LIQUIDITY TRAPS, PRUDENTIAL POLICIES, AND INTERNATIONAL SPILLOVERS*

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Abstract

We analyze the optimal design of monetary and macroprudential policies in an open economy with aggregate demand externalities and an occasionally binding zero lower bound constraint. Without macroprudential policy, monetary policy has to balance two distinctive roles, stabilizing output and reducing capital inflows. However, the optimal policy may well involve a lower or a higher nominal interest rate. With macroprudential policy, the optimal monetary policy focuses entirely on eliminating the output gap. Moreover, we find that the tighter the macroprudential policy stance, the more expansionary monetary policy is. Finally, turning to international spillovers, we demonstrate that, contrary to emerging concerns, a world economy with macroprudential policy welfare dominates a laissez-faire regime.

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1 Introduction

Macroprudential policy has emerged as a new pillar of the macroeconomic toolkit. A key premise is that the use of these policies can help manage capital flows and reduce the vulnerability to deep economic contractions. However, our understanding of how macroprudential policy should be integrated with traditional macro policies remains limited. Moreover, there is a concern that the adoption of these policies may backfire when adopted on a global scale.[1]

In this paper, we provide an integrated analysis of monetary and macroprudential policies in an an open economy with aggregate demand externalities and an occasionally binding zero lower bound constraint. We analyze theoretically and quantitatively the jointly optimal use of these policies and tackle the question of how monetary policy should be conducted when macroprudential policy is (or is not) available. In addition, we evaluate the extent to which adopting prudential policies can trigger adverse international spillovers and generate scope for coordination.

We establish the following results. First, in the absence of macroprudential policy, monetary policy faces an intertemporal tradeoff that balances the current output gap and stabilizing capital flows. Contrary to a widespread policy view, however, we show that a policy of leaning against the wind (raising the interest rate in booms) is not necessarily optimal. When the central bank raises the interest rate, this triggers an intertemporal substitution effect, leading to a decline in consumption and borrowing. At the same time, the reduction in consumption reduces output and leads to a higher need for borrowing to smooth consumption. If the elasticity of substitution across sectors is higher than the elasticity across time, a rise in the interest rate is counterproductive because it increases inefficiently the level of borrowing.

Second, when macroprudential policy is available, we establish that monetary policy is no longer used with a prudential purpose. The central bank uses monetary policy to stabilize output and taxes inflows away from the zero lower bound. While macroprudential policy can help stimulate or cool down the economy, output stability is best achieved using monetary policy. We also show that the macroprudential tax on debt is positive only if the zero lower bound is likely to bind in the following period, whereas monetary policy is used prudentially—in the absence of macroprudential policy—as long as the zero lower bound is foreseen to bind in some distant future. The lesson is that because monetary policy is a blunter instrument, it has to be used even more preemptively than

[1] Fornaro and Romei (2019) formalize this argument. See also Gourinchas (2022).

macroprudential policy. Moreover, we show that the central bank may find it optimal to restrict outflows when there is a deep downturn caused by the liquidity trap.

Third, our quantitative evaluation underscores that optimal macroprudential policy can substantially improve macroeconomic stabilization and alleviate the costs of liquidity traps. In the absence of macroprudential policy, the average unemployment, conditional on a liquidity trap, is about 6%, and the unconditional welfare cost of liquidity traps is 0.5% of permanent consumption. With macroprudential policy, unemployment becomes 1.5%, and the welfare costs fall to 0.1%. In terms of policies, we find that the ex-ante prudential tax on inflows is 0.2% while the ex-post tax on outflows is -0.05% on average. We also find that while liquidity traps are less frequent and less severe with macroprudential policy, perhaps surprisingly, they tend to last longer.

Our final set of results is concerned with international spillovers.[2] We establish that the welfare effects of changes in the stance of monetary policy or macroprudential policy abroad can be assessed entirely through whether an increase or a decrease in the real interest rate is desirable. When foreign policies lead to a reduction in the real interest rate, the domestic economy's welfare falls when it is vulnerable to a liquidity trap in the future. This is because the reduction in the real rate exacerbates the overborrowing problem. We argue that these spillovers can open the door to currency wars, calling for monetary policy cooperation. However, we argue that macroprudential policies can be used to insulate the domestic economy from monetary policy spillovers. Even though coordination is desirable, we show that macroprudential policies achieve welfare gains even in the absence of coordination.

Related literature. Our paper relates to several strands of the literature. First, our paper belongs to the literature on aggregate demand externalities that emerge from nominal rigidities and constraints on monetary policy (Schmitt-Grohé and Uribe, 2016; Farhi and Werning, 2016). Specifically, we share the focus on the zero lower bound with Korinek and Simsek (2016) and Fornaro and Romei (2019). These papers focus on the optimal macroprudential policy, given an exogenous monetary policy, or deal with jointly optimal monetary and macroprudential policy. A contribution of our paper is to analytically and quantitatively characterize how the availability or lack theorof of macroprudential policy

[2]For an overview of the policy discussions on currency wars and capital control wars, see Rey (2013), Rajan (2014), Blanchard (2021), and Kalemli-Ozcan (2019).

affect the optimal monetary policy as well as the international spillovers.[3]

Our paper is also related to the literature on liquidity traps in open economies.[4] Our results on the benign international spillovers from macroprudential policies may be surprising in light of the more negative view that emerges from important studies by Caballero, Farhi and Gourinchas (2021), Eggertsson, Mehrotra, Singh and Summers (2016) and Fornaro and Romei (2019). A key difference with the first two studies is that we consider a model with non-tradables where domestic demand matters for the determination of output. As a result, we show how policies that favor foreign savings actually increase the demand for domestic goods and thus capital flows become stabilizing at the zero lower bound.

Fornaro and Romei (2019) argue that capital account policies may lead to a global paradox of thrift, in which uncoordinated macroprudential policies at the global level lead to worse output and welfare outcomes compared with those of a laissez-faire economy without macroprudential policy. The intuition for their result is that macroprudential policy implemented by countries away from a liquidity trap reduces the world real interest rate and tighten the zero lower bound constraint of those countries in a liquidity trap. We argue, however, that allowing countries in a liquidity trap to restrict the quantity of private capital flows to the same levels as in the laissez-faire economy generates an equilibrium domestic rate equal to the laissez-faire. The implication is that a simple quantity restriction on capital flows can insulate an economy from a lower world real interest rate and render a macroprudential policy regime superior to the laissez faire.

Egorov and Mukhin (2020) and Fanelli (2017) also study optimal monetary policy and capital controls. However, they find no welfare role for the latter. Egorov and Mukhin (2020) consider a setting with dollar currency pricing. They show that although monetary policy is unable to achieve full insularity, capital controls are not desirable, because monetary policy is a better instrument to deal with domestic aggregate demand. Fanelli (2017) studies monetary policy under commitment with a rich portfolio structure

[3] Farhi and Werning (2020) is another recent paper that examines related issues, but in the context of a two-period closed economy model with behavioral features. See also Coulibaly (2020) and Basu, Boz, Gopinath, Roch and Unsal (2020) for models of optimal policies featuring pecuniary externalities. Several other studies consider monetary and macroprudential interactions but do not characterize optimal policies (e.g., Aoki, Benigno and Kiyotaki, 2016; Van der Ghote, 2021; Rubio and Yao, 2020; Ferrero, Harrison and Nelson, 2022).

[4] Examples include Cook and Devereux (2013); Devereux and Yetman (2014); Acharya and Bengui (2018); Jeanne (2009); Benigno and Romei (2014); Fornaro (2018); Corsetti, Mueller and Kuester (2019b); Corsetti, Mavroeidi, Thwaites and Wolf (2019a); Kollmann (2021) and Amador, Bianchi, Bocola and Perri (2020). Notable closed economy studies include Krugman (1998), Eggertsson and Woodford (2003), and Werning (2011).

and show that capital controls are zero to a second order. Relative to these studies, the key difference that justifies the scope for capital controls is that in our setup, the central bank cannot fully control domestic aggregate demand, owing to the zero lower bound.

Outline. Section 2 presents the model. Section 3 studies optimal monetary and macro-prudential policy. Section 5 analyzes international spillovers. Section 6 concludes.

2 Model

We consider a small open economy with nominal rigidities and an occasionally binding zero lower bound constraint. There is an infinite horizon and two types of goods: tradables and non-tradables. In this section, we describe the decisions of households and firms and the general equilibrium.

2.1 Households

There is a continuum of identical households of measure one. Households' preferences

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\prod_{k=0}^{t} \delta_k \right) \Big[U(c_t) - v(h_t) \Big], \tag{1}$$

where $\mathbb{E}_t$ denotes the time t expectation operator, $\beta\delta_t$ is the discount factor at time t and δ_t represents a discount factor shock. The utility function over consumption $u(\cdot)$ is strictly increasing and concave, and $v(\cdot)$ denotes an increasing and convex disutility function of labor. We assume that these functions are isoelastic of the form

$$U(c_t) = \frac{c_t^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}}, \quad v(h_t) = \frac{h_t^{1+\phi}}{1+\phi},$$

where σ is the elasticity of intertemporal substiution and ϕ is the inverse of the Frisch elasticity. The consumption good c_t is a composite of tradable consumption c_t^T and non-tradable consumption c_t^N, according to a constant elasticity of substitution aggregator:

$$c_t = \left[\omega (c_t^T)^{1-\frac{1}{\gamma}} + (1-\omega)(c_t^N)^{1-\frac{1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}}, \quad \text{where } \omega \in (0,1).$$

The elasticity of substitution between tradables and non-tradables is γ. For convenience, we use $u(c^T, c^N)$ to denote the utility as a function of the two consumption goods.

In each period t, households supply h_t units of labor and are endowed with y_t^T units of tradable goods. We assume that y_t^T is stochastic and follows a first-order Markov process. Households receive a wage rate, W_t, collect profits, ϕ_t^N, all expressed in terms of domestic currency, which serves as the numeraire, and receive government transfers T_t. Households trade two types of one-period non-state-contingent bonds in credit markets: a real bond b_{t+1}^*, which pays a gross return R_t^* units of tradables, and a nominal bond b_{t+1}, which pays R_t in units of domestic currency. The domestic government controls the nominal rate R_t. Both bonds are potentially subject to a tax/subsidy τ_t. When $\tau_t > 0$, households face a tax on debt issuance and a subsidy on savings. Conversely, when $\tau_t < 0$, households face a subsidy on debt issuance and taxes on savings.

The budget constraint of the representative household is therefore given by

$$P_t^N c_t^N + P_t^T c_t^T + \frac{1}{1+\tau_t}\left[\frac{b_{t+1}}{R_t} + P_t^T \frac{b_{t+1}^*}{R_t^*}\right] = \phi_t^N + W_t h_t + P_t^T(y_t^T + T_t) + b_t + P_t^T b_t^\star, \quad (2)$$

where P_t^N and P_t^T denote respectively the price of non-tradables and tradables (in terms of the domestic currency). The left-hand side represents total expenditures in tradable and non-tradable goods and purchases of bonds while the right-hand side represents total income, including the returns from bond holdings.

Optimality conditions. The households' problem consists of choosing sequences of $\{c_t^N, c_t^T, h_t, b_{t+1}, b_{t+1}^*\}$ to maximize the expected present discounted value of utility (1), subject to (2) and taking as given the sequence of tradable endowments $\{y_t^T\}$, profits $\{\phi_t^N\}$, transfers $\{T_t\}$, and prices $\{W_t, P_t^N, P_t^T, R_t, R_t^*\}$.

