.[10] A deposit tax-subsidy system provides policymakers with an additional and very powerful instrument to mitigate the adverse consequences of *both* the cost channel and the ZLB by removing the restrictions imposed otherwise on the nominal interest rate.

Finally, If we are to accept that the cost channel is indeed alive and well, as recently highlighted by Abo-Zaid (2022) and Beaudry, Hou, and Portier (2024), then one should consider the potentially Neo-Fisherian implications of (un)conventional monetary policies. In fact, Uribe (2022) demonstrates, both theoretically and empirically, that interest rates and inflation can comove also in the short-run following permanent monetary shocks, even without explicitly accounting for the cost channel.

Related Literature. – Optimal tax policies when interest rates are at the zero bound have been studied in the New Keynesian models of Eggertsson and Woodford (2006) and Correia, Farhi, Nicolini, and Teles (2013). The former illustrate how consumption taxation can be used to partially offset the adverse effects of the policy rate reaching the ZLB, while the latter show that adjusting labor and consumption taxes can circumvent the zero bound and always attain the efficient outcome. We also emphasize the need for tax flexibility to neutralize shocks, although our motivation is different. First, we focus on the cyclical properties of financial taxation as opposed to more 'standard' labor and consumption taxes. Second, we highlight the role of the supply-side monetary

policies' toolkit in the context of this paper.

[10] As is well-known, in the baseline New Keynesian model without a cost channel (or a more general form of credit friction), and in the absence of the ZLB, the nominal interest rate is free to adjust, ensuring that the Euler (AD) equation never poses a binding constraint for optimal policy design.

policy friction, which proves to be imperative to the state-dependent optimal policy plans. Our work also complements Correia, De Fiore, Teles, and Tristani (2021), who show within a classic monetary economy framework that credit subsidies to firms can prevent the economy from entering a liquidity trap and render interest rate policies redundant. Unlike their paper, we analyze the interplay between private asset income taxation and interest rate policies using a simple two-equation New Keynesian model that explicitly considers optimal discretionary versus commitment policies.

We also engage with recent literature exploring the implications of negative interest rate policies, as documented in the works of Abo-Zaid and Garín (2016), Ulate (2021), Altavilla, Burlon, Giannetti, and Holton (2022), Onofri, Peersman, and Smets (2023), and Eggertsson, Juelsrud, Summers, and Wold (2024). Complementing these studies, our paper demonstrates that incorporating asset tax-subsidy policies within a cost channel framework enables the implementation of unconventional negative nominal interest rate policies in an inflationary environment, and can alter the direction of the nominal policy rate response in a deflationary liquidity trap. Although we simplify our model by side-stepping from additional realistic important factors, such as credit spreads, balance sheet effects, and central bank reserves, our paper provides valuable insights into the macroeconomic consequences of state-dependent unconventional policies within a model that accounts for the supply-side effects of monetary policy.

Finally, relative to Fernández-Villaverde (2010), Eggertsson (2011), Ghassibe and Zanetti (2022), Lemoine and Lindé (2023), and Jo and Zubairy (2024), who examine the *positive* implications of various fiscal policies, we focus on the *normative* properties of optimal financial taxation. To the best of our knowledge, the business cycle and welfare implications of novel private asset tax-subsidy policies, and their interactions with monetary policy in response to both supply and demand shocks, have not been fully addressed in the context of a workhorse New Keynesian model augmented for the cost channel.

Outline. – The remainder of the paper proceeds as follows. Section 2 describes the model. Section 3 characterizes the long- and short-run equilibrium properties. Section 4 explains the model calibration and estimation. Section 5 examines state-dependent optimal policy, along with the induced dynamics and welfare implications. Section 6 relates the use of financial taxation to other unconventional policies studied in the literature. Section 7 concludes. Additional simulation results, including discretion versus commitment without financial taxation and optimal dynamics in a model without the ZLB, are provided in the Appendix.

2 The Model

Consider a discrete-time infinite-horizon economy populated by a representative household, a representative final good (FG) firm, a continuum of intermediate goods (IG) producers, a perfectly-competitive financial intermediary (bank), and a benevolent public authority that is responsible for monetary, fiscal, and financial policies.[11]

2.1 Households

The objective of the representative household is to maximize the following expected lifetime utility:

$$\mathbb{U}(C_t, N_t) = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t Z_t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right], \tag{1}$$

where $\mathbb{E}_0$ is the expectations operator, C_t is aggregate consumption, and N_t is the labor supply. Moreover, $\beta \in (0,1)$ is the discount factor, σ is the inverse of elasticity of intertemporal substitution, and φ is the inverse of the Frisch elasticity of labor supply. The preference (demand) shock follows an $AR(1)$ process:

$$Z_t = (Z_{t-1})^{\rho_Z} \exp(\varepsilon_{Z,t}), \tag{2}$$

where $\rho_Z \in (0,1)$ is the degree of persistence, and $\varepsilon_{Z,t} \sim i.i.d.\mathcal{N}\left(0, \sigma_Z^2\right)$.

The household enters period t with real money balances M_t, which can be interpreted as liquid *at-call deposits*. They also receive wage income $W_t N_t$ paid as cash at the beginning of period t, where W_t denotes the real wage. This cash is then used to supply interest-bearing *term deposits* D_t to the banking sector, with D_t measured in real terms. The remaining cash balances become available to purchase the aggregate consumption good subject to the following CIA constraint:

$$C_t \leq M_t + W_t N_t - D_t. \tag{3}$$

Constraint (3) represents the implicit cost of holding intraperiod illiquid time deposits that yield interest but that cannot be used for transaction services.[12] At the end of the period, the household earns the after-tax return on deposits $\left(1-\tau_t^D\right) R_t^D D_t$, where R_t^D is the gross nominal policy-deposit

[11] This model lacks a distinction between the central bank and the government, both operating under full coordination with the same objective function. Consequently, these entities collectively fall under the umbrella term of the "public authority" or "policymaker".

[12] In the cost channel literature with a CIA constraint (e.g., Christiano, Eichenbaum, and Evans 2005; Ravenna and Walsh 2006), it is commonly assumed that cash serves as the sole means of payment, rather than less liquid time deposits. For consistency with notation and terminology used in previous related studies and without loss of generality, we will refer to D_t and M_t as simply 'deposits' and 'cash' (or 'money'), respectively.

rate, and τ_t^D is the tax rate on term deposits. Importantly, τ_t^D serves as a state-dependent fiscal-financial policy instrument that can be used to stabilize the economy following various shocks resulting potentially in liquidity trap episodes. Note that we could either have $\tau_t^D > 0$, corresponding to a deposit income tax, or $\tau_t^D \leq 0$ representing a savings subsidy. Similar to Farhi and Werning (2016), τ_t^D is simply an unconventional fiscal-financial intervention.

The household receives a lump-sum transfer T_t from the public authority. Additionally, they obtain profits from the production sector Π_t^P and after-tax distributed profits from the banking sector $(1-\tau_t^\pi)\,\Pi_t^B$, where τ_t^π represents the non-distortionary bank dividend tax rate.[13] Similar to Correia, De Fiore, Teles, and Tristani (2021), we assume that a subsidy (tax) on private assets D_t is financed via a tax (subsidy) on distributed bank profits.[14] Cash carried over to period $t+1$ is then:

$$M_{t+1}\frac{P_{t+1}}{P_t} = M_t + W_t N_t - D_t - C_t + \left(1-\tau_t^D\right) R_t^D D_t + \left(1-\tau_t^\pi\right)\Pi_t^B + \Pi_t^P + T_t. \tag{4}$$

We define $\mu_{1,t} \geq 0$ and $\mu_{2,t} > 0$ as the Lagrange multipliers on constraints (3) and (4), respectively, and take real wages (W_t), prices (P_t), and financial taxes (τ_t^D) as given. Maximizing (1) subject to (3) and (4) then yields the following first-order conditions:

$$C_t: \quad C_t^{-\sigma} = \mu_{1,t} + \mu_{2,t}, \tag{5}$$

$$M_{t+1}: \quad \beta\mathbb{E}_t\left(\mu_{1,t+1} + \mu_{2,t+1}\right)\frac{Z_{t+1}}{Z_t} = \mu_{2,t}\mathbb{E}_t\frac{P_{t+1}}{P_t}, \tag{6}$$

$$D_t: \quad \mu_{2,t}\left(1-\tau_t^D\right) R_t^D = \mu_{1,t} + \mu_{2,t}, \tag{7}$$

$$N_t: \quad \left(\mu_{1,t} + \mu_{2,t}\right) W_t = N_t^\varphi. \tag{8}$$

Combining (5)-(8) by eliminating the Lagrange multipliers allows to summarize the optimality conditions as:

$$C_t^{-\sigma} = \beta\mathbb{E}_t\frac{Z_{t+1}}{Z_t}C_{t+1}^{-\sigma}\frac{\left(1-\tau_t^D\right)R_t^D}{\pi_{t+1}}, \tag{9}$$

$$N_t^\varphi C_t^\sigma = W_t, \tag{10}$$

where $\pi_{t+1} \equiv P_{t+1}/P_t$ is defined as the gross inflation rate. Equation (9) is the Euler equation augmented for financial taxation. The effective tax-augmented real interest rate is thus

[13] Financing deposit taxes / subsidies through adjustments in either bank profit taxes or lump-sum taxes yields identical results. We clarify the role of T_t in this model later in the text.

[14] In essence, when financial subsidies and/or negative interest rates are implemented, the household – also the owner of the bank and firms – effectively incurs a fee through the receipt of a reduced net bank dividend.

$\left(1-\tau_t^D\right) R_t^D / \mathbb{E}_t \pi_{t+1}$, implying that fiscal-financial interventions directly distort the household's intertemporal consumption-savings pattern. Furthermore, with time deposits used to facilitate working-capital loans supplied by the financial intermediary, a tax on deposit returns can also be viewed as a tax / subsidy on bank liquidity. Equation (10) determines the optimal labor supply.

A key feature of our model is the emergence of a lower bound equilibrium restriction on the *effective tax-augmented* nominal deposit rate; i.e., $\left(1-\tau_t^D\right) R_t^D \geq 1$. This microfounded ZLB constraint is derived from (7), after solving for $\mu_{1,t} \geq 0$, and the slackness condition $\mu_{1,t}\left(M_t + W_t N_t - D_t - C_t\right) = 0$. Specifically, merging these two equations yields:

$$\underbrace{\mu_{2,t}\left[\left(1-\tau_t^D\right) R_t^D - 1\right]}_{\mu_{1,t}}\left(M_t + W_t N_t - D_t - C_t\right) = 0.$$

For $\mu_{2,t} > 0$ and (4) holding with equality, we obtain $\left(1-\tau_t^D\right) R_t^D \geq 1$. Intuitively, the actual observed savings rate that enters the household's Euler equation accounts for potential changes in τ_t^D, and serves as the opportunity cost to money holdings. Cash, in turn, carries a zero nominal interest rate and is used to purchase consumption goods subject to (3).[15] Therefore, the effective lower bound that satisfies the household's no-arbitrage condition between cash-financed consumption and deposits must apply to $\left(1-\tau_t^D\right) R_t^D \geq 1$. When the agent holds enough money relative to consumption, the CIA constraint becomes slack, coinciding with the post-tax interest rate set at its effective lower bound. In the absence of τ_t^D and a CIA constraint, we retrieve $R_t^D \geq 1$ as in Eggertsson and Woodford (2003, 2006), among many others.

Admittedly, while this model applies the financial asset tax rate to gross returns on financial assets, it should be noted that, in practice, the U.S. tax code applies this rate to net returns. Our approach follows Eggertsson (2011) and Farhi and Werning (2016), who also implement the tax-subsidy on the stock of assets. This allows for state-dependent variations in τ_t^D even in the presence of the ZLB. Specifically, if the tax rate is applied to net returns, i.e., the effective return on assets is $\left[1+\left(1-\tau_t^D\right)\left(R_t^D-1\right)\right]$, and the economy is at the ZLB where $R_t^D = 1$, then τ_t^D would be zero by definition. As a result, such unconventional policy measure cannot stimulate the economy following shocks that lead to a liquidity trap. The *normative* policy proposals outlined below may then require meaningful institutional changes in implementing term deposit or bond tax-subsidies. These changes have the potential to transform τ_t^D into a very potent stabilization tool against inflationary and/or deflationary disturbances in both normal and abnormal times, concurrently unleashing restrictions on (un)conventional interest rate policies.

