The International Transmission of Asset Market Shocks in Liquidity Traps*

Philippe Bacchetta
University of Lausanne, SFI and CEPR

Kenza Benhima
University of Lausanne and CEPR

Yannick Kalantzis
Banque de France

Maxime Phillot
Swiss National Bank

This draft: June 18, 2025

Abstract

We build a two-country heterogenous-agent non-Ricardian model featuring asset scarcity and financial frictions in international capital markets. Due to the non-Ricardian nature of our framework, a demand for liquidity emerges and the supply of bonds matters. We show that shocks affecting the supply or demand of assets have very different international spillovers for an economy in a liquidity trap. A decrease in the supply of assets issued abroad leads to an asset shortage domestically. In normal times, the nominal interest rate decreases, stimulating investment and output. In a liquidity trap, deflation hits instead and the currency appreciates, which may cause a recession.

JEL-Classification: E40, E22, F32

Keywords: International spillovers, Zero lower bound, Liquidity trap, Asset scarcity

*We are grateful to seminar participants at University of Lausanne, Sveriges Riksbank and the SSES annual congress 2023 for useful comments. Philippe Bacchetta gratefully acknowledges financial support from the Swiss National Science Foundation. The opinions expressed in this paper are those of the authors and do not necessarily reflect views held by the Swiss National Bank, the Banque de France or the Eurosystem.

1 Introduction

In a financially integrated world, asset markets act as powerful transmission mechanisms of real, monetary, and financial shocks across countries. In normal times, monetary policy can help the economy adjust to developments in global asset markets through changes in the domestic interest rate. But when monetary policy does not react in part of the global economy, for instance because it is at the Effective Lower Bound (ELB), exchange rates become an important margin of adjustment, which has significant implications for international spillovers and opens the possibility of deep recessions. Since recent shocks affected asset markets when several countries were at the ELB, and countries may face again ELB episodes in the future, it is of interest to understand the impact of the ELB on international spillovers.

In analyzing the effect of the ELB on international spillovers, the literature has emphasized aggregate demand shocks within a New Keynesian framework. However, in presence of international financial segmentation and without Ricardian equivalence, shocks affecting the supply or the demand for asset have additional international implications. The objective of this paper is to provide a new perspective on how shocks originating abroad are transmitted domestically via asset markets, particularly when the domestic central bank is constrained by the ELB.

To examine these issues, we develop a two-country model with non-Ricardian heterogenous agents where the relative supply and demand of assets have macroeconomic effects. Our focus is on scenarios where only one country is at the ELB. In each country, there is a population of alternating savers/investors, which implies both credit-constrained agents and a demand for liquid assets as in Woodford (1990) or Bacchetta et al. (2019). We assume that international capital markets are partially segmented. First, only bonds can be traded across countries. Second, there is a cost to holding cross-border bonds, leading to a home bias. We also assume that liquidation costs in bond markets may differ across countries. Higher liquidity in one country can therefore imply a convenience yield. Finally, there are nominal rigidities.

We analyze the international spillovers of shocks in this context. In the presence of nominal rigidities, shocks are partly transmitted through aggregate demand as in New Keynesian models. Moreover, internationally segmented asset markets may lead to return differentials and gross capital flows. In addition to these more standard mechanisms, spillovers are generated by the relative supply and demand of assets. The equilibrium can actually be represented by an extended IS curve that is affected by gross capital flows and changes in the real supply of domestic assets. When assets are denominated in domestic currency, an increase in the demand for domestic assets can be accommodated by a domestic currency appreciation. This effect operates when monetary policy does not react, i.e., at the ELB, which implies a starkly different transmission mechanism for some shocks.

For example, one of the main features of the eurozone crisis in the years 2010 was a decrease in the supply of safe and liquid euro assets. This led to a portfolio reallocation towards safer or more liquid bond markets, like Switzerland or the U.S. Since policy rates in these countries were close to zero, the Swiss National Bank or the Federal Reserve could not lower their rates to face this portfolio reallocation. Consequently, the Swiss franc and the U.S. dollar appreciated. This led to subdued inflation, an increase in the real interest rate, and a loss in competitiveness that reduced output growth. This can be contrasted with the 1997 Asian crisis, when the redirection of financial flows towards the mature markets of the U.S. and European economies, at that time far from the zero lower bound, helped reduce real rates and supported growth.

We examine shocks that affect the supply or the demand for liquid assets. For example, let the two countries be Home and Foreign and consider a permanent decline in Foreign investment opportunities. This reduces Foreign investment and output, but it also reduces the supply of Foreign assets. This implies a reallocation of portfolios from Foreign to Home assets and a potential appreciation of the Home currency to accommodate the increase in the demand for home assets. The Home central bank can prevent the appreciation by lowering its interest rate. This has an expansionary impact in Home, so that there is a positive spillover from Foreign to Home. But if Home is at the ELB, the Home central bank cannot prevent the appreciation and an increase in the real interest rate, which can have a contractionary effect in the presence of nominal rigidities. In this case there is a negative spillover.

We explore these adjustment mechanisms both analytically, using a simplified version of the model, and quantitatively, within a calibrated version of the model. In both cases, we consider perfect-foresight transition dynamics resulting from permanent shocks. We specifically examine three types of shocks: a real shock characterized by a decline in opportunities for Foreign investment, a financial shock denoting an increase in the liquidation cost of Foreign bonds, and a monetary shock represented by an increase in the Foreign price level targeted by the central bank. The calibration of the model assumes two countries with different steady-state inflation rates, allowing for a comparative assessment of spillover effects when the Home economy is at the ELB but the Foreign economy is not.

