The Paradox of Global Thrift

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Abstract

This paper describes a *paradox of global thrift.* Consider a world in which interest rates are low and monetary policy is frequently constrained by the zero lower bound. Now imagine that governments implement prudential financial and fiscal policies, aiming at increasing national savings in good times to sustain aggregate demand and employment during busts. We show that these policies, while effective from the perspective of individual countries, might backfire if applied on a global scale. The reason is that prudential policies by booming countries generate a rise in the global supply of savings or, equivalently, a fall in global aggregate demand. In turn, weaker global aggregate demand exacerbates the recession in countries currently stuck in a liquidity trap. Therefore, paradoxically, the world might very well experience a fall in employment and output following the implementation of prudential policies.

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1 Introduction

The current state of the global economy is characterized by exceptionally low nominal interest rates. In recent years, in fact, policy rates have hit the zero lower bound in most advanced countries (Figure 1, left panel). Against this background, a consensus is emerging suggesting that monetary policy, which is expected to be frequently constrained by the zero lower bound in the years to come, should be complemented with prudential financial and fiscal policies. Limiting private and public debt accumulation during booms, the argument goes, will help stabilize the economy, respectively by reducing the risk of financial crises and by creating space for fiscal interventions during busts.[1]

But what happens if prudential policies are implemented on a global scale? In this paper we show that, as a result, the world can fall prey of a *paradox of global thrift*. Consider a world in which interest rates are low and monetary policy is frequently constrained by the zero lower bound. Now imagine that governments implement prudential financial and fiscal policies, aiming at increasing national savings in good times to sustain national wealth, aggregate demand and employment during busts. In a financially integrated world, these policy interventions generate a rise in the global supply of savings or, equivalently, a fall in global aggregate demand. In turn, weaker global aggregate demand exacerbates the recession in countries currently stuck in a liquidity trap. Therefore, paradoxically, the world might very well experience a fall in employment and output following the implementation of prudential policies.

To formalize this insight, we develop a tractable framework of an imperfectly financially integrated world, in which equilibrium interest rates are low and monetary policy is occasionally constrained by the zero lower bound. We study a world composed of a continuum of small open economies. Countries are hit by uninsurable idiosyncratic shocks. Because of this feature, there is heterogeneity in the demand and supply of savings across countries, and foreign borrowing and lending emerge naturally.

Due to the presence of nominal rigidities, monetary policy plays an active role in stabilizing the economy. In fact, when a country experiences a fall in aggregate demand triggered by a negative shock, the domestic interest rate has to fall to keep the economy at full employment. The zero lower bound, however, might prevent monetary policy from fully offsetting the impact of negative demand shocks on output. Indeed, if global rates are sufficiently low, the world can be stuck in a *global liquidity trap*. This is a situation in which a significant fraction of the world economy experiences a liquidity trap with unemployment. Importantly, because of the presence of idiosyncratic shocks, during a global liquidity trap not all countries need to be constrained by the zero lower bound and experience a recession. Moreover, even among those countries stuck in a liquidity trap there is asymmetry in terms of the severity of the recession. The model thus captures situations such as the asymmetric recovery that has characterized advanced countries in the aftermath of the 2008 financial crisis (Figure 1, right panel). Moreover, a global liquidity trap

[1] These arguments have been formalized in two seminal papers by Farhi and Werning (2016) and Korinek and Simsek (2016). In this literature, which we describe in detail later on, the need for government intervention arises due to an aggregate demand externality, caused by the fact that atomistic agents do not internalize the impact of their financial decisions on aggregate spending and income.

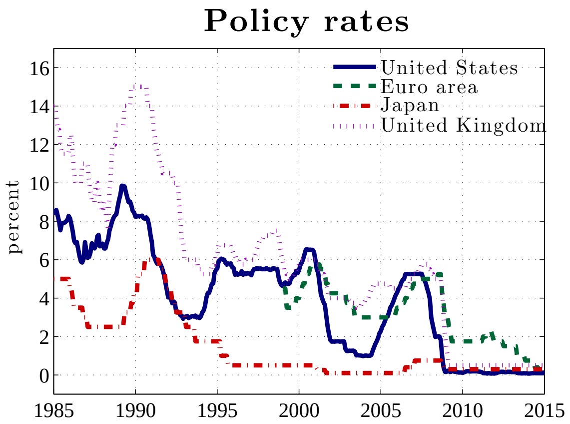

Figure 1: Policy rates and real gross domestic product per capita. Note: the left panel shows the exceptionally low interest rates characterizing the post-2008 period. The right panel highlights the relatively fast recoveries from the 2009 recession experienced by the US and Japan, and the slow recovery in the Euro area and in the United Kingdom. The figure also shows the heterogeneity between fast-recovering core Euro area countries, captured by Germany, and the stagnation experienced by peripheral Euro area countries, captured by Spain. See Appendix *E* for data sources.

can persist for an arbitrarily long time, in line with the notion of secular stagnation described by Hansen (1939) and Summers (2016).[2]

We first show that, during a global liquidity trap, governments have an incentive to run countercyclical prudential policies. This is due to the same domestic aggregate demand externality described by Farhi and Werning (2016) and Korinek and Simsek (2016). In fact, governments perceive that private agents save too little in times of robust economic performance, because they do not internalize the impact that their saving decisions will have on aggregate employment and income in the event of a future liquidity trap. Hence, governments in booming countries implement policies to increase national savings and current account surpluses beyond what private agents would choose under laissez-faire.

The key insight of the paper is that these policy interventions might trigger a paradox of global thrift, which is essentially an international, and policy-induced, version of Keynes' paradox of thrift (Keynes, 1933). By stimulating national savings and current account surpluses, governments in countries undergoing a period of robust economic performance increase the global supply of savings, depressing aggregate demand around the world. Central bank in countries stuck in a liquidity trap, however, cannot respond to the drop in global demand by lowering their policy rate. As a consequence, the implementation of prudential policies by booming countries aggravates the recession in countries experiencing a liquidity trap. Hence, prudential policy interventions might end up, paradoxically, exacerbating the global liquidity trap rather than mitigating it.

This result sounds a note of caution on the use of prudential policies as stabilization tools during periods of weak global aggregate demand. More precisely, in our analysis it is the lack of international coordination that can give rise to the paradox of global thrift. Key to our results,

[2]Both authors refer to a state of secular stagnation as characterized by low global interest rates, and by countries undergoing long-lasting liquidity traps, followed by fragile recoveries.

indeed, is the fact that governments in booming countries do not take into account the negative effects that policies fostering their national savings and current account surpluses have on countries stuck in a liquidity trap. Our analysis, which resonates with the logic of Keynes' Plan of 1941, thus suggests that during a global liquidity trap international cooperation is needed, to ensure that current account interventions by booming countries do not impart excessive negative spillovers on the rest of the world.[3]

Related literature. This paper is related to three literatures. First, the paper contributes to the emerging literature on secular stagnation in open economies (Caballero et al., 2015; Eggertsson et al., 2016). As in this literature, we study a world trapped in a global liquidity trap. This is a persistent, or even permanent, state of affairs in which global rates are extraordinarily low and countries are frequently constrained by the zero lower bound. Both Caballero et al. (2015) and Eggertsson et al. (2016) study two-country overlapping generations models, in which interest rates are low because of a global shortage of safe assets. Instead, a distinctive feature of our framework is that the shortage of safe assets driving down global rates emerges from countries' demand for precautionary savings against idiosyncratic risk. This allows us to study precautionary policies, which neither Caballero et al. (2015) nor Eggertsson et al. (2016) consider, that is policy interventions that governments implement during booms to mitigate future liquidity traps.

The paper is also related to the literature on deleveraging and liquidity traps. Eggertsson and Krugman (2012) and Guerrieri and Lorenzoni (2011) show that in closed economies deleveraging generates a drop in aggregate demand that can give rise to a recessionary liquidity trap. Benigno and Romei (2014) and Fornaro (2012) study deleveraging and liquidity traps in open economies. Building on these positive contributions, Farhi and Werning (2016) and Korinek and Simsek (2016) derive the optimal financial market interventions in closed or small open economies at risk of a liquidity trap following a deleveraging shock.[4] We contribute to this literature by showing that, under certain conditions, in a financially integrated world prudential policies can backfire and give rise to a paradox of global thrift.

Third, our paper is related to the vast literature on international policy cooperation. For instance, Obstfeld and Rogoff (2002) and Benigno and Benigno (2003, 2006) study international monetary policy cooperation in models with nominal rigidities. In these frameworks, the gains from cooperation arise because individual countries have an incentive to manipulate their terms of trade at the expenses of the rest of the world. Similarly, Acharya and Bengui (2016) show that terms of trade externalities create gains from international policy cooperation during a temporary liquidity trap. In our framework, terms of trade are constant and independent of government policy, and hence terms of trade externalities are absent. Thus, our results show that aggregate demand externalities can, on their own, create gains from international policy cooperation during a global liquidity trap. Sergeyev (2016) studies optimal monetary and financial policy in a monetary

[3] Chapter 4 of Eichengreen (2008) and chapter 7 of Temin and Vines (2014) are two excellent sources on Keynes' Plan of 1941. In a nutshell, Keynes envisaged the need for international rules to contain excessive current account surpluses by booming countries, on the ground that these surpluses would depress global demand.

[4] Farhi and Werning (2012a,b, 2014) and Schmitt-Grohé and Uribe (2015) study optimal financial market interventions when the constraint on monetary policy is due to fixed exchange rates.

union, and shows that gains from international cooperation arise because individual countries do not internalize the impact of liquidity creation by the domestic banking sector on the rest of the world. His analysis, however, abstracts from the zero lower bound, which is the source of gains from cooperation in our framework.

The rest of the paper is composed by five sections. Section 2 presents a simple baseline framework of an imperfectly financially integrated world with nominal rigidities. In Section 3 we characterize the laissez-faire equilibrium, and derive conditions under which the world ends up being stuck in a global liquidity trap. We then introduce, in Section 4, prudential policies and describe the paradox of global thrift. In Section 5 we present an extended model and perform a numerical analysis. Section 6 concludes.

2 Baseline model

In this section we present a stylized model that delivers transparently the key message of the paper. As we will show in Section 5, the intuitions from this simple model carry through to the extended framework that we use for numerical analysis.

We consider a world composed of a continuum of measure one of small open economies indexed by $i \in [0, 1]$. Each economy can be thought of as a country. Time is discrete and indexed by $t \in \{0, 1, ...\}$. Since the presence of risk is not crucial for our results, in our baseline model there is perfect foresight. We introduce uncertainty later on in Section 5.

2.1 Households

Each country is populated by a continuum of measure one of identical infinitely lived households. The lifetime utility of the representative household in a generic country i is

$$\sum_{t=0}^{\infty} \beta^t \log(C_{i,t}), \tag{1}$$

where $C_{i,t}$ denotes consumption and $0 < \beta < 1$ is the subjective discount factor. Consumption is a Cobb-Douglas aggregate of a tradable good $C_{i,t}^T$ and a non-tradable good $C_{i,t}^N$, so that $C_{i,t} = (C_{i,t}^T)^\omega (C_{i,t}^N)^{1-\omega}$ where $0 < \omega < 1$.

Each household is endowed with one unit of labor. There is no disutility from working, and so households supply inelastically their unit of labor on the labor market. However, due to the presence of nominal wage rigidities to be described below, a household might be able to sell only $L_{i,t} < 1$ units of labor. Hence, when $L_{i,t} = 1$ the economy operates at full employment, while when $L_{i,t} < 1$ there is involuntary unemployment and the economy operates below capacity.

