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Unconventional Policies in State-Contingent Liquidity Traps

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Abstract

We characterize optimal unconventional monetary and fiscal-financial policies within a tractable New Keynesian model featuring a monetary policy cost channel. State-dependent deposit tax-subsidy interventions remove the zero lower bound constraint on the nominal interest rate, thereby minimizing output and price fluctuations following both supply-driven and demand-driven liquidity traps. Specifically, deposit *subsidies* circumvent the inflation-output trade-off arising from *stagflationary shocks* by enabling the implementation of *negative* nominal interest rates. Moreover, deposit *taxes* facilitate modest interest rate *hikes* to escape *deflationary traps*. Notably, discretionary and commitment policies with deposit taxes / subsidies deliver virtually equivalent welfare gains, rendering time-inconsistent forward guidance schedules unnecessary.

JEL Classification Numbers: E32, E44, E52, E58, E63.

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) on nominal interest rates severely impeded the effectiveness of monetary policy during the liquidity trap episodes that persisted between 2008 and early 2022. 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 fiscal and monetary 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 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 (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-contingent* 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 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 use to overcome the ZLB constraint, which, according to Bernanke (2020), may become a frequent phenomenon in advanced economies with a low inflation target.[2]

We analyze the optimal monetary and private asset tax stabilization policy mix 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)* a microfounded occasionally-binding lower bound restriction on the *effective tax-augmented* nominal interest rate faced by households-depositors. Our textbook treatment of the research topic boils down the model into a familiar simplified two-equation forward-looking system consisting of an

[1] Financial taxes, (private) asset taxes, savings taxes, and deposit taxes / subsidies are used interchangeably throughout the text.

[2] Despite ongoing efforts to stabilize the inflation surge since 2021 through nominal interest rate hikes, there remains limited evidence indicating an increase in equilibrium real rates (Gopinath 2022; Holston, Laubach, and Williams 2023). Hence, there exists a significant lingering risk of a recession, wherein monetary policy alone may prove insufficient in providing the necessary means 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), and Tillmann (2008), among others.

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 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.

The present paper sheds new positive and normative insights to the ongoing debate around the role of unconventional policies, as well as to the benefits of fiscal-financial and monetary policy coordination against two different sources of business cycle fluctuations: demand and supply shocks. As recently highlighted by Ghassibe and Zanetti (2022) and Jo and Zubairy (2022), the source of economic fluctuations determines policy efficacy. We contribute to this growing literature by focusing on optimal policies against liquidity traps driven by different fundamentals.[4]

We argue that a tax-subsidy on household deposits (loanable funds) should be activated in a state-dependent fashion based on the underlying structural shock driving the economy to a liquidity trap. Access to a deposit 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 produces non-trivial stabilization and welfare benefits relative to an optimal monetary policy plan alone.

Importantly, a deposit subsidy allows to overcome 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 enable deep negative interest rates whenever needed. We show that fiscal-financial subsidies could indeed rationalize such unconventional monetary policy in the short-run, thus ending a stagflationary recession quickly or even preventing it when the policy toolkit is optimally deployed. In the steady-state, we present 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 on the effective tax-augmented savings rate.

Our main state-contingent 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

[4] 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).

tax and the nominal risk-free policy-deposit rate. In this way, the *effective tax-augmented* nominal deposit rate faced by households is completely stabilized at its long-run positive level. The lower bound constraint on the effective nominal deposit rate is therefore entirely removed with the first-best allocation attained at all times. This 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 triggers the ZLB due to the large inefficient and persistent slump in output. 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 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 fiscal-financial subsidies echo some of the non-standard policy measures undertaken by policymakers in advanced economies during the Covid-19 pandemic, and from a conceptual standpoint represent an optimal policy plan against a supply-driven liquidity trap.

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. At the same time, the 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 approach to escape a deflationary trap (e.g., Garín, Lester, and Sims 2018; Bilbiie 2022). Finally, both time-consistent and Ramsey regimes with asset tax interventions yield a near-analogous welfare gain relative to the constrained optimal monetary policy plan, despite marginal differences in the implied optimal dynamics that emerge due to policy promises under commitment. 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 deposits that our economy advocates for when the liquidity trap is demand-driven.

To underscore the significance of state-contingent deposit taxes / subsidies, we additionally analyze a model without these fiscal-financial measures. During a persistent demand-driven deflationary trap, the cost channel limits the relative spell at the ZLB instigated by optimal commitment policies compared to discretion. While notably weaker than the Neo-Fisherian effect observed with deposit taxation, as explained above, optimal monetary commitment also exhibits Neo-Fisherian characteristics. That is, increasing the nominal interest rate leads to higher medium-term inflation, facilitating an earlier exit from the ZLB (see also Chattopadhyay and Ghosh 2020). This contrasts with the benchmark New Keynesian model, where commitment typically requires a "lower-for-longer" interest rate regime. Welfare gains from monetary policy commitment over discretion in a deflationary spiral are therefore considerably larger with respect to the benefits calculated in a standard model without a cost channel.

Nevertheless, compared to the restricted regime involving only optimal monetary policy, unconstrained optimal time-consistent and Ramsey policies with a flexible dynamic deposit tax-subsidy system produce identical welfare gains in response to stagflationary supply shocks and near-equivalent gains following deflationary demand shocks. Put differently, time-inconsistent commitment policies involving optimal forward guidance are of secondary importance so long as the policymaker can optimally alter the tax rate on loanable funds - deposits.