The first-order conditions for consumption and labor yield

$$\frac{W_t}{P_t^N} = \frac{v'(h_t)}{u_N(c_t^T, c_t^N)} \quad (3)$$

$$\frac{P_t^N}{P_t^T} = \frac{1-\omega}{\omega}\left(\frac{c_t^T}{c_t^N}\right)^{\frac{1}{\gamma}} \quad (4)$$

where u_N denotes the marginal utility of non-tradable consumption in period t. Condition (3) is the labor supply optimality condition equating the marginal rate of substitution between leisure and non-tradable consumption with the wage rate in terms of non-tradables. Condition (4) equates the marginal rate of substitution between tradables and non-tradables to the relative price.

The first-order conditions for the nominal and real bond holdings yield

$$u_T(c_t^T, c_t^N) = \beta R_t^*(1+\tau_t)\mathbb{E}_t\left[\delta_{t+1} u_T(c_{t+1}^T, c_{t+1}^N)\right] \tag{5}$$

$$\frac{u_T(c_t^T, c_t^N)}{P_t^T} = \beta R_t(1+\tau_t)\mathbb{E}_t\left[\delta_{t+1}\frac{u_T(c_{t+1}^T, c_{t+1}^N)}{P_{t+1}^T}\right]. \tag{6}$$

where u_T denoting the marginal utility of tradable consumption. Households equate the marginal benefit from saving in nominal or real bonds to the marginal costs of cutting tradable consumption today to buy the bonds.

2.2 Firms

The non-tradable good is produced by a continuum of firms in a perfectly competitive market. Each firm produces a non-tradable good according to a production technology given by $y_t^N = n_t^\alpha$ and perceive profits given by

$$\phi_t^N = P_t^N n_t^\alpha - W_t n_t. \tag{7}$$

We assume that prices are perfectly rigid, $P_t^N = \bar{P}^N$, and that firms produce goods to satisfy demand. That is, labor demand in equilibrium is given by $n = (c^N)^{1/\alpha}$. We note that results can be extended to allow for partially sticky prices or optimal price setting under monopolistic competition.[5]

2.3 Government

The government sets a nominal interest rate $R_t \geq 1$ and a tax on all forms of bond issuances τ_t. As is common in the literature, this tax can be interpreted as a capital control or as a macroprudential policy (see e.g., Bianchi, 2011; Schmitt-Grohé and Uribe, 2016; and Fornaro and Romei, 2019). The tax is assumed to be rebated lump-sum to households, an assumption that is without loss of generality given that Ricardian equivalence holds.[6] That

[5] We have conducted simulations with one-period-in-advance price setting with similar results.

[6] We abstract from other the so-called unconventional fiscal policies that can relax the zero lower bound (see e.g. Correia, Farhi, Nicolini and Teles, 2013). We also abstract from differential taxes on domestic and foreign currency bonds. As examined in Acharya and Bengui (2018), differential taxes on bonds across currencies can also help relax the zero lower bound. As long as there are some limitations on the use of these policies (either political or economic), the first best cannot be implemented and our key results would remain.

is, the government budget constraint is

$$T_t = -\frac{\tau_t}{1+\tau_t}\left[\frac{b_{t+1}}{P_t^T R_t} + \frac{b_{t+1}^*}{R_t^*}\right]. \tag{8}$$

2.4 Prices, Interest Parity, and Exchange Rates

We assume that the law of one price holds for the tradable good, that is, $P_t^T = e_t P_t^{T*}$, where e is the nominal exchange rate defined as the price of the foreign currency in terms of the domestic currency, and P^{T*} is the price of the tradable good denominated in foreign currency.

Using the Euler equations for international bond (5) and domestic bond (6), we can equate the marginal benefits from buying the real and nominal bond. Together with the law of one price, this implies that the nominal exchange rate must satisfy the risk-adjusted uncovered interest parity condition:

$$R_t^* = R_t \, \mathbb{E}_t\left[\Lambda_{t+1}\frac{e_t}{e_{t+1}}\frac{P_t^{T,*}}{P_{t+1}^{T,*}}\right], \tag{9}$$

where $\Lambda_{t+1} \equiv \delta_{t+1} u_T(c_{t+1}^T, c_{t+1}^N)/\mathbb{E}_t\left[\delta_{t+1} u_T(c_{t+1}^T, c_{t+1}^N)\right]$ represents a stochastic discount factor. Condition (9) is a standard condition that relates the the foreign real interest rate and the domestic nominal interest rate to the expected depreciation of the domestic currency.

2.5 Competitive Equilibrium

Market clearing for labor requires that the units of labor supplied by households equal the aggregate labor demand by firms:

$$h_t = n_t. \tag{10}$$

Market clearing for the non-tradable good requires that output be equal to non-tradable consumption:

$$y_t^N = c_t^N. \tag{11}$$

We assume that the bond denominated in domestic currency is traded only domestically. We make this assumption to abstract from portfolio problems and from the possibility of inflating away external debt.[7] Market clearing therefore implies

$$b_{t+1} = 0. \tag{12}$$

Combining the budget constraints of households, firms, and the government, as well as market clearing conditions, we arrive at the resource constraint for tradables, or the balance of payment condition:

$$c_t^T - y_t^T = b_t^* - \frac{b_{t+1}^*}{R_t^*}, \tag{13}$$

which says that the trade balance must be financed with net bond issuances.

An equilibrium, given government policies, is defined as follows.

Definition 1. Given an initial condition b_0^*, exogenous process $\{R_t^*, y_t^T, \delta_t\}_{t=0}^{\infty}$, a rigid price $\bar{P}^N$, and government policies $\{R_t, \tau_t\}_{t=0}^{\infty}$, an equilibrium is a stochastic sequence of prices $\{e_t, P_t^{T*}, W_t\}$ and allocations $\{c_t^T, c_t^N, b_{t+1}^*, n_t, h_t\}_{t=0}^{\infty}$ such that

(i) households optimize, and hence the following conditions hold: (3), (4), (5), (6);

(ii) firms choose hours to meet demand, $h_t^\alpha = c_t^N$;

(iii) labor market clears (10) and the domestic currency bond is in zero net supply (12);

(iv) the government budget constraint (8) is satisfied;

(v) the law of one price holds: $P_t^T = e_t P_t^{T*}$.

Notice that the ideal price index (i.e., the minimum expenditure, denominated in units of tradables, required to buy one unit of the composite good c_t) is given by:

$$\mathcal{P}_t \equiv \left[\omega^\gamma + (1-\omega)^\gamma \left(\frac{\bar{P}^N}{e_t P_t^{T*}}\right)^{1-\gamma}\right]^{\frac{1}{1-\gamma}}. \tag{14}$$

In addition, for future reference, the share of expenditures in tradables is denoted by

$$\tilde{\omega}_t \equiv P_t^T c_t^T / (P_t^T c_t^T + \bar{P}^N c_t^N). \tag{15}$$

[7] See Fanelli (2017) for an interesting study of optimal monetary policy with nominal external debt and incomplete markets. In his model, the government can commit to future policies and uses monetary policy to improve risk-sharing in addition to the standard objectives.

2.6 First-Best Allocation

We conclude the description of the model by presenting the first-best allocation. We consider a benevolent social planner of the small open economy who chooses allocations subject to resource constraint. The planner's problem can be written as

$$\max_{\{b^*_{t+1}, c^N_t, c^T_t\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \left(\prod_{k=0}^{t} \beta \delta_k \right) \left[u\left(c^T_t, c^N_t\right) - v\left((c^N_t)^{1/\alpha} \right) \right], \tag{16}$$

subject to

$$c^T_t = y^T_t + b^*_t - \frac{b^*_{t+1}}{R^*_t}.$$

The first-best allocation equates the value of one additional employed unit of labor to the marginal cost of leisure

$$\alpha h_t^{\alpha-1} u_N(c^T_t, c^N_t) = v'(h_t) \tag{17}$$

It also equates the marginal utility of current consumption to the marginal utility of saving one extra unit and consuming in the next period:

$$u_T(c^T_t, c^N_t) = \beta R^*_t \mathbb{E}_t \left[\delta_{t+1} u_T(c^T_{t+1}, c^N_{t+1}) \right]. \tag{18}$$

It should be clear that the allocations in a competitive equilibrium with flexible prices would coincide with the first best. This can be seen by noting that if firms could adjust prices, we would have $\alpha h_t^{\alpha-1} = W_t / P^N_t$, which, combined with households' labor supply decision (3), would yield (17). [8] Moreover, as we will see, with sticky prices, a government that can choose monetary policy without any constraints would choose to replicate the flexible price allocation and hence implement the first-best allocations. We note that often open-economy New Keynesian models often feature monopolistic competition and terms of trade externalities which create an additional wedge between competitive equilibrium with nominal rigidities and flexible price equilibria. Our framework allows us to focus squarely on aggregate demand management considerations.

3 Optimal Monetary and Macroprudential Policies

In this section, we study optimal monetary and macroprudential policies. To shed light on the policy interactions, we first study optimal macroprudential policy given monetary

[8] In addition, notice that (18) coincides with households' optimality (5) when $\tau_t = 0$.

policy, we then study joint optimal monetary and macroprudential policy, and finally, we study optimal monetary policy given a macroprudential policy.

3.1 Macroprudential Policy

We consider a generic monetary policy that depends on the history of all shocks. We use $\{e_t\}$ to denote the nominal exchange rate policy sequence chosen by the government. An advantage of this formulation is that we are able to provide a general characterization of macroprudential policy encompassing multiple monetary policy regimes. This will set the stage to analyze the interactions between optimal monetary and macroprudential policies.

Under an arbitrary monetary policy, the production of non-tradable goods is, in general, inefficient. For example, given the sticky price $\bar{P}^N$, a low exchange rate implies a high relative price for non-tradables, in turn generating lower household demand for non-tradable goods and leading firms to reduce production. The departure of the equilibrium allocations from the first best can be conveniently summarized in the labor wedge, defined below:

$$\psi_t \equiv 1 - \frac{1}{\alpha h_t^{\alpha-1}} \frac{v'(h_t)}{u_N(c_t^T, c_t^N)}. \tag{19}$$

At a first-best allocation $\psi_t = 0$. A positive labor wedge, $\psi_t > 0$, reflects a marginal value of employment that exceeds the marginal cost from providing labor. In this sense, the economy experiences a recession. Conversely, a negative labor wedge, $\psi_t < 0$, reflects a marginal value of employment that is too low relative to the marginal cost from providing labor. In this case, the economy experiences overheating.

Given a sequence of $\{e_t\}$, the government chooses the state-contingent tax on debt $\{\tau_t\}$ that maximizes private agents' welfare among the set of competitive equilibria. The problem can be written as

$$\max_{\{b^*_{t+1}, c_t^N, c_t^T\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \left(\prod_{k=0}^{t} \beta \delta_k \right) \left[u\left(c_t^T, c_t^N\right) - v\left((c_t^N)^{1/\alpha} \right) \right], \tag{20}$$

subject to

$$c_t^T = y_t^T + b_t^* - \frac{b^*_{t+1}}{R_t^*},$$

$$c_t^N = \left[\frac{1-\omega}{\omega} \frac{P_t^{T*}}{\bar{P}^N} e_t \right]^{\gamma} c_t^T.$$

The last constraint in problem (20) relates non-tradable consumption to tradable consumption and the relative price of non-tradables. More tradable resources increase aggregate demand for both goods. Given a fixed price for non-tradables, higher resources translate into more demand for non-tradable goods, to which firms respond by raising employment. This general equilibrium feedback is key for the characterization of the optimal macroprudential tax presented below.