[15] Note that money is the only asset through which the household can smooth consumption across periods (see, e.g., Airaudo and Olivero 2019). Without constraint (3), the effective tax-augmented interest rate would always satisfy $\left(1-\tau_t^D\right) R_t^D = 1$. The CIA restriction motivates and gives rise to occasionally-binding ZLB periods.

2.2 Production

A FG firm produces aggregate output Y_t by assembling differentiated output of IG firms $Y_{j,t}$, indexed by $j \in (0,1)$, using a Dixit-Stiglitz (1977) technology: $Y_t = \left(\int_0^1 Y_{j,t}^{(\epsilon-1)/\epsilon} dj\right)^{\epsilon/(\epsilon-1)}$, with $\epsilon > 1$ denoting the constant elasticity of substitution between intermediate goods. The relative demand for intermediate good j is then given by $Y_{j,t} = (P_{j,t}/P_t)^{-\epsilon} Y_t$, where $P_t = \left(\int_0^1 P_{j,t}^{1-\epsilon} dj\right)^{1/(1-\epsilon)}$ is the aggregate price index such that $P_t Y_t = \int_0^1 P_{j,t} Y_{j,t} dj$.

There is a continuum of measure one of monopolistically-competitive IG firms who produce a differentiated good $Y_{j,t}$ using the following linear production function:

$$Y_{j,t} = N_{j,t}, \tag{11}$$

where $N_{j,t}$ is the employment demand by firm j.

To capture supply-side shocks, we assume that the IG firm may face additional production costs u_t that follow an $AR(1)$ process:

$$(1 + u_t) = (1 + u_{t-1})^{\rho_u} \exp\left(\varepsilon_{u,t}\right), \tag{12}$$

where $\rho_u \in (0,1)$ is the degree of persistence, and $\varepsilon_{u,t} \sim i.i.d.\mathcal{N}\left(0, \sigma_u^2\right)$. Our specification of supply shocks is similar to that of Andrade, Galí, Le Bihan, and Matheron (2019), who apply such shocks to the firm's output and interpret them as sales subsidies. Here, we directly impose the shock on the IG firm's total production costs, derived below, effectively characterizing u_t as a wage tax.[16] We assume that u_t is distributed to households in a lump-sum fashion through adjustments in T_t.

Each IG firm must borrow a total amount $L_{j,t} = (1 + u_t) W_t N_{j,t}$ from the bank at the gross nominal interest rate R_t^D. The total cost of labor is therefore $R_t^D (1 + u_t) W_t N_{j,t}$. Working-capital loans are secured at the beginning of the period, prior to production but after the realization of u_t. For simplicity and as in Ravenna and Walsh (2006), we assume that the nominal lending rate is set to the risk-free policy (deposit) rate without any additional financial frictions that result in a spread between these rates. This allows us to directly focus on the interactions between the monetary policy cost channel, the deposit tax-subsidy, and state-dependent liquidity traps without unnecessarily complicating our model. It is important to note that the IG firm does not face an effective lower bound constraint. In this framework, setting $R_t^D < 1$ represents an implicit subsidy from the IG firm's perspective and can constitute part of the unconventional policy mix.[17] In fact,

[16] Cost-push wage tax shocks in our model are isomorphic to the price mark-up shocks introduced in Clarida, Galí, and Gertler (1999) and Ireland (2004).

[17] While Correia, De Fiore, Teles, and Tristani (2021) highlight the stabilizing effects of direct credit subsidies to

Altavilla, Burlon, Giannetti, and Holton (2022) demonstrate that sound banks operating within the Eurozone effectively transmitted negative interest rates to firms, and that this transmission remained unimpaired even as policy rates ventured into negative territory in 2014.

The pricing decision takes place at the start of period t, after the cost-push shock is realized, and consists of two stages. In the first stage, each borrowing producer minimizes the cost of employing labor, taking its effective costs as given. The real marginal cost is the same for all IG firms and is equal to:

$$mc_{j,t} = mc_t = R_t^D (1 + u_t) W_t. \tag{13}$$

In the second stage, each IG producer chooses the optimal price for its good subject to $Y_{j,t} = (P_{j,t}/P_t)^{-\epsilon} Y_t = N_{j,t}$ and taking (13) as given. IG firms face Rotemberg (1982)-type quadratic adjustment costs in changing prices $\frac{\Theta}{2}\left(\frac{P_{j,t}}{P_{j,t-1}} - 1\right)^2 Y_t$, where $\Theta > 0$ measures the magnitude of price stickiness. Standard profit maximization under symmetry yields the non-linear New Keynesian Phillips Curve (NKPC):

$$1 - \Theta (\pi_t - 1) \pi_t + \beta \mathbb{E}_t \Theta (\pi_{t+1} - 1) \pi_{t+1} \frac{Y_{t+1}}{Y_t} = \epsilon (1 - mc_t), \tag{14}$$

with β representing the shared discount factor of the household and firms, and mc_t given by (13). In the special case where $\Theta = 0$, the price mark-up is $\mathcal{M} \equiv \frac{\epsilon}{(\epsilon - 1)} = mc_t^{-1}$.

2.3 Financial Intermediation

A perfectly-competitive financial intermediary raises term deposits from households and receives a cash injection $X_t \equiv M_{t+1}\frac{P_{t+1}}{P_t} - M_t$ from the public authority.[18] These assets are used to finance the working-capital costs of IG firms such that the bank's balance sheet satisfies:

$$L_t = D_t + X_t, \tag{15}$$

where $L_t = \int_0^1 L_{j,t} dj = (1 + u_t) W_t N_t$ is the total lending to the production industry, and $N_t = \int_0^1 N_{j,t} dj$. Assuming a perfectly-competitive banking environment and no further financial frictions, the bank sets the loan rate equal to the risk-free interest rate and earns $R_t^D (D_t + X_t) - R_t^D D_t = R_t^D X_t \equiv \Pi_t^B$ as profits (e.g., Ravenna and Walsh 2006).

firms, potentially rendering traditional interest rate policies unnecessary, we propose household private asset taxation, an income tax / subsidy on less liquid financial capital like bank bonds or term deposits. This policy restores an active role for (un)conventional monetary policy during liquidity trap episodes, as further explained below.

[18] A liquidity injection is a common feature in cost channel models à la Ravenna and Walsh (2006) that facilitates the derivation of the market clearing condition. In practice, a liquidity injection may also be used as an unconventional policy tool (see, e.g., Joyce, Miles, Scott, and Vayanos 2012; Cahn, Matheron, and Sahuc 2017).

2.4 Public Authority and Market Clearing

The public authority targets the short-term risk-free interest rate R_t^D and the financial tax rate τ_t^D that respect the ZLB constraint on the effective tax-augmented nominal deposit rate:

$$\left(1-\tau_t^D\right) R_t^D \geq 1. \tag{16}$$

Market clearing requires $Y_t = N_t$, where $N_t = N_{j,t}$ and $P_t = P_{j,t}$ in a symmetric equilibrium. With $T_t = u_t W_t N_t$ and $\tau_t^\pi R_t^D X_t = -\tau_t^D R_t^D D_t$, the aggregate resource constraint satisfies:

$$Y_t = C_t + \frac{\Theta}{2}\left(\frac{P_t}{P_{t-1}} - 1\right)^2 Y_t. \tag{17}$$

3 Equilibrium

This sections presents the long- and short-run equilibrium properties of our model. Assuming a zero-inflation steady-state ($\pi = 1$), the long-run interest rate is derived from (9) and is given by:[19]

$$R^D = \frac{1}{\left(1-\tau^D\right)\beta}. \tag{18}$$

Long-run output is calculated from the steady-state versions of equations (9)-(11), (13), and (14):

$$Y^{\sigma+\varphi} = \frac{\mathcal{M}^{-1}}{R^D\left(1+u\right)} = \frac{\beta\left(1-\tau^D\right)}{\left(1+u\right)}\mathcal{M}^{-1}, \tag{19}$$

where $Y^{\sigma+\varphi}$ is the long-run marginal rate of substitution between consumption and hours worked. The unconstrained first-best allocation, absent of the cost channel and the price mark-up, corresponds to $Y^{\sigma+\varphi} = 1$. Temporarily setting $u = 0$, this efficiency condition can be supported through the implementation of the following long-run corrective financial subsidy:

$$\tau^{D,I} = 1 - \frac{\mathcal{M}}{\beta} < 0, \tag{20}$$

where superscript I denotes the unconstrained first-best policy. Under standard parameterization with $0 < \beta < 1$ and $\mathcal{M} > 1$, a deposit subsidy helps to completely offset both the monetary policy supply-side friction and the price mark-up resulting from monopolistic competition in the deterministic steady-state. The negative relationship between Y and R^D arising from the cost

[19] The steady-state and log-linearized representations of any variable $\mathcal{X}_t$ are denoted by $\mathcal{X}$ and $\hat{\mathcal{X}}_t$, respectively.

channel enables the policymaker to eliminate steady-state distortions using a deposit *subsidy* and a *negative* interest rate policy.

Specifically, the implementation of a deposit subsidy in steady-state allows the public authority to set a negative policy rate, $R^{D,I} = \mathcal{M}^{-1} < 1$, which, together with $\tau^{D,I} < 0$, satisfy also the household's no-arbitrage condition between deposits and cash-financed consumption, i.e., $\left(1-\tau^{D,I}\right) R^{D,I} = \beta^{-1}$. Simply put, the financial subsidy corrects for the cost channel friction while the negative interest rate directly removes the price mark-up distortion. In this way, there exists a single combined policy plan of the financial tax and the nominal interest rate set to their effective lower bounds. This policy prescription represents a modified Friedman (1969) rule. Without seeking a rate of deflation, zero effective interest rates can be accomplished through the enactment of private asset subsidies. Corrective fiscal-financial interventions thus provide a justification for adopting a prolonged negative nominal interest rate; a policy measure that echoed some of the post-Great Recession practices undertaken by several central banks in advanced economies.[20]

We now log-linearize the behavioral equations and the resource constraint around the non-stochastic, zero inflation steady-state. To capture the ZLB constraint on the effective tax-augmented savings rate in the short-run, we log-linearize (16) to obtain:

$$\hat{R}_t^D - \hat{\tau}_t^D \geq \ln(\beta), \tag{21}$$

with $\hat{\tau}_t^D = -\ln \frac{\left(1-\tau_t^D\right)}{\left(1-\tau^D\right)}$.

Using the first-order and market-clearing conditions, the model can be expressed in terms of the following two dynamic equations:

$$\widehat{\pi}_t = \beta \mathbb{E}_t \widehat{\pi}_{t+1} + \lambda \left[(\sigma + \varphi) \hat{Y}_t + \hat{R}_t^D + \hat{u}_t \right], \tag{22}$$

$$\hat{Y}_t = \mathbb{E}_t \hat{Y}_{t+1} - \sigma^{-1} \left[\left(\hat{R}_t^D - \hat{\tau}_t^D \right) - \mathbb{E}_t \widehat{\pi}_{t+1} - \hat{r}_t^n \right], \tag{23}$$

with $\lambda \equiv (\epsilon - 1)/\Theta$, $\hat{u}_t = \ln \frac{(1+u_t)}{(1+u)}$, and $\hat{r}_t^n \equiv \hat{Z}_t - \mathbb{E}_t \hat{Z}_{t+1}$ defined as the natural rate of interest that is a function only of the preference shock. Equation (22) is the extended NKPC establishing the short-run aggregate supply (AS) relation between inflation and output, augmented for the the monetary policy cost channel and the cost-push shock.[21] Equation (23) is the Euler equation

[20] Abo-Zaid and Garín (2016) also find a role for implementing optimal negative nominal interest rates in a model with financial frictions and money demand. Here, the optimal long-run negative interest rate policy is rationalized by the presence of the deposit subsidy and the supply-side monetary distortion.

[21] In the absence of Total Factor Productivity (TFP) shocks, the efficient level of output is set to unity, indicating that cyclical output equals the output gap.

that determines the aggregate demand (AD) schedule, augmented for the preference shock and the deposit tax-subsidy. A lower $\hat{\tau}_t^D$ increases desired savings such that in equilibrium output falls more than in the absence of tax cuts. Nevertheless, in response to inflationary shocks, a deposit subsidy can act to stabilize inflation and consequently be welfare improving. The optimal state-dependent policy plans against supply and demand shocks are investigated below and are the key contributions of this paper.