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 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 fiscal-financial and monetary policy instruments used in the world of policy making, 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; De Paoli and Paustian 2017). Arguably, a deposit tax-subsidy may not be the first tool to spring to mind of policymakers, but its relative simplicity, effectiveness, and resemblance to other more complicated policies, could and should bring about extra consideration to this distinctive unconventional policy measure. While our contribution to the New Keynesian optimal policy literature is mainly theoretical, we believe our results are also important from a more practical viewpoint given the arguably mixed inflationary and deflationary nature of the most recent liquidity trap that resulted from the pandemic-induced recession.

Our generalized framework with deposit taxes / subsidies and the microfounded 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.

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 policy friction, which proves to be imperative to the state-dependant 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. Unlike their paper, we analyze the interplay between private asset taxation and interest rate policies using a simple two-equation New Keynesian model that explicitly considers optimal discretionary versus commitment policies, both with and without deposit taxation.

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), Eggertsson, Juelsrud, Summers, and Wold (2023), and Onofri, Peersman, and Smets (2023). Complementing these studies, our paper demonstrates that incorporating deposit 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, bank profitability, central bank reserves, and balance sheet effects, our paper provides valuable insights into the macroeconomic effects of state-dependent unconventional policies within a model that considers the supply-side effects of monetary policy.

Finally, relative to Fernández-Villaverde (2010), Eggertsson (2011), Ghassibe and Zanetti (2022), and Lemoine and Lindé (2023) who examine the *positive* implications of various fiscal policies, we study the *normative* properties of optimal financial taxation. To the best of our knowledge, the welfare and business cycle implications of novel deposit 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.

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 parameterization of the model and the solution strategy. Section 5 derives the state-contingent optimal policy target rules and studies their dynamics and welfare implications. Section 6 concludes.

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.[5]

2.1 Households

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

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

where C_t is aggregate consumption, and N_t are the total hours of labor supplied to IG firms. Moreover, $\beta \in (0,1)$ is the discount factor and φ is the inverse of the Frisch elasticity of labor supply. The preference (demand) shock follows an $AR(1)$ process:

$$Z_t = \left(Z_{t-1}\right)^{\rho_Z} \exp\left(s.d(\alpha^Z) \cdot \alpha_t^Z\right), \tag{2}$$

where $\rho_Z \in (0,1)$ is the degree of persistence, and α_t^Z is a random shock distributed as standard normal with a constant standard deviation $s.d(\alpha^Z)$.

The household enters period t with real money balances (M_t). They 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 real deposits D_t to the banking sector. The remaining cash balances become available to purchase the aggregate consumption good subject to the following cash-in-advance constraint:

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

Constraint (3) represents the implicit cost of holding intraperiod deposits that yield interest but that cannot be used for transaction services.[6] At the end of the period, the household earns the after-tax gross return on deposits, $\left(1-\tau_t^D\right) R_t^D D_t$, where R_t^D is the gross nominal policy-deposit rate, and

[5] This model features no distinction between the central bank and the government who operate under full coordination with the same objective function. These entities therefore fall under the category of the "public authority" or "policymaker".

[6] In the cost channel literature with a cash-in-advance constraint (e.g., Christiano, Eichenbaum, and Evans 2005; Ravenna and Walsh 2006), it is a common assumption that cash is used as the sole means of payment, rather than deposits.

τ_t^D is the tax rate on deposits. Importantly, τ_t^D serves as a state-contingent 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 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. Finally, the household receives a lump-sum transfer from the public authority (T_t), as well as total profits from the production and banking sectors ($\Pi_t^{P,B} \equiv \Pi_t^P + \Pi_t^B$). Thus, cash carried over to period $t+1$ is:

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

Taking real wages (W_t), prices (P_t), and financial taxes (τ_t^D) as given, the first-order conditions of the household's problem with respect to C_t, D_t, M_{t+1}, and N_t can be summarized as:[7]

$$C_t^{-1} = \beta \mathbb{E}_t \frac{Z_{t+1}}{Z_t} C_{t+1}^{-1} \frac{\left(1 - \tau_t^D\right) R_t^D}{\pi_{t+1}}, \tag{5}$$

$$N_t^{\varphi} C_t = W_t, \tag{6}$$

where $\pi_{t+1} \equiv P_{t+1}/P_t$ is defined as the gross inflation rate. Equation (5) is the Euler equation augmented for the financial tax. The effective tax-augmented real interest rate is thus $\left(1 - \tau_t^D\right) R_t^D / \mathbb{E}_t \pi_{t+1}$, implying that fiscal-financial interventions directly distort the household's intertemporal consumption-savings pattern. Furthermore, with deposits used to facilitate working-capital loans supplied by the financial intermediary, a tax on deposit returns can also be treated as a tax / subsidy on bank liquidity. Equation (6) determines the optimal labor supply.

The optimality conditions and the flow of funds constraint are written under the lower bound equilibrium restriction on the *effective tax-augmented* nominal deposit rate in which $\left(1 - \tau_t^D\right) R_t^D \geq 1$. Without unconventional fiscal-financial policies nor a cash-in-advance constraint, the non-negativity bound is attached only to the nominal risk-free interest rate (Eggertsson and Woodford 2003, 2006; Eggertsson 2011). However, the actual observed savings rate that enters the household's Euler equation accounts for any 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). Therefore, the effective lower bound that satisfies the household's no-arbitrage condition between cash-financed consumption and deposits must apply to $\left(1 - \tau_t^D\right) R_t^D \geq 1$.