Proposition 1 (Optimal macroprudential policy given $\{e_t\}$)**.** *Consider an exogenous exchange rate policy $\{e_t\}$. The optimal tax on borrowing (20) satisfies*

$$\tau_t = \frac{1}{\beta R_t^* \mathbb{E}_t \delta_{t+1} u_T(t+1)} \left\{ -\frac{1-\tilde{\omega}_t}{\tilde{\omega}_t} u_T(t)\psi_t + \beta R_t^* \mathbb{E}_t \delta_{t+1} \left[\frac{1-\tilde{\omega}_{t+1}}{\tilde{\omega}_{t+1}} u_T(t+1)\psi_{t+1} \right] \right\}, \quad (21)$$

where ψ is the labor wedge, defined in (19), and $\tilde{\omega}$ is the share of tradable expenditures defined in (15).

Proof. In Appendix A.1. □

Equation (21) provides an analytical characterization of the optimal tax that emerges to correct the aggregate demand externality at work in the model. When households take savings decisions, they do not internalize that redirecting consumption over time affects firms' demand for non-tradable goods and can move production closer or further away from the first best.

These results are related to the aggregate demand externality emphasized in Schmitt-Grohé and Uribe, 2016; Farhi and Werning, 2012) in an economy with a fixed exchange rate. Our analytical characterization uncovers that the sign of τ_t is in principle ambiguous and depends, in particular, on the relative importance of the aggregate demand externality in periods t and $t+1$. When the current labor wedge is zero, the tax on debt takes the sign of the expected risk-adjusted labor wedge. The intuition for the analytical expression is that the government internalizes that an increase in one of savings today is associated with an increase in aggregate demand tomorrow, which stimulates employment and reduces the labor wedge. When the labor wedge today and tomorrow are both positive, the government trades-off the marginal benefits from stimulating future demand and easing the recession tomorrow with the marginal costs from reducing current demand and deepening the recession today. On the other hand, if the labor wedge is negative, taxing borrowing and postponing consumption helps to reduce overheating.

We turn next to analyze the interaction between monetary policy and macroprudential policy, which is our main focus.

3.2 Joint Monetary and Macroprudential Policies

We now consider a government that conducts jointly macroprudential and monetary policy. The government chooses τ and R to maximize households' welfare. Importantly, the government is subject to a zero lower bound that restricts its ability to achieve the first-best allocations.

In contrast to the previous section, here the optimal policy for the government is subject to a time inconsistency problem, common in environments with a zero lower bound (e.g., Eggertsson and Woodford, 2003). We examine the optimal policy without commitment, which we see as the one that is practically most relevant. In particular, we study Markov perfect equilibrium in which the policies of the government at each point in time depend on the relevant payoff states. We use $s_t \equiv \{R_t^*, P_t^{T^*}, y_t^T, \delta_t\}$ to denote the date-t realizations of exogenous shocks, $\mathcal{E}(b^{*\prime}, s'), \mathcal{C}^{\mathcal{T}}(b^{*\prime}, s'), \mathcal{C}^{\mathcal{N}}(b^{*\prime}, s')$ to denote the stationary policy functions for the exchange rate and tradable and non-tradable consumption followed by future governments, and $V(b^*, s)$ to denote the value function for the government.

To set up the optimal time-consistent problem of the government optimal, we use that by setting τ, the government can control borrowing decisions, and therefore (5) is not a binding implementability constraint. We can write the problem follows:

$$V\left(b^*, s\right) = \max_{R,e,b',c^N,c^T} u\left(c^T, c^N\right) - v\left(\left(c^N\right)^{1/\alpha}\right) + \beta \mathbb{E}_{s'|s} \delta' V\left(b^{*\prime}, s'\right), \tag{22}$$

subject to

$$c^T = y^T + b^* - \frac{b^{*\prime}}{R^*}$$

$$c^N = \left[\frac{1-\omega}{\omega} \frac{P^{T*}}{\bar{P}^N} e\right]^{\gamma} c^T$$

$$R^* = R\, \mathbb{E}_{s'|s}\left[\Lambda\left(\mathcal{C}^T(b^{*\prime}, s'), \mathcal{C}^N(b^{*\prime}, s')\right) \frac{P^{T*}}{P^{T*\prime}} \frac{e}{\mathcal{E}(b^{*\prime}, s')}\right]$$

$$R \geq 1.$$

The key difference compared with problem (20), is that now the exchange rate and the nominal interest rate are choices for the government.

In a Markov perfect equilibrium as defined below, the conjectured policies for future governments have to be consistent with the actual policies chosen.

Definition 2. A Markov perfect equilibrium is defined by policies $\mathcal{R}(b^*, s), \tau(b^*, s), \mathcal{E}(b^*, s)$, $\mathcal{B}^*(b^*, s), \mathcal{C}^T(b^*, s), \mathcal{C}^N(b^*, s)$ and a value function $V(b^*, s)$ that solve the government problem (22) given future policies for $\mathcal{E}(b^*, s), \mathcal{C}^T(b^*, s), \mathcal{C}^N(b^*, s)$.

The following proposition characterizes the optimal policy of the government.

Proposition 2 (Optimal monetary and macroprudential policy)**.** *Consider the optimal monetary and capital controls policy. We have that the labor wedge satisfies $\psi_t \geq 0$ for all t and $\psi_t = 0$ if the ZLB does not bind at date t. Moreover, e_t is given by*

$$e_t = \frac{\omega}{1-\omega}\frac{\bar{P}^N}{P_t^{T*}}\left[\alpha^{\frac{\sigma}{\gamma}}(1-\omega)\left(\frac{e_t P_t^{T*}}{\bar{P}^N}\mathcal{P}(e_t)\right)^{\frac{\gamma-\sigma}{\gamma}}\right]^{\frac{\alpha}{(1-\alpha+\phi)\sigma+\alpha}}(c_t^T)^{-\frac{1}{\gamma}}. \tag{23}$$

In addition, the optimal tax on debt is given by

$$\tau_t = \frac{1}{\beta R^* \mathbb{E}_t \delta_{t+1}\left[u_T\left(c_{t+1}^T, c_{t+1}^N\right)\right]}\left\{-(1+\Theta)\frac{\xi_t}{\gamma c_t^T} + \beta R^* \mathbb{E}_t \delta_{t+1}\left[\frac{\xi_{t+1}}{\gamma c_{t+1}^T}\right]\right\}, \tag{24}$$

where $\Theta \equiv \gamma c_t^T \frac{\partial}{\partial b_{t+1}^*}\mathbb{E}_t\left[\Lambda_{t+1}\frac{P_t^T}{P_{t+1}^T}\right]$ and ξ is the non-negative Lagrange multiplier on the ZLB constraint.

Proof. In Appendix A.2. □

Proposition 2 uncovers several lessons. First, the government implements an allocation with a zero labor wedge whenever the zero lower bound is not binding. To see this, notice that if the ZLB constraint is slack, we can drop all constraints but the resource constraint. Thus, we obtain a static condition that delivers a zero labor wedge and back out R and e that implement those allocations. In particular, we obtain that the nominal interest rate is such that

$$R_t = \frac{R_t^*}{e_t}\left\{\mathbb{E}_t\left[\frac{\Lambda_{t+1}}{\mathcal{E}_{t+1}}\frac{P_t^{T*}}{P_{t+1}^{T*}}\right]\right\}^{-1}. \tag{25}$$

A second lesson is that the economy never experiences overheating (i.e., a negative labor wedge). Intuitively, the zero lower bound imposes a constraint on the ability to depreciate the exchange rate, but the government can always appreciate the exchange rate and reduce demand of non-tradables by raising the nominal interest rate. On the other hand, if the zero lower bound binds, the government is unable to depreciate the exchange rate by lowering the nominal interest rate and faces a positive labor wedge.

Regarding macroprudential policy, equation (24) shows that the tax on debt crucially depends on the current and future Lagrange multipliers on the zero lower bound constraints, denoted by ξ. Because $\xi \geq 0$, it follows that in a state in which the zero lower bound is not currently binding, the tax on debt is always positive. On the other hand,if the zero lower bound is currently binding but is not expected to bind next period with positive probability, the tax is negative.

To shed further light on these results, we can use the first-order conditions for c_t^N and e_t in (22) and obtain the following relationship between the labor wedge and the Lagrange multiplier on the zero lower bound:

$$\frac{\xi_t}{\gamma c_t^T} = \frac{1-\tilde{\omega}_t}{\tilde{\omega}_t} u_T(c_t^T, c_t^N)\psi_t. \tag{26}$$

Notice that if we replace (26) into (24), we arrive at an equation analogous to (21), the optimal tax under an arbitrary exchange rate policy. That is, it is possible to write the tax as a function of how savings affect the next-period labor wedge or as a function of how savings affect the tightness of the zero lower bound. The two expressions are linked by the government optimization and are, in fact, equivalent. Notice, however, that one difference between the two tax expressions (21) and (24) is that the latter carries an additional term, Θ, related to the restriction that the policy is consistent with an optimal time-consistent equilibrium. The additional term captures that an increase in savings alters both next-period consumption and the exchange rate followed by the next government.

In Figure 1, we illustrate numerically the tax on debt.[9] The figure shows that the tax on debt is non-monotonic on the current level of bond holdings. (In a different axis, the figure also shows the current labor wedge.) There are three distinct regions. For low bond holdings, the economy is in a liquidity trap region in which $R = 1$ and $\psi > 0$. In this region, the tax is increasing in bond holdings. It is initially negative, as the current labor wedge exceeds the expected future ones, and eventually becomes positive once bonds increase sufficiently, at which point the planner finds optimal to tax rather than subsidize inflows. For intermediate levels of bond holdings, the economy is in a fragile region in which $R > 1$ but the ZLB may become binding in the next period. In this region, the tax is positive and increasing in bond holdings. Intuitively, in this region, the planner wants to shift resources to the future when the economy may face a recession and a binding zero lower bound. Moreover, as current bond holdings increase, this leads to higher bond holdings tomorrow and thus a lower tax on debt. For sufficiently high bond holdings, the economy is in a safe region in which the tax becomes zero because there is a zero probability of a binding ZLB in the next period.

[9] The figure considers values of the shocks equal to the mean values. The calibration will be described below. The overall pattern, however, is general and does not hinge on specific parameters.

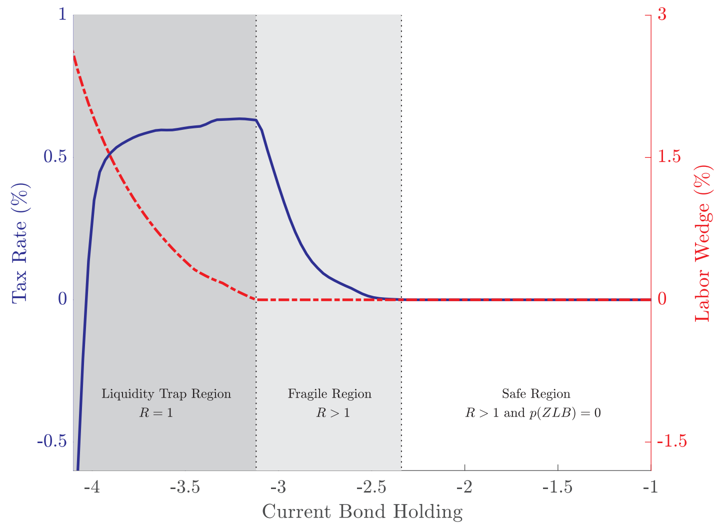

Figure 1: Optimal Macroprudential Policy

3.3 Optimal Monetary Policy without Capital Controls

In the previous section, we analyzed the joint use of monetary and macroprudential policy. We saw the optimal policy implies a zero labor wedge whenever the zero lower bound is not binding. We now study optimal monetary policy when the government *does not* have access to macroprudential policy. The key question that emerges is whether the government should use monetary policy prudentially as a substitute for macroprudential policy and, if so, what this implies for the choice of the interest rate. In particular, does a prudential monetary policy call for higher or lower interest rates?

