Aggregate Demand Externalities in a Global Liquidity Trap

Luca Fornaro and Federica Romei*

October 2016

PRELIMINARY AND INCOMPLETE, COMMENTS WELCOME

Abstract

This paper studies optimal credit market interventions during a persistent global liquidity trap. We provide a tractable multi-country 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. Idiosyncratic shocks generate capital flows and asymmetric liquidity traps across countries. Due to a domestic aggregate demand externality, it is optimal for governments to implement countercyclical macroprudential policies, taxing borrowing in good times, as a precaution against the risk of a future liquidity trap triggered by a negative shock. The key insight of the paper is that this policy is inefficient from a global perspective, because it depresses global rates and deepens the recession in the countries currently stuck in a liquidity trap. This international aggregate demand externality points toward the need for international coordination in the design of credit market interventions. Indeed, under the cooperative optimal credit policy countries internalize the fact that a stronger demand for borrowing and consumption from countries at full employment sustains global rates, reducing the recession in liquidity trap economies.

JEL Codes: E32, E44, E52, F41, F42.

Keywords: Liquidity traps, zero lower bound, secular stagnation, deleveraging, capital flows, macroprudential policies, aggregate demand externalities, international coordination.

*Fornaro: CREI, Universitat Pompeu Fabra, Barcelona GSE and CEPR; LFornaro@crei.cat. Romei: Stockholm School of Economics; federica.romei@eui.eu. We thank seminar participants at CREI for useful comments.

1 Introduction

The current state of the global economy is characterized by exceptionally low interest rates. In recent years, in fact, nominal rates have hit the zero lower bound in most advanced economies, including the US, the Euro area and Japan (Figure 1, left panel). Interestingly, all these liquidity trap episodes have started with some turmoil on financial markets, and have been accompanied by debt deleveraging (Figure 1, right panel). The link between deleveraging and liquidity traps has been formalized by Eggertsson and Krugman (2012) and Guerrieri and Lorenzoni (2011). Tight access to credit, these authors argue, depresses aggregate demand, pushing down the natural interest rate. If the underlying interest rate is low enough, a period of debt deleveraging will then be associated with a liquidity trap and an economic slump.

Motivated by these facts, a recent literature has suggested that, in a low interest rate environment, governments should actively intervene on the credit markets by implementing countercyclical macroprudential policies (Farhi and Werning, 2016; Korinek and Simsek, 2016). Limiting debt accumulation ex-ante, the argument goes, will reduce the drop in aggregate demand and the recession in the event of a deleveraging episode. 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. A benevolent government should then tax debt in periods of abundant access to credit, as a precaution against the recessionary liquidity trap that might arise following a negative financial shock.

This newborn literature has so far, understandably, focused on closed economies and on domestic aggregate demand externalities. However, low interest rates are a global phenomenon, and financial markets are now more internationally integrated than ever. Moreover, in many cases, deleveraging has featured an important international dimension. In fact, in several countries, deleveraging happened after a period of sustained current account deficits, and was accompanied by a sudden stop in capital inflows generating sharp adjustments in the external balance.[1] In spite of this, the question of how credit market interventions should be conducted in a financially integrated world characterized by low interest rates is still extremely open. Which are the international spillovers arising from credit market interventions? Are there substantial gains from cooperation? These are the questions that this paper tackles.

In this paper we study optimal credit market interventions from an international perspective. To this end, we propose 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. The model is simple enough so that many insights can be derived analytically, but still sufficiently rich to perform a quantitative analysis. To preview the main result, we find

[1] Spain is, perhaps, the best example. Between 2004 and 2008 the ratio of credit to the private non-financial sector to GDP skyrocketed from 153 to 2009 percent. Instead, the post-2008 period was marked by deleveraging, and by the end of 2015 credit to the non-financial private sector dropped to 172 percent of GDP. Around 2008 Spain also experienced a sudden stop in capital inflows. In fact, while Spain between 2004 and 2008 was running large current account deficits, on average equal to 8 percent of GDP, between 2009 and 2013 the current account improved abruptly, and the average deficit over this period was equal to 2 percent of GDP only.

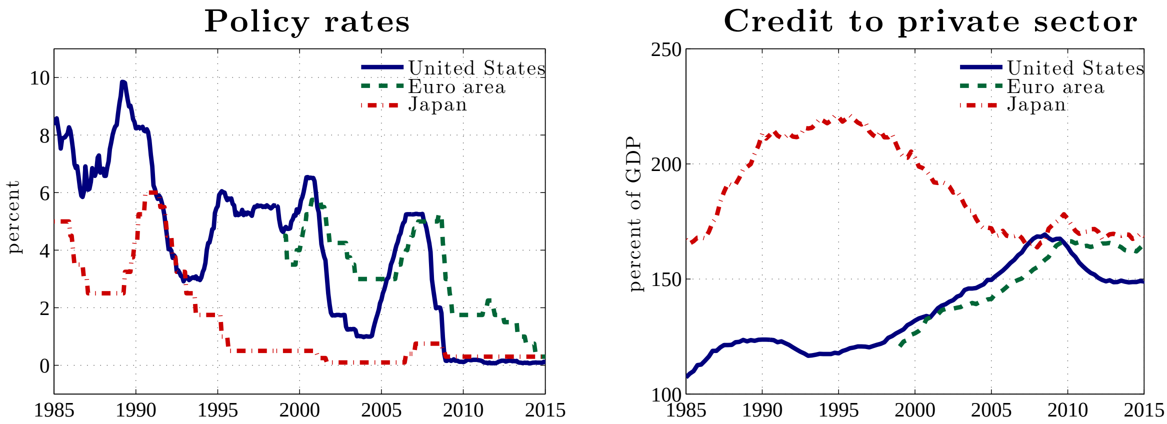

Figure 1: Policy rates and credit to the private non-financial sector. Note: the left panel shows the exceptionally low interest rates characterizing the post-2008 period. Both panels show the emergence of liquidity traps during periods of debt deleveraging by the private sector. See Appendix *D* for data sources.

important international spillovers arising from credit market policies, and gains from international coordination due to the presence of international aggregate demand externalities.

We study a world composed of a continuum of small open economies inhabited by infinitely lived agents. 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. For most of the paper, we study a stationary equilibrium in which the cross-country distribution of net foreign assets is constant. Of course, due to the idiosyncratic shocks, individual countries experience fluctuations in their foreign asset position and in economic activity over time. Aside from standard productivity shocks, we consider "deleveraging" shocks, which tighten a country's access to credit and generate sudden stops in capital inflows. The presence of uninsurable risk against these shocks gives rise to a demand for precautionary savings. In turn, precautionary savings, coupled with a limited supply of assets arising from frictions on the credit markets, depress global interest rates.

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 shocks on the economy. 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, 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 2). Interestingly, a global liquidity trap can persist for an arbitrarily long time, in line with the notion of secular stagnation described

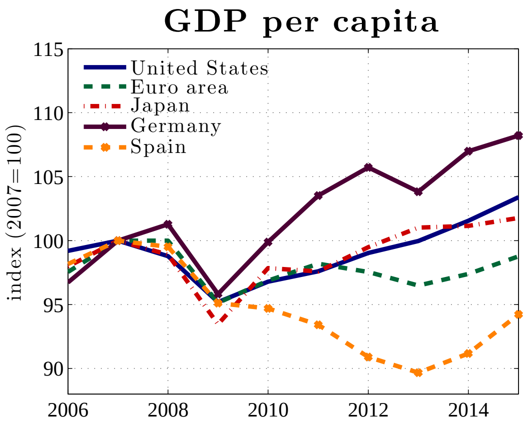

Figure 2: Real gross domestic product per capita. Note: the figure highlights the relatively fast recoveries from the 2009 recession experienced by the US and Japan, and the slow recovery in the Euro area. The figure also shows the heterogeneity between fast-recovering core Euro area countries, captured by Germany, and the stagnation experienced by peripheral Euro area countries, captured by Spain. See Appendix *D* for data sources.

by Hansen (1939) and Summers (2016).[2]

Against this background, we show that in good times governments have an incentive to subsidize private savings, or tax borrowing, as a precaution against the risk of a future liquidity trap triggered by a negative shock. 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, in the absence of international cooperation, governments in countries operating at full employment implement policies to increase savings beyond what private agents would choose in a laissez faire equilibrium.

The key insight of the paper is that this state of affair is inefficient from a global perspective. By stimulating savings, governments in countries undergoing a period of robust economic performance increase the global supply of savings, depressing interest rates around the world. This, in turn, aggravates the recession in those countries stuck in a liquidity trap. However, since individual countries are small, when acting uncooperatively governments do not internalize the impact of their credit policies on interest rates and employment in the rest of the world. This is an *international aggregate demand externality* that calls for international cooperation to be corrected. In fact, we show that in an uncooperative equilibrium governments in countries at full employment subsidize savings, or tax borrowing, at an inefficiently high rate, compared to what would happen if countries cooperate to maximize global welfare. In fact, under the cooperative optimal policy countries internalize the fact that a stronger demand for borrowing and consumption from countries at full employment sustains global rates, reducing the recession in liquidity trap economies. Indeed, in some cases, in a cooperative equilibrium countries in good times might even impose a tax on

[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.

savings, in order to stimulate global demand for consumption. Hence, our results point toward the need for international coordination in the design of credit market interventions when the world experiences a global liquidity trap.

This paper is related to two 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, we study economies inhabited by infinitely lived agents, in line with most literature on monetary economics. Moreover, 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. Finally, while both Caballero et al. (2015) and Eggertsson et al. (2016) present insightful discussions about the international spillovers arising in a global liquidity trap, we are, to the best of our knowledge, the first to derive the optimal cooperative and uncooperative credit policies in a secular stagnating world, as well as to quantify the gains from international cooperation.