The approximate competitive equilibrium is defined as a collection of real allocations $\left\{\hat{Y}_t\right\}_{t=0}^{\infty}$, prices $\{\widehat{\pi}_t\}_{t=0}^{\infty}$, interest rates $\left\{\hat{R}_t^D\right\}_{t=0}^{\infty}$, and deposit tax-subsidy policies $\{\hat{\tau}_t^D\}_{t=0}^{\infty}$ such that for a given sequence of exogenous $AR(1)$ shock processes $\left\{\hat{u}_t, \hat{Z}_t\right\}_{t=0}^{\infty}$, conditions (21)-(23) are satisfied.

A few observations merit attention at this stage. While an increase in $\hat{R}_t^D$ directly raises $\widehat{\pi}_t$, the overall time t impact, considering the intertemporal substitution channel of monetary policy when excluding expectations, is given by $\frac{\partial \widehat{\pi}_t}{\partial \hat{R}_t^D} = \lambda - \lambda \frac{(\sigma+\varphi)}{\sigma}$ or $\frac{\partial \widehat{\pi}_t}{\partial \hat{R}_t^D} = -\frac{\lambda\varphi}{\sigma} < 0$. Interestingly, when labor is indivisible ($\varphi = 0$), the immediate demand and cost channels of interest rate policies on inflation offset one another, leading to model indeterminacy under *discretion*. Introducing $\hat{\tau}_t^D$ as an additional policy instrument impacting the AD curve restores solution uniqueness when $\varphi = 0$. In this case, fluctuations in $\hat{\tau}_t^D$ under discretion become isomorphic to mirror-image fluctuations in $\hat{R}_t^D$ as in a textbook New Keynesian model without a cost channel. However, when evaluating future paths under *commitment*, a unique solution to the model exists with either one or both policy instruments employed, regardless of the value of $\varphi \geq 0$.

4 Calibration and Estimation

Although many of our results are shown analytically, the model is also solved numerically in order to illuminate the implications of the state-dependent optimal policies for economic dynamics and welfare. The model is calibrated for some parameters and estimated for others. We calibrate and estimate the model based on U.S. quarterly data. For the calibration, we employ well-established parameter values largely used in recent New Keynesian literature. At the same time, other parameter values are estimated using the generalized, robust, and relatively fast piecewise-linear Kalman filter (PKF) developed recently by Giovannini, Massimo, Pfeiffer, and Ratto (2021), as further explained below.

Starting with the calibration, the discount factor is set to $\beta = 0.997$, with the steady-state financial tax $\tau^D = 0$, given its primary purpose as a short-run stimulative unconventional policy. The implied long-run annualized risk-free interest rate for this parameterization is 1.2%. Moreover, by setting a price mark-up of 20% ($\epsilon = 6$), along with $\varphi = 0.2$, $\sigma = 1$, and $\Theta = 125$, we obtain a NKPC slope of $\lambda(\sigma + \varphi) = 0.048$. This estimate aligns with its long-term U.S. data counterpart, which has exhibited a weakened correlation between inflation and output in the NKPC over recent decades, especially following the Great Recession (see, e.g., Beaudry, Hou, and Portier 2024).[22]

To estimate the moments of the supply and demand shocks, we assume that the policymaker follows a monetary policy rule that is augmented for the ZLB constraint:

$$R_t^D = \max\left\{ \left(R_{t-1}^D\right)^{\rho_R} \left[R^D \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi} \left(\frac{Y_t}{Y}\right)^{\phi_y} \right]^{(1-\rho_R)} \exp\left(\varepsilon_{R.t}\right),\ 1 \right\}, \tag{24}$$

where $\rho_R \in (0,1)$ is a smoothing parameter, $\phi_\pi > 1$, $\phi_y \geq 0$, and $\varepsilon_{R.t} \sim i.i.d.\mathcal{N}\left(0, \sigma_R^2\right)$. The introduction of the additional monetary policy shock leads to more reliable shock moments and enables a more accurate estimation of the interest rate rule parameters: ϕ_π, ϕ_y, and ρ_R. Although this rule is discarded in the optimal policy section below, it is still necessary for (24) to be empirically consistent with the estimated supply and demand shocks examined later in the policy exercises. Notice that for the purpose of the estimation, we ignore the asset tax / subsidy ($\hat{\tau}_t^D = 0$, $\forall t$).

Following Guerrieri and Iacoviello (2015), we apply the OccBin algorithm to account for the occasionally-binding ZLB constraint and the resulting non-linear dynamics. We then run the PKF, seamlessly integrated into the Dynare software, to evaluate the likelihood and identify key parameters of the model over the period $1985 : Q1 - 2019 : Q4$.[23] Specifically, we utilize the PKF and Metropolis-Hastings sampling algorithm to compute the shock moments $[\rho_u, \sigma_u; \rho_Z, \sigma_Z; \sigma_R]$ and the policy parameters $\left[\rho_R, \phi_\pi, \phi_y\right]$ in order to solve for the innovations that minimize the distance between the data and equivalent model predictions each period. The observed simulated data for the three variables of interest – inflation, output growth, and the interest rate – include the implicit GDP deflator, detrended real GDP per-capita growth, and the federal funds rate over the sample period.[24]

Table 1 displays the postulated priors (type of distribution, mean, and standard error) as well as the estimation results (posterior mean and standard deviation) derived from the piecewise-linear model. The parameters related to the prior distributions of the estimation are standard in

[22] Our qualitative optimal policy results remain robust to alternative parameterizations involving changes in ϵ, φ, σ, and Θ.

[23] See also Cardani, Pfeiffer, Ratto, and Vogel (2023) for their application of the PKF to estimate key structural and policy parameters in the U.S. and EU economies. Giovannini, Massimo, Pfeiffer, and Ratto (2021) highlight the advantages of the PKF over the inversion filter (IF) approach used by Guerrieri and Iacoviello (2017), for example. Generally, the PKF executes a two-step process in each period. The first step, known as the prediction step, follows conventional methods used in filtering non-linear models. The second step, referred to as the update step, is customized for the piecewise-linear model. This update step involves an iterative convergence process to determine the temporary binding regime present in each period, ensuring that the ZLB constraint is not violated. It is worth mentioning that both the PKF and IF algorithms yield nearly identical estimation results in the present model, where the number of shocks equals the number of observables.

[24] All data is sourced from the Federal Reserve Economic Data (FRED) of the St. Louis Fed.

the literature (see, e.g., Atkinson, Richter, and Throckmorton 2020). Broadly speaking, despite the stylized and deliberately small-scale nature of our model, the posterior mean values largely fall within the range of the estimates reported in the papers cited in this section.[25] Moreover, the posterior standard deviations for all estimated parameters are smaller than their prior counterparts, indicating that the piecewise-linear estimation is supported by the data rather than by our initial assumptions.[26] For all simulations and welfare computations below, we use the posterior means of the shock moments, as presented in Table 1.

Table 1: Estimation Results

Parameter	Prior Shape	Prior Mean	Prior Std	Post. Mean	Post. Std
ϕ_π	Normal	2.00	0.25	2.196	0.2004
ϕ_y	Normal	0.50	0.25	1.246	0.1661
ρ_R	Beta	0.80	0.10	0.90	0.0152
ρ_u	Beta	0.80	0.10	0.79	0.0545
ρ_Z	Beta	0.80	0.10	0.89	0.0165
σ_u	InvGam	0.005	0.005	0.0132	0.0032
σ_Z	InvGam	0.005	0.005	0.0215	0.0021
σ_R	InvGam	0.002	0.002	0.0008	0.0001

Note: 'Std' - Standard Deviation; 'Post' - Posterior; InvGam - Inverse Gamma.

5 Optimal Monetary and Financial Tax Interventions at the ZLB

The presence of nominal rigidities, the cost channel, and the various shocks give rise to inefficient short-run dynamics. At the same time, a steady-state deposit subsidy combined with a negative interest rate policy can effectively address long-run inefficiencies as explained above and specifically below equation (20). Since our primary focus is on utilizing the financial tax as an unconventional stabilization tool and exploring its interactions with monetary policy in the short-term, we fix $\tau^D = 0$, and set instead a long-run wage subsidy $u < 0$ that eliminates all average distortions similar to Andrade, Galí, Le Bihan, and Matheron (2019). Setting a wage cost subsidy at the firm

[25] Naturally, there may be other shocks that are key to understanding the behavior of inflation, output growth, and the interest rate in the data. Thus, the small estimation exercise should not be viewed as a full-fledged quantitative analysis but rather a suggestive quantitative illustration of the model's predictions. The Bayesian estimation employed in this simple model with three shocks is still useful and enables a more meaningful welfare analysis compared to a model that takes shock moments as given.

[26] As in Guerrieri and Iacoviello (2017), we also find that the differences between the posterior means in the piecewise-linear OccBin and linear models are not substantial. However, the posterior standard deviations are smaller under OccBin.

level allows us to take a second-order approximation of the household's ex-ante utility function around the efficient deterministic long-term equilibrium (e.g., Ravenna and Walsh 2006; Airaudo and Olivero 2019).

The appropriate expected welfare measure is then given by:[27]

$$\mathbb{E}(\mathcal{W}) \equiv \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{(\mathbb{U}_t - \mathbb{U})}{\mathbb{U}_C C} \simeq -\frac{1}{2}\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\Theta \hat{\pi}_t^2 + (\sigma + \varphi) \hat{Y}_t^2\right]. \tag{25}$$

Period losses scaled by the price adjustment cost parameter read:

$$\Theta^{-1}\mathcal{L}_t = \frac{1}{2}\left[\hat{\pi}_t^2 + \vartheta_y \hat{Y}_t^2\right], \tag{26}$$

where $\vartheta_y \equiv (\sigma + \varphi)\Theta^{-1}$ is the relative weight on output variability. Relative welfare gains (losses) are expressed in terms of the equivalent permanent increase (reduction) in private consumption in percent of its deterministic steady-state level.

We now turn to characterize optimal monetary and deposit tax-subsidy policies subject to the unique lower bound constraint of our model. Optimal policy under discretion and commitment is solved using the linear-quadratic approach.

5.1 The Role of Deposit Tax-Subsidy Policies

Suppose the public authority has access to both the deposit tax-subsidy $\hat{\tau}_t^D$ and the nominal interest rate $\hat{R}_t^D$.