We consider again the optimal problem under lack of commitment. Relative to problem (22), the government now faces (5) as a binding implementability constraint. This distinction will generate notable differences in the optimal policy, as characterized in the proposition below:

Proposition 3 (Optimal monetary policy without capital controls)**.** *When the government does not have access to capital controls, the optimal monetary policy satisfies*

$$u_T(t)\psi_t = \frac{\tilde{\omega}_t(\sigma-\gamma)}{(1-\tilde{\omega}_t)\sigma+\tilde{\omega}_t\gamma}\mathbb{E}_t\sum_{k=1}^{\infty}\left(\prod_{j=0}^{k-1}\delta_{t+j+1}\frac{\beta R^*_{t+j}}{1+\bar{\Theta}_{t+j}}\right)\frac{\xi_{t+k}}{\gamma c^T_{t+k}}, \tag{27}$$

where $\bar{\Theta}_t \equiv \beta R^*_t \frac{1}{u_{TT}(t)}\mathbb{E}_t\delta_{t+1}\frac{\partial u_T(\mathcal{C}^T(b^*_{t+1},s_{t+1}),\mathcal{C}^N(b^*_{t+1},s_{t+1}))}{\partial b^*_{t+1}}$.

Proof. In Appendix A.3. □

Whether monetary policy is used prudentially and whether it leans *with* or *against* the wind turns out to depend on the elasticities of substitution. In the absence of capital controls, monetary policy can potentially be used as a prudential tool to stimulate precautionary savings and reduce the likelihood of future liquidity traps. However, when $\sigma = \gamma$, saving does not respond to a change in the nominal interest rate. In that case, monetary policy focuses solely on stabilizing output and is not used prudentially. When $\sigma > \gamma$, the government optimally raises the nominal interest rate to stimulate savings and reduce the likelihood of future liquidity traps at the expense of a recession today. The optimal monetary policy leans against wind. Conversely, when $\sigma < \gamma$, the government optimally cuts down the nominal interest rate to reduce the likelihood of future liquidity traps at the expense of an overheating economy. The optimal monetary policy leans with wind.

The idea is that whether an increase in the interest rate mitigates excessive borrowing ahead of a liquidity trap episode, in the absence of capital controls, depends on two opposing forces which have been extensively studied by Bianchi and Coulibaly (2022). First, there is an intertemporal substitution effect by which given prices and income, households save more externally, tilting consumption towards the future with magnitude σ. Second, there is an income general equilibrium effect by which the resulting contraction in current aggregate demand reduces output and leads to higher external borrowing with magnitude γ. When the elasticity substitution over time σ exceeds the elasticity of substitution across goods γ, raising the interest rate can indeed help reduce borrowing and indirectly mitigate the aggregate demand externality. Otherwise, it aggravates excessive borrowing.

Notice also that the optimal monetary policy—except in the knife-edge case of equal intra and inter-temporal elasticities—is used prudentially as long as the zero lower bound binds in some distant future state. This contrasts with the optimal macroprudential policy, in which a tax is imposed only if the zero lower bound binds in the next period. To put it differently, monetary policy needs to act even more preemptively than macroprudential policy. The reason for this result is that monetary policy is a blunter instrument than macroprudential policy. A binding zero lower bound in some future state k implies that the government needs to reduce overborrowing at $k - 1$. With macroprudential policy, the government introduces a tax on borrowing at $k - 1$ while preserving a zero labor wedge. On the other hand, without macroprudential policy, the government must introduce a labor wedge at $k - 1$. Doing so implies that from the perspective of $k - 2$, the government also needs to deviate from a zero labor wedge. Proceeding backwards, it implies a strong history dependent result: as long as there is a binding ZLB in some future state, the government will deviate from full-employment at any period before.

Finally, it is also interesting to examine how changes in arbitrary macroprudential policies alter the optimal monetary policy. With this goal in mind, we allow for any arbitrary tax in problem (A.20) and solve for the optimal exchange rate policy, given future policies and values. We find that for any $\tau_t \in [0, \tau_t^*]$ where τ_t^* is the optimal capital controls (24), an increase in τ_t leads to an increase in the labor wedge ψ_t under optimal monetary policy. It thus follows that that for $\gamma \leq \sigma$, increases in the macroprudential tax on debt will call for an exchange rate depreciation. Intuitively, a macroprudential tax on debt contracts aggregate demand, and so it is optimal for monetary policy to offset those effects.

4 Quantitative Results

We evaluate in this section the quantitative implications of the prudential use of monetary policy absent capital controls and the benefits from using capital controls optimally. We start by describing the calibration of the model.

4.1 Calibration

The time period is one-quarter, and data are calibrated using United Kingdom data between 1980 and 2019.[10] The labor supply elasticity is set to one-third, as in Gali and Monacelli (2005) and α is set one.

The stochastic processes for $\{y_t^T\}$, $\{R_t^*\}$ and $\{\delta_t\}$ are assumed to be independent and specified as follows. The tradable output y_t^T is measured with the cyclical component of value added in agriculture, mining, fishing and manufacturing from the World Development Indicators. The world interest rate R_t^* is measured by the United States real interest rate, which corresponds to the U.S. federal funds rate deflated with the expected US. CPI inflation. Each process is assumed to be a first-order univariate autoregressive process. The estimated processes are, $\ln y_t^T = 0.6771 \ln y_{t-1}^T + \varepsilon_t^y$ with $\varepsilon_t^y \sim N(0, 0.0377^2)$ and $\ln(R_t^*/R^*) = 0.9173 \ln(R_{t-1}^*/R^*) + \varepsilon_t^{R*}$ with $R^* = 1.0036$ and $\varepsilon_t^{R*} \sim N(0, 0.0026^2)$.

As a baseline value for the inter-temporal elasticity of substitution, we use $\sigma = 1$ which implies a coefficient of relative risk-aversion of one. For the baseline calibration, we use

[10] We focus on the United Kingdom because an as an example of an advanced small open economy. We note that the problem of the zero lower bound has indeed been more pervasive for advanced economies although a side effect of the recent increase in central bank credibility in emerging markets appears to be the increase in vulnerability to liquidity traps, as can be seen from the recent experiences of countries such as Chile and Peru (see Matthew Bristow "Paul Krugman Says the Liquidity Trap Has Spread to Emerging Markets" Bloomberg May 12, 2020).

Table 1: Calibration

Description	Parameter Value	Source/Target
Intertemporal elasticity	$\sigma = 1$	Standard value
Technology	$\alpha = 1$	Standard value
Frisch elasticity parameter	$\phi = 3$	Gali and Monacelli (2005)
Weight on tradables in CES	$\omega = 0.25$	Share of tradable output = 24%
Discount factor (long-run)	$\beta = 0.995$	Average NFA-GDP ratio = -17.4%
Transition prob. δ^L to δ^H	$P(\delta^L \vert \delta^H) = 0.20$	4 liquidity traps every century
Transition prob. δ^H to δ^H	$P(\delta^L \vert \delta^L) = 0.39$	2 years duration of liquidity traps

$\gamma = 1$, but consider alternative values of γ in our analysis. To set the long run value of the discount factor β, we target the historical average net foreign asset position (NFA) as a share of GDP of -17.4%. This calibration results in a value of $\beta = 0.995$. The discount factor shock δ_t follows a two state regime-switching Markov process, that is $\delta_t \in \{\delta^L, \delta^H\}$ with $\delta^L < \delta^H$ and ergodic mean equals 1. We set $\delta^L = 0.985$, which represents the normal regime in which households discount the future at rate 0.99. The discount factor heightens with probability $P(\delta^H|\delta^L)$ and returns to its normal value with probability $P(\delta^L|\delta^H)$. The transition probability matrix P is set to target the frequency and average duration of liquidity trap episodes. The resulting values are presented in Table 1 which imply a value of $\delta^H = 1.0049$. The weight on tradable consumption in the CES function ω is calibrated to match a 24% share of tradable output in the total value of production observed in the data over the period 1980-2019, implying that $\omega = 0.252$.

4.2 The Prudential Role of Monetary Policy

We examine here the gains from conducting prudential monetary policy in the absence of macroprudential policy. To do, we compare the frequency and duration of liquidity trap episodes under the optimal discretionary monetary policy (27) against a policy in which the government closes the labor wedge and replicates flexible price allocation as long as the economy is away from the ZLB.

The left panel of Figure 2 shows the results. We keep all parameters constant except for γ, the elasticity of substitution between tradables and non-tradables . The intertemporal elasticity of substitution is set to one. As the figure shows, when $\gamma = 1$, there no gains from prudential monetary policy, in line with Proposition 3. When $\gamma < 1$, we observe larger benefits from prudential monetary policy. In particular, we see a significantly lower duration and frequency of liquidity traps. The welfare gains in terms of current

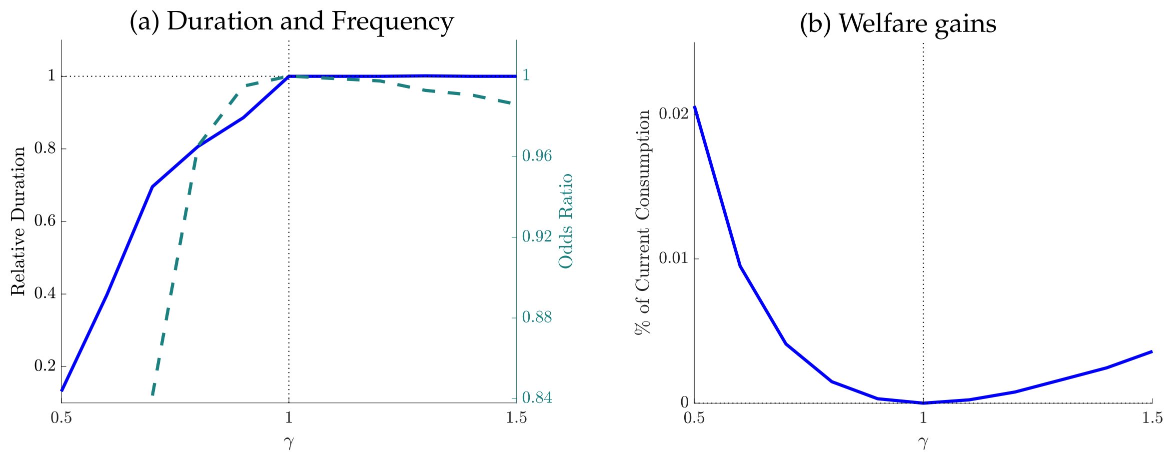

Figure 2: Gains from discretionary monetary policy relative to a full employment policy

consumption can reach 0.02 percentage points when $\gamma = 0.5$.

4.3 Long-Run Moments

Table 2 displays the likelihood and duration of liquidity trap episodes in an economy in which monetary policy is set optimally both with and without capital controls. A first lesson is that capital controls are effective at reducing the likelihood of a liquidity trap. By taxing borrowing when the economy is in the fragile region, the government is successful at making the economy less vulnerable to a liquidity trap. The ex-ante prudential capital control implies an average tax rate on inflows of 0.2% percent. When a negative shock hit the economy in the capital control regime, the government optimally lowers the nominal rate to depreciate the exchange rate and help mitigate the adverse shock. This leads to more borrowing which in turn requires a higher tax on debt to offset the aggregate demand externality. The correlation between the interest rate and the optimal tax rate on debt, conditional on not being at the ZLB varies between -0.2 and -0.6. The unconditional correlation reported in Table 2 is between -0.4 and -0.6.