Second, the paper is related to the literature on deleveraging and liquidity traps. As already discussed, 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. Building on these positive contributions, Farhi and Werning (2016) and Korinek and Simsek (2016) derive the optimal credit market interventions in closed economies at risk of a liquidity trap following a deleveraging shock.[3] Benigno and Romei (2014) and Fornaro (2012) study deleveraging and liquidity traps in open economies. Both works consider only temporary liquidity traps driven by a one-time global deleveraging shock, and do not focus on optimal credit policy. We contribute to this literature by showing that, aside from domestic aggregate demand externalities, a global liquidity trap is characterized by international aggregate demand externalities, which require international cooperation to be corrected.

The rest of the paper is composed by four sections. Section 2 presents a simple baseline framework of an imperfectly financially integrated world with nominal rigidities. In Section 3 we use the baseline model to shed light on the optimal cooperative and uncooperative credit policies during a global liquidity trap. Section 4 provides an extended version of the baseline model and provide a quantitative analysis. Section 5 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 4, the intuitions from this simple model carry through to the extended

[3] Farhi and Werning (2012) and Schmitt-Grohé and Uribe (2015) study optimal credit market interventions when the constraint on monetary policy is due to fixed exchange rate.

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 $t \in \{0, 1, ...\}$, and there is perfect foresight.

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 $C_{i,t}^N$

$$C_{i,t} = \left(C_{i,t}^T\right)^{\omega} \left(C_{i,t}^N\right)^{1-\omega},$$

where $0 < \omega < 1$.

Each household is endowed with one unit of labor. There is no disutility from working, and hence 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 hence 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 $R_{i,t}^n$.

Investment in bonds is subsidized by the government at rate $\tau_{i,t}$. $\tau_{i,t}$ can be interpreted as a subsidy on savings or, if the household is a debtor, as a tax on borrowing. This policy instrument is meant to capture a variety of credit market policies, for instance macroprudential regulation, aiming at influencing private agents' saving and borrowing decisions. Importantly, we assume that the same subsidy applies to all the financial assets purchased by households. In particular, it is not possible for the government to discriminate between domestic and foreign assets. This assumption captures a world characterized by a high degree of international financial integration and capital mobility, in which differential tax treatment between domestic and foreign assets is not possible.[4]

[4]See Farhi and Werning (2016) for an analysis of a small open economy in which the constraint on monetary policy is due to a currency peg, and in which differential tax treatment between domestic and international bonds is allowed.

The household budget constraint in terms of the domestic currency is

$$P_{i,t}^T C_{i,t}^T + P_{i,t}^N C_{i,t}^N + \frac{P_{i,t}^T B_{i,t+1}}{R_t(1+\tau_{i,t})} + \frac{B_{i,t+1}^n}{R_{i,t}^n(1+\tau_{i,t})} = W_{i,t}L_{i,t} + P_{i,t}^T Y_{i,t}^T + P_{i,t}^T B_{i,t} + B_{i,t}^n + T_{i,t}. \quad (2)$$

The left-hand side of this expression represents the household's expenditure. $P_{i,t}^T$ and $P_{i,t}^N$ denote respectively the price of a unit of tradable and non-tradable good in terms of country i currency. Hence, $P_{i,t}^T C_{i,t}^T + P_{i,t}^N C_{i,t}^N$ is the total nominal expenditure in consumption. $B_{i,t+1}$ and $B_{i,t+1}^n$ denote respectively the purchase of real and nominal bonds made by the household at time t, at prices $P_{i,t}^T/(R_t(1+\tau_{i,t})$ and $1/(R_{i,t}^n(1+\tau_{i,t})$. If $B_{i,t+1} < 0$ or $B_{i,t+1}^n < 0$ 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. $Y_{i,t}^T$ is an endowment of tradable goods received by the household. Changes in $Y_{i,t}^T$ 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. $P_{i,t}^T B_{i,t}$ and $B_{i,t}^n$ represent the gross returns on investment in bonds made at time $t-1$. Finally, $T_{i,t}$ is a lump-sum transfer that the household receives from the government.

There is a limit to the amount of debt that a household can take. For simplicity, in the baseline model we assume that households cannot borrow at all. Hence, their end-of-period bond position has to satisfy

$$B_{i,t+1} + \frac{B_{i,t+1}^n}{P_{i,t+1}^T} \geq 0, \quad (3)$$

Later on, in Section 4, we will relax this assumption and allow households to take some debt.

The household's optimization problem consists in choosing a sequence $\{C_{i,t}^T, C_{i,t}^N, B_{i,t+1}, B_{i,t+1}^n\}_t$ to maximize lifetime utility (1), subject to the budget constraint (2) and the borrowing limit (3), taking the initial bond holdings $B_{i,0}$ and $B_{i,0}^n$, a sequence for income $\{W_{i,t}L_{i,t} + P_{i,t}^T Y_{i,t}^T\}_t$, prices $\{R_t, R_{i,t}^n, P_{i,t}^T, P_{i,t}^N\}_t$, and taxes $\{\tau_{i,t}, T_{i,t}\}_t$ as given. The household's first-order conditions can be written as

$$\omega P_{i,t}^N C_{i,t}^N = (1-\omega) P_{i,t}^T C_{i,t}^T \quad (4)$$

$$\frac{1}{C_{i,t}^T} = R_t(1+\tau_{i,t}) \left(\frac{\beta}{C_{i,t+1}^T} + \mu_{i,t} \right) \quad (5)$$

$$\frac{1}{C_{i,t}^T} = \frac{R_{i,t}^n P_{i,t}^T}{P_{i,t+1}^T}(1+\tau_{i,t}) \left(\frac{\beta}{C_{i,t+1}^T} + \mu_{i,t} \right) \quad (6)$$

$$B_{i,t+1} + \frac{B_{i,t+1}^n}{P_{i,t+1}^T} \geq 0, \quad \text{with equality if } \mu_{i,t} > 0, \quad (7)$$

where $\mu_{i,t} \geq 0$ is the Lagrange multiplier associated with the borrowing constraint. Equation (4) defines the optimal allocation of consumption expenditure between tradable and non-tradable goods. Equations (5) and (6) are the Euler equations for, respectively, real and nominal bonds. Equation (7) is the complementary slackness condition associated with the borrowing constraint.

Combining (5) and (6) gives a no arbitrage condition between real and nominal bonds

$$R_{i,t}^n = R_t \frac{P_{i,t+1}^T}{P_{i,t}^T}. \tag{8}$$

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.

2.2 Firms

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

$$Y_{i,t}^N = L_{i,t}. \tag{9}$$

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

$$P_{i,t}^N = W_{i,t}. \tag{10}$$

2.3 Nominal wage rigidities

We introduce nominal rigidities by assuming 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.

The presence of downward wage rigidities implies that the labor market might not clear. In fact, equilibrium on the labor market is captured by the condition

$$L_{i,t} \leq 1, \quad \text{with equality if} \quad W_{i,t} > \gamma W_{i,t-1}. \tag{11}$$

This condition implies that unemployment arises only if the constraint on wage adjustment binds. Hence, 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.[5]

[5] 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 $\tilde{\gamma}'(\cdot) \geq 0$.

2.4 Monetary and fiscal policy

We describe monetary policy in terms of targeting rules. In particular, in our baseline model we consider central banks that target inflation of the domestically produced good. More formally, the objective of the central bank is to set

$$\frac{P_{i,t}^N}{P_{i,t-1}^N} \equiv \pi_{i,t} = \bar{\pi}.$$

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).[6]

The central bank runs monetary policy by setting the nominal interest rate $R_{i,t}^n$. We assume that the nominal interest rate is subject to a zero lower bound constraint, so that $R_{i,t}^n \geq 1$.[7] This constraint might prevent the central bank from attaining its inflation target.[8]

The government sets the subsidy $\tau_{i,t}$ and adjusts $T_{i,t}$ to run a balanced budget. Hence, every period the lump-sum transfers satisfy:

$$T_{i,t} = -\left(\frac{B_{i,t+1}}{R_t} + \frac{B_{i,t+1}^n}{P_{i,t}^T R_{i,t}^n}\right) \frac{\tau_{i,t}}{1+\tau_{i,t}}.$$

2.5 Market clearing and definition of the 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 divided by the world interest rate, $NFA_{i,t} = B_{i,t+1}/R_t$.

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

$$C_{i,t}^N = Y_{i,t}^N. \tag{12}$$

[6]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 possibility 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.

[7]We provide in appendix B 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.

[8]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.

Since nominal bonds are traded only among households belonging to the same country, and since all the households in a given country are identical, in a symmetric equilibrium it must be that

$$B^n_{i,t} = 0, \tag{13}$$

for all i and t. Hence, at the country level market clearing for the tradable consumption good requires

$$C^T_{i,t} = Y^T_{i,t} + B_{i,t} - \frac{B_{i,t+1}}{R_t}. \tag{14}$$

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

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

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, $B_{i,t}(1 - 1/R_{t-1})$.

Finally, in every period the world consumption of the tradable good has to be equal to the 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

$$\int_0^1 B_{i,t+1}\,\mathrm{d}i = 0. \tag{15}$$

Definition 1 *The equilibrium is a path of real allocations* $\{C^T_{i,t}, C^N_{i,t}, L_{i,t}, Y^N_{i,t}, B_{i,t+1}, B^n_{i,t+1}, \mu_{i,t}\}_{i,t}$, *prices* $\{P^N_{i,t}, P^T_{i,t}, W_{i,t}\}_{i,t}$ *and world interest rate* $\{R_t\}_t$, *satisfying* (4)−(7), (9)−(15), *given a path of endowments* $\{Y^T_{i,t}\}_{i,t}$, *a path of policy instruments* $\{R^n_{i,t}, \tau_{i,t}\}_{i,t}$, *and initial conditions* $\{B_{i,0}, W_{i,-1}\}_i$.