Under **discretion** the policymaker chooses $\widehat{\pi}_t$, $\hat{Y}_t$, $\hat{R}_t^D$, and $\hat{\tau}_t^D$ to maximize its objective function (26) subject to the constraints (21)-(23), taking $\hat{r}_t^n$, $\hat{u}_t$, and $\left\{\widehat{\pi}_{t+i}, \hat{Y}_{t+i}, \hat{R}_{t+i}^D, \hat{\tau}_{t+i}^D\right\}_{i=1}^{\infty}$ as given. The Lagrangian for the policymaker's problem takes the form:

$$\begin{aligned} \mathfrak{L}_t \;=\; & -\frac{1}{2}\left[\hat{\pi}_t^2 + \vartheta_y \hat{Y}_t^2\right] - \hat{\zeta}_{1,t}\left[\widehat{\pi}_t - \beta \mathbb{E}_t \widehat{\pi}_{t+1} - \lambda\left(\hat{R}_t^D + (\sigma + \varphi)\hat{Y}_t + \hat{u}_t\right)\right] \\ & -\hat{\zeta}_{2,t}\left[\hat{Y}_t - \mathbb{E}_t \hat{Y}_{t+1} + \sigma^{-1}\left(\hat{R}_t^D - \hat{\tau}_t^D - \mathbb{E}_t \widehat{\pi}_{t+1} - \hat{r}_t^n\right)\right] - \hat{\zeta}_{3,t}\left[-\hat{R}_t^D + \hat{\tau}_t^D + \ln(\beta)\right]. \end{aligned}$$

Defining $\kappa \equiv (\sigma + \varphi)\lambda$, the corresponding first-order conditions with respect to $\widehat{\pi}_t$, $\hat{Y}_t$, and $\hat{R}_t^D$ are:

$$-\widehat{\pi}_t = \hat{\zeta}_{1,t}, \tag{27}$$

[27] The derivation of the welfare function with Rotemberg (1982) pricing strictly follows Nisticò (2007). For ease of notation, we suppress third-order terms and higher, as well as terms independent of policy. The full derivation is available upon request.

$$-\vartheta_y \hat{Y}_t + \kappa \hat{\zeta}_{1,t} = \hat{\zeta}_{2,t}, \tag{28}$$

$$\lambda \hat{\zeta}_{1,t} - \sigma^{-1} \hat{\zeta}_{2,t} + \hat{\zeta}_{3,t} = 0, \tag{29}$$

with the additional optimality condition with respect to $\hat{\tau}_t^D$ given by:

$$\sigma^{-1} \hat{\zeta}_{2,t} = \hat{\zeta}_{3,t}. \tag{30}$$

Moreover, the slackness condition with taxes / subsidies is:

$$\hat{\zeta}_{3,t} \left[-\hat{R}_t^D + \hat{\tau}_t^D + \ln(\beta) \right] = 0. \tag{31}$$

Using conditions (27)-(30), the optimal target rule under discretion with $\hat{\zeta}_{3,t} > 0$ is:

$$\vartheta_y \hat{Y}_t = -\sigma \hat{\zeta}_{3,t}, \tag{32}$$

or, using the slackness condition (31):

$$\frac{\vartheta_y}{\sigma} \hat{Y}_t \left[\hat{R}_t^D - \hat{\tau}_t^D - \ln(\beta) \right] = 0; \quad \hat{R}_t^D - \hat{\tau}_t^D \geq \ln(\beta). \tag{33}$$

The financial tax-subsidy adds the first-order condition $\sigma^{-1}\hat{\zeta}_{2,t} = \hat{\zeta}_{3,t}$, which together with (29), removes the policy restriction imposed by the AS curve ($\hat{\zeta}_{1,t} = 0$). Complete price stability ($\widehat{\pi}_t = 0$) is therefore attained with the introduction of $\hat{\tau}_t^D$ under discretion.

To obtain the closed-form expressions for $\hat{Y}_t$ and $\hat{\zeta}_{3,t}$ under optimal discretion with deposit taxation at the ZLB, combine the optimality conditions above, and then impose rational private-sector expectations. The solution yields:

$$\hat{Y}_t = \frac{1}{(1-p)} \left(\hat{r}_t^n + \ln(\beta) \right), \tag{34}$$

$$\hat{\zeta}_{3,t} = -\frac{\vartheta_y}{(1-p)} \left(\hat{r}_t^n + \ln(\beta) \right), \tag{35}$$

where p satisfies $\mathbb{E}_t \hat{Y}_{t+1} = p \hat{Y}_t$ as in Clarida, Galí, and Gertler (1999). Unconstrained discretionary policy with fiscal-financial interventions eliminates the risk of entering a liquidity trap following a cost-push shock as $\hat{u}_t$ does not enter neither (34) nor (35). With the fiscal-financial policy, both $\hat{R}_t^D$ and $\hat{\tau}_t^D$ must fall in order to bring about complete output and inflation stabilization. For $\widehat{\pi}_t = 0$, $\forall t$, and $\hat{\zeta}_{3,t} > 0$, the optimal effective savings rate satisfies $\hat{R}_t^D - \hat{\tau}_t^D = \ln(\beta)$, insulating the real economy from the inflationary effect that would otherwise follow from the expansionary monetary policy. Given that the effective post-tax deposit rate is optimally set to its positive steady-state value, the ZLB restriction is removed following supply-side shocks. In contrast, large adverse demand shocks increase the likelihood of entering a liquidity trap by raising $\hat{\zeta}_{3,t}$ and as a result lowering $\hat{Y}_t$.

Under **commitment**, the benevolent public authority chooses state-dependent paths for inflation, output, the nominal interest rate, and the financial tax to maximize its objective function (25) subject to constraints (21)-(23). The associated Lagrangian is:

$$\mathfrak{L}_t = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \begin{array}{c} -\frac{1}{2}\left[\widehat{\pi}_t^2 + \vartheta_y \hat{Y}_t^2\right] - \hat{\zeta}_{1,t}\left[\widehat{\pi}_t - \beta \mathbb{E}_t \widehat{\pi}_{t+1} - \lambda\left(\hat{R}_t^D + (\sigma+\varphi)\hat{Y}_t + \hat{u}_t\right)\right] \\ -\hat{\zeta}_{2,t}\left[\hat{Y}_t - \mathbb{E}_t \hat{Y}_{t+1} + \sigma^{-1}\left(\hat{R}_t^D - \hat{\tau}_t^D - \mathbb{E}_t \widehat{\pi}_{t+1} - \hat{r}_t^n\right)\right] - \hat{\zeta}_{3,t}\left[-\hat{R}_t^D + \hat{\tau}_t^D + \ln(\beta)\right] \end{array} \right\}.$$

The resulting first-order conditions read:

$$-\widehat{\pi}_t - \hat{\zeta}_{1,t} + \hat{\zeta}_{1,t-1} + \beta^{-1}\sigma^{-1}\hat{\zeta}_{2,t-1} = 0, \tag{36}$$

$$-\vartheta_y \hat{Y}_t + \kappa \hat{\zeta}_{1,t} - \hat{\zeta}_{2,t} + \beta^{-1}\hat{\zeta}_{2,t-1} = 0, \tag{37}$$

$$\lambda \hat{\zeta}_{1,t} - \sigma^{-1}\hat{\zeta}_{2,t} + \hat{\zeta}_{3,t} = 0, \tag{38}$$

$$\sigma^{-1}\hat{\zeta}_{2,t} = \hat{\zeta}_{3,t}, \tag{39}$$

where the first-order condition with respect to $\hat{\tau}_t^D$ (equation (39)) is the same as (30). The complementary slackness constraint is:

$$\hat{\zeta}_{3,t}\left[-\hat{R}_t^D + \hat{\tau}_t^D + \ln(\beta)\right] = 0; \quad \hat{\zeta}_{3,t} \geq 0, \tag{40}$$

with the initial conditions satisfying $\hat{\zeta}_{1,-1} = \hat{\zeta}_{2,-1} = \hat{\zeta}_{3,-1} = 0$. The optimal state-dependent evolution of the endogenous variables $\left\{\widehat{\pi}_t, \hat{Y}_t, \hat{R}_t^D, \hat{\tau}_t^D\right\}$ is characterized by the above first-order conditions together with constraints (22) and (23), as well as (40). Optimal commitment policy becomes history-dependent as reflected by the lagged Lagrange multipliers in (36) and (37). These additional state variables reflect "promises" that must be kept from past commitments.

After manipulating the first-order conditions, the optimal commitment targeting rule with fiscal-financial interventions can be written as:

$$\sigma^{-1}\left[\vartheta_y \hat{Y}_t - \beta^{-1}\hat{\zeta}_{2,t-1}\right]\left[\hat{R}_t^D - \hat{\tau}_t^D - \ln(\beta)\right] = 0; \quad \hat{R}_t^D - \hat{\tau}_t^D \geq \ln(\beta), \tag{41}$$

with inflation determined by:

$$\widehat{\pi}_t = \hat{\zeta}_{1,t-1} + \beta^{-1}\sigma^{-1}\hat{\zeta}_{2,t-1}. \tag{42}$$

Unlike the discretionary case where $\widehat{\pi}_t = 0$, $\forall t$, inflation now is dictated by the inherited Lagrange multipliers from the previous period.[28] To illuminate the differences between discretion and commitment with an asset tax-subsidy, we now simulate the model in response to recessionary supply and demand shocks.[29]

Supply Shocks. – Figure 1 shows the optimal responses of key variables to a stagflationary shock corresponding to a 2.5% increase in $\hat{u}_t$. As a benchmark, we simulate the optimal commitment policy with monetary policy only (labeled "Commitment") where $\hat{\tau}_t^D = 0$, $\forall t$ and condition (39) ignored. This benchmark case is compared with the commitment regime involving deposit tax / subsidy interventions (labeled "Commitment with Tax"), and with the discretionary case that also includes the financial tax policy (labeled "Discretion with Tax").

Under commitment monetary policy, a recessionary supply shock requires an initial *cut* in the nominal interest rate despite the immediate inflationary consequences precipitated by the rise in marginal costs. A cost-push shock that directly raises inflation leads to an inefficient and entirely undesirable slump in output. The downward pressure on the real wage generated by the escalation in inflation discourages both labor supply and consumption demand, resulting in a persistent contraction in $\hat{Y}_t$. For the calibration and moments used in this exercise, a large inefficient cost-push disturbance sends the nominal interest rate to its lower bound for 2 periods, with the accommodative monetary policy helping to smooth the adjustment of output at the expense of short-lived inflationary pressures.[30] At the same time, such demand-pull inflation is mitigated by the direct monetary policy cost channel in which the fall in $\hat{R}_t^D$ contains part of the initial spike in $\widehat{\pi}_t$.

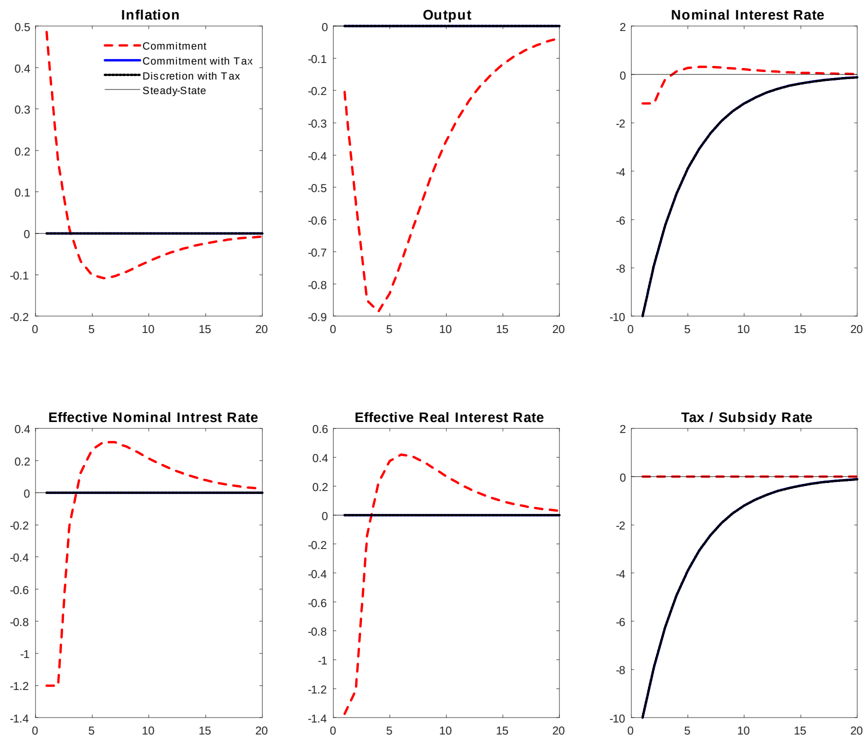
As the shock starts to dissipate, the forward-looking public authority promises to generate mild future deflation, which helps to further alleviate the immediate cost-push repercussions in the first few periods. Throughout the recovery stage under commitment, output still remains persistently below average in order to partly moderate the initial inflationary ZLB episode.

[28] Note that (41) and (42) boil down to (33) and $\widehat{\pi}_t = 0$, respectively, by setting $\hat{\zeta}_{2,t-1} = \hat{\zeta}_{2,t-1} = 0$.

[29] Using either Guerrieri and Iacoviello's (2015) OccBin piecewise-linear method or Holden's (2016) DynareOBC news shocks algorithm produces identical simulation results.

[30] We have found that an increase in the Frisch elasticity of labor supply φ^{-1} leads to higher inflation and output variability, exacerbating a supply-induced liquidity trap under commitment. Simultaneously, raising the degree of price stickiness Θ reduces variability in inflation and output, alleviating the stagflationary-driven ZLB constraint. Either way, in a New Keynesian model with a cost channel, optimal *commitment* policy following stagflationary shocks *always* calls for a nominal interest rate *cut*, contrasting sharply with the optimal monetary policy under discretion (see also additional simulations without financial taxation in the Appendix). In the textbook New Keynesian model without a cost channel, we have also found that optimal monetary commitment can trigger an interest rate reduction, but only following relatively persistent stagflationary shocks with $\rho_u > 0.42$ under our benchmark and otherwise standard parameterization.