[7] Money is the only asset through which the household can smooth consumption across periods (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 cash-in-advance restriction motivates and gives rise to occasionally-binding ZLB periods as further elaborated below.

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:

$$Y_{j,t} = N_{j,t}, \tag{7}$$

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:

$$(1 + u_t) = (1 + u_{t-1})^{\rho_u} \exp\left(s.d\left(\alpha^u\right) \cdot \alpha_t^u\right), \tag{8}$$

where $\rho_u \in (0,1)$ is the degree of persistence, and α_t^u is a white-noise process with constant standard deviation $s.d\left(\alpha^u\right)$. 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. We assume that u_t is distributed to households in a lump-sum fashion.

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-contingent 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. In fact, 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:

$$mc_{j,t} = mc_t = R_t^D (1 + u_t) W_t. \tag{9}$$

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 (9) 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):

$$1 - \Theta (\pi_t - 1) \pi_t + \beta \mathbb{E}_t \Theta (\pi_{t+1} - 1) \pi_{t+1} \frac{Y_{t+1}}{Y_t} = \epsilon (1 - mc_t), \tag{10}$$

with β representing the shared discount factor of the household and firms, and mc_t given by (9). 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 deposits from households in order to finance the working-capital costs of IG firms. The bank's balance sheet satisfies:

$$L_t = D_t, \tag{11}$$

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 policy (deposit) rate and earns zero profits.

2.4 Public Authority

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:

$$\left(1 - \tau_t^D\right) R_t^D \geq 1. \tag{12}$$

Furthermore, the public authority's budget constraint satisfies:

$$M_{t+1}\frac{P_{t+1}}{P_t} - M_t + \tau_t^D R_t^D D_t + u_t W_t N_t = T_t. \tag{13}$$

2.5 Market Clearing

Market clearing requires $Y_t = N_t$, where $N_t = N_{j,t}$ and $P_t = P_{j,t}$ in a symmetric equilibrium. Using (4), (7), the firm's profit function, and (13), we obtain the following aggregate resource constraint:

$$Y_t = N_t = C_t + \frac{\Theta}{2}\left(\frac{P_t}{P_{t-1}} - 1\right)^2 Y_t. \tag{14}$$

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 (5) and is given by:[8]

$$R^D = \frac{1}{\left(1-\tau^D\right)\beta}. \tag{15}$$

Long-run output is calculated from the steady-state versions of equations (5), (6), (7), (9), and (10):

$$Y^{1+\varphi} = \frac{\mathcal{M}^{-1}}{R^D\left(1+u\right)} = \frac{\beta\left(1-\tau^D\right)}{\left(1+u\right)}\mathcal{M}^{-1}, \tag{16}$$

where $Y^{1+\varphi}$ 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 $Y^{1+\varphi} = 1$. Temporarily setting $u = 0$, this efficiency condition can be supported through the implementation of the following long-run corrective financial subsidy:

$$\tau^{D,I} = 1 - \frac{\mathcal{M}}{\beta} < 0, \tag{17}$$

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 channel enables the policymaker to eliminate steady-state distortions using a deposit *subsidy* and

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

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., $\left(1-\tau^{D,I}\right) R^{D,I} = \beta^{-1}$. 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.[9]

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 (12) to obtain:

$$\hat{R}_t^D - \hat{\tau}_t^D \geq \ln(\beta), \tag{18}$$

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:

$$\widehat{\pi}_t = \beta \mathbb{E}_t \widehat{\pi}_{t+1} + \lambda \left[(1+\varphi)\hat{Y}_t + \hat{R}_t^D + \hat{u}_t\right], \tag{19}$$

$$\hat{Y}_t = \mathbb{E}_t \hat{Y}_{t+1} - \left[\left(\hat{R}_t^D - \hat{\tau}_t^D\right) - \mathbb{E}_t \widehat{\pi}_{t+1} - \hat{r}_t^n\right], \tag{20}$$

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 (19) 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.[10] While the direct effect of an increase in $\hat{R}_t^D$ is to raise $\widehat{\pi}_t$, the overall impact, that takes into account the standard demand channel of

[9] 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.

[10] 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. Furthermore, the cost-push wage tax shock $\hat{u}_t$ in our model is isomorphic to the price mark-up shocks introduced in Clarida, Galí, and Gertler (1999) and Ireland (2004), as well as to the sales subsidy shock examined in Andrade, Galí, Le Bihan, and Matheron (2019), as explained earlier.

monetary policy, is calculated by $\frac{\partial \widehat{\pi}_t}{\partial \hat{R}_t^D} = \lambda - \lambda\left(1+\varphi\right)$ or $\frac{\partial \widehat{\pi}_t}{\partial \hat{R}_t^D} = -\lambda\varphi < 0$.

Equation (20) is the Euler equation that determines the aggregate demand (AD) schedule, augmented for the preference shock and the deposit tax-subsidy. A lower deposit tax increases desired savings such that in equilibrium output falls more than in the absence of tax cuts. Nevertheless, in response to inflationary shocks, a savings subsidy can act to stabilize inflation and consequently be welfare improving. The optimal state-contingent policy plans against supply and demand shocks are investigated below and are the key contributions of this paper.

The competitive approximate equilibrium is defined as a collection of real allocations $\left\{\hat{Y}_t\right\}_{t=0}^{\infty}$, prices $\left\{\widehat{\pi}_t\right\}_{t=0}^{\infty}$, interest rates $\left\{\hat{R}_t^D\right\}_{t=0}^{\infty}$, and deposit tax-subsidy policies $\left\{\hat{\tau}_t^D\right\}_{t=0}^{\infty}$ such that for a given sequence of exogenous $AR(1)$ shock processes $\left\{\hat{u}_t, \hat{Z}_t\right\}_{t=0}^{\infty}$, conditions (18)-(20) are satisfied.