3 Aggregate demand externalities and credit policies in a global liquidity trap

We now characterize the equilibrium of the baseline model. We proceed in three steps. First we solve for the equilibrium of a generic small open economy i, given a path for the subsidy $\tau_{i,t}$. We then derive the uncooperative optimal credit policy, that is the optimal path $\{\tau_{i,t}\}_t$ chosen by the government of a generic country i. Finally, we derive the global equilibrium and turn to the cooperative optimal credit policy. In particular, we solve the problem of a world social planner choosing $\{\tau_{i,t}\}_{i,t}$ to maximize global welfare.

Throughout this section, we focus on a specific process for the tradable endowment that allows us to derive analytic results. We consider a case in which there are two possible realizations of the tradable endowment: high (Y^T_h) and low (Y^T_l) with $Y^T_l < Y^T_h$. We assume that half of the countries receives Y^T_h in even periods and Y^T_l in odd periods. Symmetrically, the other half receives Y^T_l during even periods and Y^T_h 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 simple endowment process is meant to capture an environment in which countries are hit by asymmetric shocks.

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 $B_{i,0} = 0$ for every country i, which we assume throughout this section. 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.

3.1 A small open economy

We now derive the equilibrium behavior of a single small open economy. We start by making some assumptions to streamline the exposition. First, we focus on credit subsidies that are a function of the endowments only, so that $\tau_{h,t} = \tau_h$ and $\tau_{l,t} = \tau_l$ for all t. We also set $\tau_l = 0$. As we will see, these are features of the optimal credit market policies that we will consider later. Second, we impose some restrictions on the world interest rate.

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

$$Y_l^T / Y_h^T \leq \beta R(1 + \tau_h) < 1.$$

We will later show that these restrictions emerge naturally in general equilibrium.

Solving for the path of tradable consumption is straightforward. From period 0 on, the economy enters a stationary equilibrium in which households are unconstrained and purchase $B_{h,t+1} = B_h \geq 0$ bonds in the high state, while the borrowing constraint binds in the low state, so that $B_{l,t+1} = B_l = 0$.[9] Since the borrowing constraint does not bind in the high state, and so $\mu_{h,t} = 0$, the Euler equation (5) implies

$$\frac{1}{C_h^T} = \beta R(1 + \tau_h)\frac{1}{C_l^T}, \tag{16}$$

where we have removed the time subscripts to simplify the notation. Combining this expression with the resource constraint (14) and using $B_l = 0$ gives the optimal demand from bonds in the high state

$$B_h = \frac{\beta R(1 + \tau_h)}{1 + \beta(1 + \tau_h)}\left(Y_h^T - \frac{Y_l^T}{\beta R(1 + \tau_h)}\right). \tag{17}$$

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

$$C_h^T = Y_h^T - \frac{B_h}{R} = \frac{1}{1 + \beta(1 + \tau_h)}\left(Y_h^T + \frac{Y_l^T}{R}\right) \tag{18}$$

[9] In fact, assumption 1 implies that the economy is sufficiently impatient with respect to the rest of the world to be borrowing constrained in the low state, but sufficiently patient to save while in the high state.

$$C_l^T = Y_l^T + B_h = \frac{\beta R(1+\tau_h)}{1+\beta(1+\tau_h)} \left(Y_h^T + \frac{Y_l^T}{R} \right). \tag{19}$$

Notice that, since $\beta R(1+\tau_h) < 1$, these expressions imply 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. To derive intuition, it is convenient to write an aggregate demand equation that relates demand for non-tradables to the policy rate. Start by rewriting equation (4) as

$$C_{i,t}^N = \frac{1-\omega}{\omega} \frac{P_{i,t}^T}{P_{i,t}^N} C_{i,t}^T.$$

According to this expression, the demand for non-tradables is decreasing in their relative price $P_{i,t}^N / P_{i,t}^T$. Moreover, the demand for non-tradables is increasing in $C_{i,t}^T$, because of households' desire to have a balanced consumption basket between tradable and non-tradable goods.

Now combine this expression with equation (8) to obtain an aggregate demand (AD) equation

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

This expression is essentially an open-economy version of the New-Keynesian IS equation. As in the standard closed economy IS equation, 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, a lower world interest rate is associated with lower demand for non-tradable consumption, because of an expenditure switching effect. A low world interest rate corresponds to a low price for consuming tradable goods in the present. Hence, a fall in the world interest rate induces households to switch expenditure away from non-tradable goods and toward tradable goods, generating a drop in the demand for non-tradables. As we will see, a low R is associated with a low world demand for tradable goods. Hence, the world interest rate is the transmission channel through which global demand affects the demand for locally-produced goods.

The second key equation to derive the equilibrium in the market for non-tradables is the monetary policy (MP) rule

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

The MP equation captures the fact that unemployment arises only if the central bank is constrained by the zero lower bound.

It is useful to start by taking a partial equilibrium approach, i.e. by deriving the equilibrium holding future variables constant. Figure 3 shows the AD and MP curves in the $R_{i,t}^n - L_{i,t}$ space,

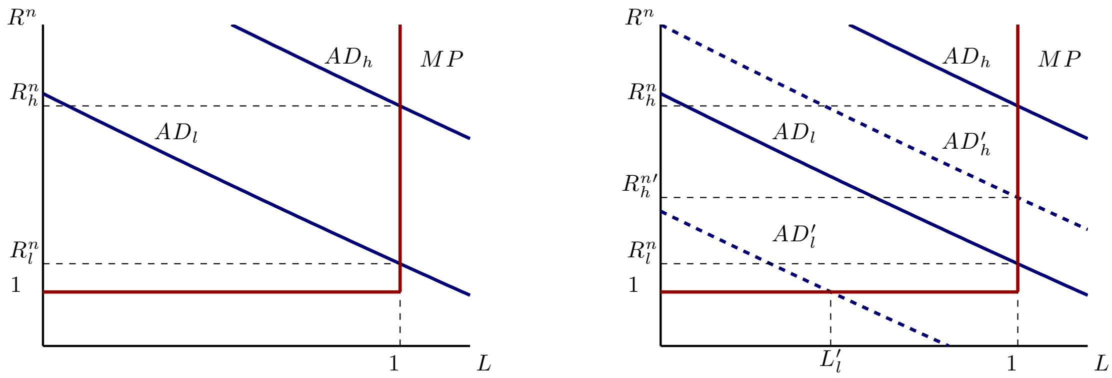

Figure 3: Aggregate demand and employment. Left panel: equilibrium on market for non-tradables. Right panel: high R (solid lines) vs. low R (dashed lines).

where we have substituted the equilibrium relationship $C_{i,t}^N = L_{i,t}$ in the AD equation. 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. 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 sustain aggregate demand.

The right panel of the diagram 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 parameter γ and the world interest rate R are such that:*

$$R\gamma > 1.$$

Proposition 1 ***Small Open Economy Equilibrium.*** *Define $R^* \equiv (\bar{\pi}\beta(1+\tau_h))^{-1/2}$. If $R \geq R^*$ then $L_h = L_l = 1$ and $R_h^n > R_l^n \geq 1$. Otherwise, $L_h = 1$ and $R_h^n > 1$, while $L_l = R^2\bar{\pi}\beta(1+\tau_h) < 1$ and $R_l^n = 1$.*

Proof. See Appendix A.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

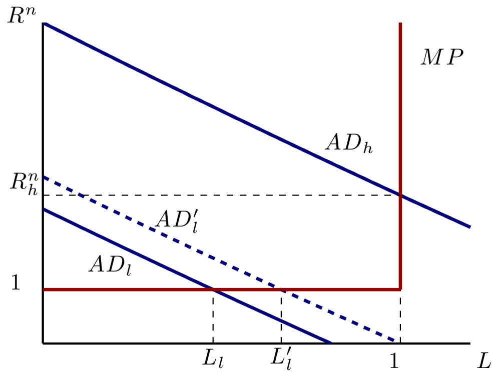

Figure 4: Response to increase in τ_h. Solid lines refer to $\tau_h = 0$, dashed lines refer to $\tau_h > 0$.

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 $L_h = 1$. 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.

We think of the case $R < R^*$ 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, as we will see, this state of affair can persist for an arbitrarily long period of time, as long as global forces imply that $R < R^*$. In this sense, the model captures in a simple way the salient features of a world undergoing a period of secular stagnation, as described by Summers (2016).

3.2 Optimal uncooperative credit policy

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

In this paper we take a different route and consider the role of credit policies, and in particular of the saving subsidy τ_h, in stabilizing aggregate demand and employment. To understand the link between τ_h and employment in the low state, consider that following Proposition 1 we can write

$$L_l = \min\left(R^2 \bar{\pi}\beta(1+\tau_h), 1\right). \tag{20}$$

This expression implies that, for given R, employment in the low state is weakly increasing in τ_h. Intuitively, a higher τ_h induces households to save more while the economy is in the high state.

Hence, the higher τ_h the higher the disposable income that households can spend in the low state, when the borrowing constraint binds. As a result, an increase in τ_h leads to a rise in tradable consumption in the low state, and, consequently, to higher aggregate demand.[10] In turn, if the central bank is constrained by the zero lower bound, higher demand leads to higher employment. Graphically, as illustrated by Figure 4, an increase in τ_h makes the AD_l curve shift right to AD_l', and generates a rise in L_l.[11]

How does a government optimally exploit the positive relationship between saving subsidy and employment arising when monetary policy is constrained by the zero lower bound? We now address this question by deriving the uncooperative optimal policy, that is the optimal subsidy from the perspective of a single small open economy. In particular, we solve the problem of a Ramsey planner choosing τ_h to maximize utility (1) subject to the demand functions for tradable goods (18) and (19), the full employment condition in the high state $L_h = 1$ and the expression determining employment in the low state (20). Importantly, since each country is infinitesimally small compared to the rest of the world, the Ramsey planner takes the world interest rate R as given.