A second lesson is that, perhaps surprisingly, liquidity traps last longer when capital controls are used jointly with monetary policy. This occurs because in a liquidity trap, the government may tax outflows, which implies that the deleveraging process is slowed down. In fact, the average tax during a liquidity trap is -0.05%. Notice that because taxes on inflows are more frequent, capital controls generate a reduction in external debt of about 7 percentage points of GDP.

Table 3 examines the average welfare cost of the ZLB and the unemployment rate

Table 2: Frequency and duration of liquidity traps

	Monetary Policy Only		Monetary & Macroprudential			
	Frequency	Duration	Frequency	Duration	mean(τ)	corr(R,τ)
$\gamma = 0.5$	3.5%	7.8	2.9%	11.4	0.2%	-0.4
$\gamma = 1.0$	4.0%	7.8	3.5%	9.3	0.2%	-0.6
$\gamma = 1.5$	4.3%	8.4	3.9%	8.9	0.2%	-0.6

Note: Duration expressed in quarters.

Table 3: Unemployment rate and welfare costs of the ZLB

	Monetary Policy Only		Monetary & Macroprudential	
	Welfare costs	Unemployment*	Welfare costs	Unemployment*
$\gamma = 0.5$	0.60%	7.98%	0.10%	1.48%
$\gamma = 1.0$	0.50%	6.14%	0.11%	1.51%
$\gamma = 1.5$	0.52%	5.43%	0.14%	1.58%

Note: Unemployment is the average unemployment rate conditional on a liquidity trap.

during a liquidity trap under optimal monetary policy with and without capital controls.[11] For a given state (b^*, s), the welfare cost of the ZLB under a policy regime is calculated as the compensating consumption variations that equalize the expected utility of a household living in an economy under that policy regime and the expected utility in the efficient allocation (without ZLB).[12]

Table 3 reports an average unemployment rate of about 1.5% with capital controls versus 6.0% when the government refrains from using capital controls. The significant reduction in both the frequency and the severity of liquidity trap episodes points toward substantial quantitative gains from capital controls. Capital controls cut the welfare cost of the ZLB by more than fourfold. The average welfare cost of the ZLB when monetary policy is supplemented with capital controls is about 0.1 percentage points of permanent consumption versus 0.5 percentage points of permanent consumption in the case without

[11] The unemployment rate is defined as the gap between the current level of employment and the efficient employment level (that is, the level that would equate the marginal value of employment to the marginal cost from providing an extra unit of labor).

[12] Formally, the welfare cost associated with a policy regime G, for a given state (b^*, s), corresponds to the value of $q(b^*, s)$ that satisfies

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\prod_{k=0}^{t} \delta_k \right) \left[\log((1+q)c_t^G) - v(h_t^G) \right] = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\prod_{k=0}^{t} \delta_k \right) \left[\log(c_t^E) - v(h_t^E) \right],$$

where c^E and h^E denote consumption and hours worked in the efficient allocation.

capital controls.

4.4 Sensitivity with Staggered Pricing

We assumed for our baseline analysis that prices were perfectly sticky. We now consider the case with staggered pricing, which is the workhorse assumption in New Keynesian models. Firms are assumed to be monopolistic competitive producers of non-tradable good varieties that face a quadratic price adjustment cost in units of the final non-tradable good $\frac{\varphi}{2}\left(\frac{P_{jt}}{P_{jt-1}}-1\right)^2 y_t^N$ where $j \in [0,1]$ is the index of the variety produced by a firm.[13] The elasticity of substitution between two varieties ε is calibrated is set to 7.66, corresponding to a 15% net markup. The price adjustment cost parameter φ_P, which determines the degree of price stickiness, is set to $\varphi_P = 120$. This implies that all prices would adjust on average after 3.2 quarters, or equivalently 9.6 months in the range of the estimates of Nakamura and Steinsson (2008).

Table 4 shows how the frequency and average duration of liquidity traps as well as the unemployment rate and welfare costs of a ZLB vary with the alternative price setting assumption for $\sigma = \gamma = 1$. The average tax on debt in the staggered price model where prices are allowed to adjust slowly is 0.2% as in the benchmark model with fixed prices. Liquidity traps are also found to last longer when monetary policy is supplemented with macroprudential policy, with a difference in the average duration of liquidity trap episodes of about 2 quarters. While the average duration is shorter with monetary policy only, recessions turn out to be more severe with the average unemployment rate multiplied by a factor of four as in the benchmark model (4.1% versus 1.1% with optimal macroprudential policy).

Table 4: Macroprudential policy and liquidity traps with sticky prices

	Frequency of ZLB	Duration of ZLB	Unemployment at the ZLB	Welfare costs
Monetary Policy Only	2.7%	3.3	4.12%	0.63%
Monetary & Macroprudential	2.5%	5.4	1.09%	0.07%

Note: Duration expressed in quarters.

Table also 4 shows that absent macroprudential policy, the welfare cost of the ZLB is about 0.6 percentage points of permanent consumption, larger than the one in the model

[13]See Appendix C for a full description of the firm problem.

with fixed prices (0.5 percentage points). This result can seem surprising but is in line with the notion present in closed economies that higher price flexibility can be detrimental in an economy subject to a zero lower bound (e.g. Werning, 2011; Galí, 2013).

5 International Spillovers

So far, we have considered a small open economy. Motivated by policy discussions regarding global imbalances and currency wars, we now extend our framework to tackle how monetary and macroprudential policies abroad affect welfare at home and how they alter the optimal policy response.

We consider a world economy that is composed of a continuum of small open economies of the type described in Section 2. For simplicity, we abstract from uncertainty. Using $e^H_{G,t}$ to denote the bilateral exchange rate between two countries H and F, we obtain the following arbitrage condition between bonds in different currencies.

$$R_{H,t} = R_{F,t}(e^H_{Ff,t}/e^H_{F,t+1}),$$

The definition of competitive equilibrium extends the definition of Section 2. We now have a sequence of prices and allocations, one for each country. In addition, the real interest rate R^*_t is endogenous, and we have that aggregate savings equal zero at the world level.

5.1 Monetary Spillovers and Currency Wars

We start by examining the spillover from changes in policy rates abroad.

Proposition 4. *Consider a change in the foreign nominal interest rate in a set of countries F and let us start from a situation where $b^H_1 = 0$. To a first order, the effect on a home country's welfare is given by*

$$\frac{\partial V_{H,0}}{\partial R_{F,0}} = \frac{u_T(c^T_{H,0}, c^N_{H,0})}{R^*_0}\left[\frac{1-\tilde{\omega}_{H,0}}{\tilde{\omega}_{H,0}}\gamma c^T_{H,0}\psi_{H,0} + \left(\tilde{\omega}_{H,0} + (1-\tilde{\omega}_{H,0})\frac{\gamma}{\sigma}\right)\upsilon_{H,0}\right]\frac{\partial R^*_0}{\partial R_{F,0}}, \quad (28)$$

where $\upsilon_{H,0}$ is the Lagrange multiplier on the households' Euler equation (18).

Proof. In Appendix B.1 □

The proposition underscores that from the perspective of a small open economy, the relevant spillover is through the changes in the world real interest rate.[14] If the real interest rate were invariant to changes in nominal rates, which occurs in our setup when $\gamma = \sigma$, then there are no spillovers. However, away from this case, foreign monetary policy does affect home welfare.

Let us examine the case in which the home country is *away* from a liquidity trap. Using the results from Proposition 3 and eq. (28), we have that the welfare effects of a monetary expansion abroad reduce to

$$\frac{\partial V_{H,0}}{\partial R_{F,0}} = \left[\frac{u_T(c^T_{H,0}, c^N_{H,0})}{R^*_0} v_{H,0} \right] \frac{\partial R^*_0}{\partial R_{F,0}}. \tag{29}$$

Notice that now the sign of the welfare effect depends on the interaction of $v_{H,0}$, the Lagrange multiplier on the households' Euler equation (18), and the direction of the world interest rate in response to the monetary policy abroad—recall that we start from a situation where the domestic economy is neither a net borrower nor a net saver.[15] There are two important cases to consider depending on whether macroprudential policy is available or not.

Without macroprudential policy. From the analysis in Section 3.3, we know that $v_{H,t} > 0$ when the ZLB is not currently binding but is expected to bind in the future.[16] A strictly positive Lagrange multiplier reflects that agents tend to overborrow relative to the constrained-efficient benchmark (see Section 3). If the monetary policy abroad generates a reduction in the world real interest rate, this causes a reduction in welfare in the home country. Intuitively, the reduction in the real interest rate generates incentives for households to borrow more—from an already inefficiently high level—and increases the vulnerability to a liquidity trap.

As shown in Proposition 3, a small open economy indeed has incentives to increase the net foreign asset position so as to become less vulnerable to a binding zero lower bound, lowering the interest rate when $\gamma > \sigma$ and increasing it otherwise. As a result, this generates a form of currency war, in which every country has incentives to push savings up and this ends up distorting output. However, countries have incentives to pursue a

[14]Because tradable goods have flexible prices, a reduction in the foreign nominal interest rate leads simultaneously to an appreciation of the domestic currency and to an increase in the foreign price level. Through the law of one price, this implies that the domestic price remains the same.

[15]Away from the ZLB, as shown in (A.28) in Appendix A.3, the optimal monetary policy in its target form (27) can be rewritten as $\psi_{H,0} = \tilde{\omega}(\gamma^{-1} - \sigma^{-1}) v_{H,0}/c^T_{H,0}$. Combining this with (28), we obtain (29).

[16]Formally, this can be seen in eq. (A.32) in Appendix A.3.

depreciation of their currency only if $\gamma > \sigma$. We summarize this result in the corollary below.

Corollary 1 (Currency wars)**.** *When a government does not use macroprudential policy, a prudential monetary intervention abroad lowers home welfare, strictly so if the zero lower bound binds in the future.*

Proof. In Appendix B.2. □

Otherwise, if $\gamma < \sigma$. the world equilibrium is such that all countries raise the interest rate relative to the level that would be collectively optimal. Under both parameterizations, however, the results suggest that there are gains from cooperation.[17]

With macroprudential policy. On the other hand, when the government has access to macroprudential policy, there is no inefficiency stemming from domestic households' saving decisions ($\upsilon_{H,0} = 0$). Hence, (28) shows that a foreign monetary policy intervention has no effect on domestic households' welfare. The intuition is that domestic monetary policy optimally closes the labor wedge ($\psi_{H,0} = 0$) away from the liquidity trap, while macroprudential policy ensures that the level of borrowing is inefficient. The joint optimal monetary and macroprudential policy response, therefore, renders the domestic country insulated from foreign policy shocks.

Corollary 2 (No currency wars with macroprudential policy)**.** *When a government uses macroprudential policy, a monetary policy intervention abroad does not affect welfare away from the zero lower bound.*

Proof. In Appendix B.3 □

5.2 Macroprudential Policy Spillovers

We argued in the previous section that macroprudential policy can serve to insulate a country from foreign monetary policy spillovers. In particular, if a country is away from a liquidity trap, we show that changes in the world real rate do not have first-order effects on welfare. A question that emerges, however, is what happens when all countries use macroprudential policy? Is it possible that the use of this policy backfire at a global scale when some countries are in a liquidity trap?

[17] See Fornaro and Romei (2022) and Bianchi and Coulibaly (2023) for recent work on the optimal cooperative monetary policy.

Fornaro and Romei (2019) indeed argue that it is indeed possible that a global economy would macroprudential policies would be Pareto dominated by an economy without macroprudential policies. In particular, they consider an economy with "zero liquidity" where this result is demonstrated analytically. Their insight is that when countries impose macroprudential policy, this lowers the world real rate and can make the zero lower bound more binding. They dub this phenomenon a "paradox of global thrift."