The analytical discussion and the simulation results demonstrate that the nature of shocks and the presence of the ELB have substantial implications for international spillovers. In the absence of the ELB, a decrease in the liquidity of Foreign bonds induces capital inflows from Foreign to Home markets, thereby boosting Home investment and output. However, under the ELB constraint, these spillovers reverse, resulting in deflation and a currency appreciation, which may lead to an increase in unemployment in the Home country. Similarly, shocks implying a lower supply of Foreign bonds and monetary shocks induce distinct patterns of spillovers depending on the presence of the ELB constraint.

Interestingly, the impact on the Foreign economy is also different when Home is at the ELB. Our analysis reveals non-negligible spillbacks arising at the ELB. All three shocks cause the Home currency to appreciate for a number of periods, resulting in a temporary increase in the excess return in Home currency. In the short run, this further drives capital away from Foreign. This greater capital flight increases the Foreign real interest rate temporarily, resulting in a greater reduction in capital accumulation and output than outside of the ELB.

The paper focuses on two extreme responses of monetary policy: the ideal scenario of a robust monetary reaction effectively stabilizing prices, and the ELB characterized by no response. Between those two scenarios, there is a continuum, where too weak a monetary response fails to fully insulate prices from the effect of international asset market shocks. In those intermediate cases, adjustment comes from a mix of interest rate cuts and below-target inflation with currency appreciation and, possibly, unemployment. Our findings would carry over to these intermediate cases, underscoring the key role of monetary policy in shaping international spillovers.

Overall, this paper sheds light on the international spillovers and spillbacks that occur within a theoretical framework featuring financial frictions and different monetary policy responses, including the ELB constraint. By analyzing various types of shocks, we unveil the transmission mechanisms operating between economies when assets are scarce. Our findings highlight the critical role that monetary policy plays in determining the magnitude and sign of spillovers. Some of the shocks may have large negative implications for countries at the ELB. These theoretical insights have important policy implications, underscoring the need for measures that carefully consider the constraints imposed by the ELB in a financially integrated world where the availability of assets matters.

Literature. — The existing literature on international spillovers at the ELB predominantly focuses on New Keynesian mechanisms. For example, Jeanne (2009) examines how a global economy reacts to demand shocks in a global liquidity trap, where low interest rates and high unemployment prevent recovery.[1] In a similar context, Fujiwara

[1] A long-standing literature analyzes the challenges posed to macroeconomic stabilization by persistent liquidity traps in a closed-economy setting. For example, see Krugman (1998), Auerbach and

et al. (2013) as well as Cook and Devereux (2013) study optimal monetary policy. Similarly, Cook and Devereux (2011) investigate fiscal policy and Devereux and Yetman (2014) capital controls. Corsetti et al. (2017) and Corsetti et al. (2019) focus on the role of exchange rate regimes in mitigating the international spillovers faced by small open economies in a liquidity trap. Kollmann (2021) allows for expectations-driven sunspot equilibria, and Bianchi and Coulibaly (2022) investigate the transmission channels of prudential policies.

Our paper contributes to this literature by employing a non-Ricardian framework with financial frictions to unveil additional spillover mechanisms arising from shocks to both asset supply and demand. Our focus on the impact of asset scarcity in a non-Ricardian framework aligns with Caballero et al. (2021), who propose a perpetual youth model *à la* Blanchard (1985)[2], analyzing the possibility of a global ELB in a financially integrated world economy. They also examine the transmission of shocks through capital flows, but they focus more on currency and trade wars than on the transmission of shocks. Moreover, they do not consider the asymmetric case where only one country is at the ELB.

Our model is inspired by earlier work emphasizing the demand for liquid assets in models with non-Ricardian agents. In the tradition of Woodford (1990), various papers appeal to heterogeneous agents that stochastically cycle between between asset market activity and inaction, such as Bacchetta and Benhima (2015) or Nistico (2016). In these models, as in ours, a demand for liquidity emerges and the supply of bonds matters. For instance, Guerrieri and Lorenzoni (2017) and Buera and Nicolini (2020) investigate in a closed-economy setting where a tightening in borrowing and collateral constraints respectively trigger a credit crunch, with adverse effects on output that result in deflationary pressures and push the economy to the ELB.[3] In our open-economy framework, real, financial and monetary shocks abroad have implications for the domestic economy, analogous to a credit crunch. The mechanism operates through the reallocation of international portfolios towards one country's assets, resulting in the shortage of private bonds which leads to excess saving. The incorporation of non-Ricardian agents facing binding borrowing constraints enables us to focus on an asset-scarce equilibrium, crucial for the emergence of the ELB. Consequently, this setup allows us study the influence of the ELB on international spillovers resulting from asset market shocks.

Other papers have analyzed international spillovers in models incorporating financial

Obstfeld (2005), Werning (2011), Eggertsson and Krugman (2012), Michau (2018), Bacchetta, Benhima, and Kalantzis (2019).

[2]Other papers using this approach to break the Ricardian equivalence include Di Giorgio and Nisticò (2007), Di Giorgio et al. (2018), Di Giorgio and Traficante (2018), Caballero and Farhi (2018).

[3]In a similar context, Ragot (2023) studies optimal monetary policy.

frictions. For example, Fornaro and Romei (2019) propose a tractable framework for a financially integrated world with an occasionally binding ELB. In their model, financial frictions prevent agents from insuring against country-specific shocks, resulting in a shortage of safe assets. While their primary focus is on prudential policies and the call for international cooperation in shaping them, our emphasis is on international spillovers.