Proposition 2 ***Optimal Uncooperative Credit Policy.*** *Consider the problem of a Ramsey planner choosing τ_h to maximize (1) subject to (18), (19), $L_h = 1$ and (20). Define $\tau_h^* \equiv \left(R^2\bar{\pi}\beta\right)^{-1} - 1$, as the smallest subsidy consistent with full employment in the l state. The solution is*

$$\begin{cases} \tau_h^u = 0 & \text{if } \tau_h^* \leq 0 \\ \tau_h^u = \frac{1}{\omega-\beta(1-\omega)} - 1 & \text{if } \tau_h^* > \frac{1}{\omega-\beta(1-\omega)} - 1 \\ \tau_h^u = \tau_h^* & \text{otherwise} , \end{cases}$$

where τ_h^u denotes the optimal subsidy under the uncooperative policy. Moreover, if $\tau_h^* > \frac{1}{\omega-\beta(1-\omega)} - 1$ then under the optimal policy $L_l < 1$, otherwise $L_l = 1$.

Proof. See Appendix A.2. ■

Proposition 2 highlights two key results. First, if for $\tau_h = 0$ the zero lower bound never binds and so $L_h = L_l = 1$, then the planner does not distort private saving decisions and sets $\tau_h^u = 0$. This result highlights the fact that in our simple model there is no need for the government to intervene on the credit markets if monetary policy is not constrained by the zero lower bound.

Second, if at $\tau_h = 0$ the zero lower bound binds in the low state, then the planner sets $\tau_h^u > 0$. Intuitively, the planner intervenes on the credit market because atomistic agents do not internalize the fact that higher savings in the high state lead, when the zero lower bound binds, to higher employment and consumption of the non-tradable good in the low state. This is a *domestic*

[10] Instead, there is no role for τ_l to increase aggregate demand in the low state. In fact, as long as τ_l is low enough so that $(\beta R)^2(1+\tau_h)(1+\tau_l) \leq 1$ holds, in the low state the borrowing constraint binds and changes in τ_l do not affect the borrowing decisions. Moreover, setting τ_l high enough so that the borrowing constraint no longer binds in the low state would lead to a fall in C_l^T, and thus depress aggregate demand in periods of low endowment.

[11] One can show that, in our baseline model, the subsidy does not alter aggregate demand in the high state, and hence the AD_h curve does not move after an increase in the subsidy.

aggregate demand externality, that the planner corrects by subsidizing savings in the high state. This intervention, however, comes at the cost of distorting the path of tradable consumption. The optimal policy strikes a balance between the benefit of increasing L_l against the cost of distorting C_h^T/C_l^T.

Proposition 2 extends the results of Farhi and Werning (2016) and Korinek and Simsek (2016) to our open economy setting. As in their works, due to the presence of domestic aggregate demand externalities, credit policies act as a complement for monetary policy when the monetary authority is constrained by the zero lower bound. While this point is well understood, little is known about the international implications of these credit market interventions. We tackle this issue next.

3.3 Global equilibrium and cooperative optimal policy

We start this section by solving for the global equilibrium. We focus on a symmetric equilibrium in which all the countries choose the same subsidy τ_h. The first step consists in deriving the equilibrium world interest rate, that is the interest rate that clears the world bond market. Bonds are supplied by countries in the low state. Since these countries are against the borrowing constraint, the supply of bonds is $-B_l = 0$.[12] Demand for bonds comes from countries in the high state, and hence is given by equation (17). Equating demand and supply gives the equilibrium world interest rate

$$R = \frac{Y_l^T}{\beta(1+\tau_h)Y_h^T}. \tag{21}$$

Expression (21) relates the world interest rate to the fundamentals of the economy. Naturally, a higher β leads to a higher demand for bonds by saving countries, and thus to a lower interest rate. Moreover, the 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 $Y_l^T/Y_h^T \leq \beta R(1+\tau_h) < 1$, consistent with Assumption 1. Moreover, at this interest rate countries end up consuming exactly their endowment of tradable goods so that $C_h^T = Y_h^T$ and $C_l^T = Y_l^T$. We collect these results in the following lemma.

Lemma 1 ***Global Equilibrium.*** *In a global equilibrium* $C_{h,t}^T = Y_h^T$, $C_{l,t}^T = Y_l^T$ *and* $R_t = Y_l^T/(\beta(1+\tau_h)Y_h^T)$ *for all* t.

Importantly, in a global equilibrium the subsidy cannot alter the path of tradable consumption. This is because, since countries cannot issue debt, in a symmetric equilibrium all the countries must hold zero bonds. However, the subsidy τ_h affects the world interest rate by determining the demand for bonds by countries in the high state. To gain intuition, consider a case in which all the countries increase the subsidy. The higher subsidy increases the world supply of savings, or equivalently reduces the world demand for tradable goods. To restore equilibrium the interest rate has to fall, so as to bring back the saving supply to its equilibrium value of zero. Graphically, as

[12] Hence, our baseline model is in the spirit of the zero liquidity economy studied by Werning (2015).

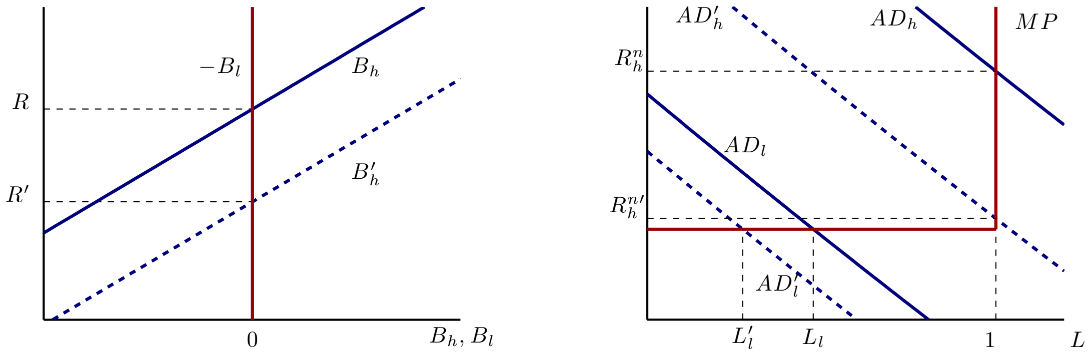

Figure 5: Global response to rise in τ_h. Solid lines: $\tau_h = 0$. Dashed lines: $\tau_h > 0$.

shown by the left panel in Figure 5, a higher subsidy makes the B_h curve shift toward the right and leads to a fall in the world interest rate.

As we have seen, a low world demand for tradable consumption makes it more likely that monetary policy is constrained by the zero lower bound, and hence that unemployment arises, in countries hit by negative shocks. This is illustrated by the right panel of Figure 5, which shows that in general equilibrium a higher subsidy implemented by countries in the high state makes the AD curves shift left, leading to a rise in unemployment in countries in the low state. Through this channel, interventions on the credit markets generate international spillovers, or *international aggregate demand externalities*, not internalized by individual countries. It is then interesting to understand how a global planner that aims at maximizing global welfare chooses credit market interventions optimally.

Proposition 3 ***Optimal Cooperative Credit Policy.*** *Consider a global Ramsey planner that chooses* τ_h *to maximize*

$$\int_0^1 \sum_{t=0}^{\infty} \log(C_{i,t}) di,$$

subject to $C_h^T = Y_h^T$, $C_l^T = Y_l^T$, $L_h = 1$, (20) *and* (21). *The solution* τ_h^c *is*

$$\tau_h^c \leq \left(\frac{Y_l^T}{Y_h^T}\right)^2 \frac{\bar{\pi}}{\beta} - 1 \quad \rightarrow \quad L_l = 1.$$

Moreover, if τ_h^* *evaluated at* $\tau_h = 0$ *satisfies* $\tau_h^* > 0$ *it must be that* $\tau_h^c < 0 < \tau_h^u$, *and that setting* $\tau_h = \tau_h^c$ *leads to a Pareto improvement compared to setting* $\tau_h = \tau_h^u$.

Proof. See Appendix *A.3*. ■

Proposition 3 contains the key insight of the paper. In fact, it states that, if unemployment arises under laissez faire, the subsidy under the optimal cooperative policy is unambiguously lower than the one in the uncooperative equilibrium. This result is due to the fact that the planner, contrary to the governments of atomistic countries, internalizes that a rise in τ_h depresses the world demand for consumption, and increases unemployment in countries hit by a negative shock. This means that, when acting uncooperatively, governments in surplus countries implement inefficiently high saving subsidies, because they do not internalize the negative demand spillovers imposed on countries currently experiencing a liquidity trap. This result points toward the need to coordinate internationally credit market interventions.

The proposition also states some additional results, more specific to the simplified baseline model. First, it states that under the cooperative optimal policy there is always full employment. Intuitively, since in equilibrium every country must hold zero bonds, changes in the subsidy τ_h do not affect the path of tradable consumption, but only the world interest rate.[13] Hence, effectively the global planner is free to choose any value of R without distorting the path of tradable consumption. Since a higher world interest rate leads to higher employment and non-tradable consumption in countries in the low state, it is then always optimal for the global planner to set τ_h low enough so that all the countries always operate at full employment. Second, in the baseline model all the countries are better off under the cooperative optimal policy compared to the uncooperative one. This result is due to the fact that the optimal cooperative policy restores full employment, without distorting the path of tradable consumption.[14]

Summarizing, we have shown that the combination of borrowing constraint and shocks to the endowment can give rise to a low interest rate world, in which countries frequently experience liquidity traps and unemployment due to weak aggregate demand. In this world, due to domestic aggregate demand externalities, governments have an incentive to subsidize savings in good times as a precaution against the risk of a future liquidity trap triggered by a negative shock. However, this policy, by decreasing world demand for consumption, imposes negative externalities on the countries currently experiencing a liquidity trap. This result points toward the need for cooperation when implementing macroprudential policies in order to correct for aggregate demand externalities.