We argue, however, that it is possible to design a macroprudential policy that eliminates the possibility of a paradox of global thrift. In particular, if a country restricts the level of capital flows at the same level as the laissez-faire, it leaves an individual country as well-off as in the laissez-faire equilibrium in a world where all countries are using macroprudential policy. The basic insight is that by using quantity macroprudential policy, the government can ensure that the economy features the same domestic real rate as in the laissez-faire economy, regardless of macroprudential policy abroad. By ensuring the same interest rate, the government can achieve at least the same level of welfare. Of course, it is also possible that the government could do strictly better by choosing a different macroprudential policy.[18] The proposition below formalizes this result.

Proposition 5 (Welfare dominance of quantity-macroprudential policy)**.** *Consider the welfare of the home country under laissez-faire versus the welfare under a macroprudential policy regime in which the government controls directly the country's capital account, starting from a symmetric equilibrium with zero net positions. Then, home welfare is weakly higher in the macroprudential policy regime.*

Proof. In Appendix B.4 □

6 Conclusion

In this paper, we provide an integrated analysis of monetary and macroprudential policies in an open economy subject to an occasionally binding zero lower bound constraint. We show that although monetary policy can be used prudentially, leaning with the wind may not be optimal. Capital controls on both inflows and outflows ameliorate monetary policy tradeoffs and provide substantial welfare gains. Our analysis also provides a more benign

[18] It is possible to show that if no borrowing is allowed, the welfare effect is necessarily strict, as the interest rate in autarchy is higher than under laissez faire. In a previous version of the paper, we also provide general conditions under which taxes on capital flows, as opposed to quantity restrictions, can generate a Pareto improvement relative to a laissez-faire regime. See also the previous version for a characterization of the optimal macroprudential policy under cooperation.

perspective on international spillovers in contrast to widespread policy concerns. We show that a country's ability to deploy capital controls can provide insulation from adverse effects and help prevent the outbreak of a currency war.

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Appendix to "Liquidity Traps, Prudential Policies and International Spillovers"

A Proofs for Section 3

A.1 Proof of Proposition 1

Proof. The problem of the government consists in choosing τ to maximize households' welfare subject to the equilibrium conditions (3), (4), (5), (6) and (13). For a given exogenous path of the nominal exchange rate $\{e_t\}$, we solve the relaxed problem of the government:

$$\max_{\left\{b^*_{t+1}, c^N_t, c^T_t\right\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\prod_{k=0}^{t} \delta_k \right) \left[u\left(c^T_t, c^N_t\right) - v\left((c^N_t)^{1/\alpha} \right) \right] \tag{A.1}$$

subject to

$$c^T_t = y^T_t + b^*_t - \frac{b^*_{t+1}}{R^*_t} \tag{A.2}$$

$$c^N_t = \left[\frac{1-\omega}{\omega} \frac{P^{T*}_t}{\bar{P}^N} e_t \right]^{\gamma} c^T_t \tag{A.3}$$

After solving (A.1), we back out τ_t using (5). Taking the first-order conditions, we arrive at

$$c^T_t : \quad \lambda_t = u_T(t) + \vartheta_t \frac{c^N_t}{c^T_t} \tag{A.4}$$

$$c^N_t : \quad \vartheta_t = u_N(t) - \frac{1}{\alpha}(h_t)^{1-\alpha} v'\left((c^N_t)^{1/\alpha} \right) \tag{A.5}$$

$$b^*_{t+1} : \quad \frac{z_t \lambda_t}{R^*_t} = \beta \mathbb{E}_t z_{t+1} \lambda_{t+1} \tag{A.6}$$

where $\lambda_t \geq 0$ and ϑ_t are the Lagrange multipliers on constraints (A.2) and (A.3) respectively. Combining (A.4) and (A.5), we have

$$\lambda_t = u_T(t) + u_T(t) \frac{\bar{P}^N c^N_t}{P^T_t c^T_t} \psi_t \tag{A.7}$$

where we use $\frac{\bar{P}^N}{P^T_t} = \frac{u_N(t)}{u_T(t)}$. We then substitute (A.7) into (A.6) to get

$$u_T(t) \left[1 + \frac{\bar{P}^N c^N_t}{P^T_t c^T_t} \psi_t \right] = \beta R^*_t \mathbb{E}_t \left\{ \delta_{t+1} u_T(t+1) \left[1 + \frac{\bar{P}^N c^N_{t+1}}{P^T_{t+1} c^T_{t+1}} \psi_{t+1} \right] \right\} \tag{A.8}$$

We can now derive the optimal tax rate on debt by plugging (5) into (A.8) which leads to

$$\tau_t = \frac{1}{\beta R_t^* \mathbb{E}_t \delta_{t+1} u_T(t+1)} \left\{ -\frac{1-\tilde{\omega}_t}{\tilde{\omega}_t} u_T(t)\psi_t + \beta R_t^* \mathbb{E}_t \delta_{t+1} \left[\frac{1-\tilde{\omega}_{t+1}}{\tilde{\omega}_{t+1}} u_T(t+1)\psi_{t+1} \right] \right\}.$$

□

A.2 Proof of Proposition 2 (Monetary Policy and Capital Controls)

Proof. The problem of the government in recursive form is given by:

$$V(b^*, s) = \max_{R,\tau,e,b^{*\prime},c^N,c^T} u\left(c^T, c^N\right) - v\left(\left(c^N\right)^{1/\alpha}\right) + \beta \mathbb{E}_{s'|s} \delta' V\left(b^{*\prime}, s'\right)$$

subject to

$$c^T = y^T + b^* - \frac{b^{*\prime}}{R^*} \tag{A.9}$$

$$c^N = \left[\frac{1-\omega}{\omega} \frac{P^{T*}}{\bar{P}^N} e\right]^\gamma c^T \tag{A.10}$$

$$u_T(c^T, c^N) = \beta R^* (1+\tau)\, \mathbb{E}_{s'|s} \left[\delta' u_T\left(\mathcal{C}^T(b^{*\prime}, s'), \mathcal{C}^N(b^{*\prime}, s')\right)\right] \tag{A.11}$$

$$R^* = R\mathbb{E}_{s'|s}\left[\Lambda\left(\mathcal{C}^T(b^{*\prime}, s'), \mathcal{C}^N(b^{*\prime}, s')\right) \frac{P^{T*}}{P^{T*\prime}} \frac{e}{\mathcal{E}(b^{*\prime}, s')}\right] \tag{A.12}$$

$$R \geq 1 \tag{A.13}$$

Because τ only appears in (A.11), it is immediate that (A.11) does not bind. Let $\lambda \geq 0$, ϑ, v, χ and $\xi \geq 0$ be the Lagrange multiplier on (A.9), (A.10), (A.11), (A.12) and (A.13) respectively. The optimality conditions, after substituting for χ, are

$$\xi = \gamma c^N \vartheta \tag{A.14}$$

$$\vartheta = u_N(c^T, c^N) - \frac{v'(h)}{\alpha h^{\alpha-1}} \tag{A.15}$$

$$\lambda = u_T(c^T, c^N) + \frac{c^N}{c^T}\vartheta \tag{A.16}$$

$$\lambda = -\xi\, \mathbb{E}_{s'|s} \frac{\partial}{\partial b^{*\prime}} \left[\frac{\Lambda(b^{*\prime}, s')}{\mathcal{E}(b^{*\prime}, s')} \frac{eP^{T*}}{P^{T*\prime}}\right] + \beta R^* \mathbb{E}_{s'|s} \delta' \lambda' \tag{A.17}$$

We combine (A.14) and (A.15) to obtain

$$\xi = \gamma c^T \frac{1-\tilde{\omega}}{\tilde{\omega}} u_T(c^T, c^N)\psi \tag{A.18}$$

This corresponds to (26) in the text.

Next, we determine the optimal exchange rate when the ZLB is not binding. When the ZLB is not binding $\xi = 0$ which implies that $\psi = 0$, and by (19) we have

$$\psi = 0 \Leftrightarrow \left(c^N\right)^{\frac{1-\alpha+\phi}{\alpha}+\frac{1}{\sigma}} = \alpha(1-\omega)\left(\frac{c}{c^N}\right)^{\frac{1}{\gamma}-\frac{1}{\sigma}}$$
$$\Leftrightarrow \left(c^N\right)^{\frac{(1-\alpha+\phi)\sigma+\alpha}{\alpha\sigma}} = \alpha(1-\omega)^{\frac{\gamma}{\sigma}}\left[\omega^{\gamma}\left(\frac{eP^{T*}}{\bar{P}^N}\right)^{1-\gamma} + (1-\omega)^{\gamma}\right]^{\frac{1}{\gamma-1}\frac{\sigma-\gamma}{\sigma}}$$

where the second equality uses (A.10). Using again (A.10) and $\mathcal{P}$ defined in (14), we simplify both sides of the equation and we arrive at

$$\left[\left(\frac{1-\omega}{\omega}\frac{P^{T*}}{\bar{P}^N}e\right)^{\gamma} c^T\right]^{\frac{(1-\alpha+\phi)\sigma+\alpha}{\alpha\sigma}} = \alpha(1-\omega)^{\frac{\gamma}{\sigma}}\left[\frac{eP^{T*}}{\bar{P}^N}\mathcal{P}\right]^{\frac{\sigma-\gamma}{\sigma}}$$

which implies that

$$e = \frac{\omega}{1-\omega}\frac{\bar{P}^N}{P^{T*}}\left[\alpha^{\frac{\sigma}{\gamma}}(1-\omega)\left(\frac{eP^{T*}}{\bar{P}^N}\mathcal{P}\right)^{\frac{\gamma-\sigma}{\gamma}}\right]^{\frac{\alpha}{(1-\alpha+\phi)\sigma+\alpha}}\left(c^T\right)^{-\frac{1}{\gamma}}$$

Finally, we turn to deriving the optimal tax. Defining $\Theta \equiv \gamma c^T \frac{\partial}{\partial b^{*\prime}}\mathbb{E}_{s'|s}\left[\frac{\Lambda(b^{*\prime},s')}{\mathcal{E}(b^{*\prime},s')}\frac{eP^{T*}}{P^{T*\prime}}\right]$ and plugging (A.16) into (A.17), we get

$$u_T(c^T,c^N) + (1+\Theta)\frac{\xi}{\gamma c^T} = \beta R^*\mathbb{E}_{s'|s}\delta'\left[u_T\left(c^{T\prime},c^{N\prime}\right) + \frac{\xi'}{\gamma c^{T\prime}}\right] \tag{A.19}$$

Then, we substitute (A.11) into (A.19) and obtain

$$\tau = \frac{1}{\beta R^*\mathbb{E}_{s'|s}\delta'\left[u_T\left(c^{T\prime},c^{N\prime}\right)\right]}\left\{-(1+\Theta)\frac{\xi}{\gamma c^T} + \beta R^*\mathbb{E}_{s'|s}\delta'\left[\frac{\xi'}{\gamma c^{T\prime}}\right]\right\}$$

□

A.3 Proof of Proposition 3 (Monetary Policy without Capital Controls)

Preliminaries. Absent capital controls, the government sets its policy $\{R\}$ to maximize households' welfare subject to resource and implementability constraints, and a zero lower bound constraint on nominal interest rate. The government problem is given by:

$$V\left(b^{*}, s\right)=\max_{R, e, b^{*\prime}, c^{N}, c^{T}} u\left(c^{T}, c^{N}\right)-v\left(\left(c^{N}\right)^{1 / \alpha}\right)+\beta \mathbb{E}_{s^{\prime} \mid s} \delta^{\prime} V\left(b^{*\prime}, s^{\prime}\right) \tag{A.20}$$

subject to

$$c^{T}=y^{T}+b^{*}-\frac{b^{*\prime}}{R^{*}} \tag{A.21}$$

$$c^{N}=\left[\frac{1-\omega}{\omega} \frac{P^{T *}}{\bar{P}^{N}} e\right]^{\gamma} c^{T} \tag{A.22}$$

$$u_{T}(c^{T}, c^{N})=\beta R^{*}\, \mathbb{E}_{s^{\prime} \mid s} \delta^{\prime}\left[u_{T}\left(\mathcal{C}^{T}(b^{*\prime}, s^{\prime}), \mathcal{C}^{N}(b^{*\prime}, s^{\prime})\right)\right] \tag{A.23}$$

$$R^{*}=R \mathbb{E}_{s^{\prime} \mid s}\left[\Lambda\left(\mathcal{C}^{T}(b^{*\prime}, s^{\prime}), \mathcal{C}^{N}(b^{*\prime}, s^{\prime})\right) \frac{P^{T *}}{P^{T * \prime}} \frac{e}{\mathcal{E}(b^{*\prime}, s^{\prime})}\right] \tag{A.24}$$

$$R \geq 1 \tag{A.25}$$

We let $\lambda \geq 0$ be the Lagrange multiplier on (A.21), ϑ, v and χ the multiplier on (A.22), (A.23) and (A.24) respectively, and $\xi \geq 0$ the multiplier on (A.25).