Figure 1. - Stagflationary Shock: Commitment & Discretionary Policies with Financial Taxes



Note: The tax / subsidy rate, interest rates, and inflation are measured in annualized percentage point deviations. Output is measured in annualized percentage deviations.

More formally, by combining conditions (36)-(38) with $\hat{\tau}_t^D = 0$, $\forall t$ and without the first-order condition (39), the optimal targeting rule under monetary policy commitment can be written as:

$$\left[\left(\frac{\kappa}{\sigma} - \lambda\right)\widehat{\pi}_t + \frac{\vartheta_y}{\sigma}\hat{Y}_t - \left(\frac{\kappa}{\sigma} - \lambda\right)\hat{\zeta}_{1,t-1} - \frac{\left(\frac{\kappa}{\sigma} - \lambda + 1\right)}{\sigma\beta}\hat{\zeta}_{2,t-1}\right]\left[\hat{R}_t^D - \ln(\beta)\right] = 0; \quad \hat{R}_t^D \geq \ln(\beta). \tag{43}$$

Values of the Lagrange multipliers in (43) reveal that once the economy enters a supply-driven liquidity trap, the policymaker commits to future deflation as a substitute for nominal rate cuts. The coefficients multiplying $\hat{\zeta}_{1,t-1}$ and $\hat{\zeta}_{2,t-1}$ in the targeting rule are increasing with λ, suggesting that the cost channel amplifies expected deflationary pressures. As a result, the interest rate must gradually increase to lower future prices, which ultimately keeps output below target for a longer period of time. In sum, our model can explain why nominal policy rates may hover around their lower bounds also in response to inflationary cost-push shocks, as well as the 'missing deflation puzzle' observed during the Great Recession and the COVID-19 pandemic.

Introducing direct fiscal-financial interventions enable an *unrestricted* reduction in the nominal interest rate that, in combination, insulate the economy from the adverse repercussions of the stagflationary shock. In both the discretionary and commitment policies, $\hat{R}_t^D$ should be lowered one-to-one with respect to the cut in $\hat{\tau}_t^D$ such that the effective savings rate remains constant at its positive steady-state level.

Intuitively, the nominal interest rate curtails the cost-push inflationary impact of the shock, and alleviates the drop in output via a standard intertemporal substitution effect. To prevent inflation escalating due to the monetary expansion, the financial tax instrument should track the short-run contemporaneous movements in the nominal interest rate. A deposit subsidy raises the effective interest rate and incentivizes savings, both of which offset the output expansion caused by the monetary easing. The *ceteris paribus* decline in $\hat{Y}_t$ attributed to the deposit subsidy exerts downward pressure on prices due to an intertemporal substitution channel. Specifically, demand-pull inflation is neutralized with output kept at its long-run level. Taking stock, the monetary expansion directly cushions cost-push effects, while the private asset subsidy prevents any demand-pull inflationary pressures.

A more formal proof exemplifies this point even further. Suppose the policymaker sets $\widehat{\pi}_t = \hat{Y}_t = 0$, $\forall t$. Then, from the *AS* curve (22) we have $\hat{R}_t^D = -\hat{u}_t$. To satisfy the *AD* curve (23), the tax instrument should be set to $\hat{\tau}_t^D = -\hat{u}_t$ in order undo any effect of $\hat{R}_t^D$ on $\hat{Y}_t$. This outcome, however, is not unique, as it can be shown that both eigenvalues of the system lies outside the unit circle. This shortcoming leads us to consider the following monetary and financial tax policy rules:

$$\hat{R}_t^D = -\hat{u}_t, \tag{44}$$

$$\hat{\tau}_t^D = -\hat{u}_t - \phi_\pi^\tau \mathbb{E}_t \widehat{\pi}_{t+1}, \tag{45}$$

where ϕ_π^τ is a coefficient that measures the strength of the deposit tax-subsidy response to variations in expected inflation. In this case, an optimal tax policy rule with a forward-looking inflation target satisfying $\phi_\pi^\tau > 1$ guarantees equilibrium uniqueness. For $\phi_\pi^\tau > 1$, the constrained-efficient allocation is attained as the distinct equilibrium outcome. Unlike the basic New Keynesian model, the Taylor principle is applied to the tax instrument, and is independent of the parameter values. Moreover, for $\widehat{\pi}_t = \hat{Y}_t = 0$, $\forall t$, and from an *ex-post* perspective, the interest rate and the deposit tax-subsidy satisfy $\hat{R}_t^D = -\hat{u}_t$ and $\hat{\tau}_t^D = -\hat{u}_t$. The presence of a "threat" to adjust $\hat{\tau}_t^D$ in reaction to deviations in expected future inflation leads to a determinate equilibrium outcome, and is sufficient to rule out any variations in equilibrium. According to the optimal fiscal-financial policy rule, a rise in expected inflation warrants a more than one-to-one deposit tax cut. The latter, in turn, acts to raise the real interest rate and thus limit fluctuations in output, which would otherwise result in inefficient variations in inflation. In this way, full access to monetary and deposit tax-subsidy policies, which include a credible signal to modify $\hat{\tau}_t^D$ in response to any deviations in expected inflation, yields the first-best *time-consistent* allocation. This optimal policy prescription holds regardless of whether the economy enters a liquidity trap or not.

Furthermore, the identical optimal dynamics implied from the unconstrained Ramsey and time-consistent policies with deposit subsidy interventions yield an equivalent welfare gain of 0.011% relative to the constrained optimal monetary policy commitment case.[31] Unconventional fiscal-financial policies remove the ZLB constraint for monetary policy, and enable the policymaker to set negative nominal interest rates without violating the household's no-arbitrage condition between deposits and holding cash for consumption purposes.

The policies advocated in this paper are not inconsistent with the practices of some central banks in advanced economies who set unprecedented negative nominal interest rates with the aim to stimulate aggregate demand in the aftermath of the Great Recession and during the start of the COVID-19 crisis. Our model shows that these policies are indeed feasible and can even be pushed further so long as fiscal-financial policy measures are implemented correctly and in a state-dependent fashion. Deploying deposit subsidies nullifies the value of time-inconsistent commitment strategies.

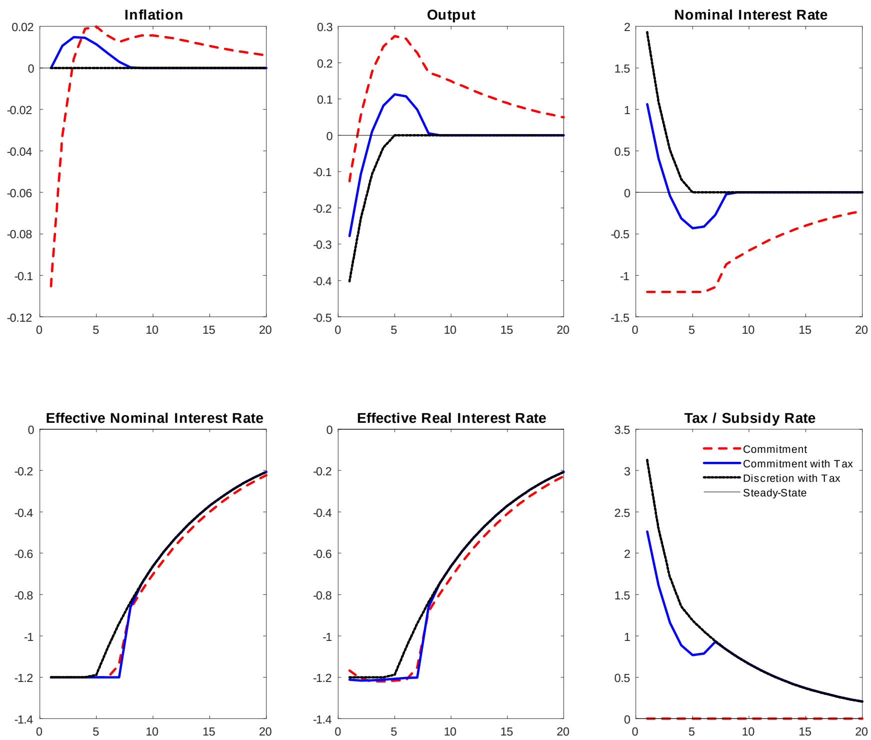
Demand Shocks. – Figure 2 presents the optimal responses of key variables to a negative $2 \times \sigma_Z$ demand shock, equivalent to a 0.47% drop in $\hat{r}_t^n$. The joint optimal monetary and tax / subsidy policy plan under commitment (labeled "Commitment with Tax") is compared with the corresponding discretionary regime ("Discretion with Tax"), and with the benchmark constrained commitment regime that involves only monetary policy as a stabilization tool ("Commitment").

Under monetary policy commitment with $\hat{\tau}_t^D = 0$, $\forall t$, a negative demand shock provokes the policymaker to slash the nominal interest rate and keep it at its lower bound for 6 quarters in order to induce a persistent, yet gradual, economic expansion from the second period. At the same time, the initial interest rate reduction places downward pressure on inflation due to the presence of the cost channel. Compared to Adam and Billi (2006) and Nakov (2008), the amplified fluctuations generated in this model by the cost channel prompts the public authority to drive output above its steady-state level for a longer period of time stretching even beyond the lifespan of the trap. The objective here is to dampen the fall in prices at the time of the disturbance, as well as to raise expected inflation in order to drive down the real interest rate. The added stimulus to the system led by the promise to keep expected inflation and output positive even after the economy escapes

[31] Following supply shocks, the complete equivalence in welfare gains from discretion and commitment with $\hat{\tau}_t^D$ remains valid irrespective of the parameter values.

the liquidity trap substitutes for further nominal interest rate cuts. Such result is reinforced by the expected hike in $\hat{R}_t^D$ from the seventh period that mildly accelerates medium-run inflationary pressures via the monetary policy cost channel.

Figure 2. - Adverse Demand Shock: Commitment & Discretionary Policies with Financial Taxes



Note: The tax / subsidy rate, interest rates, and inflation are measured in annualized percentage point deviations. Output is measured in annualized percentage deviations.

With a credible commitment to adjust both the nominal interest rate and the tax instrument, the dynamics of inflation is considerably subdued compared to the case where $\hat{\tau}_t^D$ is not available. In the scenario where the financial tax is deployed, the negative demand shock does not require a zero nominal interest rate. Instead, and similar to the discretion case, optimal policy involves an increase in the deposit tax rate and a more subtle initial hike in the nominal interest rate such that only the effective tax-augmented nominal savings rate reaches its floor. This policy configuration attenuates the drop in output via a standard intertemporal demand channel, and limits deflationary pressures through the cost channel.

Notice, however, that in relation to the optimal monetary commitment strategy on its own, fluctuations in output are larger during the initial periods under the unrestricted discretionary and commitment policies with deposit taxes. Yet, the medium-term output overshooting effect is more pronounced when the policymaker implements optimal monetary policy commitment. In either case, both the discretion and commitment outcomes involving an increase in $\hat{R}_t^D$ and $\hat{\tau}_t^D$ represent a Neo-Fisherian approach to escape a deflationary liquidity trap.

Moreover, conditions (41) and (42) reveal that once $\hat{\tau}_t^D$ is accessible, the policymaker commits to future inflation as a substitute for the inability to further lower the effective savings rate. Specifically, for $\sigma^{-1}\hat{\zeta}_{2,t} = \hat{\zeta}_{3,t}$ and $\hat{\zeta}_{1,t} = 0$, promised inflation is positive as shown in (42). Note that compared to the discretionary case with financial taxes, the effective tax-augmented nominal deposit rate is kept at its floor for 2 additional periods under the unconstrained optimal commitment regime with $\hat{\tau}_t^D$. Importantly, the longer and looser anticipated policy mix, involving a modest nominal interest rate cut from the third period, dampens the initial decline in output and inflation but requires a small rise in these two variables for a short period of time in the future.

Comparing discretion versus commitment from a welfare perspective, the first few periods more cushioned drop in output under the commitment case offsets the optimal amount of costly above-target promised inflation and output. Quantitatively, unconstrained commitment and discretionary policies with fiscal-financial interventions yield a near-identical welfare gain of 0.0014% relative to the constrained commitment policy comprising only of monetary policy.[32] Despite the very modest welfare gains, the use of the tax policy is part of the optimal policy mix and achieves better stabilization outcomes in particular when it comes to minimizing price fluctuations.