4 Parameterization and Solution Strategy

Although many of our results are shown analytically, the model is also solved numerically in order to illuminate the implications of the state-contingent optimal policies for economic dynamics and welfare. We employ parameters largely used in the New Keynesian literature and which match some moments in the U.S. data.

The discount factor is set to $\beta = 0.9975$, while the steady-state financial tax is $\tau^D = 0$ given its main purpose as a short-run stimulative unconventional policy. The implied long-run annualized risk-free interest rate for this parameterization is 1%. Moreover, using a price mark-up of 20% ($\epsilon = 6$), $\varphi = 0.5$, and $\Theta = 200$, yields a NKPC slope of $\lambda\left(1+\varphi\right) = 0.0375$. This estimate roughly corresponds with the long-run U.S. data that has exhibited a weakened relationship between inflation and output in the NKPC over recent decades and particularly following the Great Recession.[11]

We use standard Bayesian techniques and employ the piecewise-linear OccBin methodology developed in Guerrieri and Iacoviello (2015) to estimate the persistence and standard deviations of the structural shock processes.[12] Our optimal policy analysis is examined with respect to the cost-push supply and preference demand shocks, but to obtain more reliable shock moments, we introduce an additional shock through a monetary policy rule:

$$\hat{R}_t^D = \max\left[\rho_R \hat{R}_{t-1}^D + \left(1-\rho_R\right)\left(\phi_\pi \widehat{\pi}_t + \phi_y \hat{Y}_t\right) + \hat{\varrho}_t,\ \ln\left(\beta\right)\right], \tag{21}$$

where ρ_R is a smoothing parameter, $\phi_\pi > 1$, and $\phi_y \geq 0$. The interest rate shock $\hat{\varrho}_t$ follows an

[11] Our qualitative results are robust to alternative parameterizations.

[12] The simulation results presented below are confirmed with Holden's (2016) DynareOBC news shocks algorithm.

$AR(1)$ process with persistence ρ_ϱ and a standard deviation $s.d(\alpha^\varrho)$. We fix $\rho_R = 0.7$, $\phi_\pi = 2.5$, and $\phi_y = 0.25$ (e.g., Lemoine and Lindé 2023), and use the same priors as in Andrade, Galí, Le Bihan, and Matheron (2019) to calculate the shock moments. Particularly, we compute the posterior means of the six parameters ρ_u, $s.d(\alpha^u)$; ρ_Z, $s.d(\alpha^Z)$; and ρ_ϱ, $s.d(\alpha^\varrho)$, to approximately match the standard deviations in inflation, output growth, and the effective federal funds rate over the period $1985 : Q1 - 2021 : Q2$. This estimation yields $\rho_u = 0.88$, $s.d(\alpha^u) = 0.0275$; $\rho_Z = 0.95$, $s.d(\alpha^Z) = 0.025$; and $\rho_\varrho = 0.71$, $s.d(\alpha^\varrho) = 0.017$. Despite the stylized and deliberately small-scale nature of our model, these shock moments are within range of the estimated values obtained in Christiano, Motto, and Rostagno (2014) and Andrade, Galí, Le Bihan, and Matheron (2019).[13]

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

The appropriate welfare measure is then given by:[14]

$$\mathcal{W}_t = \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \frac{(\mathbb{U}_t - \mathbb{U})}{\mathbb{U}_C C} \simeq -\frac{1}{2} \mathbb{E}_t \sum_{t=0}^{\infty} \beta^t \left[\Theta \hat{\pi}_t^2 + (1+\varphi) \hat{Y}_t^2 \right]. \tag{22}$$

Period losses scaled by the price adjustment cost parameter read:

$$\Theta^{-1} \mathcal{L}_t = \frac{1}{2} \left(\hat{\pi}_t^2 + \vartheta \hat{Y}_t^2 \right), \tag{23}$$

[13] 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.

[14] 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.

where $\vartheta \equiv (1+\varphi)\,\Theta^{-1}$ is the relative weight on output variations. 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 is solved using the linear-quadratic approach.

5.1 Discretion and Commitment Policies without Financial Taxes / Subsidies

Before discussing the implications of fiscal-financial and monetary policy interactions in liquidity traps, we first present the optimal monetary policy solution under discretion and commitment. In this subsection, $\hat{R}_t^D$ acts as the sole stabilization tool available to the policymaker with $\hat{\tau}_t^D = 0$.

Under **discretion**, the policymaker chooses $\widehat{\pi}_t$, $\hat{Y}_t$, and $\hat{R}_t^D$ to maximize its objective function (23) subject to the constraints (18)-(20), taking $\hat{r}_t^n$, $\hat{u}_t$, and $\left\{\widehat{\pi}_{t+i}, \hat{Y}_{t+i}, \hat{R}_{t+i}^D\right\}_{i=1}^{\infty}$ as given. The Lagrangian for this problem takes the form:

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

where $\hat{\zeta}_{1,t}, \hat{\zeta}_{2,t}$, and $\hat{\zeta}_{3,t}$ are the Lagrange multipliers on constraints (19), (20), and (18), respectively. The corresponding optimality conditions with respect to $\widehat{\pi}_t$, $\hat{Y}_t$, and $\hat{R}_t^D$ are:

$$-\widehat{\pi}_t = \hat{\zeta}_{1,t}, \tag{24}$$

$$-\vartheta \hat{Y}_t + \kappa \hat{\zeta}_{1,t} = \hat{\zeta}_{2,t}, \tag{25}$$

$$\lambda \hat{\zeta}_{1,t} - \hat{\zeta}_{2,t} + \hat{\zeta}_{3,t} = 0, \tag{26}$$

and the slackness condition:

$$\hat{\zeta}_{3,t}\left(-\hat{R}_t^D + \ln(\beta)\right) = 0, \tag{27}$$

where $\kappa \equiv (1+\varphi)\,\lambda$.