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.

4 Quantitative analysis

In this section we relax some of the assumptions of the baseline model presented in Section 2, and we perform a quantitative analysis. Our goal is to understand whether there are large gains from international cooperation in designing credit market policies.

[13] Notice the asymmetry with respect to a national planner. Since every country is infinitesimally small, a national planner takes the world interest rate as given, and hence does not internalize the impact of changes in τ_h on R.

[14] In Appendix C we consider a version of the baseline model in which borrowing is allowed. In that version of the model changes in the subsidy have an impact on the path of tradable consumption in general equilibrium. In the appendix, we discuss the trade-offs faced by the global socail planner, and show that it might not be optimal for the global planner to restore full employment.

4.1 Extended model

We extend the baseline model in several directions. We generalize the utility function to

$$E_t \left[\sum_{t=0}^{\infty} \beta^t \frac{C_{i,t}^{1-\sigma} - 1}{1-\sigma} \right]$$

$$C_{i,t} = \left[\omega \left(C_{i,t}^T \right)^{1-\frac{1}{\xi}} + (1-\omega) \left(C_{i,t}^N \right)^{1-\frac{1}{\xi}} \right]^{\frac{\xi}{\xi-1}},$$

where $\sigma > 0$ and $\xi > 0$.

We also allow countries to take some positive amount of debt. In particular, we replace the borrowing limit (3) with

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

where $\kappa_{i,t} > 0$. This constraint captures in a simple way a case in which agents have a limited commitment to repay future debts, so that expected payment to creditors in period $t+1$ cannot exceed $\kappa_{i,t}$ units of tradables. As we will see, this assumption, coupled with the idiosyncratic shocks, generates a rich distribution of net foreign assets across countries.

Finally, we introduce uncertainty through two channels. First, the assume that the endowment of tradable goods is stochastic. This is meant to capture stochastic variations in the productivity of tradable goods, or in their terms of trade. Second, we introduce financial, or deleveraging shocks, by assuming that the borrowing limit $\kappa_{i,t}$ is stochastic.

It is not possible to find analytic solutions for this extended version of the model. Hence, we analyze its properties using numerical simulations. In order to capture the non-linearities present in the model, we use a global solution method.

4.2 Parameters

One period corresponds to one year. We set some parameters in line with the international macroeconomics literature. Hence, we set the coefficient of relative risk aversion to $\sigma = 2$, the elasticity of substitution between tradable and non-tradable goods to $\xi = .5$, and the share of tradable goods in consumption expenditure to $\omega = .25$. These values are inside the range commonly considered by the literature.

We set the discount factor to $\beta = 0.985$, so that in the stationary equilibrium without credit market interventions the world interest rate is $R = 1.01$. This is meant to capture the low interest rate environment that has characterized advanced economies since the 2008 global financial crisis. For comparison, between 2009 and 2013 the the average of the world real interest rate estimated by King and Low (2014) is 0.85%

We set the parameter that governs the downward wage rigidity to $\gamma = 1$, meaning that firms cannot lower nominal wages. This is in the range of the estimates provided by Schmitt-Grohé and Uribe (2015). Moreover, the annual inflation rate target is set to $\bar{\pi} = 1.02$, in line with the

Table 1: Parameters

	Value	Source/Target
Risk aversion	$\sigma = 2$	Standard value
Elasticity consumption aggr.	$\xi = 0.5$	Standard value
Tradable share in expenditure	$\omega = 0.25$	Standard value
Discount factor	$\beta = 0.985$	$R = 1.01$
Downward wage rigidities	$\gamma = 1$	Schmitt-Grohé and Uribe (2015)
Inflation target	$\bar{\pi} = 1.02$	Standard value
Endowment process	$\sigma_\epsilon = 0.041,\ \rho = 0.78$	Estimate for advanced economies
Tradable output high mean	$\mu_l = \log(1.7)$	Estimate for the advanced economies
Tradable output low mean	$\mu = 0$	Normalization
Fraction of very rich countries	$\pi_{l,l} = 0.96$	Estimate for the advanced countries
Prob. of remaining in high mean	$\pi_{h,h} = 0.78$	Standard deviation NFA/GDP =0.55
Bond supply r.o.w.	$B_{rw} = 0.28$	$B_{rw}/\int_0^1 GDP_{i,t} di = 7\%$
High borrowing limit	$\kappa_h = 0.2.75$	
Low borrowing limit	$\kappa_l = 2.27$	
Persistence deleveraging	$\rho_\kappa = 0.7$	
Prob. entry deleveraging	$P_{entry} = 0.08$	
Prob. exit deleveraging	$P_{exit} = 0.51$	

inflation targets of the Federal Reserve and the European Central Bank. This means that, at full employment, real wages can fall by up to 2% per year.

We choose the remaining parameters to match a set of empirical observations for a sample of advanced economies.[15] In particular, we are interested in capturing some salient characteristics of the behavior of tradable output and net foreign assets.

We model the tradable sector output process as:

$$\log Y_{i,t}^T = (1-\rho)\mu_{i,t} + \rho \log Y_{i,t-1}^T + \sigma_\epsilon \epsilon_{i,t}$$

where $0 < \rho < 1$, $\epsilon_{i,t}$ follows a standard normal distribution, and $\mu_{i,t}$ is the mean of the process, which we allow to vary across countries and over time. This process is flexible enough to capture both the business cycle behavior of tradable output, as well as more structural and persistent differences in tradable output across countries.

The parameters ρ and σ_y govern the behavior of the business-cycle component of tradable output. To estimate them, we start by constructing series of the business cycle component of tradable output in our sample countries. We identify tradable output in the data as the sum of gross value added in agriculture and manufacturing.[16] The sample period goes from 1980 to 2014. For every country we then compute the standard deviation and first order autocorrelation of the de-trended series. We set $\sigma_\epsilon = 0.0414$ and $\rho = .7873$, so that the standard deviation and first order autocorrelation of our tradable output process are equal to the average values of its empirical counterparts across our sample countries.

We estimate the process for $\mu_{i,t}$ to capture long-run differences in tradable output across coun-

[15] Our sample of advanced economy is composed of Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States.

[16] Data are form the OECD. The series are expressed at constant prices, constant PPP and OECD base year.

tries. We introduce this further degree of heterogeneity in tradable output across countries because it will help us captures the cross-country distribution of net foreign assets observed in the data. We assume that $\mu_{i,t}$ can take two values: (μ_h) and $(\mu < \mu_h)$. We identify countries with $\mu_{i,t} = \mu_h$ as very rich countries which are characterized by particularly high values of tradable output per capita. For instance, this could be due to the presence of natural resources such as oil. To estimate μ_h and μ, we start by identifying a group of very rich countries. These are defined in each period as the set of countries whose per capita tradable output realization exceeds the ninetieth percentile of the normal distribution centered around a cross-sectional mean, and whose output has consistently been above this threshold.[17] We normalize μ to zero, and set μ_h to equal the logarithm of the ratio of the sample means of tradable sector output in the two groups. This gives us $\mu_h = \log(1.7)$.

Countries transition across the two groups according to the following Markov chain:

$$H_\mu = \begin{pmatrix} \pi_{l,l} & 1-\pi_{l,l} \\ 1-\pi_{h,h} & \pi_{h,h} \end{pmatrix}$$

where $\pi_{l,l}$ is the probability of remaining in a low mean group and $\pi_{h,h}$ is the probability of remaining in a high mean group. The fraction of countries who has been in the low mean group varies year by year, from a minimum of 72% to a maximum of 95%. Hence, we set the fraction of countries in the low mean group, Π_l, to equal 0.85, which falls within this range. We set the last remaining parameter, $\pi_{h,h}$, to match the average of the cross-sectional standard deviation of the Net International Investment Position to GDP ratio from 2000 to 2014.[18]

Since the 2008 global financial countries, our sample of advanced economies has been characterized by a negative aggregate net foreign asset position with respect to the rest of the world. To captures this fact, we assume that the rest of the world demands inelastically and amount of bonds B_{rw}. We set $B_{rw} = 0.28$, so that our economies have on aggregate a negative net foreign asset position with respect to the rest of the world equal to 7% of world GDP, in line with the corresponding empirical statistic observed between 2008 and 2014.

Finally, we turn to the calibration of the shocks to the borrowing limit. We model these shocks to capture the episodes of deleveraging that have affected several countries in our sample, especially in the aftermath of the 2008 financial crisis. We start by assuming that an economy can be either in normal times, or in an episode of deleveraging. In normal times, access to credit is abundant, and $\kappa_{i,t} = \kappa_h$. Instead, when a country enters an episode of deleveraging, its borrowing limit evolves according to

$$\log(\kappa_{i,t}) = \rho_\kappa \log(\kappa_{i,t-1}) + (1-\rho_\kappa)\log(\kappa_l),$$

where $\kappa_l < \kappa_h$. Hence, when a country is hit by a deleveraging shock it experiences a progressive

[17] More precisely, the threshold is defined as the cross-sectional average augmented by 1.28 times the cross-sectional standard deviation. Countries' tradable output realization must have been above the threshold for at least 15% of the years available. The threshold is computed In our sample, very rich countries include Austria, Germany, Ireland, Norway and Switzerland.

[18] We collect the data on NIIP from International Financial Statistics dataset of IMF. Data are all in US dollars. GDP data are taken from OECD website. GDP is at constant price and constant exchange rate.