Households can trade in one-period real and nominal bonds. Real bonds are denominated in units of the tradable consumption good and pay the gross interest rate R_t. The interest rate on real bonds is common across countries, and R_t can be interpreted as the *world interest rate.* Nominal bonds are denominated in units of the domestic currency and pay the gross nominal interest rate

$R^n_{i,t}$. $R^n_{i,t}$ is the interest rate controlled by the central bank, and thus can be thought of as the domestic policy rate.[5]

The household budget constraint in terms of the domestic currency is

$$P^T_{i,t}C^T_{i,t} + P^N_{i,t}C^N_{i,t} + P^T_{i,t}B_{i,t+1} + B^n_{i,t+1} = W_{i,t}L_{i,t} + P^T_{i,t}Y^T_{i,t} + P^T_{i,t}R_{t-1}B_{i,t} + R^n_{i,t-1}B^n_{i,t}. \quad (2)$$

The left-hand side of this expression represents the household's expenditure. $P^T_{i,t}$ and $P^N_{i,t}$ denote respectively the price of a unit of tradable and non-tradable good in terms of country i currency. Hence, $P^T_{i,t}C^T_{i,t} + P^N_{i,t}C^N_{i,t}$ is the total nominal expenditure in consumption. $B_{i,t+1}$ and $B^n_{i,t+1}$ denote respectively the purchase of real and nominal bonds made by the household at time t. If $B_{i,t+1} < 0$ or $B^n_{i,t+1} < 0$ the household is holding a debt.

The right-hand side captures the household's income. $W_{i,t}$ denotes the nominal wage, and hence $W_{i,t}L_{i,t}$ is the household's labor income. Labor is immobile across countries and so wages are country-specific. $Y^T_{i,t}$ is an endowment of tradable goods received by the household. Changes in $Y^T_{i,t}$ can be interpreted as movements in the quantity of tradable goods available in the economy, or as shocks to the country's terms of trade. $P^T_{i,t}R_{t-1}B_{i,t}$ and $R^n_{i,t-1}B^n_{i,t}$ represent the gross returns on investment in bonds made at time $t-1$.

There is a limit to the amount of debt that a household can take. In particular, the end-of-period bond position has to satisfy

$$B_{i,t+1} + \frac{B^n_{i,t+1}}{P^T_{i,t}} \geq -\kappa_{i,t}, \quad (3)$$

where $\kappa_{i,t} > 0$. In words, the maximum amount of debt that a household can take is equal to $\kappa_{i,t}$ units of tradable goods.

The household's optimization problem consists in choosing a sequence $\{C^T_{i,t}, C^N_{i,t}, B_{i,t+1}, B^n_{i,t+1}\}_t$ to maximize lifetime utility (1), subject to the budget constraint (2) and the borrowing limit (3), taking initial wealth $P^T_0 R_{-1}B_{i,0} + R^n_{i,-1}B^n_{i,0}$, a sequence for income $\{W_{i,t}L_{i,t} + P^T_{i,t}Y^T_{i,t}\}_t$, and prices $\{R_t, R^n_{i,t}, P^T_{i,t}, P^N_{i,t}\}_t$ as given. The household's first-order conditions can be written as

$$\frac{\omega}{C^T_{i,t}} = R_t \frac{\beta\omega}{C^T_{i,t+1}} + \mu_{i,t} \quad (4)$$

$$\frac{\omega}{C^T_{i,t}} = \frac{R^n_{i,t}P^T_{i,t}}{P^T_{i,t+1}} \frac{\beta\omega}{C^T_{i,t+1}} + \mu_{i,t} \quad (5)$$

$$B_{i,t+1} + \frac{B^n_{i,t+1}}{P^T_{i,t}} \geq -\kappa_{i,t} \quad \text{with equality if} \quad \mu_{i,t} > 0 \quad (6)$$

$$C^N_{i,t} = \frac{1-\omega}{\omega} \frac{P^T_{i,t}}{P^N_{i,t}} C^T_{i,t}, \quad (7)$$

[5] Alternatively, we could allow households to trade nominal bonds denominated in foreign currencies. Given the structure of the economy, however, allowing households to trade foreign nominal bonds would not affect the equilibrium allocation of the baseline model.

where $\mu_{i,t}$ is the nonnegative Lagrange multiplier associated with the borrowing constraint. Equations (4) and (5) are the Euler equations for, respectively, real and nominal bonds. Equation (6) is the complementary slackness condition associated with the borrowing constraint. Equation (7) determines the optimal allocation of consumption expenditure between tradable and non-tradable goods. Naturally, demand for non-tradables is decreasing in their relative price $P^N_{i,t}/P^T_{i,t}$. Moreover, demand for non-tradables is increasing in $C^T_{i,t}$, due to households' desire to consume a balanced basket between tradable and non-tradable goods.

2.2 Exchange rates, interest rates and aggregate demand

In our model, monetary policy affects the real economy through its impact on households' expenditure on non-tradable goods.[6] Before moving on, it is then useful to illustrate the channels through which the policy rate and the world interest rate affect demand for non-tradable goods.

Let us start by establishing a link between demand for non-tradables and the exchange rate. Since the law of one price holds for the tradable good we have that[7]

$$P^T_{i,t} = S_{i,t} P^T_t, \tag{8}$$

where $P^T_t \equiv \exp\left(\int_0^1 \log P^T_{j,t} dj\right)$ is the average world price of tradables, while $S_{i,t}$ is the effective nominal exchange rate of country i, defined so that an increase in $S_{i,t}$ corresponds to a nominal depreciation.

To gain intuition, let us now keep $P^N_{i,t}$ and P^T_t constant, so that the nominal and the real exchange rate, given by $P^N_{i,t}/(S_{i,t}P^T_t)$, move together. Then equations (7) and (8) jointly imply that an exchange rate depreciation increases demand for the non-tradable good. Intuitively, when the exchange rate depreciates the relative price of non-tradables falls, inducing households to switch expenditure away from tradable goods and toward non-tradable goods.

We now relate the exchange rate to the policy and the world interest rates. Combining (4) and (5) gives a no arbitrage condition between real and nominal bonds

$$R^n_{i,t} = R_t \frac{P^T_{i,t+1}}{P^T_{i,t}}. \tag{9}$$

This is a standard uncovered interest parity condition, equating the nominal interest rate to the real interest rate multiplied by expected inflation. Since real bonds are denominated in units of the tradable good, the relevant inflation rate is tradable price inflation. Combining this expression

[6] Instead, our model abstracts from the impact that monetary policy might have on the terms of trade. Recent research by GOPINATH suggests that these effects are small.

[7] To derive this expression, consider that by the law of one price it must be that $P^T_{i,t} = S^j_{i,t} P^T_{j,t}$. for any i and j, where $S^j_{i,t}$ is defined as the nominal exchange rate between country i's and j's currencies, that is the units of country i's currency needed to buy one unit of country j's currency. Taking logs and integrating across j gives $P^T_{i,t} = S_{i,t} P^T_t$, where $S_{i,t} \equiv \exp\left(\int_0^1 \log S^j_{i,t} dj\right)$ and $P^T_t \equiv \exp\left(\int_0^1 \log P^T_{j,t} dj\right)$.

with (8) gives

$$R_{i,t}^n = R_t \frac{S_{i,t+1}}{S_{i,t}} \frac{P_{t+1}^T}{P_t^T}.$$

Taking everything else as given, this expression implies that a drop in $R_{i,t}^n$ produces a rise in $S_{i,t}$. In words, a fall in the policy rate leads to an exchange rate depreciation, which induces households to switch expenditure out of tradable goods and toward non-tradables. Through this channel, a cut in the policy rate boosts demand for non-tradable goods. Conversely, a fall in the world interest rate R_t generates an exchange rate appreciation which, due to its expenditure switching effect, depresses demand for non-tradables.

To capture these effects more compactly, it is useful to combine (7) and (9) into a single aggregate demand (AD) equation

$$C_{i,t}^N = \frac{R_t \pi_{i,t+1}}{R_{i,t}^n} \frac{C_{i,t}^T}{C_{i,t+1}^T} C_{i,t+1}^N, \tag{AD}$$

where $\pi_{i,t} \equiv P_{i,t}^N / P_{i,t-1}^N$. This expression is essentially an open-economy version of the New-Keynesian aggregate demand block. As in the standard closed-economy New-Keynesian model, demand for non-tradable consumption is decreasing in the real interest rate $R_{i,t}^n / \pi_{i,t+1}$ and increasing in future non-tradable consumption $C_{i,t+1}^N$. In addition, changes in the consumption of tradable goods act as demand shifters. As already explained, a higher current consumption of tradable goods increases the current demand for non-tradables. Instead, a higher future consumption of tradables induces households to postpone their non-tradable consumption, thus depressing current demand for non-tradable goods. Finally, due to the expenditure switching effect just discussed, a lower world interest rate is associated with lower demand for non-tradable consumption.

2.3 Firms and nominal rigidities

Non-traded output $Y_{i,t}^N$ is produced by a large number of competitive firms. Labor is the only factor of production, and the production function is $Y_{i,t}^N = L_{i,t}$. Profits are given by $P_{i,t}^N Y_{i,t}^N - W_{i,t} L_{i,t}$, and the zero profit condition implies that in equilibrium $P_{i,t}^N = W_{i,t}$.

We introduce nominal rigidities by assuming, in the spirit of Akerlof et al. (1996), that nominal wages are subject to the downward rigidity constraint

$$W_{i,t} \geq \gamma W_{i,t-1},$$

where $\gamma > 0$. This formulation captures in a simple way the presence of frictions to the downward adjustment of nominal wages, which might prevent the labor market from clearing. In fact, equilibrium on the labor market is captured by the condition

$$L_{i,t} \leq 1, \quad W_{i,t} \geq \gamma W_{i,t-1} \quad \text{with complementary slackness.} \tag{10}$$

This condition implies that unemployment arises only if the constraint on wage adjustment binds.[8]

2.4 Monetary policy and inflation

We describe monetary policy in terms of targeting rules. In particular, we consider central banks that target inflation of the domestically produced good. More formally, the objective of the central bank is to set $\pi_{i,t} = \bar{\pi}$. Throughout the paper we focus on the case $\bar{\pi} > \gamma$, so that when the inflation target is attained the economy operates at full employment ($\pi_{i,t} = \bar{\pi} \rightarrow L_{i,t} = 1$). Hence, monetary policy faces no conflict between stabilizing inflation and attaining full employment, thus mimicking the divine coincidence typical of the baseline New Keynesian model (Blanchard and Galí, 2007).[9]

The central bank runs monetary policy by setting the nominal interest rate $R_{i,t}^n$, subject to the zero lower bound constraint $R_{i,t}^n \geq 1$.[10] Monetary policy can then be captured by the following monetary policy (MP) rule[11]

$$R_{i,t}^n = \begin{cases} \geq 1 & \text{if } Y_{i,t}^N = 1, \pi_{i,t} = \bar{\pi} \\ = 1 & \text{if } Y_{i,t}^N < 1, \pi_{i,t} = \gamma, \end{cases} \tag{MP}$$

where we have used (10) and the equilibrium relationships $W_{i,t} = P_{i,t}^N$ and $L_{i,t} = Y_{i,t}^N$. The (MP) equation captures the fact that unemployment ($Y_{i,t}^N < 1$) arises only if the central bank is constrained by the zero lower bound ($R_{i,t}^n = 1$). As we show in Appendix *D*, this policy is also constrained efficient as long as the central bank operates under discretion, and faces an arbitrarily small cost from deviating from its inflation target.[12]

[8] This form of wage rigidity gives rise to a non-linear wage Phillips curve. For values of wage inflation lower than γ the relationship between wage inflation and employment is vertical. Instead, in presence of unemployment the wage Phillips curve becomes horizontal. It would be easy to allow for an upward-sloped wage Phillips curve. For instance, one could assume that

$$W_{i,t} \geq \tilde{\gamma}(L_{i,t})W_{i,t-1},$$

where $\tilde{\gamma}'(\cdot) \geq 0$, to capture a setting in which wages are more downwardly flexible the lower employment. For simplicity, in our baseline model we focus on the special case $\tilde{\gamma}'(\cdot) = 0$, but our results readily extend to the more general case $\tilde{\gamma}'(\cdot) \geq 0$.