The implications of financial frictions introduced in our paper align with Gabaix and Maggiori (2015). They introduce financial intermediaries with limited risk-bearing capacity, akin to our approach where credit-constrained investors face currency management and liquidation costs. These financial market imperfections create a wedge in the Uncovered Interest Rate Parity (UIP). Consequently, as in Gabaix and Maggiori's model, our framework implies that exchange rates are more closely related to financial factors, such as the supply and demand for assets denominated in different currencies, than to macroeconomic fundamentals.[4] Importantly, these financial frictions give rise to distinct nominal interest rates between countries, enabling a comprehensive analysis of the domestic consequences from asset market shocks abroad, especially when Home is at the ELB.

The remainder of this paper is organized as follows. Section 2 presents the theoretical framework. Section 3 provides analytical insights on the spillovers resulting from asset market shocks. Section 4 shows the results from the simulation of a calibrated version of the model under different sets of assumptions. Section 5 discusses policy options and Section 6 concludes.

2 A Two-Country Model with Financial Frictions

This section starts by describing the model with financial frictions and nominal rigidities. Then it characterizes an asset scarce equilibrium.

2.1 The Setup

There are two countries, Home and Foreign, each made of heterogenous investors, workers and firms. Investors alternate between periods of saving and periods of investing in projects, in the spirit of Woodford (1990) or Bacchetta et al. (2019). Firms produce a single, identical good, with price P_t (P_t^*) in the Home (Foreign) currency.[5] The law of one price holds with $P_t = S_t P_t^*$ where S_t is the price in Home currency of one unit of

[4] Naturally, other papers interested in the ELB share this property. Among others, Amador et al. (2020) and Kolasa and Wesołowski (2020) respectively look at exchange rate policy and quantitative easing in a liquidity trap. In all these models as in ours, shocks in one country are transmitted to other countries via capital flows.

[5] In what follows, we denote with superscripts '$*$' variables pertaining to Foreign.

Foreign currency—the nominal exchange rate (the Home currency depreciates when S_t increases).

In each country, there are two types of assets: nominal one-period bonds denominated in domestic currency issued domestically by investors or the government, and capital.[6] Home bonds issued in period t repay i_t Home currency units in period $t+1$, while Foreign bonds yield i_t^* units of Foreign currency. The ELB is a zero lower bound (ZLB) on interest rates $i_t, i_t^* > 1$. Financial markets are subject to several frictions and borrowing is limited.

Financial Frictions.— Financial markets are subject to three types of frictions. First, there is no trade in capital across countries. Second, bonds are subject to a liquidation cost, with a higher cost for cross-currency bonds. A Home saver invests a proportion $1 - x_t$ in Home currency bonds and a proportion x_t in Foreign currency bonds. If she invests a total of A_t in bonds, she has to pay real liquidation costs $\frac{1}{2}\left[\lambda(1-x_t)^2 + (\kappa+\lambda^*)x_t^2\right] A_t$ in period $t+1$. Symmetrically, savers in Foreign pay $\frac{1}{2}\left[(\kappa+\lambda)(x_t^*)^2 + \lambda^*(1-x_t^*)^2\right] A_t^*$, where x_t^* is their share of Home currency bonds. These costs are linear in the size of the balance sheet of savers and quadratic in the portfolio shares, with parameters $\lambda, \lambda^*, \kappa \geq 0$. The parameters λ and λ^* reflect the liquidity of the bond market in each country. If $\lambda > \lambda^*$, the Foreign country has a relative convenience yield. The parameter κ, assumed to be the same for Home and Foreign investors, represent the cost of holding the other country's currency, e.g., because of currency management costs or the risk that governments can take actions to expropriate foreign investors (e.g., as in Tirole, 2003, Broner and Ventura, 2011, Fornaro, 2021). This implies a local currency bias, as documented in Maggiori et al. (2020).

Finally, all private borrowing, in both Home and Foreign currency, must be collateralized by capital. More precisely, the expected total repayment cannot exceed a share ϕ_t of the expected total return on capital (see below for the details). We think of ϕ as a reduced-form variable capturing the microstructure of financial intermediation, risk-management practices by financial intermediaries, and macro-prudential regulation.

Investors.— In what follows and for the sake of brevity, we focus on Home investors as the assumptions on Foreign ones are identical. There is a measure-1 continuum of investors who receive investment opportunities stochastically. We call I-investor an investor who receives an investment opportunity and we refer to all other investors as S-investors or simply savers. These opportunities follow a two-state Markov process. An S-investor, i.e., an investor j with no investment opportunity at time $t-1$, becomes an I-investor at time t with probability $\eta \in (0, 1]$, and can buy capital K_t^j. An I-investor

[6] Note that we abstract from money for simplicity, as the incorporation of nominal government bonds suffices to deliver our central message.

at time $t-1$ receives no investment opportunity at time t and becomes an S-investor again. With no investment opportunity in period t, $K_t^j = 0$. While investors face risk at the individual level, there is no risk in the aggregate, as the fraction of I-investors is always $\eta/(1+\eta)$. A useful and simple benchmark is the deterministic limit $\eta = 1$. In that case, investors receive investment opportunities every other period and there is no heterogeneity across S-investors.