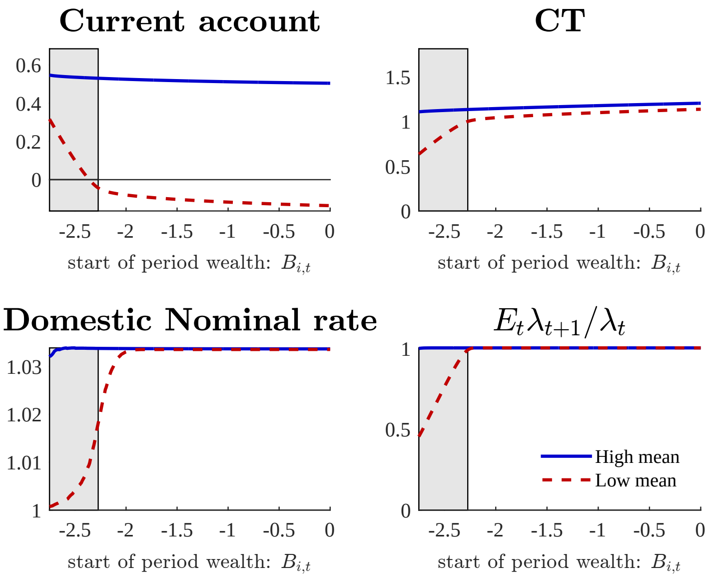

Figure 6: Policy functions.

tightening in the access to credit. We define P_{entry} as the probability that a country in normal times enters and episode of deleveraging. Instead, during an episode of deleveraging, each period a country has a probability P_{exit} of going back to normal times.

We set $\kappa_h, \kappa_l, P_{entry}$ and P_{exit} as follows. First, we identify in the data an episode of deleveraging has a year in which household debt decreases with respect to the previous year and GDP is below its trend.[19] We set $P_{entry} = .08$ and $P_{exit} = .51$ to match the transition probabilities between the two states in our sample. We set $\kappa_H = 2.75$, to match the average negative Net International Investment Position to GDP ratio from 2000 to 2014, that is -38%. We set $\kappa_l = 2.27$. This implies a fall of 18% of the debt limit from peak to through. We set this parameter to match the fall of household debt to GDP in the United States from 2008 to 2014.[20] Finally we set $\kappa = 0.7$.

4.3 Stationary equilibrium under laissez-faire

In this section we analyze the equilibrium emerging under laissez-faire, that is when every country sets $\tau_{i,t} = 0$. We focus on a stationary equilibrium, in which both the interest rate and the net foreign asset distribution across countries are constant. Figure 6 displays the current account balance, consumption of tradable goods, the domestic nominal interest rate and the expected growth of Lagrange multipliers on the budget constraint as a function of the stock of net foreign assets held by the country at the start of the period. We consider countries hit by a deleveraging shock. The solid lines refer to a country with high mean tradable output, while the dashed lines refer to a country with low mean tradable output. The grey shaded area is the region of the state space between the two realizations of the borrowing constraint shocks. We will call this area the deleveraging area.

[19] Data are from the Bank of International Settlement.
[20] We are abstracting from changes in GDP during the process.

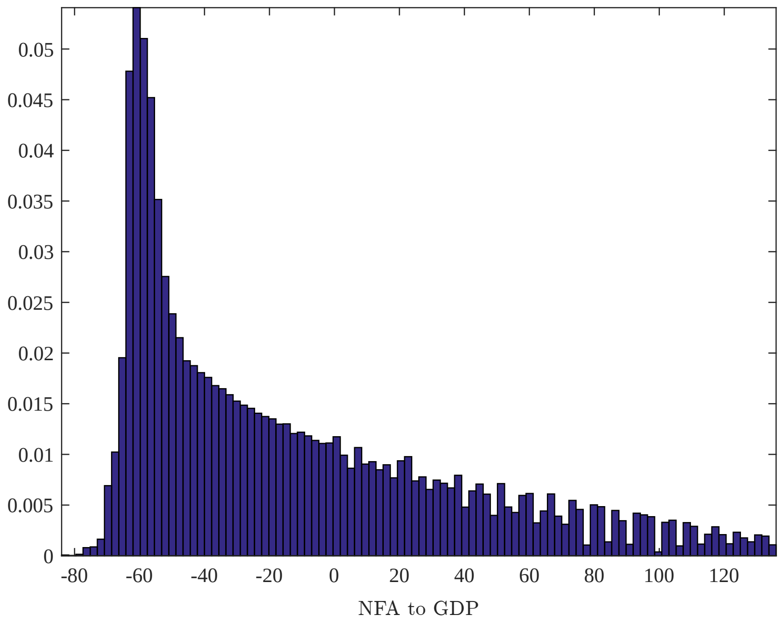

Figure 7: Stationary distribution of net foreign asset to GDP.

Let us start from the behavior of the current account. In general, a country runs a current account surplus when tradable endowment is high, and a deficit when the endowment is low. This is due to the fact that countries use the international credit markets to smooth consumption over time. However, for high level of initial foreign debt, countries hit by the deleveraging shock are forced to reduce their external debt. This explains why countries with low mean tradable in the deleveraging region experience rises in the current account following a deleveraging shock for high levels of initial debt. Essentially, in high-debt countries a deleveraging shock generates a sudden stop in capital inflows, which translates into a large increase in the current account. As shown by the top-right panel of the figure, in high debt countries deleveraging is associated with a large drop in tradable consumption. As we have seen in the baseline model, this corresponds to a negative demand shock for non-tradable consumption. In turn, as shown by the bottom-left panel, the central bank responds to that by lowering the nominal rate, and might end up being constrained by the zero lower bound. Finally, the expected growth of the Lagrange multiplier is a proxy for the severity of the borrowing constraint. A low value for this variable indicates that the constraint is binding. As shown in Figure 6, low mean countries in the deleveraging area are the ones for which the borrowing constraint binds.

Figure 7 shows the stationary distribution of net foreign asset position to GDP. The distribution of net foreign asset is skewed and truncated toward the left. This is due to the presence of the borrowing constraint. In fact, there is no limit to the stock of positive assets that a country can accumulate, while the borrowing limit puts a lower bound on the net foreign asset position. In our model, the highest value of external debt reached in equilibrium is around 80% of GDP. This is a bit lower, but not too far, from the level of external debt seen in peripheral euro area countries since the 2008 financial crisis. Moreover, our model generates a very wide distribution of net foreign

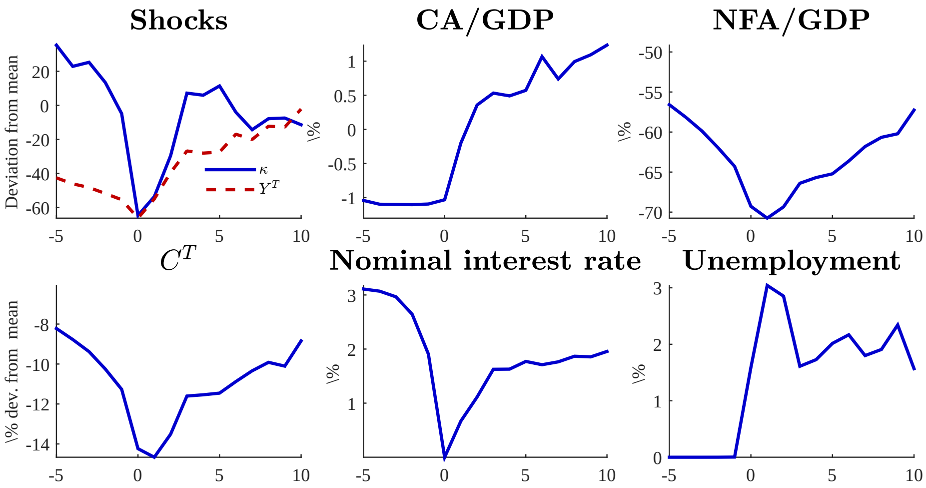

Figure 8: Typical liquidity trap episode

assets position. In line with the data, the standard deviation of net foreign asset position to GDP is 35%, as per our calibration target.

We now turn to analyze a typical liquidity trap episode in our model. We define a liquidity trap as an episode in which the economy spends at least one year at the zero lower bound and it was not at the zero lower bound in the previous ten years. To analyze the behavior of several macroeconomic indicators around liquidity trap episodes we follow this procedure. First, we run long simulation of a small open economy in our model second, we collect all the liquidity trap episodes experienced by the economy. We then take the average behavior of the variables of interest around all the episodes. Figure 8 shows the results of this experiment. In the upper panels we display the exogenous shocks, the current account balance to GDP and the ratio of net foreign asset position to GDP. In the lower panels we display consumption of tradable goods, the domestic nominal interest rate and unemployment. All panels show average realizations in the five years prior and in the ten years that follow a liquidity trap episode.[21]

Four key facts about a typical liquidity trap episode can be noted by observing Figure 8. First, economies enter a liquidity trap after a tightening of the borrowing constraint that follows a sequence of negative tradable good endowment shocks. This can be observed in the first panel of Figure 8. Second, the current account balance improves in economies that hit the zero lower bound. As a consequence, their net foreign asset position improves as well. Third, consumption of tradables drops significantly on impact, and it remains depressed thereafter. Finally, the nominal interest rate stays low, on average, for more than ten years after the shock. The low average nominal interest rate conceals the fact that some economies spend several periods at the zero lower bound, while others exit the liquidity trap. As a result, the average unemployment rate remains above its natural level for a long amount of time.

[21] All variables are in levels except for the exogenous shocks and tradable consumption. The former are expressed in absolute deviation from the mean divided by the standard deviation of each process in percentage points. The latter is expressed as percentage deviation from the mean.