To summarize, a deposit tax in a deflationary liquidity trap is in line with the unconventional policy attempts taken by the ECB to lower effective deposit rates in light of the persistent low inflation experienced in the Eurozone between 2014 and 2020. We show that a tax on term deposits stands out as a natural policy tool to address the inefficiencies associated with liquidity traps instigated by deflationary shocks. In fact, the results following both supply and demand shocks suggest that policymakers can significantly limit the time-inconsistency involved with commitment interest rate and government spending policies once the unconventional deposit tax-subsidy instrument is effectively utilized.

5.2 Robust Optimal Policy Rules

So far, we have expressed optimal policy and targeting rules either in terms of Lagrange multipliers and/or responses to shocks. Moreover, we have implicitly assumed that the monetary and fiscal-

[32] These welfare gains are the same up to the 5^{th} decimal point. Thus, we comfortably argue that time-consistent and Ramsey plans with deposit taxation are roughly coequal from a quantitative welfare perspective. The near-identical, yet small, welfare gains from discretion and commitment with deposit tax policies holds for various parameterizations.

financial policy instruments can freely adjust without exhibiting inertia. In practice, however, the nature of shocks and shadow costs are not directly observed, and policies may lack versatility and exhibit strong history-dependence. In this section, we build on the approach of Giannoni and Woodford (2003) to derive implementable and robust optimal policy rules for $\hat{R}_t^D$ and $\hat{\tau}_t^D$ by penalizing variations in these instruments in the welfare loss function. Our aim here is to express optimal policy in terms of rules conditional on observed macroeconomic variables.

Consider the expected value of an augmented welfare loss criterion, which takes the following form:

$$\mathbb{E}(\mathcal{W}) \equiv -\frac{1}{2}\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \tilde{\mathcal{L}}_t, \tag{46}$$

where the period losses now read:

$$\tilde{\mathcal{L}}_t = \hat{\pi}_t^2 + \vartheta_y \hat{Y}_t^2 + \vartheta_r \left(\hat{R}_t^D - \hat{\tau}_t^D\right)^2. \tag{47}$$

The relative weight on output variability $\vartheta_y \equiv (\sigma + \varphi)\,\Theta^{-1}$ is the same as before. The parameter $\vartheta_r > 0$ represents the weight attached to variations in the *effective* nominal interest rate, which can be seen as a 'consolidated' policy tool reflecting the opportunity cost of holding cash. Recall that a key feature of our model is the microfounded ZLB restriction stemming from the CIA constraint. Thus, following Giannoni and Woodford (2003) and Woodford (2003), it is reasonable to assume that the policymaker might find it optimal to allow for more inflation and/or output variability to avoid the relevant post-tax savings rate hitting the ZLB. In the current framework, the size of ϑ_r depends on how frequently and to what extent the tax-augmented interest rate reaches its lower bound.[33]

The augmented Lagrangian policy problem, incorporating a penalty function to approximate the model-implied ZLB, can be expressed as follows:

$$\mathfrak{L}_t = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \begin{array}{c} -\frac{1}{2}\left[\hat{\pi}_t^2 + \vartheta_y \hat{Y}_t^2 + \vartheta_r \left(\hat{R}_t^D - \hat{\tau}_t^D\right)^2\right] - \tilde{\zeta}_{1,t}\left[\widehat{\pi}_t - \beta \mathbb{E}_t \widehat{\pi}_{t+1} - \lambda\left(\hat{R}_t^D + (\sigma+\varphi)\,\hat{Y}_t + \hat{u}_t\right)\right] \\ -\tilde{\zeta}_{2,t}\left[\hat{Y}_t - \mathbb{E}_t \hat{Y}_{t+1} + \sigma^{-1}\left(\hat{R}_t^D - \hat{\tau}_t^D - \mathbb{E}_t \widehat{\pi}_{t+1} - \hat{r}_t^n\right)\right] \end{array} \right\},$$

where the terms $\tilde{\zeta}_{1,t}$ and $\tilde{\zeta}_{2,t}$ are the Lagrange multipliers on the AS and AD curves, respectively. Note that in the present setup, introducing a quadratic penalty for policy variability in the loss function – which serves as a mechanism for achieving an approximate ZLB – replaces the slackness

[33] Alternatively, concerns for stabilizing the effective post-tax nominal interest rate (opportunity cost of money) in the loss function can be justified through transaction frictions, specifically by introducing real money balances into the household's utility function (see Woodford 2003). Under such setup, ϑ_r is directly related to the elasticity of the utility function with respect to M_t/P_t or the estimated money demand function.

constraint (40). Defining $\kappa \equiv (\sigma + \varphi)\lambda$, the resulting first-order conditions with respect to $\widehat{\pi}_t$, $\hat{Y}_t$, $\hat{R}_t^D$, and $\hat{\tau}_t^D$ are:

$$-\widehat{\pi}_t - \tilde{\zeta}_{1,t} + \tilde{\zeta}_{1,t-1} + \beta^{-1}\sigma^{-1}\tilde{\zeta}_{2,t-1} = 0, \tag{48}$$

$$-\vartheta_y \hat{Y}_t + \kappa\tilde{\zeta}_{1,t} - \tilde{\zeta}_{2,t} + \beta^{-1}\tilde{\zeta}_{2,t-1} = 0, \tag{49}$$

$$-\vartheta_r \left(\hat{R}_t^D - \hat{\tau}_t^D\right) + \lambda\tilde{\zeta}_{1,t} - \sigma^{-1}\tilde{\zeta}_{2,t} = 0, \tag{50}$$

$$\vartheta_r \left(\hat{R}_t^D - \hat{\tau}_t^D\right) + \sigma^{-1}\tilde{\zeta}_{2,t} = 0, \tag{51}$$

for each date $t \geq 0$, together with the initial conditions:

$$\tilde{\zeta}_{1,-1} = \tilde{\zeta}_{2,-1} = 0. \tag{52}$$

To attain the optimal policy rules, we first combine (50) and (51) to obtain $\tilde{\zeta}_{1,t} = 0$. Second, we infer the values of $\tilde{\zeta}_{2,t}$ and $\tilde{\zeta}_{2,t-1}$ from $\left(\hat{R}_t^D - \hat{\tau}_t^D\right)$ and $\left(\hat{R}_{t-1}^D - \hat{\tau}_{t-1}^D\right)$ in (51), and substitute these values together with $\tilde{\zeta}_{1,t} = 0$ into (49). Third, we substitute the implied values of $\tilde{\zeta}_{1,t-1}$ and $\tilde{\zeta}_{2,t-1}$ in (48). After some algebra, we derive the following feedback rules that are consistent with the optimal state-contingent plan:

$$\left(\hat{R}_t^D - \hat{\tau}_t^D\right) = \beta^{-1}\left(\hat{R}_{t-1}^D - \hat{\tau}_{t-1}^D\right) + \sigma^{-1}\frac{\vartheta_y}{\vartheta_r}\hat{Y}_t, \tag{53}$$

$$\widehat{\pi}_t + \beta^{-1}\vartheta_r\left(\hat{R}_{t-1}^D - \hat{\tau}_{t-1}^D\right) = 0, \tag{54}$$

where $\beta^{-1}\vartheta_r < 1$ for any standard parameterization.[34] Thus, the monetary and fiscal-financial policy instruments are inertial, respond to output and inflation fluctuations, and exhibit strong interdependence. One can show that for any parameter values σ, ϑ_y, $\vartheta_r > 0$ and $\beta \in (0, 1)$, a commitment to the rules described in (53) and (54) implies a determinate rational-expectations equilibrium.

Importantly, the rules (53) and (54) have the advantage of being robustly optimal, in the sense that they are independent of the shock processes. Furthermore, the explicit rules are tractable and directly react to observable economic indicators. This feature is particularly beneficial for policymaking, especially in situations where it is challenging to determine the nature of the shocks affecting the economy.

Table 2 presents the annualized standard deviations in inflation, output, the nominal interest rate, the financial tax rate, and the welfare-relevant post-tax nominal interest rate under two

[34] In Woodford (2003), for example, ϑ_r ranges from 0 to 0.277, implying that $\beta^{-1}\vartheta_r$ is significantly lower than 1.

scenarios: *i)* when the optimal commitment policy is derived in the piecewise-linear model and based on the welfare function (25) – labeled "OccBin"; and *ii)* when the optimal commitment policy is solved under the penalty function approach and follows (53) and (54) – labeled "Penalty Function". The annualized standard deviations are calculated with both shocks active, using shock moments and all other parameters as specified in the previous sections.

With a penalty function on the variance of $\left(\hat{R}_t^D - \hat{\tau}_t^D\right)$ and a commitment policy using both instruments, we set $\vartheta_r = 0.12$. This implies a 15.4% probability that the effective tax-augmented nominal interest rate will hit the ZLB. Bernanke (2020) demonstrates that short-term interest rates are likely to hover around the ZLB about 30% of the time in the absence of unconventional policies. When various unconventional policies are considered, this probability ranges from around 11% to 23%. Therefore, our target probability of breaching the ZLB falls within the range reported by Bernanke (2020) when the interest rate policy is supplemented with unconventional instruments. Additionally, our choice of $\vartheta_r = 0.12$ lies within the spectrum of estimates used in Woodford (2003).

Table 2: Volatility of Key Macroeconomic and Policy Variables

	$\sigma\left(\widehat{\pi}_t\right)\%$	$\sigma\left(\hat{Y}_t\right)\%$	$\sigma\left(\hat{R}_t^D\right)\%$	$\sigma\left(\hat{\tau}_t^D\right)\%$	$\sigma\left(\hat{R}_t^D - \hat{\tau}_t^D\right)\%$	ZLB Probability(%)
OccBin	0.14	0.62	8.70	8.86	1.61	38.4
Penalty Function	0.14	0.69	8.78	8.90	1.17	15.4

The key message from Table 2 is that imposing a penalty on effective interest rate variability results in lower volatility in $\hat{R}_t^D - \hat{\tau}_t^D$, but at the cost of higher variations in $\hat{Y}_t$ compared to the OccBin case. Interestingly, the standard deviations in $\widehat{\pi}_t$ remain virtually the same in both setups. Intuitively, given the relatively low weight attached to output variability in the loss function with our calibration, the policymaker is willing to accept higher volatility in $\hat{Y}_t$ to reduce the variance in the tax-augmented nominal interest rate. Further, the probability of reaching the effective ZLB is significantly lower with the penalty function approach.[35] Finally, to achieve lower variability in the effective savings rate relevant to the household's intertemporal decisions, high variations in each of the two tools are necessary. This result echoes our earlier analysis, where we showed that relatively large changes in both $\hat{R}_t^D$ and $\hat{\tau}_t^D$ are necessary to stabilize the economy following supply- and demand-driven liquidity traps.

[35] The result wherein the asset tax and the nominal interest rate fall one-for-one following adverse supply shocks (as shown in Figure 1) also holds with the penalty function approach. This indicates that the frequency of hitting the ZLB on the effective interest rate under optimal commitment policy is driven primarily by demand shocks. Simulations demonstrating the equivalence between the dynamics under optimal commitment with and without the penalty function following cost-push shocks are available upon request.

6 Relation to Unconventional and Macroprudential Policies

Despite the transparent economic stabilization benefits of deploying state-dependent deposit taxes / subsidies, this direct measure has not received the deserved attention in the literature and in policy circles. We believe it should. Our arguably more agnostic modeling approach to dynamic private asset taxation may initially be viewed as conflicting with other, more intricate unconventional and macroprudential policies implemented in real-world contexts.

Nevertheless, the stylized characterization of unconventional policies in the form of more general asset taxes / subsidies that are revenue neutral is in line with Farhi and Werning (2016) and Korinek and Simsek (2016), among others. In particular, Farhi and Werning (2016) show that the implications of (macroprudential) financial taxation may be equivalent to the effects of different policy instruments in terms of achieving constrained-efficient allocations in environments characterized by nominal rigidities and aggregate demand externalities. We conjecture that in a stylized model like ours with a CIA constraint, a microfounded effective ZLB floor, a cost channel, and potential *supply-driven* liquidity traps, other dynamic unconventional policies such as QE and loan-to-value (LTV) ratios – impacting either the AD and/or AS curves – can mitigate the restrictions imposed on standard interest rate policies. These policies can then achieve superior welfare outcomes similar to deposit taxes / subsidies though likely operating through different transmission channels.