To get closed-form solutions, logarithmic utility is assumed. An investor j maximizes $U_t^j = \sum_{s=0}^{\infty} \beta^s \mathbb{E}_t \log(C_{t+s}^j)$, where C_t^j refers to her consumption in period t, subject to a sequence of budget constraints and borrowing constraints. The budget constraint in period t is

$$C_t^j + \frac{i_{t-1} D_{t-1}^{H,j}}{P_t} + K_t^j + A_t^j = \rho_t K_{t-1}^j + \frac{D_t^{H,j}}{P_t}$$
$$+ \left[(1 - x_{t-1}^j) \frac{i_{t-1} P_{t-1}}{P_t} + x_{t-1}^j \frac{i_{t-1}^* P_{t-1}}{S_{t-1}} \frac{S_t}{P_t} - \frac{1}{2} \lambda (1 - x_{t-1}^j)^2 - \frac{1}{2} (\lambda^* + \kappa)(x_{t-1}^j)^2 \right] A_{t-1}^j. \tag{1}$$

The investor consumes, pays back her nominal debt $D^{H,j}$ in Home currency, buys capital if she has an investment opportunity in t, and accumulates real financial wealth $A_t^j \geq 0$. She allocates a fraction $1 - x_t^j$ of this wealth to Home currency bonds and x_t^j to Foreign currency bonds. In the next period, she collects the real gross rate of return on capital ρ_{t+1}, bond returns, net of the liquidation cost (λ, λ^*) on both Home and Foreign currency bonds and the additional cost (κ) on Foreign currency bonds.

I-investors are the only agents able to hold domestic capital goods. Since capital is the only collateral available, they are also the only private agents able to borrow. In equilibrium, they will take a leveraged position in capital. Total nominal debt repayment is collateralized by a share ϕ of the expected total nominal return on capital:[7]

$$i_t D_t^{H,j} \leq E_t(\phi_t \rho_{t+1} P_{t+1} K_t^j). \tag{2}$$

Firms.—In each country, there is a unit measure of firms. Home firms rent capital K_{t-1} at rate ρ_t, hire labor L_t at real wage W_t/P_t, produce output $Y_t = Z K_{t-1}^{\alpha} L_t^{1-\alpha}$ which they sell together with depreciated capital. Firms maximize profits

$$Y_t + (1-\delta) K_{t-1} - \rho_t K_{t-1} - \frac{W_t}{P_t} L_t.$$

[7]This type of borrowing constraint arises if lenders are able to seize a fraction $1 - \phi_t$ of the collateral, and if the decision to default is taken before the realization of period-$t+1$ shocks. It represents the borrower's participation constraint.

The corresponding first-order conditions are

$$(\rho_t + \delta - 1)K_{t-1} = \alpha Y_t, \tag{3}$$

$$\frac{W_t}{P_t} L_t = (1-\alpha) Y_t. \tag{4}$$

Workers. — There is a unit measure of workers, each endowed with one unit of labor. Home workers supply labor L_t at real wage W_t/P_t, receive nominal transfers T_t from the government, consume C_t^W and save A_t^W in bonds with a share x_t^W of Foreign bonds. They maximize $\mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \log(C_{t+s}^W)$, subject to a borrowing constraint $A_t^W \geq 0$ and a budget constraint. We will focus on (asset-scarce) equilibria where the borrowing constraint is binding in the vicinity of a steady state and workers will just consume their wage and government transfer:

$$C_t^W = \frac{W_t}{P_t} L_t + \frac{T_t}{P_t}. \tag{5}$$

The Government and the Fiscal and Monetary Regime. — The Home government issues Home currency bonds B_t^H at time t and makes nominal transfers to workers.

$$\frac{B_t^H}{P_t} = \frac{T_t}{P_t} + \frac{i_{t-1} B_{t-1}^H}{P_t}. \tag{6}$$

Inside the government, we assume that the fiscal authority exogenously chooses a path for nominal debt B_t^H. Absent shocks, they are assumed to grow at the gross rate θ. Monetary policy then determines the price level or the nominal interest rate.

We assume the monetary authority follows price targeting policy. Whenever it can, it chooses the nominal interest rate to target $P_t = \theta^t \bar{P}$. At the ZLB, it simply sets $i_t = 1$ and lets the market determine the price level P_t. This implies the following complementary slackness condition:

$$(i_t - 1)\left(\theta^t \bar{P} - P_t\right) = 0, \qquad i_t \geq 1, \qquad \theta^t \bar{P} \geq P_t. \tag{7}$$

We make the following parametric assumption:

Assumption 1. *$\theta > \beta$ and $\theta^* > \beta^*$.*

When the Home economy is at the ZLB, its real gross rate of interest is $1/\theta$ in the steady state. Assumption 1 ensures that it is strictly lower than $1/\beta$. This implies that borrowing constraints will be binding for workers and investors in steady states close enough to the ZLB. A sufficient condition for this is $\theta \geq 1$, that is non-negative steady-state inflation.

Downward Wage Rigidity.—Nominal wages are assumed to be downwardly rigid in the spirit of Schmitt-Grohé and Uribe (2016): they cannot grow at a (gross) rate lower than $\gamma \in (0, \theta)$. Labor supply by Home workers has then an inverted L-shape given by the following complementary slackness condition:

$$(W_t - \gamma W_{t-1})(1 - L_t) = 0, \qquad W_t \geq \gamma W_{t-1}, \qquad L_t \leq 1.$$

There is full employment $L_t = 1$ as long as the corresponding market-clearing wage is greater or equal than γW_{t-1}. Otherwise, there is unemployment: $L_t < 1$. Using firms' labor demand (4), equilibrium employment is given by

$$L_t = \min\left\{1, \left[\frac{(1-\alpha)ZP_t}{\gamma W_{t-1}}\right]^{\frac{1}{\alpha}} K_{t-1}\right\}. \tag{8}$$

In a steady state, the downward wage rigidity constraint is not active since the nominal wage grows at the gross rate θ larger than γ. Similar conditions must hold in Foreign for full employment $L_t^* = 1$ to prevail.