[9] Since only the non-tradable good is produced, we are in practice assuming that the central bank follows a policy of producer price inflation targeting. This is a common assumption in the open economy monetary literature. Another option is to consider a central bank that targets consumer price inflation. We have experimented with this possibility, and found that the results are robust to this alternative monetary policy target. The analysis is available upon request.

[10] We provide in appendix *C* some possible microfoundations for this constraint. In practice, the lower bound on the nominal interest rate is likely to be slightly negative. In this paper, with a slight abuse of language, we will refer the the lower bound on $R_{i,t}^n$ as the zero lower bound. It should be clear, though, that conceptually it makes no difference between a small positive or a small negative lower bound.

[11] One could think of the central bank as setting $R_{i,t}^n$ according to the rule

$$R_{i,t}^n = \max\left(\bar{R}_{i,t}^n \left(\frac{\pi_{i,t}}{\bar{\pi}}\right)^{\phi_\pi}, 1\right),$$

where $\bar{R}_{i,t}^n$ is the value of $R_{i,t}^n$ consistent with $\pi_{i,t} = \bar{\pi}$. In the baseline model we focus on the limit $\phi_\pi \rightarrow \infty$. This means that the inflation target can be missed only if the zero lower bound constraint binds.

[12] Deviating from the inflation target could be costly for the central bank due to institutional reasons, capturing the price stability mandate characterizing central banks in most advanced countries. Alternatively one could assume, as in the standard New Keynesian model, that deviations of inflation from target are costly because they distort

It turns out that changes in inflation do not play any major role in our analysis. Hence, in what follows we will focus on the constant-inflation limit $\bar{\pi} \rightarrow \gamma$. This corresponds to an extremely flat Phillips curve, such that changes in unemployment do not significantly affect inflation. While this assumption is by no mean crucial for our results, it allows to streamline the exposition and simplifies the derivation of some of the results that follow.

2.5 Market clearing and definition of competitive equilibrium

Since households inside a country are identical, we can interpret equilibrium quantities as either household or country specific. For instance, the end-of-period net foreign asset position of country i is equal to the end-of-period holdings of bonds of the representative household, $NFA_{i,t} = B_{i,t+1} + B^n_{i,t+1}/P^T_{i,t}$. Throughout, we focus on equilibria in which nominal bonds are in zero net supply, so that

$$B^n_{i,t} = 0, \tag{11}$$

for all i and t. This implies that the net foreign asset position of a country is exactly equal to its investment in real bonds, i.e. $NFA_{i,t} = B_{i,t+1}$.

Market clearing for the non-tradable consumption good requires that in every country consumption is equal to production

$$C^N_{i,t} = Y^N_{i,t}. \tag{12}$$

Instead, market clearing for the tradable consumption good requires

$$C^T_{i,t} = Y^T_{i,t} + R_{t-1}B_{i,t} - B_{i,t+1}. \tag{13}$$

This expression can be rearranged to obtain the law of motion for the stock of net foreign assets owned by country i, i.e. the current account

$$NFA_{i,t} - NFA_{i,t-1} = CA_{i,t} = Y^T_{i,t} - C^T_{i,t} + B_{i,t}\left(R_{t-1} - 1\right).$$

As usual, the current account is given by the sum of net exports, $Y^T_{i,t} - C^T_{i,t}$, and net interest payments on the stock of net foreign assets owned by the country at the start of the period, $B_{i,t}(R_{t-1} - 1)$.

Finally, in every period the world consumption of the tradable good has to be equal to world production, $\int_0^1 C^T_{i,t}\,\mathrm{d}i = \int_0^1 Y^T_{i,t}\,\mathrm{d}i$. This equilibrium condition implies that bonds are in zero net supply at the world level

$$\int_0^1 B_{i,t+1}\,\mathrm{d}i = 0. \tag{14}$$

We are now ready to define a competitive equilibrium.

Definition 1 ***Competitive equilibrium.*** *A competitive equilibrium is a path of real allocations* $\{C^T_{i,t}, C^N_{i,t}, Y^N_{i,t}, B_{i,t+1}, B^n_{i,t+1}, \mu_{i,t}\}_{i,t}$*, policy rates* $\{R^n_{i,t}\}_{i,t}$ *and world interest rate* $\{R_t\}_t$*, satisfying*

relative prices.

(4), (6), (11), (12), (13), (14), (AD) *and* (MP) *given a path of endowments* $\{Y_{i,t}^T\}_{i,t}$, *a path for the borrowing limits* $\{\kappa_{i,t}\}_{i,t}$, *and initial conditions* $\{B_{i,0}\}_i$.

2.6 Some useful simplifying assumptions

We now make some simplifying assumptions that allow us to solve analytically the baseline model. We will relax these assumptions in Section 5, where we perform a numerical analysis.

We want to consider a world in which the global supply of saving instruments is limited, and in which borrowing constraints are tight. The simplest way to formalize this idea is to focus on the limit $\kappa_{i,t} = \kappa \to 0$ for all i and t, so that households cannot take any (significant amount of) debt. This corresponds to a zero liquidity economy, in the spirit of Werning (2015). Later on, in Section **??**, we will relax this assumption and allow households to take some debt.

We also focus on a specific process for the tradable endowment. We consider a case in which there are two possible realizations of the tradable endowment: high (Y_h^T) and low (Y_l^T) with $Y_l^T < Y_h^T$. We assume that half of the countries receives Y_h^T in even periods and Y_l^T in odd periods. Symmetrically, the other half receives Y_l^T during even periods and Y_h^T during odd periods. From now on, we will say that a country with $Y_{i,t}^T = Y_h^T$ is in the high state, while a country with $Y_{i,t}^T = Y_l^T$ is in the low state. This endowment process captures in a tractable way an environment in which countries are hit by asymmetric shocks.

Finally, we are interested in studying stationary equilibria in which the world interest rate and the net foreign asset distribution are constant. As we will see, this requires that the initial bond position satisfies $B_{i,0} \approx 0$ for every country i, which we assume throughout our analysis of the baseline model. Moreover, we focus on equilibria in which all the countries with the same endowment shock behave symmetrically. Hence, with a slight abuse of notation, we will sometime omit the i subscripts, and denote with a h (l) subscript variables pertaining to countries in the high (low) state.

3 Equilibrium under laissez faire

We start by characterizing the equilibrium under laissez faire. This will serve as a benchmark against which to contrast the equilibrium with government intervention through fiscal and financial policy. We start by solving for the behavior of a single small open economy, taking the world interest rate as given. We then turn to the global equilibrium, in which the world interest rate is endogenously determined.

3.1 Small open economy

To streamline the exposition, we impose some restrictions on the world interest rate. We will later show that these restrictions emerge naturally in the global equilibrium.

Assumption 1 *The world interest rate is constant* ($R_t = R$ *for all* t) *and satisfies* $\beta R < 1$.

Solving for the path of tradable consumption is straightforward. Intuitively, households smooth tradable consumption by saving in the high state, when the endowment is high, and borrowing in the low state, when the endowment is low. More precisely, from period 0 on, the economy enters a stationary equilibrium in which households purchase $B_{h,t+1} = B_h \geq -\kappa \approx 0$ bonds in the high state, while the borrowing constraint binds in the low state, so that $B_{l,t+1} = B_l = -\kappa \approx 0$.The Euler equation (4) in the high state then implies

$$\frac{1}{C_h^T} \geq \beta R \frac{1}{C_l^T}, \tag{15}$$

where we have removed the time subscripts to simplify the notation. Combining this expression with the resource constraint (13) and using $B_l = 0$ gives the optimal demand for bonds in the high state

$$B_h = \max\left\{\frac{\beta}{1+\beta}\left(Y_h^T - \frac{Y_l^T}{\beta R}\right), -\kappa\right\}, \tag{16}$$

From this expression it is then easy to solve for C_l^T and C_h^T using

$$C_h^T = Y_h^T - B_h \tag{17}$$

$$C_l^T = Y_l^T + RB_h. \tag{18}$$

Notice that, since $\beta R < 1$ and $Y_h^T > Y_l^T$, the equilibrium is such that $C_h^T > C_l^T$. Hence, fluctuations in the endowment translate into fluctuations in the consumption of tradable goods.

We now turn to the market for non-tradable goods. Equilibrium on this market is reached at the intersection of the (AD) and (MP) equations, which we rewrite here for convenience[13]

$$Y_{i,t}^N = \frac{R\pi_{i,t+1}}{R_{i,t}^n} \frac{C_{i,t}^T}{C_{i,t+1}^T} Y_{i,t+1}^N. \tag{AD}$$

$$R_{i,t}^n = \begin{cases} \geq 1 & \text{if } Y_{i,t}^N = 1 \\ = 1 & \text{if } Y_{i,t}^N < 1 \end{cases} \tag{MP}$$

where we have used the equilibrium condition $C_{i,t}^N = Y_{i,t}^N$. Let us start by taking a partial equilibrium approach, i.e. by deriving the equilibrium holding future variables constant. Figure 2 shows the AD and MP curves in the $R_{i,t}^n - Y_{i,t}^N$ space. The AD curve captures the negative relationship between aggregate demand and the policy rate, while the L-shape of the MP curve captures the aggressive response of the central bank to unemployment. In the left panel, we have drawn two AD curves. The AD$_h$ curve refers to demand in the high state, while AD$_l$ captures demand in the low state. The diagram shows that changes in tradable consumption act as demand shifters, so that aggregate demand is lower in the low state compared to the high state. Hence, when the economy transitions from the high to the low state the central bank decreases the policy rate to

[13]Recall that we are focusing on the limit $\bar{\pi} \to \gamma$.

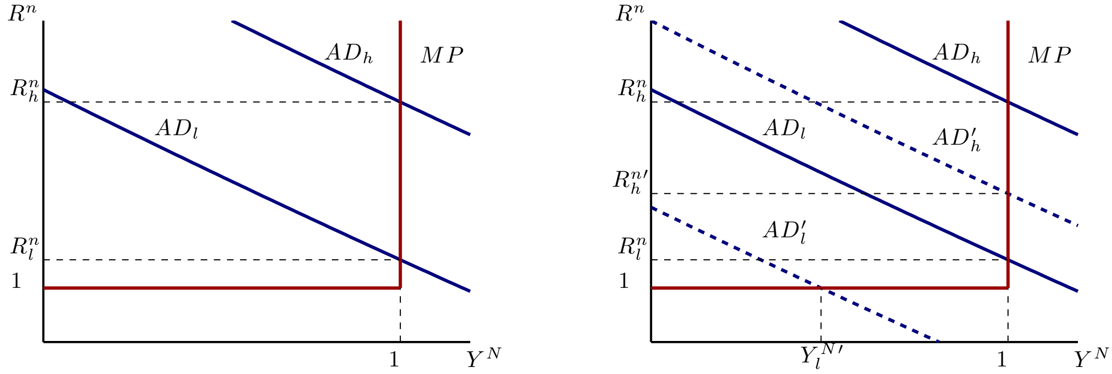

Figure 2: Equilibrium on market for non-tradables. Right panel: high R (solid lines) vs. low R (dashed lines).

sustain aggregate demand.

The right panel of the figure shows how the equilibrium is affected by changes in the world interest rate R. The solid lines capture a world in which R is high. In this case, aggregate demand is sufficiently strong for the economy to operate at full employment in both states. Instead, the dashed lines refer to a low R world. In this case, in the low state aggregate demand is so weak that monetary policy is constrained by the zero lower bound and the economy experiences unemployment.

It turns out that the insights of the partial equilibrium analysis extend to the general equilibrium. We summarize these results in the following proposition.

Assumption 2 *The inflation target* $\bar{\pi}$ *and the world interest rate* R *are such that* $R\bar{\pi} > 1$.

Proposition 1 ***Small open economy under laissez faire.*** *There exists a threshold* R^**, such that if* $R \geq R^*$ *then* $Y^N_h = Y^N_l = 1$*, otherwise* $Y^N_h = 1$ *and* $Y^N_l = R\bar{\pi} \max\left(\beta R, Y^T_l / Y^T_h\right) < 1$. R^* *solves* $R^* \bar{\pi} \max\left(\beta R^*, Y^T_l / Y^T_h\right) = 1$.