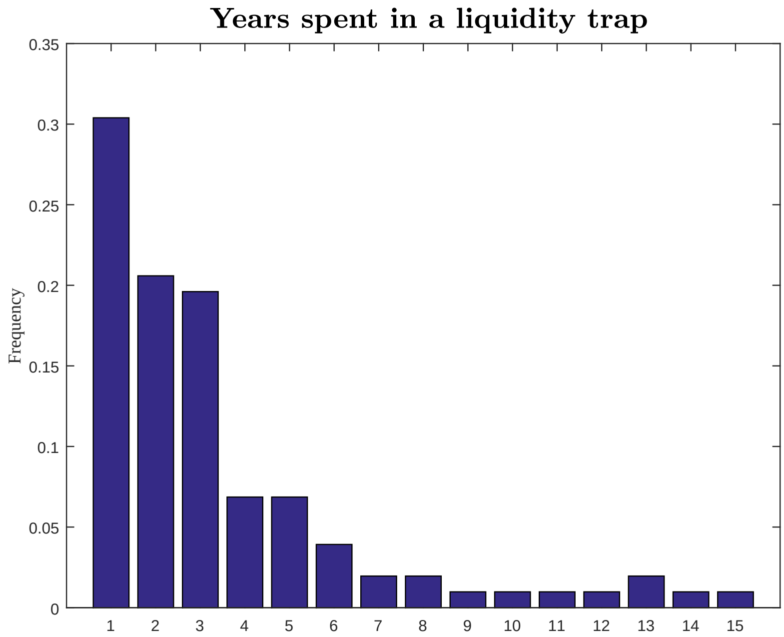

Figure 9: Average time spent in a liquidity trap

Our model thus captures some salient features of the episodes of deleveraging cum liquidity traps observed in advanced economies. Before the trap, the economy experiences a period of fast debt accumulation. Then, following a tightening of financial conditions, the economy enters a period of deleveraging. During deleveraging domestic demand is low, forcing the central bank to cut the policy rate. However, the zero lower bound prevents the central bank from cutting the domestic rate enough to maintain the economy at full employment. As a result, deleveraging is associated with a liquidity trap with high unemployment.

One interesting aspect, is that our model generates persistent liquidity traps, in line with the actual experience of countries such as Japan, the US or the euro area. Figure 9 displays the distribution of countries by length of the liquidity trap episode that they experience, conditional on being in a liquidity trap. The figure shows that it is not uncommon for a country to experience a liquidity trap that extends over several years.

4.4 Optimal credit market interventions

TO BE WRITTEN

5 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 this behavior generates international aggregate demand externalities. 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 Proofs

A.1 Proof of proposition 1

It is useful to start by rewriting the AD equation in the high and low states as:

$$L_h = \frac{R\pi_l}{R_h^n}\frac{C_h^T}{C_l^T}L_l = \frac{R\pi_l}{R_h^n}\frac{1}{\beta R(1+\tau_h)}L_l \tag{A.1}$$

$$L_l = \frac{R\pi_h}{R_l^n}\frac{C_l^T}{C_h^T}L_h = \frac{R\pi_h}{R_l^n}\beta R(1+\tau_h)L_h, \tag{A.2}$$

where the second equality in both expressions makes use of the Euler equation (16).

We now prove that $R_h^n \geq R_l^n$. Suppose that this is not the case. Combining ($A.1$) and ($A.2$) gives that if $R_l^n > R_h^n$ then

$$\beta R(1+\tau_h) > \frac{L_l}{L_h}\frac{\pi_l}{\pi_h}.$$

However, by assumption (1) the left-hand side of this inequality is smaller than one. Moreover, if $R_l^n > R_h^n$, the right-hand side is always greater than or equal to one. Hence, we have found a contradiction, which implies that $R_h^n \geq R_l^n$.

We now show that $R_h^n > 1$. Combining ($A.1$) and ($A.2$) gives

$$R_h^n = \frac{R^2\pi_l\pi_h}{R_l^n}.$$

Suppose that $R_h^n = 1$. Then it must be that $\pi_h = \gamma$, and, since $R_h^n \geq R_l^n$, $\pi_l = \gamma$ and $R_l^n = 1$. In this case, the equation above reduces to $1 = R^2\gamma^2$. However, assumption (2) implies $R^2\gamma^2 > 1$. This is a contradiction, and hence it must be that $R_h^n > 1$, and so $\pi_h = \bar{\pi}$ and $L_h = 1$.

Using $L_h = 1$ and $\pi_h = \bar{\pi}$, we can write ($A.2$) as

$$L_l = \frac{R\bar{\pi}}{R_l^n}\beta R(1+\tau_h).$$

Combining this expression with the (MP) equation, it is easy to see that if $R \geq R^*$, then $L_l = 1$ and $R_l^n \geq 1$, otherwise $R_l^n = 1$ and $L_l = R^2\bar{\pi}\beta(1+\tau_h) < 1$. ■

A.2 Proof of proposition 2

We take the perspective of a Ramsey planner that in the high state chooses τ_h to maximize

$$\max_{\tau_h} \omega \log C_h^T + (1-\omega)\log L_h + \beta\left(\omega \log C_l^T + (1-\omega)\log L_l\right),$$

subject to

$$C_h^T = \frac{1}{1+\beta(1+\tau_h)}\left(Y_h^T + \frac{Y_l^T}{R}\right) \tag{A.3}$$

$$C_l^T = \frac{\beta R(1+\tau_h)}{1+\beta(1+\tau_h)}\left(Y_h^T + \frac{Y_l^T}{R}\right) \tag{A.4}$$

$$L_h = 1 \tag{A.5}$$

$$L_l = \min\left(R^2\bar{\pi}\beta(1+\tau_h), 1\right). \tag{A.6}$$

Plugging the constraints in the objective function the problem can be written as

$$\max_{\tau_h} f(\tau_h) + g(\tau_h) + \text{t.i.p.}, \tag{A.7}$$

where

$$f(\tau_h) \equiv \omega\left(\beta \log(1+\tau_h) - (1+\beta)\log(1+\beta(1+\tau_h))\right) \tag{A.8}$$

$$g(\tau_h) = \beta(1-\omega)\left(\log\left(\min\left(R^2\bar{\pi}\beta(1+\tau_h), 1\right)\right)\right), \tag{A.9}$$

while t.i.p. collects terms independent of policy. The function $f(\tau_h)$ reaches its maximum at $\tau_h = 0$ and it is monotonically decreasing for $\tau_h > 0$. The function $g(\tau_h)$ is strictly increasing for $\tau_h \leq \tau_h^* \equiv \left(R^2\bar{\pi}\beta\right)^{-1} - 1$, and equal to 1 for $\tau_h > \tau_h^*$.

Define τ_h^u as the value of τ_h that solves the maximization problem. If $\tau_h^* \leq 0$ the solution is $\tau_h^u = 0$ and the economy always operates at full employment ($L_l = 1$). Now suppose that $\tau_h^* > 0$. Clearly, $\tau_h^u > \tau_h^*$ cannot be a solution, because the objective function is strictly decreasing for any τ_h greater than τ_h^*. If the solution is such that $\tau_h^u < \tau_h^*$ then the optimal subsidy can be obtained by taking the first order condition with respect to τ_h. This gives

$$\tau_h^u = \frac{1}{\omega - (1-\omega)\beta} - 1 \equiv \tilde{\tau}_h.$$

If $\tilde{\tau}_h < \tau_h^*$ then $\tau_h^u = \tilde{\tau}_h$ is the solution, and $L_l < 1$. Instead, if $\tilde{\tau}_h \geq \tau_h^*$ then the solution is $\tau_h^u = \tau_h^*$ and $L_l = 1$. ■

A.3 Proof of proposition 3

We consider a global Ramsey planner that sets τ_h to maximize

$$\max_{\tau_h} \omega \log C_h^T + (1-\omega)\log L_h + \omega \log C_l^T + (1-\omega)\log L_l,$$

subject to

$$C_h^T = Y_h^T \tag{A.10}$$

$$C_l^T = Y_l^T \tag{A.11}$$

$$L_h = 1 \tag{A.12}$$

$$L_l = \min\left(R^2\bar{\pi}\beta(1+\tau_h), 1\right). \tag{A.13}$$

$$R = \frac{Y_l^T}{\beta(1+\tau_h)Y_h^T}. \tag{A.14}$$

Substituting the constraints in the objective function the problem simplifies to

$$\max_{\tau_h}(1-\omega)\log\left(\min\left(\left(\frac{Y_l^T}{Y_h^T}\right)^2\frac{\bar{\pi}}{\beta(1+\tau_h)}, 1\right)\right) + t.i.p., \tag{A.15}$$

where t.i.p. collects terms independent of policy. Defining τ_h^c as the value of τ_h that solves the maximization problem we have that any

$$\tau_h^c \leq \left(\frac{Y_l^T}{Y_h^T}\right)^2\frac{\bar{\pi}}{\beta} - 1, \tag{A.16}$$

is a solution.

Now consider a case in which τ_h^* evaluated at $\tau_h = 0$ satisfies $\tau_h^* > 0$, that is a world in which when $\tau_h = 0$ there is $L_l < 1$. From proposition 2 we know that in this case $\tau_h^u > 0$. Instead, equation ($A.16$) implies that $\tau_h^c < 0$. This proves $\tau_h^c < 0 < \tau_h^u$. Now consider that in general equilibrium the welfare of any country is proportional to ($A.15$). Since ($A.15$) is decreasing in τ_h welfare for any country is unambiguously higher in the cooperative equilibrium compared to the uncooperative one. ■

B Microfoundations for 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.[22] 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. Finally, we assume that investment in money is subject to the same subsidy as the other assets available. We makes this assumption because we are interested in policies that affect agents' incentives to save or borrow. Instead, we abstract from policies aiming at modifying agents' portfolio decisions.