Market Clearing for Bonds and Capital.—Equilibrium in Home and Foreign markets for capital is given by:

$$K_t = \int_0^1 K_t^i di, \tag{9}$$

$$K_t^* = \int_0^1 K_t^{j*} dj, \tag{10}$$

where i indexes Home investors and j indexes Foreign investors.

Equilibrium in the markets for bonds in Home and Foreign currency is given by:

$$\int_0^1 \frac{D_t^{H,i}}{P_t} di + \frac{B_t^H}{P_t} = \int_0^1 (1 - x_t^i) A_t^i di + \int_0^1 x_t^{j*} A_t^{j*} dj \tag{11}$$

$$\int_0^1 \frac{D_t^{F,j*}}{P_t^*} dj + \frac{B_t^{F*}}{P_t^*} = \int_0^1 x_t^i A_t^i di + \int_0^1 (1 - x_t^{j*}) A_t^{j*} dj \tag{12}$$

2.2 Asset-Scarce Equilibrium

To simplify notations, we use lower-case letters to denote appropriately normalized variables. Price levels, nominal wages, government transfers, and bond supplies in Home (Foreign) are normalized by θ^t (θ^{*t}), e.g., $p_t = P_t/\theta^t$. The normalized nominal exchange rate is defined by $s_t = (\theta^*/\theta)^t S_t$. To limit the sources of heterogeneity between Home and Foreign, we assume that α, β, γ, κ, and δ are the same in both countries. Countries can have different steady-state inflation rates θ, θ^*, investment opportunities η, η^*, collateral and liquidity parameter, ϕ, ϕ^*, λ, and λ^*.

An *asset-scarce* equilibrium is an equilibrium where the borrowing constraints for investors (2) and workers ($A_t^W \geq 0$) are binding in the steady state in both Home and Foreign. In the following, we restrict the analysis to such asset-scarce equilibria. Binding borrowing constraints prevent borrowers from supplying the saving instruments needed by savers. The steady state is then characterized by low real rates: $i/\theta, i^*/\theta^* < 1/\beta$. For small enough shocks, borrowing constraints will also be binding during all transition dynamics, which we assume throughout.

Consider an exogenous sequence of government debts $\{b_t^H, b_t^{F*}\}_{t\geq 0}$, an exogenous sequence of investment opportunities, collateral and liquidity parameters $\{\eta_t, \eta_t^*, \phi_t, \phi_t^*, \lambda_t, \lambda_t^*\}_{t\geq 1}$, and initial conditions k_0^i, k_0^{j*}, $d_0^{H,i}$, $d_0^{F,j*}$, a_0^i, a_0^{j*}, x_0^i, x_0^{j*}, p_0, p_0^*, i_0, i_0^*. An asset-scarce equilibrium is an allocation $\{L_t, L_t^*, k_t^i, k_t^{j*}, c_t^i, c_t^W, c_t^{j*}, c_t^{W*}, a_t^i, a_t^{j*}\}_{t\geq 1}$, a set of portfolio choices $\{x_t^i, x_t^{j*}, d_t^{H,i}, d_t^{F,j*}\}_{t\geq 1}$, a policy $\{i_t, i_t^*, t_t, t_t^*\}_{t\geq 1}$ and a price vector $\{p_t, p_t^*, w_t, w_t^*, \rho_t, \rho_t^*\}_{t\geq 1}$ that solve the maximization problems of investors, firms, and workers in Home and Foreign, where the borrowing constraints for investors (2) and workers ($A_t^W = 0$) are binding, and satisfy the government budget constraints (6), the complementary slackness conditions of monetary policy (7) and of the labor markets (8), and the market-clearing conditions for capital (9) and (10), and for bonds (11) and (12). The nominal exchange rate s_t is omitted from this definition since it is simply given by $s_t = p_t/p_t^*$.

3 Analytical Insights

In this section, we consider a simpler version of the model where we can derive intuitive analytical results. We assume that capital fully depreciates ($\delta = 1$) and that we are in the deterministic limit of alternating investment opportunities ($\eta = 1$). We relax both assumptions in numerical simulations in the following section. We characterize the optimal decisions in this case and show that equilibrium behavior can be represented by modified IS equations. Using a graphical analysis, we then discuss the impact of shocks when Foreign is outside the ZLB. We show that the spillover of shocks is dramatically different whether Home is at the ZLB or not.

3.1 Optimal Saving and Portfolio Decisions

The optimization problem of investors can be split into two independent problems: a saving-consumption choice and a portfolio choice. The model is set up to get a very tractable saving-consumption choice. Expected next-period wealth of investors is a linear function of their current saving. As is well known, with logarithmic utility, this implies that investors choose to save a fraction β of their beginning-of-period wealth. Assuming a binding borrowing constraint (2) and using the first-order condition (3) with full capital depreciation and deterministic investment opportunities, the normalized aggregate beginning-of-period wealth of Home savers is $\alpha(1 - \phi_{t-1})y_t$. Hence, real aggregate financial wealth is given by

$$a_t = \beta\alpha(1-\phi_{t-1})y_t. \tag{13}$$

In the asset-scarce equilibria we are interested in, the return on capital will be strictly larger than the cost of borrowing. Then, I-investors simply choose to buy capital with the maximum allowed leverage. Their borrowing constraint (2) is binding.