Proof. See Appendix *B*.1. ■

Proposition 1 states that there exists a threshold R^* for the world interest rate, such that if $R \geq R^*$ the economy always operates at full employment. Instead, if $R < R^*$ aggregate demand in the high state is strong enough to guarantee full employment, while in the low state aggregate demand is sufficiently weak so that monetary policy is constrained by the zero lower bound and unemployment arises. The role of Assumption 2 is to guarantee that demand in the high state is always strong enough so that $Y^N_h = 1$. While in principle one could imagine a case in which liquidity traps have infinite duration, here we restrict attention to the, more traditional, case in which liquidity traps are temporary.

3.2 Global equilibrium

We now solve for the global equilibrium. In a global equilibrium the world bond market has to clear, so that (14) holds. Bonds are supplied by countries in the low state. These countries are against the borrowing constraint, and hence the supply of bonds is $-B_l = -\kappa \approx 0$. Demand for bonds comes from countries in the high state and is given by B_h. The world bond market then clear when $B_h = -B_l = \kappa \approx 0$. In words, our focus on a zero liquidity economy implies that for any country equilibrium savings have to be (approximately) equal to zero. Hence, in a global equilibrium the allocation of tradable consumption corresponds to the financial autarky one, so that every country consumes exactly its endowment ($C_h^T = Y_h^T$, $C_l^T = Y_l^T$).

The equilibrium world interest rate must be such that countries in the high state do not want to borrow or save.[14] The value of the equilibrium world interest rate can then be found by substituting $C_h^T = Y_h^T$ and $C_l^T = Y_l^T$ in (15) holding with equality

$$R = \frac{Y_l^T}{\beta Y_h^T} \equiv R^{lf}, \tag{19}$$

where the superscript lf stands for *laissez faire*. Expression (19) relates the world interest rate to the fundamentals of the economy. Naturally, a higher discount factor β leads to a higher demand for bonds by saving countries, and thus to a lower world interest rate. Moreover, the world interest rate is decreasing in Y_h^T/Y_l^T, because a higher distance between the two realizations of the endowment increases the desire to save to smooth consumption for countries in the high state. Notice that the equilibrium interest rate satisfies $\beta R < 1$, consistent with Assumption 1. We collect these results in the following lemma.

Lemma 1 ***Global equilibrium under laissez faire.*** *In a global equilibrium $C_{h,t}^T = Y_h^T$, $C_{l,t}^T = Y_l^T$. Under laissez faire the equilibrium world interest rate is $R_t = Y_l^T/(\beta Y_h^T) \equiv R^{lf} < 1/\beta$ for all t.*

Depending on fundamentals, R^{lf} might be greater or smaller than R^*, the threshold world interest rate below which the zero lower bound binds for countries in the low state.[15] We think of the case $R^{lf} < R^*$ as capturing a world trapped in a global liquidity trap. In such a world, global aggregate demand is weak and countries hit by negative shocks experience liquidity traps with unemployment. Interestingly, this state of affair can persist for an arbitrarily long period of time, as long as the fundamentals of the global economy imply that $R^{lf} < R^*$. In this sense, the model captures in a simple way the salient features of a world undergoing a period of secular stagnation, in which interest rates are low and liquidity traps frequent (Summers, 2016).

4 Current account policies and the paradox of global thrift

Since there is no disutility from working, unemployment in our model is inefficient. Hence, governments have an incentive to implement policies that limit the incidence of liquidity traps on employment. For instance, a large literature has emphasized how raising expected inflation can

[14] In fact, if the borrowing constraint were to bind in the high state, all the countries in the world would want to borrow (albeit an infinitesimally small amount) preventing equilibrium from being reached.

[15] Precisely, $R^{lf} < R^*$ if $\bar{\pi} < \beta(Y_h^T/Y_l^T)^2$, otherwise $R^{lf} \geq R^*$.

mitigate the inefficiencies due to the zero lower bound. However, a robust conclusion of this literature is that, in presence of inflation costs, circumventing the zero lower bound by raising inflation expectations is not an option when the central bank lacks commitment (Eggertsson and Woodford, 2003).[16]

In this paper we take a different route and consider the role of policies that affect agents' saving and borrowing decisions, such as fiscal or financial policies, in stabilizing aggregate demand and employment. While these policies can take a variety of forms, their common trait is that they influence national savings and the country's current account, and hence we refer to them as *current account policies*. In practice, we implement the notion of current account policies by endowing governments with the power to choose directly their country's net foreign asset position and the path of tradable consumption, as long as these do not violate the resource constraint (13) and the borrowing limit (3).

Definition 2 ***Equilibrium with current account policy.*** *An equilibrium with current account policy is a path of real allocations* $\{C^T_{i,t}, C^N_{i,t}, Y^N_{i,t}, B_{i,t+1}, B^n_{i,t+1}\}_{i,t}$*, policy rates* $\{R^n_{i,t}\}_{i,t}$ *and world interest rate* $\{R_t\}_t$*, satisfying* (3)*,* (11)*,* (12)*,* (13)*,* (14)*,* (AD) *and* (MP) *given a path of endowments* $\{Y^T_{i,t}\}_{i,t}$*, a path for the borrowing limits* $\{\kappa_{i,t}\}_{i,t}$*, and initial conditions* $\{B_{i,0}\}_i$*.*

An equilibrium with current account policy has to satisfy all the conditions of a competitive equilibrium, except for the Euler equation (4). Crucially, even in presence of current account policies the market for non-tradable goods clears competitively, so that the (AD) and (MP) equations have to hold.

Notice that to derive that (AD) equation we have used the no arbitrage condition between real and nominal bonds. Hence, we are effectively assuming that governments cannot influence households' decision on how to allocate their savings between the two bonds. This assumption captures a world with a high degree of capital mobility, in which it is difficult for governments to discriminate, for instance through capital controls, between domestic and foreign assets.[17] This assumption resonates with the fact, documented by Ilzetzki et al. (2017), that capital controls have essentially been absent in advanced economies since the early 1990s.

4.1 Small open economy

Let us start by considering a single small open economy. To understand why a government might choose to intervene on the current account to stabilize employment, consider that, combining (AD) and (MP), output in the low state under laissez faire can be written as

$$Y^N_l = \min\left(R\bar{\pi}C^T_l/C^T_h, 1\right), \tag{20}$$

[16] As we prove in appendix D, this insight extends to our framework.

[17] OUR ANALYSIS IS COMPLEMENTARY TO See XX for analyses of capital control policies inspired by emerging markets experiences.

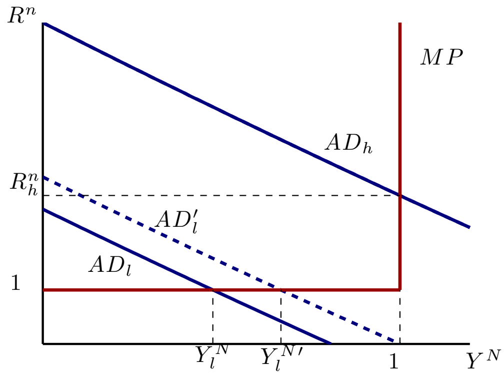

Figure 3: Response to increase in B_h. Solid lines refer to low B_h, dashed lines refer to high B_h.

where we have used the fact that Proposition 1 implies $Y_h^N = 1$. Now consider a case in which the zero lower bounds binds, so $Y_l^N < 1$ and output in the low state is demand determined. Imagine that the government implements a policy that leads to an increase in households' savings, and thus in the country's current account surplus, while the economy is booming, so that B_h increases. On the one hand, higher savings in the high state depress C_h^T. On the other hand, households now enter the low state with higher wealth and, since they are borrowing constrained, increase spending so that C_l^T rises. The net result is that C_l^T/C_h^T increases, boosting demand for non-tradables in the low state. In turn, since the central bank is constrained by the zero lower bound, higher demand for non-tradables leads to higher output and employment. Graphically, as illustrated by Figure 3, an increase in B_h makes the AD_l curve shift right to AD_l', and generates a rise in Y_l^N.[18] Notice that atomistic households, which take aggregate demand and employment as given, do not internalize the impact of tradable consumption decisions on production of non-tradable goods. As we will see, the presence of this *domestic aggregate demand externality* might lead governments to implement current account policies to influence private agents' saving and borrowing decisions.

4.1.1 National planner

How does a government optimally intervene on the current account? We address this question by taking the perspective of a national planner that designs current account policies to maximize domestic households' welfare.[19] Importantly, the national planner does not internalize the impact of its decisions on the rest of the world. Hence, the planning allocation that we consider corresponds to the non-cooperative optimal current account policy.

As it turns out, the planning allocation might differ depending on whether the planner operates under commitment or discretion. Rather than considering both cases, throughout the paper we restrict attention to a planner that lacks commitment. We make this choice because the existing literature has shown that, if the government operates under commitment, monetary policy alone

[18] One can show that in our baseline model, as long as $Y_l^N < 1$, changes in C_l^T/C_h^T do not alter aggregate demand in the high state, and hence the AD_h curve does not move after the increase in B_h.

[19] Later on, in Section 4.1.2, we show that a government can implement the planning allocation as part of a competitive equilibrium using some simple fiscal or financial policy instruments.

can mitigate substantially the inefficiencies due to the zero lower bound. This suggests that alternative policies, such as current account interventions, are most useful when the government operates under discretion.

Formally, we focus on Markov-stationary policy rules that are functions of the payoff-relevant state variables $(B_{i,t}, Y^T_{i,t})$ only. Since the planner operates under discretion, it chooses its policy rules in any given period taking as given the policy rules associated with future planner's decisions. A Markov-perfect equilibrium is then characterized by a fixed point in these policy rules. Intuitively, at this fixed point the current planner does not have an incentive to deviate from future planner's policy rules, so that these rules are time consistent. In what follows, we define $\mathcal{B}(B_{i,t}, Y^T_{i,t})$ as the policy rule for bond holdings of future planners, while $\{\mathcal{C}^T(B_{i,t}, Y^T_{i,t}), \mathcal{Y}_N(B_{i,t}, Y^T_{i,t})\}$ are the functions that return the values of the corresponding variables associated with the planners' policy rules.

The problem of the national planner in a generic country i can be represented as

$$V(B_{i,t}, Y^T_{i,t}) = \max_{C^T_{i,t}, Y^N_{i,t}, B_{i,t+1}} \omega \log C^T_{i,t} + (1-\omega) \log Y^N_{i,t} + \beta V(B_{i,t+1}, Y^T_{i,t+1}) \tag{21}$$

subject to

$$C^T_{i,t} = Y^T_{i,t} - B_{i,t+1} + RB_{i,t} \tag{22}$$

$$B_{i,t+1} \geq -\kappa_{i,t} \tag{23}$$

$$Y^N_{i,t} \leq 1 \tag{24}$$

$$Y^N_{i,t} \leq C^T_{i,t} R\bar{\pi} \frac{\mathcal{Y}^N(B_{i,t+1}, Y^T_{i,t+1})}{\mathcal{C}^T(B_{i,t+1}, Y^T_{i,t+1})}. \tag{25}$$

The resource constraints are captured by (22) and (24). (23) implies that the government is subject to the same borrowing constraint imposed by the markets on individual households.[20] Instead, constraint (25), which is obtained by combining the (AD) and (MP) equations, encapsulates the requirement that production of non-tradable goods is constrained by private sector's demand. The functions $\mathcal{C}^T(B_{i,t+1}, Y^T_{i,t+1})$ and $\mathcal{Y}^N(B_{i,t+1}, Y^T_{i,t+1})$ determine respectively consumption of tradable goods and production of non-tradable goods in period $t+1$ as a function of the country's stock of net foreign assets $(B_{i,t+1})$ and the endowment of tradables $(Y^T_{i,t+1})$ at the beginning of next period. Since the current planner cannot make credible commitments about its future actions, these variables are not into its direct control. However, the current planner can still influence these quantities through its choice of net foreign assets. In what follows, we focus on equilibria in which these functions are differentiable, and in which $\mathcal{C}^T(B_{i,t+1}, Y_{i,t+1})$ is non-decreasing in $B_{i,t+1}$.