We proceed by first defining a Markov perfect equilibrium in the absence of capital controls and then characterizing the optimal monetary policy.

Definition A.1 (Markov perfect equilibrium absent capital controls)**.** A Markov perfect equilibrium is defined by the current government policy functions $R(b^*, s)$, $\mathcal{E}(b^*, s)$ with associated decision rules $c^T(b^*, s)$, $b'(b^*, s)$ $c^N(b^*, s)$, and value function $V(b^*, s)$, and the conjectured function characterizing the decision rule of future governments $\mathcal{R}(b^*, s)$, $\mathcal{B}(b^*, s)$ and the associated decision rules $\mathcal{C}^T(b^*, s)$, $\mathcal{C}^N(b^*, s)$, such that: (i) given the conjecture of future policies, the value function and the policy functions solve the government problem (A.20); and (ii) The conjectured policy rules that represent optimal choices of future governments coincide with the solutions to (A.20).

Optimal monetary policy. The first-order conditions with respect to e and c^N are

$$\xi=\gamma c^{N} \vartheta \tag{A.26}$$

$$\vartheta=u_{N}(c^{T}, c^{N})-\frac{v^{\prime}(h)}{\alpha h^{\alpha-1}}-u_{TN}(c^{T}, c^{N}) v \tag{A.27}$$

where we use the optimality condition for R to substitute for χ. To derive the optimal monetary policy when the ZLB is not binding, we substitute (A.26) into (A.27) to get

$$\begin{aligned} \xi &= \gamma c^{N}\left[u_{N}(c^{T}, c^{N}) \psi-u_{TN}(c^{T}, c^{N}) v\right] \\ &= \gamma c^{N} u_{N}(c^{T}, c^{N})\left[\psi-\frac{\tilde{\omega}(\sigma-\gamma)}{\sigma \gamma} \frac{v}{c^{T}}\right] \end{aligned}$$

Thus, when the ZLB does not bind

$$\psi = \frac{\tilde{\omega}(\sigma - \gamma)}{\sigma\gamma} \frac{v}{c^T} \tag{A.28}$$

We now need to determine v. Using the first order conditions with respect to tradable consumption c^T and foreign bonds b'^*

$$\lambda = u_T(c^T, c^N) - u_{TT}(c^T, c^N)v + \frac{c^N}{c^T}\vartheta \tag{A.29}$$

$$\begin{aligned}\lambda = \beta R^* \mathbb{E}_{s'|s}\delta'\lambda' - \xi\, \mathbb{E}_{s'|s}\frac{eP^{T*}}{P^{T*\prime}}\frac{\partial}{\partial b^{*\prime}}\left[\frac{\Lambda\left(b^{*\prime}, s'\right)}{\mathcal{E}(b^{*\prime}, s')}\right] \\ + v\, \beta R^* E_{s'|s}\delta' \frac{\partial}{\partial b^{*\prime}}\left[u_T\left(\mathcal{C}^T(b^{*\prime}, s'), \mathcal{C}^N(b^{*\prime}, s')\right)\right]\end{aligned} \tag{A.30}$$

and plugging (A.29) into (A.30), we get

$$u_T(c^T, c^N) - (1 + \bar{\Theta})u_{TT}(c^T, c^N)v = \beta R^* \mathbb{E}_{s'|s}\delta'\left[u_T(c^{T\prime}, c^{N\prime}) - u_{TT}(c^{T\prime}, c^{N\prime})v' + \frac{\xi'}{\gamma c^{T\prime}}\right]$$

where $\bar{\Theta} \equiv \frac{1}{u_{TT}(c^T, c^N)}\beta R^* \mathbb{E}_{s'|s}\delta' \frac{\partial}{\partial b^{*\prime}} u_T\left(c^{T\prime}, c^{N\prime}\right) > 0$. Then, substituting the implementability constraint (A.23) into this equation leads to

$$-u_{TT}(c^T, c^N)v = \beta R^*(1 + \bar{\Theta})^{-1}\mathbb{E}_{s'|s}\delta'\left[-u_{TT}(c^{T\prime}, c^{N\prime})v' + \frac{\xi'}{\gamma c^{T\prime}}\right] \tag{A.31}$$

Iterating forward (A.31) and using the transversality condition, we obtain (for convenience, the equations are written in their sequential form)

$$\begin{aligned} v_t &= \frac{1}{-u_{TT}(t)}\mathbb{E}_t \sum_{k=1}^{\infty} \bar{Q}_{k|0}\frac{\xi_{t+k}}{\gamma c^T_{t+k}} \\ \frac{v_t}{c^T_t} &= \frac{1}{u_T(t)}\frac{\sigma\gamma}{(1 - \tilde{\omega}_t)\sigma + \tilde{\omega}_t\gamma}\mathbb{E}_t \sum_{k=1}^{\infty} \bar{Q}_{t+k|t}\frac{\xi_{t+k}}{\gamma c^T_{t+k}} \end{aligned} \tag{A.32}$$

where $\bar{Q}_{t+k|t} = \beta^k \prod_{j=0}^{k-1}\left(\delta_{t+j+1}\frac{R^*_{t+j}}{1+\bar{\Theta}_{t+j}}\right)$. Finally, we substitute (A.32) into (A.28) to get the optimal monetary policy in its target form

$$u_T(t)\psi_t = \frac{\tilde{\omega}_t(\sigma - \gamma)}{(1 - \tilde{\omega}_t)\sigma + \tilde{\omega}_t\gamma}\mathbb{E}_t \sum_{k=1}^{\infty} \bar{Q}_{t+k|t}\frac{\xi_{t+k}}{\gamma c^T_{t+k}}.$$

□

B Proofs for Section 5

B.1 Proof of Proposition 4

Proof. From the perspective of the SOE, we have to infer the effects of the foreign monetary policy shock on P^{T*}, R^*, which are taken as given by the SOE. Let $V_{H,0}(b^*_{H,0}, \{P^{T*}, R^*\})$ denote the welfare of households in the SOE at the initial period and $c^N_{H,0}(b^*_{H,0}, \{P^{T*}, R^*\})$, $c^T_{H,0}(b^*_{H,0}, \{P^{T*}, R^*\})$, $b^*_{H,1}(b^*_{H,0}, \{P^{T*}, R^*\})$, $e_{H,0}(b^*_{H,0}, \{P^{T*}, R^*\})$ the associated policy functions. The effect on welfare is then given by

$$\frac{dV_{H,0}}{dR_{F,0}} = \sum_{t=0}^{\infty} \frac{\partial V_{H,0}}{\partial P^{T*}_t} \frac{dP^{T*}_t}{dR_{F,0}} + \sum_{t=0}^{\infty} \frac{\partial V_{H,0}}{\partial R^*_t} \frac{dR^*_t}{dR_{F,0}} \tag{B.1}$$

We determine $\partial V_{H,0}/\partial P^{T*}$ and $\partial V_{H,0}/\partial R^*$ by applying the envelope theorem to the SOE problem that follows

$$V_{H,0} = \max_{c^N_{H,0}, c^T_{H,0}, b^*_{H,1}, e_{H,0}} u\left[y^T_{H,0} + b^*_{H,0} - \frac{b^*_{H,1}}{R^*_0}, c^N_{H,0}\right] - v\left[(c^N_{H,0})^{1/\alpha}\right] + \beta \frac{z_{H,1}}{z_{H,0}} V_{H,1}(b^*_{H,1})$$

subject to

$$c^T_{H,0} = y^T_{H,0} + b^*_{H,0} - \frac{b^*_{H,1}}{R^*_0} \qquad (\times \lambda_{H,0})$$

$$c^N_{H,0} = \left[\frac{1-\omega}{\omega} \frac{P^{T*}_0}{\bar{P}^N} e_{H,0}\right]^{\gamma} c^T_{H,0} \qquad (\times \vartheta_{H,0})$$

$$u_T(c^T_{H,0}, c^N_{H,0}) = \beta R^*_0 (1 + \tau_{H,0}) \frac{z_{H,1}}{z_{H,0}} \left[u_T\left(\mathcal{C}^T(b^*_{H,1}), \mathcal{C}^N(b^*_i)\right)\right] \qquad (\times v_{H,0})$$

$$1 \geq \frac{1}{R^*_0} \frac{e_{H,0}}{\mathcal{E}_H(b^*_{H,1})} \frac{P^{T*}_0}{P^{T*}_1} \qquad (\times \xi_{H,0})$$

where we omitted the arguments for the value function $V_{H,0}$ and policy functions $c^N_{H,0}$, $c^T_{H,0}$, $b^*_{H,1}$, $e_{H,0}$ to simplify the expressions. We therefore have using the envelope condition that the partial derivative of the home households' welfare with respect to P^{T*}_0 is given by

$$\frac{\partial V_{H,0}}{\partial P^{T*}_0} = \gamma c^N_{H,0} \vartheta_{H,0} - \xi_{H,0} = 0 \tag{B.2}$$

where the second equality uses the government's first order condition with respect to the nominal exchange rate. For the derivative with respect to P^{T*}_1,

$$\frac{\partial V_{H,0}}{\partial P^{T*}_1} = -\gamma c^N_{H,0} \vartheta_{H,0} + \xi_{H,0} = 0 \tag{B.3}$$

Next, applying the envelope condition to $\partial V_{H,0}/\partial P_t^{T*}$ for $t > 1$, and $\partial V_{H,0}/\partial R_t^*$ for $t \geq 1$, it is straightforward to see that

$$\frac{\partial V_{H,0}}{\partial P_t^{T*}} = 0 \ \text{ for } t > 1, \quad \text{and} \quad \frac{\partial V_{H,0}}{\partial R_t^*} = 0 \ \text{ for } t \geq 1. \tag{B.4}$$

It remains to determine $\partial V_{H,0} \partial R_0^*$. Use once again the envelope condition to arrive to

$$\frac{\partial V_{H,0}}{\partial R_0^*} = \lambda_{H,0} \frac{b_{H,1}^*}{(R_0^*)^2} + \frac{1}{R_0^*} \left[u_T(c_{H,0}^T, c_{H,0}^N) v_{H,0} + \xi_{H,0} \right] \tag{B.5}$$