Home savers choose the portfolio share x_t that maximizes the expected return net of liquidation cost $(1-x_t)\frac{i_t p_t}{\theta p_{t+1}} + x_t \frac{i_t^* p_t/s_t}{\theta^* p_{t+1}/s_{t+1}} - \frac{1}{2}\lambda(1-x_t)^2 - \frac{1}{2}(\lambda^*+\kappa)(x_t)^2$ subject to the savers' no-borrowing constraint $x_t \geq 0$. The first-order condition gives the optimal portfolio share, common across all savers. When the savers' borrowing constraint is not binding ($x_t \geq 0$), we have:

$$x_t = \frac{\lambda}{\lambda+\lambda^*+\kappa} + \frac{1}{\lambda+\lambda^*+\kappa}\Big[\frac{i_t^* p_t^*}{\theta^* p_{t+1}^*} - \frac{i_t p_t}{\theta p_{t+1}}\Big]. \tag{14}$$

The first term on the right-hand side is a reference portfolio share of Foreign currency bonds. It depends on the relative total cost of holding and liquidating Home and Foreign currency bonds. A higher management cost of foreign currency holdings κ decreases the reference share of Foreign currency bonds. The second term is the real excess return on Foreign currency. The higher it is, the more investors hold Foreign currency assets.

A similar equation obtains in Foreign:

$$x_t^* = \frac{\lambda^*}{\lambda+\lambda^*+\kappa} + \frac{1}{\lambda+\lambda^*+\kappa}\Big[\frac{i_t p_t}{\theta p_{t+1}} - \frac{i_t^* p_t^*}{\theta^* p_{t+1}^*}\Big]. \tag{15}$$

It is interesting to note that Equations (14) and (15) together imply that the cross border flows $x_t + x_t^* = \frac{\lambda+\lambda^*}{\lambda+\lambda^*+\kappa}$ are decreasing in international financial frictions κ, and increasing in domestic financial frictions $\lambda+\lambda^*$ whenever $\kappa > 0$. The convex nature of the liquidation costs implies that there is an incentive to hold both assets at all times for savers worldwide. Furthermore, the desire to acquire a larger number of these assets becomes more acute when domestic frictions increase.

3.2 Generalized IS Curves

Using the binding borrowing constraint (2) together with the first-order condition (3), and the expression for real saving (13), the market-clearing conditions for Home and Foreign currency bonds simplify to

$$\beta(1-\phi_{t-1})(1-x_t)y_t + \beta(1-\phi_{t-1}^*)x_t^* y_t^* = \phi_t \frac{\theta p_{t+1}}{i_t p_t} y_{t+1} + \frac{b_t^H}{\alpha p_t}, \tag{16}$$

$$\beta(1-\phi_{t-1}^*)(1-x_t^*)y_t^* + \beta\left(1-\phi_{t-1}\right)x_t y_t = \phi_t^* \frac{\theta^* p_{t+1}^*}{i_t^* p_t^*} y_{t+1}^* + \frac{b_t^{F*}}{\alpha p_t^*}, \tag{17}$$

along a perfect foresight equilibrium.[8]

Consider Equation (16). On the left-hand side is the demand for Home currency assets, composed of the demand by Home savers, which is a fraction $1 - x_t$ of the total Home saving $\beta(1 - \phi_t)y_t$ and the demand by Foreign savers, which is a fraction x_t^* of the total Foreign saving $\beta(1 - \phi_t^*)y_t^*$. On the right-hand side is the supply, composed of the supply by Home investors and by the Home government. Similarly, the left-hand side of Equation (17) is the demand for Foreign currency assets by Foreign and Home savers, while the right-hand side is the supply by Foreign investors and the Foreign government.

Notice that, for $0 < \phi_t < 1$, Equation (16) relates current Home output y_t positively to the future output y_{t+1} and negatively to the real interest rate $\theta p_{t+1}/i_t p_t$, just like the textbook New Keynesian IS curve albeit with a richer view on the bond market. While in the textbook model, this relation directly comes from the Euler equation of the representative agent, here it also includes bond demand and supply and is best understood as describing equilibrium on the bond markets. Other things being equal, a higher current output increases Home saving, which has to be absorbed by an increase in bond supply. This can happen through a relaxation of the Home credit constraint, which requires a decrease in the real interest rate, given future output. However, other terms affect this equilibrium, such as Foreign saving and the Home government bond supply, through non-Ricardian effects.[9] A similar reasoning applies to Equation (17). Equations (16) and (17) can thus be considered as generalized IS curves.

Since the government exogenously sets a nominal supply of bonds, the price level, and not just expected inflation, also matters for the IS curve. When $b^H > 0$, a lower price level p_t, other things equal, sustains output y_t in the same way as a lower real interest rate. This is known as a real balance or Pigou effect. This effect is not present for private debt, which depends on real collateral.

The channel for the international transmission of shocks is the supply of and demand for assets. International shocks will affect Equations (16) and (17) through the portfolio shares x_t and x_t^*. In addition, the transmission of shocks is affected by the capacity of the central bank to adjust its interest rate. We illustrate this point in more details in

[8]These expressions need not apply in case of an unexpected shock in period t. Indeed, they assume that repayment of debt issued by investors is equal to a share ϕ of the *realized* total nominal return on capital, instead of the one *expected in the previous period* as in (2). For instance, an unexpected decrease in the price level may increase real debt repayment.

[9]Two elements generate these non-Ricardian effects. First, the fact that other agents in the economy (here, workers) receive government transfers and pay taxes implies that holding government debt is actually a net asset from the point of view of savers. Second, because savers are constrained in the next period, their consumption-smoothing horizon is shorter than the horizon at which the government repays its debt.

the next subsection.