We modify the borrowing limit (3) to

$$B_{i,t+1} + \frac{B_{i,t+1}^n}{P_{i,t+1}^T} + \frac{M_{i,t+1}}{P_{i,t+1}^T} \geq 0,$$

where $M_{i,t+1}$ is the stock of money held by the representative household in country i at the end of

[22] 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.

period t. The optimality condition for money holdings can be written as

$$\frac{1}{C_{i,t}^T} = \beta \frac{P_{i,t}^T}{P_{i,t+1}^T}(1+\tau_{i,t})\left(\frac{\beta}{C_{i,t+1}^T} + \mu_{i,t}\right) + (1+\tau_{i,t})\mu_{i,t}^M,$$

where $\mu_{i,t}^M \geq 0$ is the Lagrange multiplier on the non-negativity constraint for private money holdings, divided by $\beta P_{i,t}^T$. Combining this equation with (6) gives

$$\left(R_{i,t}^n - 1\right)\left(\frac{\beta}{C_{i,t+1}^T} + \mu_{i,t}\right) = \mu_{i,t}^M.$$

Since $\mu_{i,t}^M \geq 0$, this expression implies that $R_{i,t}^n \geq 1$. Moreover, if $R_{i,t}^n > 1$, then agents choose to hold no money. If instead $R_{i,t}^n = 1$, agents are indifferent between holding money, domestic bonds or foreign bonds. We resolve this indeterminacy by assuming that the aggregate stock of money is infinitesimally small for any country and period.

C Baseline model with positive liquidity

In this appendix we study a version of the baseline model in which positive borrowing is allowed. The model is identical to the one studied in Sections 2 and 3, except that the borrowing limit (3) is replaced by

$$B_{i,t+1} + \frac{B_{i,t+1}^n}{P_{i,t+1}^T} \geq \kappa,$$

where $\kappa \geq 0$. The model studied in Section 3 then corresponds to the special case $\kappa = 0$.

As in Section 3, we focus on a stationary equilibrium with a constant world interest rate. This requires setting the initial bond distribution to $B_{l,0} = -B_{h,0} = \kappa$.

C.1 Small open economy and uncooperative credit policy

The analysis of the small open economy is essentially unchanged with respect to the case with zero borrowing ($\kappa = 0$). To ensure that the economy saves when the endowment is high and borrows when the endowment is low, a modified version of Assumption 1 needs to hold, in which $Y_l^T/Y_h^T \leq \beta R(1+\tau_h)$ is replaced by

$$Y_h^T - \frac{Y_l^T}{\beta R(1+\tau_h)} - \kappa\left(1 + \frac{1}{\beta R^2(1+\tau_h)}\right) \geq 0.$$

It is then easy to show that the borrowing constraint binds in the low state, so that $B_l = -\kappa$, while in the high state the Euler equation holds and savings are equal to

$$B_h = \frac{\beta R(1+\tau_h)}{1+\beta(1+\tau_h)}\left[Y_h^T - \frac{Y_l^T}{\beta R(1+\tau_h)} - \kappa\left(1 + \frac{1}{\beta R^2(1+\tau_h)}\right)\right], \tag{C.1}$$

while tradable consumption is equal to

$$C_h^T = Y_h^T - \kappa - \frac{B_h}{R} = \frac{1}{1+\beta(1+\tau_h)}\left[Y_h^T + \frac{Y_l^T}{R} + \kappa\left(\frac{1}{R^2}-1\right)\right]$$

$$C_l^T = Y_l^T + B_h + \frac{\kappa}{R} = \frac{\beta R(1+\tau_h)}{1+\beta(1+\tau_h)}\left[Y_h^T + \frac{Y_l^T}{R} + \kappa\left(\frac{1}{R^2}-1\right)\right].$$

The derivation of the equilibrium in the market for non-tradables is exactly the same as in Section 3. Moreover, Propositions 1 and 2 hold also for the case $\kappa > 0$. In particular, the possibility of positive borrowing does not alter the conditions under which the government subsidizes savings under the uncooperative optimal policy.

C.2 Global equilibrium and cooperative optimal credit policy

To find the world interest rate we use the equilibrium condition $B_h = -B_l$. Using $B_l = -\kappa$ and (C.1) implies that in the equilibrium world interest rate solves

$$R = \frac{1}{\beta(1+\tau_h)}\frac{Y_l^T + \kappa\left(1+\frac{1}{R}\right)}{Y_h^T - \kappa\left(1+\frac{1}{R}\right)}.$$

This expression implies that R is decresing in τ_h. Moreover, a higher κ leads to a higher R. Intuitively, a higher supply of assets that can be purchased by savers leads to a higher world interest rate.

With positive borrowing allowed, the equilibrium no longer coincides with the autarky one, in which every country consumes its endowment of tradables. Instead, changes in the interest rate and in the subsidy change the allocation of tradable consumption between the high and the low state. This complicates the global social planning problem.

The global social planner problem can be written as

$$\max_{\tau_h, R, C_h^T, C_l^T} \omega \log C_h^T + (1-\omega)\log L_h + \omega \log C_l^T + (1-\omega)\log L_l,$$

subject to

$$C_h^T + C_l^T = Y_h^T + Y_l^T \tag{C.2}$$

$$C_l^T = \beta R(1+\tau_h) C_h^T \tag{C.3}$$

$$L_h = 1 \tag{C.4}$$

$$L_l = \min\left(R^2 \bar{\pi}\beta(1+\tau_h), 1\right). \tag{C.5}$$

$$\beta R(1+\tau_h) = F(R), \tag{C.6}$$

where $F(R) = (Y_l^T + \kappa\left(1+\frac{1}{R}\right))/(Y_h^T - \kappa\left(1+\frac{1}{R}\right))$ and hence $F'(\cdot) < 0$. To gain some intuition about the trade-offs faced by the planner, it is useful to substitute constraint (C.6) in (C.3) and

($C.5$) to write

$$C_l^T = F(R)C_h^T \tag{C.7}$$

$$L_l = \min\left(R\bar{\pi}F(R), 1\right). \tag{C.8}$$

As it was the case for $\kappa = 0$, by setting τ_h the planner can choose its desired value for R. However, now the objective function is no longer monotonically increasing in R. This is because a change in R has three distinct effects. As it was the case for $\kappa = 0$, a higher R relaxes the zero lower bound constraint and (weakly) increases employment in countries in the low state. Moreover, there are two new effects. First, according to ($C.7$) a higher R lowers tradable consumption in countries in the low state, and increases it in countries in the high state. This happens because a higher interest rate redistributes wealth from debtors to creditors. Moreover, since a higher R leads to a lower C_l^T/C_h^T, it also depresses demand in the low state. This effect points toward lower employment and consumption of non-tradables in the low state.

To gain further insights, we can substitute the constraints in the objective function to write the planning problem as

$$\max_R \omega\left(\log(F(R)) - 2\log(1 + F(R))\right) + (1 - \omega)\log\left(\min(RF(R), 1\right) + t.i.p.,$$

where $t.i.p.$ captures terms independent of policy. To solve this problem, start by noticing that the first two terms reach a maximum when $F(R) = 1$. Intuitively, ignoring any impact on non-tradable consumption, the optimal allocation of tradable consumption over states requires $C_h^T = C_l^T$, which happens when $F(R) = 1$. In words, by setting $F(R) = 1$ the planner obtains perfect consumption smoothing across states and countries. Instead, the second term reaches it maximum when $RF(R) \geq 1$. This captures the impact of changes in the world interest rate on employment. When setting the optimal interest rate, the world planner trades off tradable consumption smoothing across countries against changes in non-tradable consumption in countries in the low state.

TO BE COMPLETED

D 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.

References

Benigno, Pierpaolo and Federica Romei (2014) "Debt Deleveraging and the Exchange Rate," *Journal of International Economics*, Vol. 93, pp. 1–16.

Blanchard, Olivier and Jordi Galí (2007) "Real wage rigidities and the New Keynesian model," *Journal of Money, Credit and Banking*, Vol. 39, No. s1, pp. 35–65.

Caballero, Ricardo J, Emmanuel Farhi, and Pierre-Olivier Gourinchas (2015) "Global Imbalances and Currency Wars at the ZLB," NBER Working Paper No. 21670.

Eggertsson, G. and P. Krugman (2012) "Debt, Deleveraging, and the Liquidity Trap: a Fisher-Minsky-Koo Approach," *The Quarterly Journal of Economics*, Vol. 127, No. 3, pp. 1469–1513.

Eggertsson, G. and M. Woodford (2003) "The Zero Bound on Interest Rates and Optimal Monetary Policy," *Brookings Papers on Economic Activity*, Vol. 2003, No. 1, pp. 139–211.

Eggertsson, Gauti, Neil Mehrotra, Sanjay Singh, and Lawrence Summers (2016) "A Contagious Malady? Open Economy Dimensions of Secular Stagnation," NBER Working Paper No. 22299.

Farhi, Emmanuel and Iván Werning (2012) "Fiscal unions," NBER Working Paper No. 18381.

——— (2016) "A theory of macroprudential policies in the presence of nominal rigidities," *Econometrica, forthcoming.*

Fornaro, Luca (2012) "International Debt Deleveraging," CREI working paper.

Guerrieri, V. and G. Lorenzoni (2011) "Credit Crises, Precautionary Savings, and the Liquidity Trap," NBER Working Paper No. 17583.

Hansen, Alvin H (1939) "Economic Progress and Declining Population Growth," *The American Economic Review*, Vol. 29, No. 1, pp. 1–15.

Korinek, Anton and Alp Simsek (2016) "Liquidity trap and excessive leverage," *The American Economic Review*, Vol. 106, No. 3, pp. 699–738.

Schmitt-Grohé, Stephanie and Martín Uribe (2015) "Downward Nominal Wage Rigidity, Currency Pegs, and Involuntary Unemployment," *Journal of Political Economy, forthcoming.*

Summers, Lawrence (2016) "The Age of Secular Stagnation," Foreign Affairs, February 15.

Werning, Iván (2015) "Incomplete markets and aggregate demand," NBER Working Paper No. 21448.