Notice that, since each country is infinitesimally small, the domestic planner takes the world interest rate R as given. This feature of the planning problem encapsulates the lack of international coordination in the design of current account policies.

[20] To write this constraint we have used the equilibrium condition $B^n_{i,t+1} = 0$. It is straightforward to show that allowing the government to set $B^n_{i,t+1}$ optimally would not change any of the results.

The first order conditions of the planning problem can be written as

$$\bar{\lambda}_{i,t} = \frac{\omega}{C^T_{i,t}} + \bar{\upsilon}_{i,t}\frac{Y^N_{i,t}}{C^T_{i,t}} \tag{26}$$

$$\frac{1-\omega}{Y^N_{i,t}} = \bar{\nu}_{i,t} + \bar{\upsilon}_{i,t} \tag{27}$$

$$\bar{\lambda}_{i,t} = \beta R \bar{\lambda}_{i,t+1} + \bar{\mu}_{i,t} + \bar{\upsilon}_{i,t} Y^N_{i,t}\left[\frac{\mathcal{Y}^N_B(B_{i,t+1}, Y^T_{i,t+1})}{\mathcal{Y}^N(B_{i,t+1}, Y^T_{i,t+1})} - \frac{\mathcal{C}^T_B(B_{i,t+1}, Y^T_{i,t+1})}{\mathcal{C}^T(B_{i,t+1}, Y^T_{i,t+1})}\right] \tag{28}$$

$$B_{i,t+1} \geq -\kappa_{i,t} \quad \text{with equality if} \quad \bar{\mu}_{i,t} > 0 \tag{29}$$

$$Y^N_{i,t} \leq 1 \quad \text{with equality if} \quad \bar{\nu}_{i,t} > 0 \tag{30}$$

$$Y^N_{i,t} \leq C^T_{i,t} R \bar{\pi} \frac{\mathcal{Y}^N(B_{i,t+1}, Y^T_{i,t+1})}{\mathcal{C}^T(B_{i,t+1}, Y^T_{i,t+1})} \quad \text{with equality if} \quad \bar{\upsilon}_{i,t} > 0, \tag{31}$$

where $\bar{\lambda}_{i,t}, \bar{\mu}_{i,t}, \bar{\nu}_{i,t}, \bar{\upsilon}_{i,t}$ denote respectively the nonnegative Lagrange multipliers on constraints (22), (23), (24) and (25), while $\mathcal{Y}^N_B(B_{i,t+1}, Y^T_{i,t+1})$ and $\mathcal{C}^T_B(B_{i,t+1}, Y^T_{i,t+1})$ are the partial derivatives respectively of $\mathcal{Y}^N(B_{i,t+1}, Y^T_{i,t+1})$ and $\mathcal{C}^T(B_{i,t+1}, Y^T_{i,t+1})$ with respect to $B_{i,t+1}$.

It is instructive to combine (26) and (28) to obtain

$$\frac{1}{C^T_{i,t}}\left(\omega + \bar{\upsilon}_{i,t} Y^N_{i,t}\right) = \frac{\beta R}{C^T_{i,t+1}}\left(\omega + \bar{\upsilon}_{i,t+1} Y^N_{i,t+1}\right) + \bar{\mu}_{i,t}$$
$$+ \bar{\upsilon}_{i,t} Y^N_{i,t}\left[\frac{\mathcal{Y}^N_B(B_{i,t+1}, Y^T_{i,t+1})}{\mathcal{Y}^N(B_{i,t+1}, Y^T_{i,t+1})} - \frac{\mathcal{C}^T_B(B_{i,t+1}, Y^T_{i,t+1})}{\mathcal{C}^T(B_{i,t+1}, Y^T_{i,t+1})}\right]. \tag{32}$$

This is the planner's Euler equation. Comparing this expression with the households' Euler equation (4), it is easy to see that the marginal benefit from a rise in $C^T_{i,t}$ perceived by the planner differs from households' whenever $\bar{\upsilon}_{i,t} > 0$ in any period t, that is when the zero lower bound constraint binds. This happens because, contrary to atomistic households, the government internalizes the aggregate demand externalities that financial decisions have on the domestic economy.

For instance, consider a case in which the borrowing constraint does not bind $\bar{\mu}_{i,t} = 0$, the economy operates at full employment in the present $\bar{\upsilon}_{i,t} = 0$, but the zero lower bound binds next period $\bar{\upsilon}_{i,t+1} > 0$. In this case, the planner's Euler equation reduces to

$$\frac{\omega}{C^T_{i,t}} = \frac{\beta R}{C^T_{i,t+1}}\left(\omega + \bar{\upsilon}_{i,t+1} Y^N_{i,t+1}\right).$$

Comparing this expression with the households' Euler equation (4), shows that in this case savings are higher in the planning allocation compared to the laissez faire equilibrium. The planner, in fact, internalizes that increasing savings in the present leads to higher aggregate demand and output next period.

The next proposition characterizes the solution to the national planning problem as a function of the world interest rate.

Proposition 2 ***National planner allocation.*** *Consider stationary solutions to the national planning problem. Define* $R^{**} = \omega Y_l^T/(\beta Y_h^T)$ *and* $\tilde{R} \equiv (\omega/(\bar{\pi}\beta))^{1/2}$*. The planning allocation is such that* $Y_h^N = 1$, $Y_l^N = Y_l^{Np}$, $B_h = B_h^p$ *and* $B_l = 0$, *where* Y_l^{Np} *and* B_h^p *are defined as*

$$\begin{cases} B_h^p = 0, Y_l^{Np} = R\bar{\pi}Y_l^T/Y_h^T < 1 & \textit{if} \quad R < R^{**} \\ B_h^p = \frac{\beta}{\omega+\beta}\left(Y_h^T - \frac{\omega Y_l^T}{\beta R}\right), Y_l^{Np} = R^2\bar{\pi}\beta/\omega < 1 & \textit{if}\ R^{**} \leq R < \tilde{R} \\ B_h^p = \frac{Y_h^T - R\bar{\pi}Y_l^T}{1+R^2\bar{\pi}}, Y_l^{Np} = 1 & \textit{if}\ \tilde{R} \leq R < R^* \\ B_h^p = \max\left\{\frac{\beta}{1+\beta}\left(Y_h^T - \frac{Y_l^T}{\beta R}\right), 0\right\}, Y_l^{Np} = 1 & \textit{if}\ R^* \leq R. \end{cases} \tag{33}$$

Moreover, $\bar{\mu}_h > 0$ *if* $R < R^{**}$ *or* $R^* \leq R < Y_l^T/(Y_h^T\beta)$*, otherwise* $\bar{\mu}_h = 0$.

Proof. See Appendix B.2. ■

Corollary 3 *Consider a small open economy facing the world interest rate* R*. If* $R^{**} < R < R^*$ *both* Y_l^N *and* B_h *are higher under the national planner allocation than under laissez faire, otherwise the two allocations coincide.*

Corollary 3 provides two results. First, if $R \geq R^*$, so that the zero lower bound never binds, the planner chooses the same path for tradable consumption and bonds that households would choose under laissez faire. This result highlights the fact that in our simple model there is no incentive for the domestic government to intervene on the current account if monetary policy is not constrained by the zero lower bound.

Second, when the zero lower bound binds in the low state ($R < R^*$), the government intervenes on the current account to stabilize output. These interventions have a prudential flavor. In fact, the government intervenes to improve the current account in the high state, when the economy is booming, so that the economy enters the liquidity trap associated with the low state with a higher stock of external wealth. This policy intervention boosts aggregate demand and mitigates the recession occurring when the economy transitions to the low state.

4.1.2 Decentralization through financial or fiscal policy

Before moving on, it is useful to spend some words on the instruments that a government needs to decentralize the planning allocation. One possibility is to give to the government the power to impose a borrowing limit tighter than the market one, so that (3) is replaced by

$$B_{i,t+1} + \frac{B_{i,t+1}^n}{P_{i,t}^T} \geq -\min\left\{\kappa_{i,t}, \kappa_{i,t}^g\right\},$$

where $\kappa_{i,t}^g$ is the borrowing limit set by the government. By setting this financial policy instrument appropriately, the government can replicate the planning allocation as part of a competitive equilibrium.

Proposition 3 ***Decentralization with financial policy.*** *The planning allocation characterized in Proposition 2can be implemented as part of a competitive equilibrium by setting*

$$\kappa_h^g = -B_h^{sp} < \kappa$$

$$\kappa_l^g = \kappa.$$

In words, to decentralize the planning allocation with financial policy the government should tighten households' access to credit when the economy is in the high state.

Alternatively, the planning allocation could be decentralized using fiscal policy. Consider a case in which the government can levy lump-sum taxes on households $T_{i,t}$, to be paid with tradable goods. Moreover, the government can purchase foreign bonds, and its budget constraint is $B_{i,t+1}^g = T_{i,t} + R_{t-1}B_{i,t}^g$, where $B_{i,t}^g$ denotes the stock of foreign bonds held by the government at the start of period t.[21] Under these assumptions, equation (13) is replaced by

$$C_{i,t}^T = Y_{i,t}^T + R_{t-1}B_{i,t} - B_{i,t+1} + R_{t-1}B_{i,t}^g - B_{i,t+1}^g.$$

By setting $B_{i,t+1}^g$ appropriately the government can replicate the planning allocation described in Proposition 2 as part of a competitive equilibrium.

Proposition 4 ***Decentralization with fiscal policy.*** *The planning allocation characterized in Proposition 2 can be implemented as part of a competitive equilibrium with fiscal policy by setting*

$$B_h^g = B_h^{sp} + \kappa$$

$$B_l^g = 0.$$

Intuitively, the government accumulates foreign reserves while the economy is booming, and rebates them to households when the economy is in the low state. This simple for of fiscal policy is effective because, due to the presence of the borrowing limit, households cannot undo the accumulation of reserves by the government through an increase in private borrowing.

This section extends the results of the literature on aggregate demand externalities and prudential policy interventions to our setting (Farhi and Werning, 2016; Korinek and Simsek, 2016). Due to the presence of domestic aggregate demand externalities, prudential current account policies act as a complement to monetary policy when the monetary authority is constrained by the zero lower bound. While this point is well understood, little is known about the global implications of these policy interventions. We tackle this issue in the next section.

[21] To prevent governments from circumventing the private borrowing limit, we also assume that governments cannot issue bonds, i.e. $B_{i,t+1}^g \geq 0$.

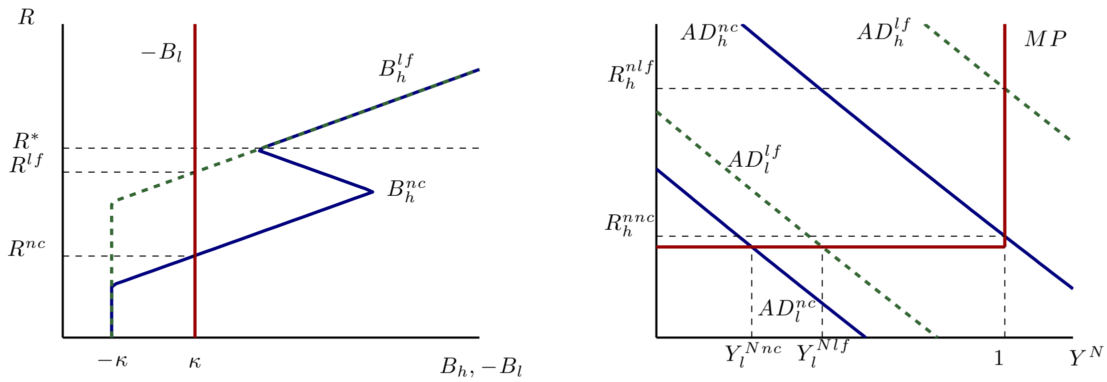

Figure 4: Impact of non-cooperative current account policy in a global liquidity trap.