Then, combine the government's first order condition with respect to e and c^N to get

$$\begin{aligned} \xi_{H,0} &= \gamma c_{H,0}^N \left[u_N(c_{H,0}^T, c_{H,0}^N) \psi_{H,0} - u_{TN}(c_{H,0}^T, c_{H,0}^N) v_{H,0} \right] \\ &= \gamma c_{H,0}^N u_N(c_{H,0}^T, c_{H,0}^N) \psi_{H,0} - \gamma c_{H,0}^N \frac{\tilde{\omega}}{c_{H,0}^T} u_N(c_{H,0}^T, c_{H,0}^N) \frac{\sigma - \gamma}{\sigma \gamma} v_{H,0} \\ &= u_T(c_{H,0}^T, c_{H,0}^N) \left[\frac{1 - \tilde{\omega}_{H,0}}{\tilde{\omega}_{H,0}} \psi_{H,0} - (1 - \tilde{\omega}_{H,0}) \frac{\sigma - \gamma}{\sigma \gamma} v_{H,0} \right] \end{aligned} \tag{B.6}$$

Plugging (B.6) into (B.5), and given that we start from $b_{H,1}^* = 0$, we get

$$\frac{\partial V_{H,0}}{\partial R_0^*} = \frac{u_T(c_{H,0}^T, c_{H,0}^N)}{R_0^*} \left[v_{H,0} + \frac{1 - \tilde{\omega}_{H,0}}{\tilde{\omega}_{H,0}} \gamma c_{H,0}^T \psi_{H,0} - (1 - \tilde{\omega}_{H,0}) \frac{\sigma - \gamma}{\sigma} v_{H,0} \right] \tag{B.7}$$

Finally, we substitute (B.2), (B.3), (B.4) and (B.7) into (B.1) to obtain the equation (28) in the text, that is

$$\frac{dV_{H,0}}{dR_{F,0}} = \frac{u_T(c_{H,0}^T, c_{H,0}^N)}{R_0^*} \left[\frac{1 - \tilde{\omega}_{H,0}}{\tilde{\omega}_{H,0}} \gamma c_{H,0}^T \psi_{H,0} + \left(\tilde{\omega}_{H,0} + (1 - \tilde{\omega}_{H,0}) \frac{\gamma}{\sigma} \right) v_{H,0} \right] \frac{dR_0^*}{dR_{F,0}}.$$

□

B.2 Proof of Corollary 1

Proof. The proof of the corollary follows from equation (29). Consider a prudential monetary policy intervention that aims at increasing aggregate savings in order to mitigate overborrowing. From (**??**) in Appendix **??**, the overall effect of a change in the foreign nominal interest rate on aggregate savings is given by

$$db_{F,1}^* = R^*(1 - \mu_F) c_F^T \, (1 - \tilde{\omega}_F)(\sigma - \gamma) dR_{F,0} \tag{B.8}$$

Thus, an increase in aggregate savings $db^*_{F,1} > 0$ requires

$$(\sigma - \gamma) dR_{F,0} > 0 \tag{B.9}$$

In line with Proposition 3, equation (B.9) states that when $\sigma > \gamma$ the prudential monetary intervention is contractionary $dR_{F,0} > 0$ and it turns out be expansionary $dR_{F,0} < 0$ when $\sigma < \gamma$. Next, we turn to deriving $dR^*_0/dR_{F,0}$. In addition to its direct effect on aggregate savings, a prudential monetary intervention has an indirect effect on aggregate savings at home and foreign through the potential change in the world interest rate. From (**??**) in Appendix **??**,, we have that,

$$db^*_{F,1} = R^*(1-\mu_F)c^T_F \left[(\sigma\tilde{\omega}_F + \gamma(1-\tilde{\omega}_F)) \frac{\partial \log R^*_0}{\partial R_{F,0}} \right] dR_{F,0} \tag{B.10}$$

$$db^*_{H,1} = R^*(1-\mu_H)c^T_H \left[(\sigma\tilde{\omega}_H + \gamma(1-\tilde{\omega}_H)) \frac{\partial \log R^*_0}{\partial R_{F,0}} \right] dR_{F,0} \tag{B.11}$$

Then, combine (B.8), (B.10) and (B.11) and use the market clearing condition for bond, $n\ db^*_{H,1} + (1-n)db^*_{F,1} = 0$, to obtain

$$d\log R^*_0 = -\frac{(1-n)(1-\mu_F)c^T_F\ (1-\tilde{\omega}_F)}{\sum_{i\in\{H,F\}}(1-\mu_i)c^T_i(\sigma\tilde{\omega}_i + \gamma(1-\tilde{\omega}_i))}(\sigma-\gamma)dR_{F,0} < 0$$

where the inequality uses (B.9). Therefore, from equation (29), it follows that

$$\frac{\partial V_{H,0}}{\partial R_{F,0}} = \left[\frac{u_T(c^T_{H,0}, c^N_{H,0})}{R^*_0} v_{H,0} \right] \frac{\partial R^*_0}{\partial R_{F,0}} \leq 0 \tag{B.12}$$

where $v_{H,0} > 0$ if the ZLB binds in the future (see (A.28)). Thus, prudential monetary intervention abroad lowers home welfare, strictly so if the ZLB binds in the future. □

B.3 Proof of Corollary 2

Proof. The proof of the corollary follows from equation (**??**)

$$\frac{\partial V_{H,0}}{\partial R_{F,0}} = \frac{u_T(c^T_{H,0}, c^N_{H,0})}{R^*_0} \left[\frac{1-\tilde{\omega}_{H,0}}{\tilde{\omega}_{H,0}} \gamma c^T_{H,0} \psi_{H,0} \right] \frac{\partial R^*_0}{\partial R_{F,0}}$$

As shown in Proposition 2, away from the ZLB the labor wedge under optimal monetary and capital controls policy satisfies $\psi_{H,0} = 0$. Therefore,

$$\frac{\partial V_{H,0}}{\partial R_{F,0}} = 0.$$

□

B.4 Proof of Proposition 5

Consider the welfare of an individual country in a regime where all countries are using macroprudential policy. Let V_{MP} be the welfare and R_{MP} the world real interest rate. If the country is not at the ZLB, it is immediate that welfare cannot be lower, under the assumption that country is neither a net borrower nor a net saver. Consider then the case at the ZLB. Let $\hat{R}$ be the real interest rate in the domestic economy after imposing a quantity control $\hat{b}'$ on capital inflows. The resulting problem is:

$$
\begin{aligned}
V_{MP,t}(b^*) = \max_{e,c^N,\hat{R}^*,\hat{b}^{*\prime}} \; & u(c^T, c^N) - v\left((c^N)^{1/\alpha}\right) + \beta V_{MP,t+1}(\hat{b}^{*\prime}) \\
\text{subject to} & \\
\hat{c}^T &= y_t^T + b^* - \frac{\hat{b}^{*\prime}}{R^*_{MP}} \\
c^N &= \left[\frac{1-\omega}{\omega}\,\frac{P^{T*}}{\bar{P}^N}\,e\right]^{\gamma} \hat{c}^T \\
u_T(\hat{c}^T) &= \beta \hat{R}^* u_T\left(\mathcal{C}^T(b^{*\prime}, y_{t+1}^T)\right) \\
\hat{R}^* &= \frac{P^{T*}}{P^{T*\prime}}\frac{e}{\mathcal{E}(b^{*\prime}, y_g^T)} \\
\hat{b}^{*\prime} &\geq \bar{b}
\end{aligned}
$$

Let $\hat{b}^{*\prime}(b^*, y_t^T)$ be the level of debt from the decentralized equilibrium in the no capital control regime. Assume that in the current period the government chooses directly this level of borrowing and blocks all private inflows or outflows. It thus follows that the level of tradable consumption is given by

$$
\hat{c}^T(b^*, y_t^T) = y_t^T + b^* - \frac{\hat{b}^{*\prime}(b^*, y_t^T)}{R^*_{MP}} \tag{B.13}
$$

The resulting equilibrium real interest rate thus satisfies:

$$
u_T(\hat{c}^T(b^*, y_t^T)) = \beta \hat{R}^* u_T\left(\mathcal{C}^T\left(\hat{b}^{*\prime}(b^*, y_t^T), y_{t+1}^T\right)\right) \tag{B.14}
$$

where $\mathcal{C}^T\left(\hat{b}^{*\prime}(b^*, y_t^T), y_g^T\right)$ is also the equilibrium policies in the laissez-faire equilibrium. This follows from the observation that for $\sigma = \gamma$ the government also closes the labor wedge in the laissez-faire equilibrium in the good state. It is then immediate that $\hat{R}^*$ equals the interest rate in the no capital control regime. Moreover, e and c^N satisfy

$$e = \mathcal{E}(\hat{b}^{*\prime}(b^*, y_t^T), y_g^T)\hat{R}^* \frac{P^{T*\prime}}{P^{T*}},$$
$$c^N = \left[\frac{1-\omega}{\omega} \frac{P^{T*}}{\hat{P}^N} e\right]^{\gamma} \hat{c}^T,$$

and thus, allocations are identical to the laissez faire equilibrium. Therefore, in a capital control regime governments in the bad state can at least the same welfare as in the no capital control regime.

C Extension with Staggered Pricing

Derivation of the Phillips curve. We describe here the environment with staggered price setting and derive firms' optimal pricing decisions. There is a continuum of firms, each using a constant return to scale technology that uses labor as the sole input to produce a unique variety j, $y_{j,t}^N = n_{j,t}$. Firms are monopolistic competitors and are subject to Rotemberg (1982) price-adjustment costs measured in terms of the final non-tradable good,

$$\frac{\varphi}{2}\left(\frac{P_{j,t}^N}{P_{j,t-1}^N} - 1\right)^2 y_t^N$$

where φ is an adjustment cost parameter and the final non-tradable good y_t^N is defined as a Dixit-Stiglitz aggregator of the continuum of non-tradable varieties indexed by $j \in [0,1]$

$$y_t^N = \left(\int_0^1 y_{j,t}^{N\,\frac{\varepsilon-1}{\varepsilon}} dj\right)^{\frac{\varepsilon}{\varepsilon-1}}$$

Cost minimization implies that the marginal costs of production are: $MC_t = (1-\tau^n)W_t$ where $\tau^n = \frac{1}{\varepsilon}$ is labor subsidy. Taking as given the sequence for mc_t and y_t^N, a monopolist j chooses $P_{j,t}^N$ to maximize the stream of its expected discounted profit:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \frac{\Theta_t}{\Theta_0} \left[\left(P_{j,t}^N - MC_t\right)\left(\frac{P_{j,t}^N}{P_t^N}\right)^{-\varepsilon} P_t^N y_t^N - \frac{\varphi}{2}\left(\frac{P_{j,t}^N}{P_{j,t-1}^N} - 1\right)^2 P_t^N y_t^N\right], \quad \text{(B.15)}$$

Θ_t/Θ_0 is the stochastic discount factor with $\Theta_t \equiv \beta^t z_t U'(c_t)/P_t$ and where P_t is the consumer price index. Notice also by households optimality condition $\Theta_t/\Theta_0 = \beta^t \frac{u_N(c_t^T, c_t^N)/P_t^N}{u_N(c_0^T, c_0^N)/P_0^N}$. Let The first order condition of the firm's problem then yields the following optimal pricing rule or dynamic Phillips curve:

$$\pi_t^N(1+\pi_t^N) = \frac{\varepsilon-1}{\varphi}\left[\frac{\varepsilon(1-\tau^n)}{\varepsilon-1}\frac{W_t}{P_t^N}-1\right] + \mathbb{E}_t\frac{\Theta_{t+1}}{\Theta_t}\left[\frac{y_{t+1}^N}{y_t^N}\pi_{t+1}^N(1+\pi_{t+1}^N)\right] \tag{B.16}$$

where $1+\pi_t^N \equiv P_t^N/P_{t-1}^N$ denote the inflation rate in the non-tradable sector. Notice also that, given the labor subsidy, $\frac{\varepsilon(1-\tau^n)}{\varepsilon-1} = 1$.