Consider the case where the nominal interest rate is at its lower bound ($\hat{\zeta}_{3,t} > 0$). The optimal discretionary targeting rule in this scenario is:

$$\vartheta \hat{Y}_t = -(\kappa - \lambda)\,\widehat{\pi}_t - \hat{\zeta}_{3,t}, \tag{28}$$

or:

$$\left(\left(\kappa-\lambda\right)\widehat{\pi}_t+\vartheta\hat{Y}_t\right)\left(\hat{R}_t^D-\ln\left(\beta\right)\right)=0;\quad \hat{R}_t^D\geq\ln\left(\beta\right). \tag{29}$$

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 (19) and (20):

$$\widehat{\pi}_t=\beta\mathbb{E}_t\widehat{\pi}_{t+1}+\lambda\left[\left(1+\varphi\right)\hat{Y}_t+\hat{u}_t\right], \tag{30}$$

$$\hat{Y}_t=\mathbb{E}_t\hat{Y}_{t+1}+\mathbb{E}_t\widehat{\pi}_{t+1}+\hat{r}_t^n. \tag{31}$$

The discretionary rational expectations equilibrium at the ZLB is then determined by equations (28), (30), and (31), taking expectations and the $AR(1)$ shocks as given.

Substituting (30) and (31) in (28) 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 benevolent public authority chooses state-contingent paths for inflation, output, and the nominal interest rate to maximize its objective function (22) subject to constraints (18), (19), and (20). The associated Lagrangian is:

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

The resulting first-order conditions read:

$$-\widehat{\pi}_t-\hat{\zeta}_{1,t}+\hat{\zeta}_{1,t-1}+\beta^{-1}\hat{\zeta}_{2,t-1}=0, \tag{32}$$

$$-\vartheta\hat{Y}_t+\kappa\hat{\zeta}_{1,t}-\hat{\zeta}_{2,t}+\beta^{-1}\hat{\zeta}_{2,t-1}=0, \tag{33}$$

$$\lambda\hat{\zeta}_{1,t}-\hat{\zeta}_{2,t}+\hat{\zeta}_{3,t}=0. \tag{34}$$

The complementary slackness constraint is:

$$\hat{\zeta}_{3,t}\left(-\hat{R}_t^D+\ln(\beta)\right)=0;\quad \hat{\zeta}_{3,t}\geq 0, \tag{35}$$

where the initial conditions satisfy $\hat{\zeta}_{1,-1}=\hat{\zeta}_{2,-1}=\hat{\zeta}_{3,-1}=0$. The optimal state-contingent evolution of the endogenous variables $\left\{\widehat{\pi}_t,\hat{Y}_t,\hat{R}_t^D\right\}$ is characterized by the above first-order conditions together with constraints (19) and (20), as well as (35). Optimal commitment policy becomes history-dependent as reflected by the lagged Lagrange multipliers in (32) and (33). These additional state variables reflect "promises" that must be kept from past commitments. After manipulating the first-order conditions, the optimal monetary commitment targeting rule can be written as:

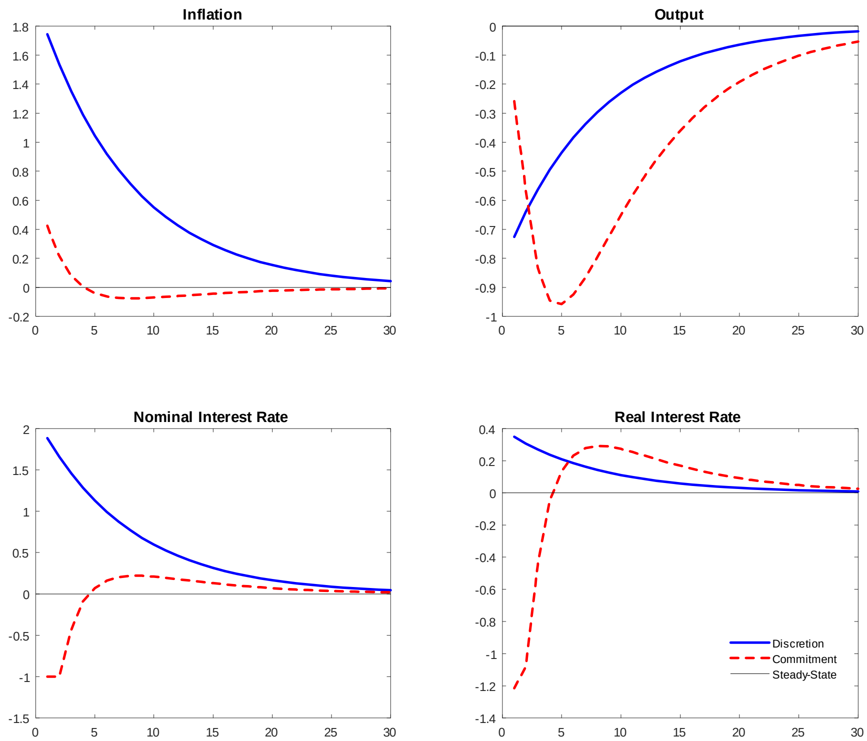
$$\left[(\kappa-\lambda)\,\widehat{\pi}_t+\vartheta\hat{Y}_t-(\kappa-\lambda)\,\hat{\zeta}_{1,t-1}-(\kappa-\lambda+1)\,\beta^{-1}\hat{\zeta}_{2,t-1}\right]\left(\hat{R}_t^D-\ln(\beta)\right)=0;\quad \hat{R}_t^D\geq\ln(\beta)\,. \tag{36}$$