4.2 Global equilibrium with current account policies

We now characterize the global equilibrium when all the countries implement the current account policy described in Proposition 2. Our key result is that, once general equilibrium effects are taken into account, uncoordinated government interventions on the international credit markets can backfire by exacerbating the global liquidity trap and give rise to a paradox of global thrift.

Start by considering that, since countries cannot issue (any significant amount of) debt, in a global equilibrium all the countries must hold (approximately) zero bonds. It follows that, just as in the laissez-faire equilibrium, the allocation of tradable consumption corresponds to the autarky one ($C_l^T = Y_l^T$, $C_h^T = Y_h^T$). Hence, in equilibrium governments' efforts to alter the path of tradable consumption are ineffective.

This does not, however, mean that current account policies do not have an effect on other variables or on welfare. The following proposition characterizes the impact of non-cooperative current account policy, when fundamentals are such that the equilibrium under laissez faire corresponds to a global liquidity trap.

Proposition 5 ***Global equilibrium with current account policies.*** *Suppose that $R^{lf} < R^*$. Then $R^{nc} < R^{lf}$, where R^{nc} is the equilibrium interest rate under the non-cooperative current account policy. Moreover, switching from laissez faire to non-coordinated current account interventions lead to lower output and welfare for every country.*

Proof. See Appendix *B*.3. ■

Proposition 5 provides a striking result: non-cooperative current account interventions exacerbate the global liquidity trap, and have a negative impact on global output and welfare. Perhaps the best way to gain intuition about this result is through a diagram. The left panel of Figure 4 displays the demand B_h and supply $-B_l$ of bonds as a function of the world interest rate R. The solid line B_h^{nc} corresponds to the demand for bonds when governments intervene on the international credit markets, while the dashed line B_h^{lf} displays the demand for bonds under laissez faire. Notice that for $R^{**} < R < R^*$ demand for bonds under current account policy is higher than under laissez faire. Indeed, this is the range of R for which governments in high-state countries intervene to increase the current account surplus. The supply of bonds, instead, does not depend on whether governments intervene. In fact, in both cases countries in the low state end up being borrowing constrained, and the supply of bonds is $-B_l = \kappa$.

The equilibrium world interest rate is found at the intersection of the B_h and $-B_l$ curves. The diagram shows that $R^{nc} < R^{lf}$, meaning that the world interest rate is lower under non-cooperative current account policies compared to laissez faire. To gain intuition, consider a world with no current account interventions. Now imagine that governments in countries in the high state start to intervene to increase their current account surpluses. This generates an increase in the global demand for bonds. World bonds supply, however, is fixed because countries in the low state are borrowing constrained. To restore equilibrium the interest rate has to fall, so as to bring back the demand for bonds to its equilibrium value of zero.

We now describe how the market for non-tradable goods adjusts to the fall in the world interest rate caused by the implementation of non-cooperative current account policies. As shown by the right panel of Figure 4, a lower world interest rate depresses demand for non-tradable consumption across the whole world, and deepens the recession in countries experiencing a liquidity trap. Through this channel, current account interventions in booming countries exacerbate the liquidity trap in the rest of the world, leading to a world with lower non-tradable output, and welfare, compared to the unregulated economy.[22] This is the essence of the paradox of global thrift. Prudential policies aiming at mitigating the output losses during liquidity traps end up exacerbating them.

We now consider the impact of non-cooperative current account interventions when fundamentals are such that $R^{lf} \geq R^*$. This corresponds to a case in which, under laissez faire, the world interest rate is sufficiently high so that the zero lower bound never binds.

Proposition 6 ***Multiple equilibria with non-cooperative current account policy.*** *Suppose that $R^{lf} \geq R^*$. Then $R^{nc} = R^{lf}$ is an equilibrium under the non-cooperative current account policy. This equilibrium is isomorphic to the laissez faire one. However, if $R^{**} < R^*$, there exists at least another equilibrium under the non-cooperative current account policy with associated world interest rate $R^{nc\prime} < R^*$. This equilibrium features lower output and welfare than the laissez faire one.*

Proof. See Appendix B.4. ■

One might be tempted to conclude that if $R^{lf} \geq R^*$ then governments will not intervene on the international credit markets, and the equilibrium under the non-cooperative policy will coincide with the laissez faire one. Indeed, Proposition 6 states that this is a possibility. However, Proposition 6 also states that there might be other equilibria, characterized by current account interventions and associated with global liquidity traps. Hence, the fact that fundamentals are sufficiently good to rule out a global liquidity trap under laissez faire, does not exclude the possibility of a global liquidity trap when governments intervene on the international credit markets

[22] To see why welfare is lower under the non-cooperative policy compared to laissez faire, consider that current account policies do not affect the equilibrium path of tradable consumption. It follows that their impact on welfare is fully captured by the drop in non-tradable output and consumption.

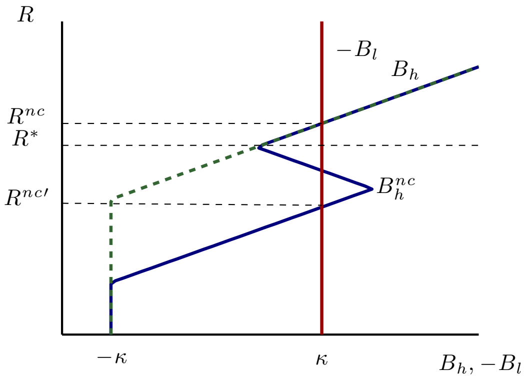

Figure 5: Multiple equilibria with non-cooperative current account policy.

in absence of international coordination. This result is illustrated by Figure 5, which shows that multiple intersections between the B_h and $-B_l$ curves are possible under uncoordinated current account interventions.

To gain intuition about this result, consider that governments' actions depend on their expectations about the path of the world interest rate. This happens because the zero lower bound binds only if the world interest rate is sufficiently low. For instance, consider a case in which governments expect that the world interest rate will be always larger than R^*. In this case, governments expect that the zero lower bound will never bind, and hence do not intervene. Since we are focusing on the case $R^{lf} \geq R^*$, in absence of policy interventions the zero lower bound will indeed never bind, confirming the initial expectations. But now think of a case in which governments anticipate that the world interest rate will be always smaller than R^*, so that the zero lower bound is expected to bind in the low state. Then, governments subsidize savings in an attempt to reduce future unemployment. These interventions increase the global supply of savings above its value under laissez faire, putting downward pressure on the world interest rate. If $R^{**} < R^*$ holds, the drop in the interest rate is sufficiently large so that $R < R^*$, validating governments' initial expectations. Thus, in absence of international cooperation, expectations of a future global liquidity trap might generate a global liquidity trap in the present.

We have seen that non-cooperative current account interventions, while being desirable from the point of view of a single country, can lead to perverse outcomes once their general equilibrium effects are taken into account. First, unilateral implementation of financial regulation during a global liquidity trap generates a drop in output and welfare. Second, uncoordinated interventions on the financial markets open the door to global liquidity traps purely driven by pessimistic expectations. Since all these general equilibrium effects are mediated by the world interest rate, which countries take as given, domestic governments do not internalize the side effects of their financial policies on the rest of the world. These results suggest that international cooperation is beneficial when designing macroprudential policies in a global liquidity trap.

So far we have drawn conclusions based on an admittedly stylized model. While this model is useful to derive intuition, one might wonder whether these results are driven by some of the specific assumptions that we have made. In what follows, we consider a more realistic framework and show that our conclusions hold true even in a more general setting.

5 Extended model and numerical analysis

TO BE WRITTEN

6 Conclusion

In this paper we have studied optimal credit market interventions during a persistent global liquidity trap. When acting uncooperatively, governments implement macroprudential policies to correct for domestic aggregate demand externalities. The key result of the paper is that these policies can trigger a paradox of global thrift. This happens because when taxing borrowing, governments in countries operating at full employment depress the world interest rate, deepening the recession in countries currently experiencing a liquidity trap. This result points toward the need for international coordination in designing credit market policies in a low interest rate world.

This paper is a first step toward understanding whether gains from cooperation arise in a low interest rate and financially integrated world. A natural future step in this research program would be to analyze the need for coordination arising from other policies. A natural candidate would be fiscal policy. What are the international spillovers from fiscal interventions arising during a global liquidity trap? Is there a need for international coordination when designing public debt policy? We believe that our framework, which strikes a balance between tractability and the ability to deliver quantitative results, represents an excellent laboratory to address these questions.

Appendix

A Additional lemmas

Lemma 2 *Suppose that the market for non-tradable goods clears competitively, so that the (AD) and (MP) equations hold. Then there cannot be a stationary equilibrium with $Y_{i,t}^N < 1$ for all t. Moreover if $C_h^T \geq C_l^T$ then $Y_h^N = 1$.*

Proof. The proof is by contradiction. Suppose that $Y_{i,t}^N < 1$ for all t. (MP) then implies $R_{i,t}^n = 1$ for all t. In a stationary equilibrium the AD equation in the low and high state can then be written as

$$Y_h^N = R\bar{\pi}\frac{C_h^T}{C_l^T}Y_l^N \tag{A.1}$$

$$Y_l^N = R\bar{\pi}\frac{C_l^T}{C_h^T}Y_h^N. \tag{A.2}$$

Combining these equations gives $1 = (R\bar{\pi})^2$.[23] This contradicts Assumption (2), which states $R\bar{\pi} > 1$. Hence, in a stationary equilibrium it must be that $\max\{Y_h^N, Y_l^N\} = 1$.

We now prove that if $C_h^T \geq C_l^T$ then $Y_h^N = 1$. Suppose that this is not the case and $Y_h^N < 1$. Then (MP) implies $R_h^N = 1$ and $Y_l^N = 1$. We can then write the (AD) equation in the high state as

$$Y_h^N = R\bar{\pi}\frac{C_h^T}{C_l^T}. \tag{A.3}$$

Assumption (2) and $C_h^T \geq C_l^T$ imply that the right-hand side is larger than one. Hence, $Y_h^N > 1$. We have found a contradiction, and so $C_h^T \geq C_l^T$ implies $Y_h^N = 1$. ■

Lemma 3 *Suppose that $\bar{Y}_h^N$, $\bar{\upsilon}_h$ and $\bar{\mu}_l$ are part of a stationary equilibrium with financial policy. Then $\bar{Y}_h^N = 1$, $\bar{\upsilon}_h = 0$ and $\bar{\mu}_l > 0$.*

Proof.

Throughout the proof, we will denote with a $\bar{}$ the value of the corresponding variable in the equilibrium with financial policy.

We start by showing that $\bar{Y}_h^N = 1$, that is that under financial policy the economy operates at full employment in the high state. Suppose, to reach a contradiction, that $\bar{Y}_h^N < 1$. Applying Lemma 2, we can set $\bar{Y}_l^N = 1$. Thus, (25) in the high state implies $R\bar{\pi}\bar{C}_h^T/\bar{C}_l^T < 1$. Since by Assumption (2) $1 < R\bar{\pi}$, then $\bar{C}_l^T > \bar{C}_h^T$. Since $Y_h^T > Y_l^T$ and $B_l \geq -\kappa \approx 0$, this is possible only if $\bar{B}_h > 0$ and so if $\bar{\mu}_h = 0$. Combining (27) and (32) in the high state and rearranging then gives[24]

$$\frac{\bar{C}_l^T}{\bar{C}_h^T} = \beta R(1 - \bar{\nu}_l) - (1 - \omega)\frac{\mathcal{C}_{B_h}^T(B_h, Y_l^T)}{\mathcal{C}^T(B_h, Y_l^T)}. \tag{A.4}$$

[23] We do not consider equilibria featuring $Y_h^N = Y_l^N = 0$.

[24] We have used $\bar{\mu}_h = 0$ and $\mathcal{Y}_l^N = 0$.