Sims and Wu (2021, 2023), for example, show that QE has both demand and supply side effects and can offset credit market disruptions while alleviating the costs of a binding ZLB. Rubio and Yao (2020) and Ferrero, Harrison, and Nelson (2024), on the other hand, use New Keynesian models with housing and credit constraints to showcase that time-varying LTV limits can damper and even prevent the occurrence of demand-driven liquidity traps. These papers also provide evidence on the practical use of such instruments.

Of course, modelling more complex policy tools would require the introduction of richer heterogeneity, a state variable like physical capital and/or housing, as well as financial frictions that stray beyond merely the cost channel (e.g., default risk and financial intermediaries balance sheet effects). The analysis of more detailed unconventional and macroprudential instruments in a cost channel model like ours with these additional important features extends beyond the scope of this paper but warrants further investigation in future research.

7 Conclusion

This paper has studied the properties of optimal time-consistent and Ramsey policies in the context of a stylized New Keynesian model modified for a cost channel and a CIA-induced lower bound constraint on the effective tax-augmented nominal deposit rate. The model sheds new insights on the stabilization roles and transmission mechanisms of monetary and fiscal-financial interventions in liquidity traps driven by different fundamentals. We have shown that varying the deposit tax-subsidy according to the state of the business cycle has meaningful effects on the behavior of key macroeconomic variables, and substantially alters the transmission of optimal monetary policy.

The monetary policy cost channel highlighted in this paper presents an additional motivation for deploying state-dependent fiscal-financial measures. In a liquidity trap, deposit tax-subsidy policies lift the restrictions imposed on the nominal policy rate, and substantially diminish the adverse consequences of both recessionary demand and supply shocks. Finally, the normative implications of optimal unconstrained time-consistent policies with private asset tax interventions are remarkably similar to their Ramsey counterparts. These results suggest that forward guidance (or more generally commitment) policies are of secondary importance so long as the policymaker can optimally alter the financial tax on loanable funds.

Like Correia, Farhi, Nicolini, and Teles (2013), Eichenbaum (2019), and Correia, De Fiore, Teles, and Tristani (2021), our state-dependent policy recommendations require highly adaptable taxes / subsidies in times of economic uncertainty. It is well known that fiscal and financial policy tools may not be as versatile as monetary policy instruments, and require a long legislative process until they can actually be executed. Writing automatic stabilizer financial programs into law during tranquil times could circumvent these political and economic challenges faced by policymakers in the midst of a crisis. Either way, we make a normative point that financial tax-subsidy policies should be at least as proactive and aggressive as monetary policy, so long as the policymaker can correctly identify the source and the size of the shock distorting the economy. Alternatively, implementable robust optimal policy rules that respond to observable variables may also serve as a useful prescription against economic shocks when policymakers cannot easily determine the extent to which business cycles are supply- and/or demand-driven.

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prudential Policies, Inequality and Financial Inclusion Workshop (City University); Norges Bank; and Spring Midwest Macroeconomics Meeting. Earlier and markedly distinct versions of this paper, now dormant, were circulated under the titles "Macroprudential Interventions in Liquidity Traps", "Monetary and Financial Tax Interventions in Liquidity Traps", "Taxation, Credit Spreads, and Liquidity Traps", and "Unconventional Policies in State-Contingent Liquidity Traps".

Data Availability

Data will be made available on request.

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Appendix

A: Optimal Policy *without* Financial Taxes / Subsidies

To emphasize the importance of the cost channel in the present framework, we also examine optimal policy without unconventional financial taxation. In this Appendix section, $\hat{R}_t^D$ acts as the sole stabilization tool available to the policymaker with $\hat{\tau}_t^D = 0$, $\forall t$.

Under **discretion**, the optimal targeting rule when the nominal interest rate is at its lower bound ($\hat{\zeta}_{3,t} > 0$) is derived from conditions (27)-(29) and (31) with $\hat{\tau}_t^D = 0$, $\forall t$, and can be written as:

$$\vartheta_y \hat{Y}_t = -\left(\kappa - \sigma\lambda\right)\widehat{\pi}_t - \sigma\hat{\zeta}_{3,t}, \tag{55}$$

or:

$$\left[\left(\frac{\kappa}{\sigma} - \lambda\right)\widehat{\pi}_t + \frac{\vartheta_y}{\sigma}\hat{Y}_t\right]\left[\hat{R}_t^D - \ln\left(\beta\right)\right] = 0; \quad \hat{R}_t^D \geq \ln\left(\beta\right). \tag{56}$$

Thus, for a given variation in inflation, a tighter constraint on $\hat{R}_t^D = \ln\left(\beta\right)$, as measured by $\hat{\zeta}_{3,t} > 0$, leads to a more substantial fall in output following a deflationary demand shock. Once at the ZLB, the interest rate is pegged and follows $\hat{R}_t^D = 0$. Equilibrium paths for inflation and output during the ZLB episode are obtained by substituting $\hat{R}_t^D = 0$ in (22) and (23):

$$\widehat{\pi}_t = \beta \mathbb{E}_t \widehat{\pi}_{t+1} + \lambda \left[(\sigma + \varphi) \hat{Y}_t + \hat{u}_t \right], \tag{57}$$

$$\hat{Y}_t = \mathbb{E}_t \hat{Y}_{t+1} + \sigma^{-1} \left(\mathbb{E}_t \widehat{\pi}_{t+1} + \hat{r}_t^n \right). \tag{58}$$

The discretionary rational expectations equilibrium at the ZLB is then determined by equations (55), (57), and (58), taking expectations and the $AR(1)$ shocks as given.

Substituting (57) and (58) in (55) reveals that $\hat{\zeta}_{3,t}$ is a negative function of $\hat{r}_t^n$, and a positive function of $\hat{u}_t$. A sizeable negative demand shock that pushes $\hat{Y}_t$ and $\widehat{\pi}_t$ in the same direction lowers the natural rate of interest and increases the risk of entering a liquidity trap, hence tightening the ZLB constraint. In contrast, a favorable cost-push shock that lowers inflation acts to lift the real interest rate and further depress aggregate demand. Our model gives rise to a variant of the 'paradox of toil' (as popularized by Eggertsson 2010), wherein otherwise expansionary supply shocks can paradoxically lead to lower welfare by amplifying deflationary pressures and keeping the nominal interest rate at its lower bound.

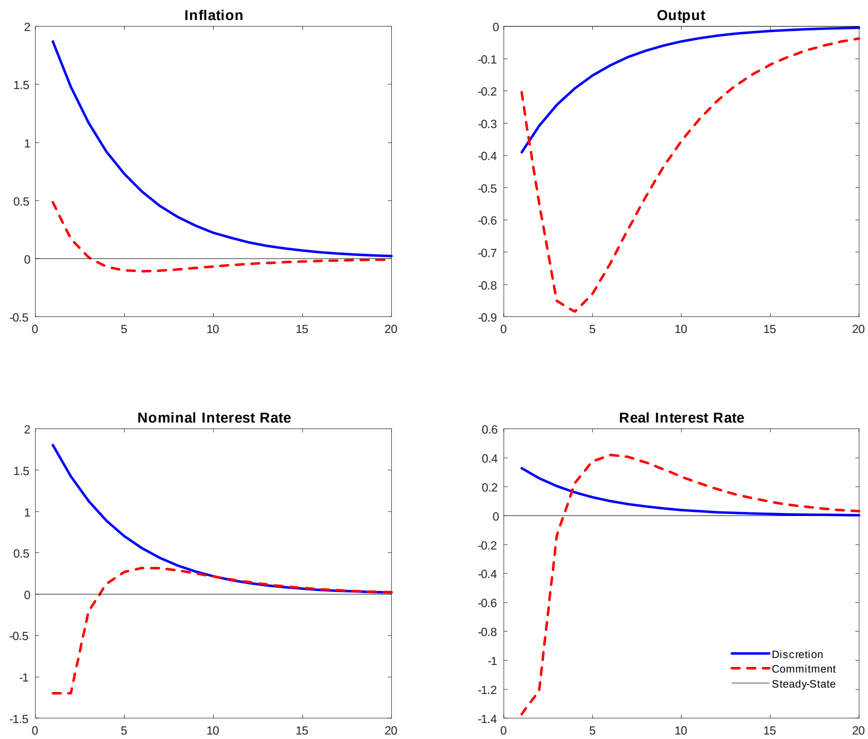
Under **commitment**, the optimal monetary commitment targeting rule is represented by (43) in the main text and re-written here for convenience:

$$\left[\left(\frac{\kappa}{\sigma} - \lambda \right) \widehat{\pi}_t + \frac{\vartheta_y}{\sigma} \hat{Y}_t - \left(\frac{\kappa}{\sigma} - \lambda \right) \hat{\zeta}_{1,t-1} - \frac{\left(\frac{\kappa}{\sigma} - \lambda + 1 \right)}{\sigma \beta} \hat{\zeta}_{2,t-1} \right] \left[\hat{R}_t^D - \ln(\beta) \right] = 0; \quad \hat{R}_t^D \geq \ln(\beta). \tag{59}$$

Notice that (59) boils down to the discretionary targeting rule (56) when the policymaker is not bound by past commitments (or when the lagged Lagrange multipliers are set to zero; $\hat{\zeta}_{1,t-1} = \hat{\zeta}_{2,t-1} = 0$). In both discretion and commitment cases, optimal monetary policy at the ZLB is affected by the presence of the cost channel as captured by the term λ attached to $\widehat{\pi}_t$ in (56), and that multiplies $\widehat{\pi}_t$, $\hat{\zeta}_{1,t-1}$, and $\hat{\zeta}_{2,t-1}$ in (59). We now turn to compare monetary discretion and commitment policies with an occasionally-binding ZLB constraint following recessionary shocks.

Supply Shocks. – Figure A1 shows the optimal responses of key variables to a stagflationary shock corresponding to a 2.5% increase in $\hat{u}_t$ under discretionary and commitment monetary policy. Note that the dashed impulse response functions (IRFs) in Figure A1 are the same as the dashed IRFs in Figure 1.

Figure A.1. - Stagflationary Shock: Monetary Policy Discretion vs. Commitment with the ZLB



Note: Interest rates and inflation are measured in annualized percentage point deviations.

Output is measured in annualized percentage deviations.

When examining discretionary monetary policy against the backdrop of an inflationary shock in this framework, it is important to first reiterate that the coefficient on $\widehat{\pi}_t$ in the targeting rule (55) is $(\kappa - \sigma\lambda)/\vartheta_y$. Variability in inflation is larger because a rise in $\hat{R}_t^D$ not only acts to reduce $\hat{Y}_t$ and $\widehat{\pi}_t$ through a standard demand effect, but also serves to increase $\widehat{\pi}_t$ and amplify the fall in $\hat{Y}_t$ via the monetary policy cost channel. These effects make inflation stabilization more costly in terms of output stability, triggering a monetary policy trade-off (Ravenna and Walsh 2006). Optimal discretionary monetary policy warrants a contractionary and aggressive interest rate reaction against an inflationary shock. In particular, the cost channel escalates the hike in $\hat{R}_t^D$ following a stagflationary shock. The upshot is a more pronounced inflation surge, which forces the optimizing discretionary policymaker to raise $\hat{R}_t^D$ by around 1.8 percentage points. The strict interest rate response accelerates the contraction in aggregate demand, which, in turn, dampens inflation via both the intertemporal substitution mechanism and the cost channel. Hence, under discretionary monetary policy, the ZLB constraint is less consequential following a rise in $\hat{u}_t$.