3.3 The Impact of Shocks in an Asymmetric Setting

In the remainder of the paper, we consider a slightly asymmetric case where Foreign inflation is higher than Home, while all other parameters are the same in both countries. We make the following assumption:

Assumption 2. $\theta^* > \theta$.

If the other parameters are identical in both countries, they face the same real interest rate $i/\theta = i^*/\theta^*$. Assumption 2 then implies that Home has a lower nominal interest rate than Foreign. This makes it possible for Home to be at the ZLB while Foreign is not.

Suppose we start at $t = 0$ in such a slightly asymmetric steady state and there is an unexpected contractionary shock in Foreign at $t = 1$, for instance a once-and-for-all increase in the liquidity parameter λ^*. We assume that Foreign stays outside of the ZLB, while Home may or may not be at the ZLB. The initial steady state is derived analytically in Appendix A.2.

By decreasing the liquidity of Foreign bonds, the shock effectively increases asset scarcity in Foreign and leads savers in both countries to reallocate their portfolio towards Home bonds (x_t^* increases and x_t decreases), as Equations (14) and (15) show. According to Equation (17), the lower demand for Foreign bonds puts upward pressure on the Foreign real interest rate. The Foreign monetary authority reacts to this shock by increasing the nominal interest rate i^* to keep prices on target.

The portfolio reallocations lead to a capital inflow into Home assets and a sale of Home holdings of Foreign assets, which both contribute to a net capital inflow into Home and an increase in net saving in Home. Indeed, in the Home IS curve (16), the increase in x^* and the decline in x generate an excess demand for Home assets. By buying Home currency bonds issued by Home investors, Foreign and Home savers transmit the lack of assets to the Home economy.

Now consider the adjustment mechanisms in Home. The increase in the net demand for Home assets can be absorbed either by a decrease in the Home interest rate i_t, which would relax the financial constraint and stimulate the supply of Home assets by I-investors, or by a decrease in the Home price, which would increase the real value of government debt. If the nominal interest rate i_t cannot fall because it is at the ZLB, then the Home price level must decline.

Therefore, if Home is outside the ZLB, the Foreign shock leads to a drop in the Home interest rate, to keep the Home price level on target. Capital inflows generate lower real interest rates in Home, which stimulates output and investment. This adjustment mechanism, a mix of lower interest rate and lower net foreign asset position, prevents Home output to be severely affected in the short run.

Things are different when Home is at the ZLB and the monetary authority cannot decrease the interest rate. Then, the adjustment comes from a lower price level and an appreciation of the nominal exchange rate. In the presence of downward wage rigidity, this can generate an increase in the real wage, which has a negative impact on labor demand and on output.

One can interpret these mechanisms as alternative clearing mechanisms for the global asset market. To see this, consolidate the two generalized IS curves (16) and (17) with $\phi_t = \phi_t^* = \phi$:

$$\beta(1-\phi)\left(1+\frac{y_t^*}{y_t}\right) = \phi\left(\frac{\theta p_{t+1}y_{t+1}}{i_t p_t y_t} + \frac{\theta^* p_{t+1}^* y_{t+1}^*}{i_t^* p_t^* y_t^*}\frac{y_t^*}{y_t}\right) + \frac{1}{\alpha p_t y_t}\left(b_t^H + s_t b_t^{F*}\right) \tag{18}$$

This equation describes the equilibrium between the global demand for assets (left-hand side) and the global supply of assets (right-hand side), normalized by domestic output. An asset market shock in Foreign increases the interest rate i_t^* , and hence decreases the foreign supply of assets. This decrease in the foreign supply of assets must be compensated by an increase in the Home supply through a decrease in the domestic interest rate i_t outside the ZLB. At the ZLB, it will be compensated by an increase in the real supply of assets in Home via a decrease in p_t. In the presence of downward wage rigidity and a drop in output, the adjustment will also come partially from a decrease in the demand for assets in Home, due to the decrease in investors' revenue.

3.4 Graphical Analysis

The impact of shocks can be analyzed graphically under some simplifying assumptions. First, suppose that movements in x^*y^*/y (xy/y^*) are dominated by movements in x^* (x). This is for example the case in the log-linear approximation of the model, when cross-border bond holdings x, x^* are small in the initial steady state (see Appendix A.3). Since $y^* = y$ in the initial steady state, x^*y^*/y (xy/y^*) can then simply be replaced by x^* (x). The generalized IS curves of Home and Foreign simplify to

$$1+(x_t^* - x_t) = \frac{\phi}{1-\phi}\frac{\theta p_{t+1}y_{t+1}}{\beta i_t p_t y_t} + \frac{1}{1-\phi}\frac{b_t^H}{\beta\alpha p_t y_t}, \tag{IS}$$

$$1-(x_t^* - x_t) = \frac{\phi}{1-\phi}\frac{\theta^* y_{t+1}^*}{\beta i_t^* y_t^*} + \frac{1}{1-\phi}\frac{b_t^{F*}}{\beta\alpha p_t^* y_t^*}, \tag{IS*}$$

where we have used the fact that $\phi^* = \phi$ and that Foreign stays out of the ZLB, so that $p_{t+1}^* = p_t^*$.