Since $\beta R < 1$, $\bar{\nu}_l \geq 0$ and $\mathcal{C}^T_{B_h}(B_h, Y^T_l) \geq 0$, the right-hand side of this equation is always smaller than 1, implying that $\bar{C}^T_l < \bar{C}^T_h$. We have thus reached a contradiction and proved that $\bar{Y}^N_h = 1$ and $\pi_h = \bar{\pi}$.

We turn to prove that $\bar{v}_h = 0$, that is that the zero lower bound does not bind in the high state. To reach a contradiction, assume instead that $\bar{v}_h > 0$. Since we proved that $\bar{Y}^N_h = 1$, we can use (25) to write

$$1 = R\bar{\pi}\frac{\bar{C}^T_h}{\bar{C}^T_l}Y^N_l. \tag{A.5}$$

First, suppose that $\bar{v}_l > 0$. Equation (25) implies $\bar{Y}^N_l = R\bar{\pi}\bar{C}^T_l/\bar{C}^T_l$. Using these two conditions equation ($A.5$) reduces to $1 = (R\bar{\pi})^2$, that contradicts our assumption $R\bar{\pi} > 1$. Therefore, it does not exist an equilibrium under non-cooperative financial policy characterized by $\bar{v}_l > 0$ and $\bar{v}_h > 0$.

Let us now turn to analyze the case $\bar{v}_l = 0$ and $\bar{v}_h > 0$. Since in this case $\bar{Y}^N_l = 1$, (25) implies $1 \leq R\bar{\pi}\bar{C}^T_l/\bar{C}^T_h$. Moreover, by using ($A.5$), we get $\bar{C}^T_l/\bar{C}^T_h = R\bar{\pi}$. Jointly, these two conditions imply $\bar{C}^T_h \leq \bar{C}^T_l$. Since $Y^T_h > Y^T_l$ and $B_l \geq -\kappa \approx 0$, this is possible only if $B_h > 0$ and so if $\bar{\mu}_h = 0$. Note that if $\bar{v}_l = \bar{\mu}_h = 0$ and $\bar{Y}^N_h = 1$, we can write equation (32) in the high state as

$$\frac{\omega + \bar{v}_h}{\bar{C}^T_h} = \beta R\frac{\omega}{\bar{C}^T_l} - \bar{v}_h\frac{\mathcal{C}^T_B(B_h, Y^T_l)}{\mathcal{C}^T(B_h, Y^T_l)}. \tag{A.6}$$

Since $\beta R < 1$ and $\mathcal{C}^T(.) \geq 0$, this expression implies $\bar{C}^T_l < \bar{C}^T_h$. We have reached a contradiction. Thus, an equilibrium under non-cooperative financial policy is characterized by $\bar{v}_h = 0$.

We are left to prove that $\bar{\mu}_l > 0$, that is that the borrowing constraint binds in the low state. Suppose that it exists an equilibrium under non-cooperative financial policy characterized by $\bar{\mu}_l = 0$. Thus the Euler equation (32) in the low state implies

$$\frac{\omega + \bar{v}_l\bar{Y}^N_l}{\bar{C}^T_l} = \beta R\frac{\omega}{\bar{C}^T_h} - \bar{v}_l\frac{\mathcal{C}^T_B(B_l, Y_h)}{\mathcal{C}^T(B_l, Y^T_h)}. \tag{A.7}$$

Since $\beta R < 1$ and $\mathcal{C}^T_B(.) \geq 0$, the following condition needs to hold $\bar{C}^T_h < \bar{C}^T_l$. Since $Y^T_h > Y^T_l$ and $B_l \geq -\kappa \approx 0$, this is possible only if $B_h > 0$ and so if $\bar{\mu}_h = 0$. Then the Euler equation (32) in the high state is

$$\frac{\omega}{\bar{C}^T_h} = \beta R\frac{\omega + \bar{v}_l\bar{Y}^N_l}{\bar{C}^T_l}. \tag{A.8}$$

By combining ($A.7$) and ($A.8$), we find $1 = (\beta R)^2$. This contradicts the assumption $\beta R < 1$. Thus, the equilibrium under non-cooperative financial policy features $\bar{\mu}_l > 0$. ■

B Proofs

B.1 Proof of Proposition 1

Proposition 1 ***Small open economy under laissez faire.*** *There exists a threshold R^*, such that if $R \geq R^*$ then $Y^N_h = Y^N_l = 1$, otherwise $Y^N_h = 1$ and $Y^N_l = R\bar{\pi}\max\left(\beta R, Y^T_l/Y^T_h\right) < 1$. R^**

solves $R^*\bar{\pi}\max\left(\beta R^*, Y_l^T/Y_h^T\right) = 1$.

Proof. Since the competitive equilibrium is stationary and satisfies $C_h^T > C_l^T$ Lemma 2 applies. Hence, $Y_h^N = 1$. Using these conditions the (AD) equation in the low state can be written as

$$Y_l^N = \frac{R\bar{\pi}}{R_l^n}\frac{C_l^T}{C_h^T} = \frac{R\bar{\pi}}{R_l^n}\max\left\{\beta R, \frac{Y_l^T}{Y_h^T}\right\},$$

where the second equality makes use of (16), (17) and (18). Define R^* as the solution to $1 = R^*\bar{\pi}\max\left\{\beta R^*, Y_l^T/Y_h^T\right\}$. Combining the expression above with the (MP) equation, gives that if $R \geq R^*$, then $Y_l^N = 1$ and $R_l^n \geq 1$, otherwise $R_l^n = 1$ and $Y_l^N = R\bar{\pi}\max\left(\beta R, Y_l^T/Y_h^T\right) < 1$. ■

B.2 Proof of Proposition 2

Proposition 2 ***Planning allocation in small open economy.*** *Consider stationary solutions to the planning problem. Define* $R^{**} = \omega Y_l^T/(\beta Y_h^T)$ *and* $\tilde{R} \equiv (\omega/(\bar{\pi}\beta))^{1/2}$. *The planning allocation is such that* $Y_h^N = 1$, $B_l = -\kappa \approx 0$ *and*

$$\begin{cases} B_h = -\kappa \approx 0, Y_l^N = R\bar{\pi}Y_l^T/Y_h^T < 1 & \text{if} \quad R < R^{**} \\ B_h = \frac{\beta}{\omega+\beta}\left(Y_h^T - \frac{\omega Y_l^T}{\beta R}\right), Y_l^N = R^2\bar{\pi}\beta/\omega < 1 & \text{if } R^{**} \leq R < \tilde{R} \\ B_h = \frac{Y_h^T - R\bar{\pi}Y_l^T}{1+R^2\bar{\pi}}, Y_l^N = 1 & \text{if } \tilde{R} \leq R < R^* \\ B_h = \max\left\{\frac{\beta}{1+\beta}\left(Y_h^T - \frac{Y_l^T}{\beta R}\right), 0\right\}, Y_l^N = 1 & \text{if } R^* \leq R. \end{cases}$$

Moreover, $\bar{\mu}_h > 0$ *if* $R < R^{**}$ *or* $R^* \leq R < Y_l^T/(Y_h^T\beta)$, *otherwise* $\bar{\mu}_h = 0$.

Proof. In this proof we solve for the equilibrium under non-cooperative financial policy as a function of R. Throughout the proof, we will denote with a $\bar{}$ the value of the corresponding variable in the equilibrium under non-cooperative financial policy, while a $\hat{}$ will denote the value of a variable under laissez faire.

We start by considering the case $R \geq R^*$. Our goal is to show that in this case the equilibrium under financial policy and the one under financial laissez faire coincide. Let us start by guessing that $\bar{\upsilon}_{i,t}^{sp} = 0$ for all t. In this case, the Euler equation in an economy regulated by non-cooperative financial policy (32) is identical to (4), the households' Euler equation in the financial laissez faire. It follows that $\bar{C}_{i,t}^T = \hat{C}_{i,t}^T$ and $\bar{B}_{i,t+1} = \hat{B}_{i,t+1}$ for all t. Since $R \geq R^*$, Proposition 1 implies $\hat{C}_{i,t}^N = 1$ for all t. Moreover, following the steps of the proof of Proposition 1, it is easy to check that $\bar{C}_{i,t}^N = \hat{C}_{i,t}^N = 1$ for all t. This implies that it is possible to set $\bar{\nu}_{i,t}^{sp} > 0$ for all t, and that we can set $\bar{\upsilon}_{i,t}^{sp} = 0$ for all t without violating the optimality condition (27). This verifies our initial guess $\bar{\upsilon}_{i,t}^{sp} = 0$ for all t, and it proves that if $R \geq R^*$ the equilibrium under non-cooperative financial policy and the one under financial laissez faire coincide.

We now turn to the case $R < R^*$. Lemma 3 implies that $\bar{C}_h^N = 1$, $\bar{\upsilon}_h = 0$ and $\bar{\mu}_l > 0$. The next step of the proof establishes that if $R < R^*$ then $\bar{\upsilon}_l > 0$, that is the zero lower bound binds in the low state. Suppose the contrary, meaning that $R < R^*$ and $\bar{\upsilon}_l = 0$. Then (32) is identical to (4) and the equilibrium under non-cooperative financial policy and the one under financial laissez faire coincide. Note that, following Proposition 1, $R < R^*$ implies $\hat{C}_l^N < 1$. Therefore, condition (27) implies $\bar{\upsilon}_l > 0$ contradicting our initial assumption. This proves that if $R < R^*$ then $\bar{\upsilon}_l > 0$. For future reference, note that consequently when $R < R^*$ the optimality condition (25) in the low state implies

$$\bar{C}_l^N = R\bar{\pi}\bar{C}_l^T/\bar{C}_h^T. \tag{B.1}$$

We now solve for $\bar{C}_l^N$ and $\bar{B}_h$ as a function of $R < R^*$. We start by deriving conditions under which $\bar{C}_l^N = 1$. Note that if $R < R^*$ there cannot be an equilibrium with $\bar{C}_l^N = 1$ and $\bar{\mu}_h > 0$. [25] Setting $\bar{\mu}_h = 0$, we can write (32) in the high state as

$$\frac{\omega}{\bar{C}_h^T} = \frac{\beta R}{\bar{C}_l^T}(\omega + \bar{\upsilon}_l\bar{C}_l^N) = \frac{\beta R}{\bar{C}_l^T}(1 - \bar{\nu}_l), \tag{B.2}$$

where the second equality makes use of $\bar{C}_l^N = 1$ and (27). Moreover, equation (B.1) implies

$$1 = R\bar{\pi}\bar{C}_l^T/\bar{C}_h^T. \tag{B.3}$$

Combining (B.2) and (B.3) gives

$$\omega = R^2\bar{\pi}\beta(1 - \bar{\nu}_l). \tag{B.4}$$

Since we are free to set $\bar{\nu}_l$ to any non-negative number, the expression above implies that in order for $\bar{C}_l^N = 1$ to be a solution it must be that $R \geq (\omega/(\bar{\pi}\beta))^{1/2} \equiv \tilde{R}$. To solve for $\bar{B}_h$ we can use (17), (18) and (B.3) to write

$$\bar{B}_h = \frac{Y_h^T - R\bar{\pi}Y_l^T}{1 + R^2\bar{\pi}}. \tag{B.5}$$

It is straightforward to prove that $R < R^*$ implies $Y_h^T > R\bar{\pi}Y_l^T$, and hence $\bar{B}_h > 0$.[26] We can then conclude that for $\tilde{R} \leq R < R^*$ the equilibrium under non-cooperative financial policy features $\bar{C}_l^N = 1 > \hat{C}_l^N$, while $\bar{B}_h$ is given by (B.5).

Finally we characterize the equilibria where $\bar{C}_l^N < 1$. We set $\bar{\nu}_l = 0$ and we use (27) to obtain $\bar{\upsilon}_l = (1 - \omega)\bar{C}_l^N$. Suppose that the equilibrium is such that $\bar{\mu}_h = 0$. Plugging this condition in the Euler equation for the high state gives

$$\frac{\bar{C}_l^T}{\bar{C}_h^T} = \frac{\beta R}{\omega}. \tag{B.6}$$

By combining the expression above with (B.1) we can write $\bar{C}_l^N$ as a function of exogenous pa-

[25] To see this point, assume that $\bar{\mu}_h > 0$ and $\bar{C}_l^N = 1$. Since by Lemma 3 also $\bar{\mu}_l > 0$ then $C_h^T = Y_h^T$ and $C_l^T = Y_l^T$. Hence, in order for equation (B.1) to hold it must be that $R\bar{\pi}Y_l^T/Y_h^T = 1$. But this is consistent with $R < R^*$. We have found a contradiction. Thus, if $R < R^*$ and $\bar{C}_l^N = 1$, it must be that $\bar{\mu}_h = 0$.