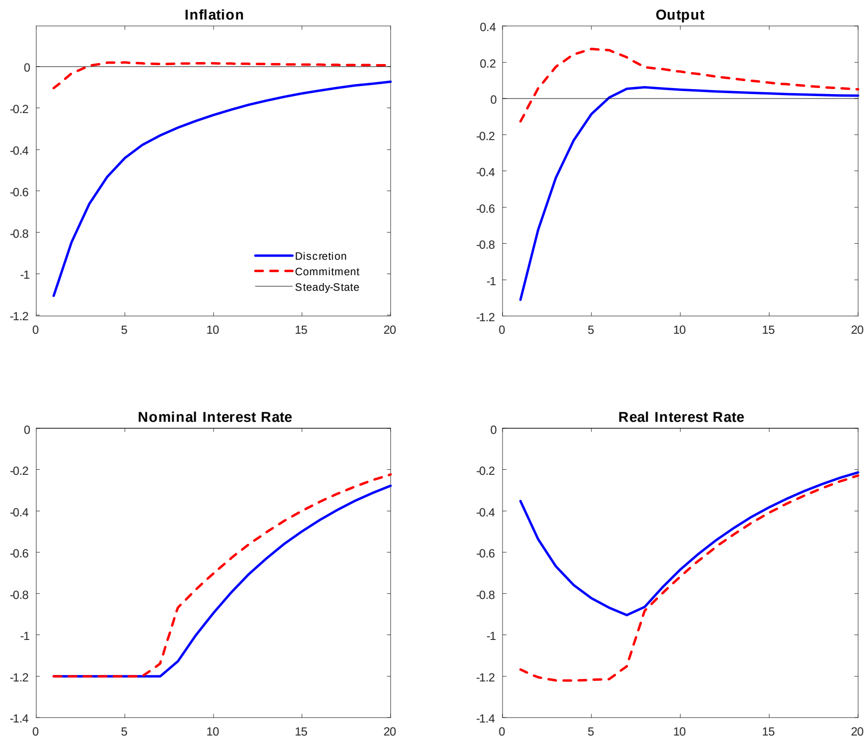
In sharp contrast, commitment does trigger a supply-side liquidity trap despite the immediate inflationary pressures stemming from increased marginal costs, as explained in the main text. Additionally, in the medium-run and during the recovery stage, output is driven below the level implied by discretion with the aim to alleviate the rise in prices in the first few periods.

Nonetheless, given the mitigated initial fluctuations in output upon the impact of the supply shock under commitment and the muted asymptotic volatility in prices, commitment considerably outperforms discretion, yielding an unconditional expected welfare gain of 0.097%. Without a cost channel but with the occasionally-binding ZLB constraint, welfare gains from commitment over discretion following cost-push shocks stand at only 0.02% under our benchmark parameterization. In other words, welfare gains in an otherwise textbook New Keynesian model that excludes the potential supply-side effects of monetary policy are considerably undervalued.

Demand Shocks. – Figure A2 presents the optimal responses of key variables to a negative natural real interest rate shock of size $2 \times \sigma_Z$ under discretionary and commitment monetary policy. Notice that the dashed IRFs in Figure A2 are the same as the dashed IRFs in Figure 2.

Under discretionary policy and in a demand-driven liquidity trap, output, the marginal cost, and prices decline. Beyond this direct *demand-pull* deflationary consequence, the fall in $\hat{R}_t^D$ magnifies the deflationary impact of the shock and deepens the economic recession by keeping the real interest rate at elevated levels. This amplification effect is captured by λ, as can be inferred from (55), and serves as a *cost-push* deflationary by-product. More formally, re-arranging (55) yields $\hat{\zeta}_{3,t} = -\sigma^{-1}\left[(\kappa - \sigma\lambda)\,\widehat{\pi}_t + \vartheta_y \hat{Y}_t\right]$, implying that $\hat{\zeta}_{3,t}$ rises with λ for a given large decline in $\widehat{\pi}_t$ and $\hat{Y}_t$. Thus, beyond the direct adverse implications of the exogenous shock, the release date from the ZLB under discretion is further postponed when the cost channel is present, intensifying the severity of the liquidity trap. As a result, the public authority generates a moderate output overshooting even under discretion, while keeping the zero interest rate policy intact for 7 quarters. Importantly, this duration exceeds the time spent at the ZLB in the benchmark New Keynesian model – lasting only 5 periods with the same parameterization and shock moments as applied in this exercise.

Figure A.2. - Adverse Demand Shock: Monetary Policy Discretion vs. Commitment with the ZLB



Note: Interest rates and inflation are measured in annualized percentage point deviations.

Output is measured in annualized percentage deviations.

A non-trivial result arising from the analysis in this section and the baseline calibration with a sufficiently persistent demand shock is that the liquidity trap spell is *shorter* under commitment than under discretion (see also Chattopadhyay and Ghosh 2020).[36] This comes in stark contrast to the textbook New Keynesian model where optimal monetary policy under commitment always warrants a later exit date from the ZLB and a slower adjustment of the policy rate towards its steady-state. By minimizing the present discounted value of welfare, the anticipated future eco-

[36] We have observed that when demand shocks are less persistent (specifically when $\rho_Z < 0.875$), monetary commitment leads to a longer period at the ZLB compared to discretion. However, the cost channel still reduces the *relative* duration of the liquidity trap under commitment versus discretion when compared to a standard frictionless New Keynesian model. Given the paper's primary focus on deposit taxes and subsidies, we leave the exploration of the role of persistence in explaining monetary commitment versus discretion policies at the ZLB within a cost channel framework for future research. As explained earlier, shock moments in our setup are based on a Bayesian estimation of the occasionally-binding model and we therefore set $\rho_Z = 0.89$ throughout all our demand shock simulations. It is important to note that the qualitative policy implications of optimal tax-subsidy interventions presented throughout the main text remain unaffected by the persistence of shocks.

nomic stimulus emerging from the commitment policy (as explained above), together with the positive impact of the cost channel on inflation as the economy exits the liquidity trap, enables the policymaker to raise the interest rate at an earlier date relative to discretion. The Neo-Fisherian property observed under commitment in a cost channel model implies that "low-for-longer" optimal forward guidance policies in the standard model may be exaggerated in terms of the time spent at the ZLB.

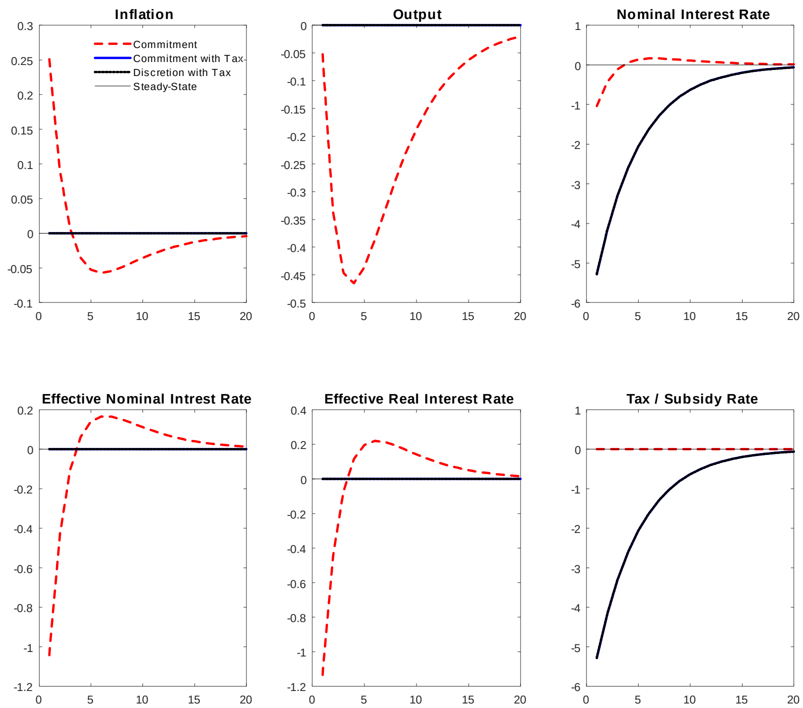
Finally, we find that the optimal commitment regime attains an unconditional expected welfare gain of 0.21% compared to the discretionary outcome. In the basic New Keynesian model that applies the same calibration as in this exercise, the welfare improvement from optimal forward guidance amounts to only 0.043%. As a result, and similar to the situation involving supply shocks, welfare gains from commitment in the basic New Keynesian model are significantly underestimated when excluding the cost channel but accounting for an occasionally-binding ZLB constraint.

B: Optimal Dynamics in a Model *without* the ZLB

Figures B1 and B2 show the equilibrium responses to a $1 \times \sigma_u$ supply and $1 \times \sigma_Z$ demand shocks, respectively. As a benchmark, we simulate the optimal commitment policy with monetary policy only (labeled "Commitment") where $\hat{\tau}_t^D = 0, \forall t$. This benchmark case is compared with the commitment regime involving deposit tax / subsidy interventions (labeled "Commitment with Tax"), and with the discretionary case that also includes the financial tax policy (labeled "Discretion with Tax"). The ZLB is ignored in all simulations below, with all other parameters set to the values specified in the main text.

Notice that, following supply-side shocks, both discretion and commitment policies with financial taxation achieve zero fluctuations in inflation and output. Optimal policy in both cases calls for an equal reduction in the nominal interest rate and the financial tax, similar to the scenario where the ZLB is occasionally-binding. The key difference here from the main text is that the nominal interest rate does *not* hit the ZLB under monetary policy commitment due to the smaller shock size. Nevertheless, monetary policy commitment still calls for an interest rate reduction despite the inflationary pressures caused by the adverse supply shock.

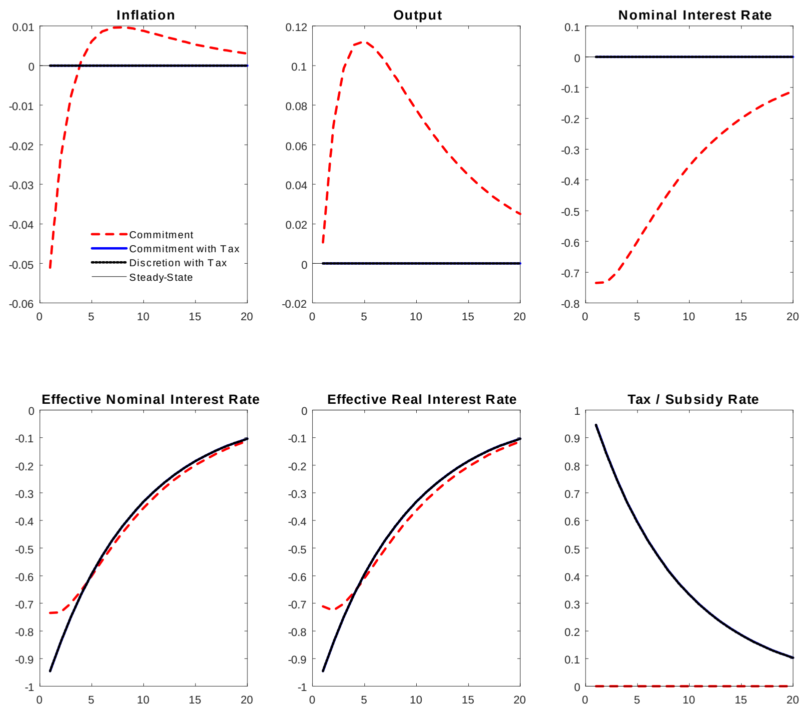
Figure B.1. - Stagflationary Shock: Commitment & Discretionary Policies with Financial Taxes / No ZLB



Note: The tax / subsidy rate, interest rates, and inflation are measured in annualized percentage point deviations. Output is measured in annualized percentage deviations.

Following demand shocks, the cost channel causes output overshooting when monetary policy commitment is enacted and the ZLB is never binding. In a standard New Keynesian model without a cost channel and the ZLB, monetary policy commitment always achieves the first-best allocation that is consistent with zero deviations in output and inflation.

Figure B.2. - Adverse Demand Shock: Commitment & Discretionary Policies with Financial Taxes / No ZLB



Note: The tax / subsidy rate, interest rates, and inflation are measured in annualized percentage point deviations. Output is measured in annualized percentage deviations.

When financial taxes are available, both discretion and commitment policies achieve full economic stabilization. Optimal policy involves maintaining the nominal interest rate at its long-run level while raising *only* the asset tax. This approach lowers the effective tax-augmented interest rate, minimizing fluctuations in both inflation and output. Because the nominal interest rate inflicts both demand and supply side effects through intertemporal substitution and the cost channel, respectively, optimal policy is achieved through alterations in $\hat{\tau}_t^D$ only, which, in turn, directly and solely impacts the AD curve.