Notice that (36) boils down to the discretionary targeting rule (29) 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 (29), and that multiplies $\widehat{\pi}_t$, $\hat{\zeta}_{1,t-1}$, and $\hat{\zeta}_{2,t-1}$ in (36). We now turn to compare discretion and commitment policies with an occasionally-binding ZLB constraint following recessionary cost-push and natural real rate shocks.

Supply Shocks.- Figure 1 displays the optimal responses of the key variables of the model to a $1\cdot s.d(\alpha^u)$ stagflationary shock.

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 (28) is $(\kappa-\lambda)/\vartheta$. 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 1.9 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 $\hat{u}_t$.

Figure 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.

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. 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 $\widehat{\pi}_t$.

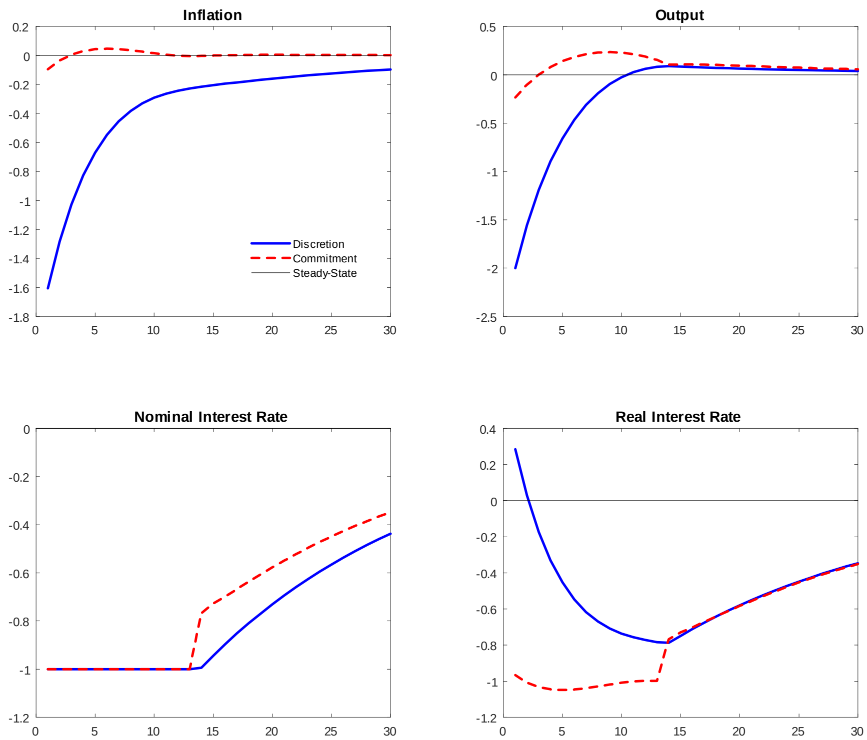
As the shock starts to dissipate, the forward-looking public authority promises to generate mild future deflation, which helps to further alleviate the immediate cost-push repercussions in the first few periods. Throughout the recovery stage under commitment, output is driven below the level implied by the discretionary outcome in order to partly moderate the initial inflationary ZLB episode. Values of the Lagrange multipliers in (36) 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. However, given the mitigated initial drop in output upon the impact of the shock and the muted asymptotic volatility in prices, commitment considerably outperforms discretion and yields an unconditional expected welfare gain of 2.92%.

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.

Demand Shocks.- Figure 2 presents the optimal responses of key variables to a negative natural real interest rate shock of size $3 \cdot s.d(\alpha^Z)$.

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 (28), and serves as a *cost-push* deflationary by-product. More formally, re-arranging (28) yields $\hat{\zeta}_{3,t} = -(\kappa - \lambda)\,\widehat{\pi}_t - \vartheta \hat{Y}_t$, 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, making the liquidity trap more severe. As a result of the larger welfare losses caused by the cost channel and given our calibration, the public authority creates an output overshooting even under discretion, and extends the zero interest rate policy to 14 quarters. One can show that this duration is longer than the time spent at the ZLB in the benchmark New Keynesian model, wherein the liquidity trap lasts for only 9 periods if the same parameterization and shock moments as used in this exercise are applied.

Figure 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.

Under commitment policy, a negative demand shock provokes the policymaker to slash the nominal interest rate and keep it at its lower bound for 13 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 welfare losses 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 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 thirteenth period that accelerates medium-run inflationary pressures via the monetary policy cost channel.

A non-trivial result arising from the analysis above and the baseline calibration with a *sufficiently persistent* demand shock is that the liquidity trap spell is slightly *shorter* under commitment than under discretion (see also Chattopadhyay and Ghosh 2020).[15] 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 economic 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 7.06% 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 1.21%. As a result, welfare gains from commitment at the ZLB in the basic New Keynesian model without the cost channel are significantly underestimated.