[26] Since $R < R^*$, it is sufficient to prove that $\bar{\pi}R^* \leq Y_h^T/Y_l^T$. Consider that R^* solves $1 = R^*\bar{\pi}\max\{\beta R^*, Y_l^T/Y_h^T\}$. Suppose that $\beta R^* > Y_l^T/Y_h^T$, meaning $R^* = (\beta\bar{\pi})^{-1/2}$. Then, $(\beta/\bar{\pi})^{1/2} = \frac{1}{\bar{\pi}R^*} > Y_l^T/Y_h^T$. Assume instead $\beta R^* \leq Y_l^T/Y_h^T$, it follows that $\bar{\pi}R^* = Y_h^T/Y_l^T$. Thus, since $R^* \leq \frac{Y_h^T}{Y_l^T\bar{\pi}}$, all $R < R^* < \frac{Y_h^T}{Y_l^T\bar{\pi}}$.

rameters, meaning

$$\bar{C}_l^N = \bar{\pi}\frac{\beta R^2}{\omega}. \tag{B.7}$$

This is a solution if $\bar{B}_h \geq 0$. To solve for $\bar{B}_h$ we can use (17), (18) and (B.6) to write

$$\bar{B}_h = \frac{\beta}{\omega+\beta}\left(Y_h^T - \frac{\omega Y_l^T}{\beta R}\right). \tag{B.8}$$

Hence in the interval $\omega Y_l^T/(\beta Y_h^T) \equiv R^{**} < R < \min\left(R^*, \tilde{R}\right)$, $\bar{C}_l^N = \bar{\pi}\beta R^2/\omega > \bar{\pi}R\max\{\beta R, Y_l^T/Y_h^T\}$ $= \hat{C}_l^N$, while $\bar{B}_h$ is given by (B.8) . Instead if $R \leq R^{**}$ then $\bar{\mu}_h > 0$ and the equilibrium under non-cooperative financial policy and the equilibrium under financial laissez faire coincide. ■

B.3 Proof of Proposition 5

Proposition 3 ***Global equilibrium with non-cooperative financial policy.*** *Suppose that $R^{lf} < R^*$. Then $R^{nc} < R^{lf}$, where R^{nc} is the equilibrium interest rate under the non-cooperative financial policy. Moreover, switching from financial laissez faire to non-coordinated financial market interventions lead to lower output and welfare for every country.*

Proof. Define the function $\mathcal{B}_h(R)$, as the planner's demand for bonds in the high state (33). A solution has to feature $\mathcal{B}_h(R^{nc}) = 0$ and $\bar{\mu}_h = 0$. We start by observing that $R^{nc} \geq R^{**}$. This follows from Proposition 2 which states that if $R < R^{**}$ then $\bar{\mu}_h > 0$.

We now show that if $R^{lf} < R^*$ then there exist a unique $R^{nc} < R^{lf}$. Clearly $R^{nc} \geq R^*$ cannot be a solution. In fact, for $R \geq R^*$ the demand for bonds coincide under financial laissez faire and under non-cooperative financial policy, and so $\mathcal{B}(R) > 0$. Moreover, $\tilde{R} \leq R^{nc} < R^*$ cannot be a solution. Consider that $\mathcal{B}(R^*) > 0$, and that over the range $\tilde{R} \leq R^{nc} < R^*$ we have $\mathcal{B}'(R) > 0$. This implies that there cannot be an $\tilde{R} \leq R < R^*$ such that $\mathcal{B}(R) = 0$. It must then be that $R^{**} \leq R^{nc} < R^*$. Note R^{nc} is such that $\mathcal{B}(R^{nc}) = 0$, thus we have $R^{nc} = \omega Y_l^T/(\beta Y_h^T) = R^{**}$. Moreover since $\omega < 1$, we obtain $R^{nc} < R^{lf}$.

We now show that Y_l^N and welfare are lower under the non-cooperative interventions compared to laissez faire. Independently of whether governments intervene on the credit markets $C_l^T = Y_l^T, C_h^T = Y_h^T, Y_h^N = 1$ and $\pi_h = \bar{\pi}$. Using (20), we can then write output in the low state as

$$Y_l^N = \min\left(R\bar{\pi}Y_l^T/Y_h^T, 1\right).$$

Since $R^{nc} < R^{lf}$ it immediately follows that Y_l^N is lower under the non-cooperative financial policy equilibrium than under laissez faire equilibrium. Since the impact on welfare of credit market interventions is fully determined by Y_l^N, it follows that welfare is lower under non-cooperative financial policy than under financial laissez faire. ■

B.4 Proof of Proposition 6

Proposition 4 ***Multiple equilibria with non-cooperative financial policy.*** *Suppose that $R^{lf} \geq R^*$. Then $R^{nc} = R^{lf}$ is an equilibrium under the non-cooperative financial policy. This equilibrium is isomorphic to the laissez faire one. However, if $R^{**} < R^*$, there exists at least another equilibrium under the non-cooperative financial policy with associated world interest rate $R^{nc\prime} < R^*$. This equilibrium features lower output and welfare than the laissez faire one.*

Proof. A solution must be such that $\mathcal{B}_h(R^{nc}) = 0$ and $\hat{\mu}_h = 0$. Notice that $R^{nc} = R^{lf}$ is a solution. This is the case because $R^{lf} \geq R^*$ implies that at the solution the demand for bonds in the competitive and uncooperative equilibrium coincide. If $R^{**} \geq R^*$, this is the unique solution, because the demand for bonds are identical for any value of R. Now assume that $R^{**} < R^*$. Then there exists a second solution $R^{nc\prime} = R^{**}$, because $\mathcal{B}_h(R^{**}) = 0$. Moreover, since $R^{**} < R^*$ this second solution corresponds to a global liquidity trap. The welfare statement can be proved following the steps in the proof to Proposition 6. ■

C Microfoundations for the zero lower bound constraint

In this appendix we provide some possible microfoundations for the zero lower bound constraint assumed in the main text. First, let us introduce an asset, called money, that pays a private return equal to zero in nominal terms.[27] Money is issued exclusively by the government, so that the stock of money held by any private agent cannot be negative. Moreover, we assume that the money issued by the domestic government can be held only by domestic agents.

We modify the borrowing limit (3) to

$$B_{i,t+1} + \frac{B^n_{i,t+1}}{P^T_{i,t}} + \frac{M_{i,t+1}}{P^T_{i,t}} \geq -\kappa_{i,t},$$

where $M_{i,t+1}$ is the stock of money held by the representative household in country i at the end of period t. The optimality condition for money holdings can be written as

$$\frac{1}{C^T_{i,t}} = \frac{P^T_{i,t}}{P^T_{i,t+1}} \frac{\beta}{C^T_{i,t+1}} + \mu_{i,t} + \mu^M_{i,t},$$

where $\mu^M_{i,t} \geq 0$ is the Lagrange multiplier on the non-negativity constraint for private money holdings, divided by $P^T_{i,t}$. Combining this equation with (5) gives

$$\left(R^n_{i,t} - 1\right) \frac{\beta}{C^T_{i,t+1}} = \mu^M_{i,t}.$$

Since $\mu^M_{i,t} \geq 0$, this expression implies that $R^n_{i,t} \geq 1$. Moreover, if $R^n_{i,t} > 1$, then agents choose to

[27] Here we focus on the role of money as a saving vehicle, and abstract from other possible uses. More formally, we place ourselves in the cashless limit, in which the holdings of money for purposes other that saving are infinitesimally small.

hold no money. If instead $R^n_{i,t} = 1$, agents are indifferent between holding money and bonds. We resolve this indeterminacy by assuming that the aggregate stock of money is infinitesimally small for any country and period.

D Optimal discretionary monetary policy

We derive the constrained efficient allocation by taking the perspective of a benevolent central bank that operates in a generic country i, and solves its maximization problem in period τ. For given initial net foreign assets $B_{i,\tau}$ and paths $\{Y^T_{i,t}, \kappa_{i,t}, R_t\}_{t\geq\tau}$, the central bank maximizes equation (1) subject to equations (4), (6), (11), (13) and[28]

$$C^N_{i,t} = \min\left(\frac{R_t \pi_{i,t+1} C^T_{i,t} C^N_{i,t+1}}{R^n_{i,t} C^T_{i,t+1}}, 1\right) \tag{D.1}$$

$$C^N_{i,t} \leq 1, \pi_{i,t} \geq \gamma \quad \text{with complementary slackness} \tag{D.2}$$

$$R^n_{i,t} \geq 1, \tag{D.3}$$

for any $t \geq \tau$. Start by considering that from equations (4), (6), (11) and (13) it is possible to solve for the paths $\{C^T_{i,t}, B_{i,t+1}\}_{t\geq\tau}$ independently of monetary policy. Hence, monetary policy can affect utility only through its impact on $\{C^N_{i,t}\}_{t\geq\tau}$. Moreover, notice that $B_{i,t+1}$ represents the only endogenous state variable of the economy.

We now restrict attention to a central bank that operates under discretion, that is by taking future policies as given. Since monetary policy cannot affect the state variables of the economy, it follows that a central bank operating under discretion cannot influence future variables at all. The problem of the central bank can be thus written as

$$\max_{R_{i,\tau}, C^N_{i,\tau}, \pi_{i,\tau}} \log(C^N_{i,\tau}), \tag{D.4}$$

$$C^N_{i,\tau} = \min\left(\nu_{i,\tau}/R^n_{i,\tau}, 1\right) \tag{D.5}$$

$$C^N_{i,\tau} \leq 1, \pi_{i,\tau} \geq \gamma \quad \text{with complementary slackness} \tag{D.6}$$

$$R^n_{i,\tau} \geq 1, \tag{D.7}$$

where $\nu_{i,\tau} \equiv R_\tau \pi_{i,\tau+1} C^T_{i,\tau} C^N_{i,\tau+1}/C^T_{i,\tau+1}$. The central bank takes $\nu_{i,\tau}$ as given because it is a function of present and future variables that monetary policy cannot affect.

The solution to this problem can be expressed as

$$R^n_{i,\tau} \geq 1, C^N_{i,\tau} \leq 1 \quad \text{with complementary slackness.} \tag{D.8}$$

[28]Constraint (*D*.1) is obtained by combining (*AD*) and (12) with the restriction $Y^N_{i,t} \leq 1$. Constraint (*D*.2) is obtained by combining (10) with $L_{i,t} = Y^N_{i,t} = C^N_{i,t}$ and $P^N_{i,t} = W_{i,t}$.

Intuitively, it is optimal for the central bank to lower the policy rate until the economy reaches full employment or the zero lower bound constraint binds. Moreover, it follows from constraint ($D.6$) that any $\pi_{i,\tau} \geq \gamma$ is consistent with constrained efficiency. In fact, as long as the central bank faces an infinitesimally small cost from deviating from its inflation target $\bar{\pi}$, then the constrained efficient allocation features $\pi_{i,\tau} = \bar{\pi}$.[29] This is exactly the policy implied by the rule (MP).

E Data sources

- Policy rate, US: Board of Governors of the Federal Reserve System (US), Effective Federal Funds Rate.
- Policy rate, Euro area and Japan: International Monetary Fund, Discount Rate.
- Credit to private non-financial sector: Bank for International Settlements, Total Credit to Private Non-Financial Sector, Adjusted for Breaks.
- GDP per capita: World Development Indicators, Constant GDP per capita.

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[29] Recall that we are assuming $\bar{\pi} > \gamma$.

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