5.2 Introducing Deposit Tax-Subsidy Policies

Now 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 Lagrangian for the policymaker's problem takes the form:

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

[15] We find that when demand shocks are less persistent (specifically when $\rho_Z < 0.92$), 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 framework are based on a Bayesian estimation of the occasionally-binding model and we therefore set $\rho_Z = 0.95$ throughout all our demand shock simulations. It is important to note that the qualitative policy implications of optimal tax-subsidy interventions presented below remain unaffected by the persistence of shocks.

The corresponding first-order conditions with respect to $\widehat{\pi}_t$, $\hat{Y}_t$, and $\hat{R}_t^D$ are the same as in (24)-(26), with the additional optimality condition with respect to $\hat{\tau}_t^D$ given by:

$$\hat{\zeta}_{2,t} = \hat{\zeta}_{3,t}. \tag{37}$$

Moreover, the modified slackness condition with taxes / subsidies is:

$$\hat{\zeta}_{3,t}\left(-\hat{R}_t^D + \hat{\tau}_t^D + \ln(\beta)\right) = 0. \tag{38}$$

Using conditions (24)-(26) and (37), the optimal target rule under discretion with $\hat{\zeta}_{3,t} > 0$ becomes:

$$\vartheta \hat{Y}_t = -\hat{\zeta}_{3,t}, \tag{39}$$

or, using the slackness condition (38):

$$\vartheta \hat{Y}_t\left(\hat{R}_t^D - \hat{\tau}_t^D - \ln(\beta)\right) = 0; \quad \hat{R}_t^D - \hat{\tau}_t^D \geq \ln(\beta). \tag{40}$$

The financial tax-subsidy adds the first-order condition $\hat{\zeta}_{2,t} = \hat{\zeta}_{3,t}$, which together with (34), 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 $\hat{\tau}_t^D$.

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:

$$\hat{Y}_t = \frac{1}{(1-p)}\left(\hat{r}_t^n + \ln(\beta)\right), \tag{41}$$

$$\hat{\zeta}_{3,t} = -\frac{\vartheta}{(1-p)}\left(\hat{r}_t^n + \ln(\beta)\right), \tag{42}$$

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 (41) nor (42). Intuitively, without $\hat{\tau}_t^D$, optimal time-consistent policy in the face of a stagflationary shock warrants a rise in $\hat{R}_t^D$. The ZLB constraint is therefore uneventful. 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 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 $\hat{Y}_t$.

With **commitment** and deposit taxes / subsidies, the optimal targeting rule is shown to satisfy:

$$\left(\vartheta \hat{Y}_t - \beta^{-1}\hat{\zeta}_{2,t-1}\right)\left(\hat{R}_t^D - \hat{\tau}_t^D - \ln(\beta)\right) = 0; \quad \hat{R}_t^D - \hat{\tau}_t^D \geq \ln(\beta), \tag{43}$$

with inflation determined by:

$$\widehat{\pi}_t = \hat{\zeta}_{1,t-1} + \beta^{-1}\hat{\zeta}_{2,t-1}. \tag{44}$$

Unlike the discretionary case where $\widehat{\pi}_t = 0$, inflation now is dictated by the inherited Lagrange multipliers from the previous period.[16] To illuminate the differences between discretion and commitment with a deposit tax-subsidy, we turn to simulate the model following supply and demand shocks in line with the analysis conducted in the previous subsection.

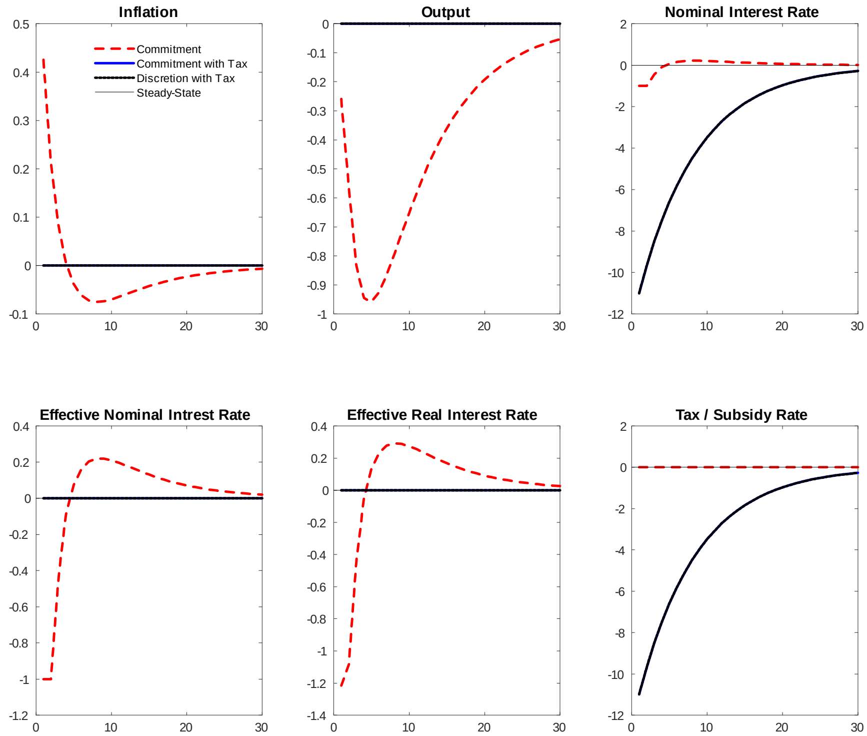
Supply Shocks.- Figure 3 shows the optimal responses of the key variables of the model to a stagflationary shock of size $1 \cdot s.d(\alpha^u)$. We compare the optimal commitment policy with monetary policy only, same as in Figure 1 (labeled "Commitment"), with the commitment regime involving deposit tax / subsidy interventions (labeled "Commitment with Tax"), and with the discretionary case that also includes the financial tax policy (labeled "Discretion with Tax").

Under unconstrained commitment policies, direct fiscal-financial interventions allow for 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 deposit subsidy prevents any demand-pull inflationary pressures.

[16] Note that (43) and (44) boil down to (40) and $\widehat{\pi}_t = 0$, respectively, by setting $\hat{\zeta}_{2,t-1} = \hat{\zeta}_{2,t-1} = 0$.

Figure 3 - 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.

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 (19) we have $\hat{R}_t^D = -\hat{u}_t$. To satisfy the AD curve (20), 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:

$$\hat{R}_t^D = -\hat{u}_t, \tag{45}$$

$$\hat{\tau}_t^D = -\hat{u}_t - \phi_\pi^\tau \mathbb{E}_t \widehat{\pi}_{t+1}, \tag{46}$$

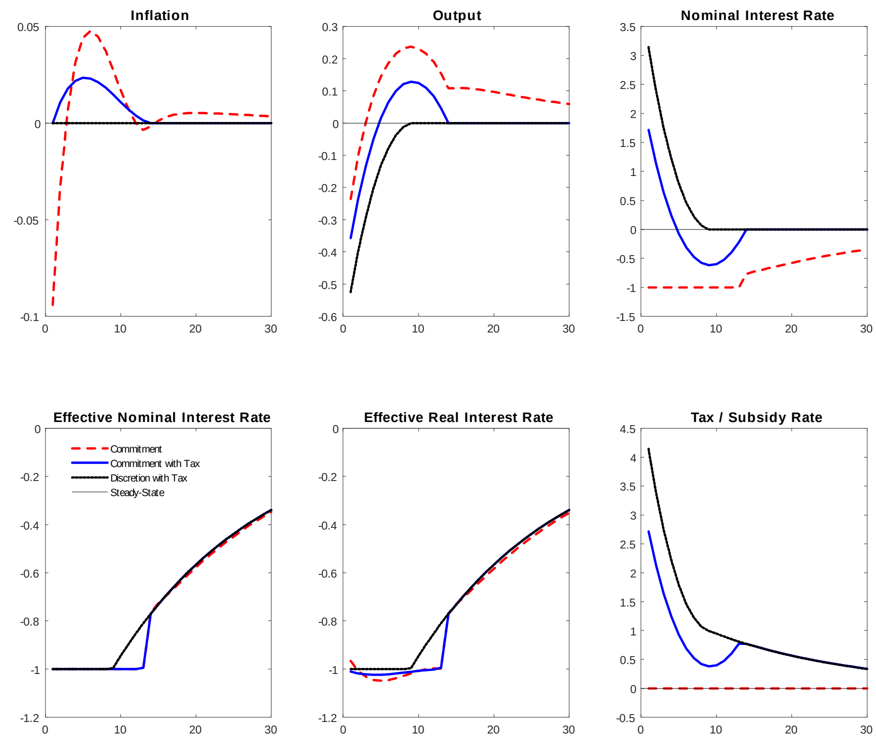
where ϕ_π^τ is a coefficient that measures the strength of the deposit tax-subsidy response to variations in expected inflation. In this case, an optimal tax policy rule with a forward-looking inflation target satisfying $\phi_\pi^\tau > 1$ guarantees equilibrium uniqueness. For $\phi_\pi^\tau > 1$, 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 0.075% relative to the constrained optimal monetary policy commitment case.[17] 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. Such policies 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 so long as fiscal-financial policy measures are implemented correctly and in a state-contingent fashion. Deploying deposit subsidies nullifies the value of time-inconsistent commitment strategies.

Demand Shocks.- Figure 4 presents the optimal responses of key variables to a negative $3 \cdot s.d(\alpha^Z)$ demand shock. 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 constrained commitment regime that involves only monetary policy as a stabilization tool ("Commitment").

[17] Following supply-side shocks, the equivalence between discretion and commitment with $\hat{\tau}_t^D$ remains valid irrespective of the parameter values.

Figure 4 - 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. Either way, 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 (43) and (44) 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 $\hat{\zeta}_{2,t} = \hat{\zeta}_{3,t}$ and $\hat{\zeta}_{1,t} = 0$, promised inflation is positive as shown in (44). Note that compared to the discretionary case with financial taxes, the effective tax-augmented nominal deposit rate is kept at its floor for 3 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 fourth 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.[18] 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.

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 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.

6 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 microfounded 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-

[18] These welfare gains are the same up to the 6^{th} decimal point. Thus, we comfortably argue that time-consistent and Ramsey plans with deposit taxation are coequal from a *quantitative welfare* perspective. This near-identical welfare outcome for discretion and commitment with deposit tax policies holds for various calibration values.

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 under both discretion and commitment.

The monetary policy cost channel highlighted in this paper presents an additional motivation for deploying state-contingent fiscal-financial measures. In a liquidity trap, deposit tax-subsidy policies unleash 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 taxes / subsidies to be highly adaptable 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. Nonetheless, recent economic turmoils have led to much more flexibility in terms of implementing rapid fiscal and financial policies. 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. Given that our quantitative and qualitative policy prescriptions depend crucially upon the source of economic fluctuations and the type of liquidity traps that follow, determining the extent to which business cycles are supply- and/or demand-driven is of paramount importance.

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