Both IS curves are conditioned by the relative share of cross-border bond holdings $x^* - x$, an indicator of the Foreign net position. Using (14) and (15), this relative share is determined by a portfolio schedule (PF):

$$x_t^* - x_t = \frac{\lambda^* - \lambda}{\lambda + \lambda^* + \kappa} - \frac{2}{\lambda + \lambda^* + \kappa}\left[\frac{i_t^*}{\theta^*} - \frac{i_t p_t}{\theta p_{t+1}}\right]. \tag{PF}$$

We consider the short run, so we focus on period t, the period where the shock occurs, and take expectations of future variables as given—we will discuss later how expectations alter the picture. Figure 1 represents the PF and the IS curves in the $(x^* - x, i^*)$ and $(x^* - x, i)$ spaces, conditional on expectations. The details are given in Appendix B.

First, it is easy to see that the (PF) curve is downward-sloping in the $(x^* - x, i^*)$ space, for a given real domestic interest rate $i_t p_t / p_{t+1}$, and upward sloping in the $(x^* - x, i)$ space, for a given foreign real interest rate i_t^*/θ^*, as shown in Figure 1. Second, the (IS*) curves is upward sloping, as shown in Figure 1a. Third, the (IS) curve is downward sloping until it reaches the ZLB. After that point, it becomes horizontal, as shown in Figure 1b. Outside the ZLB, nominal GDP is constant because period 1 output is given by predetermined capital and full employment and changes in i_t (i_t^*) stabilize p_t (p_t^*); so the (IS*) curve is horizontal in the bottom of Figure 1a. At the ZLB, given expectations of future variables, the (IS) curve now determines nominal GDP $p_t y_t$, as shown in the bottom of Figure 1b.

Consider an asset market shock that deteriorates foreign bonds' liquidity: an increase in λ^*. This leads to a higher net Foreign position $x^* - x$ and shifts the (PF) schedule to the right. For Foreign, this leads to a higher interest rate i^* in Figure 1a. For Home, the shock is assumed large enough so that it reaches the ZLB in equilibrium B. In this case, nominal GDP declines at impact, as shown in Figure 1b.

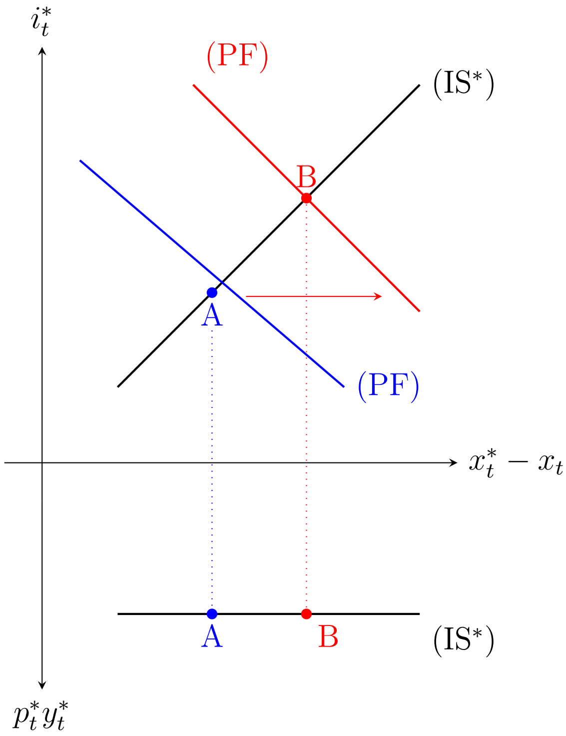
When the shock is small, this decline in nominal GDP is achieved entirely through a decrease in the price level. When the shock is large enough, the downward wage rigidity binds and the adjustment in nominal GDP is driven jointly by an output decline and a price decrease. Indeed, we can prove the following lemma which holds in the general case, regardless of the simplifying assumptions made in the this section.

Lemma 1. *Starting from full employment, employment declines if and only if nominal output declines more than γ/θ:*

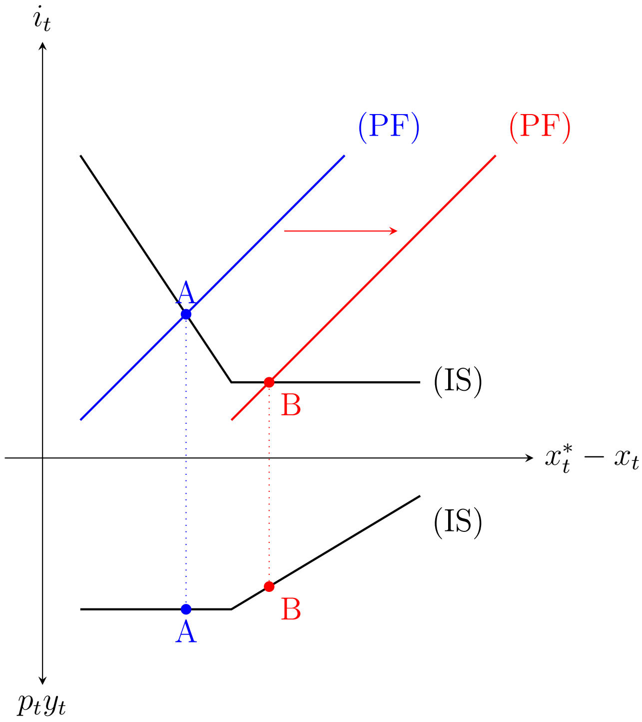
$$\text{if } L_{t-1} = 1, \quad L_t = \begin{cases} 1 & \text{if } p_t y_t \geq \frac{\gamma}{\theta} p_{t-1} y_{t-1}, \\ \frac{\theta}{\gamma} \dfrac{p_t y_t}{p_{t-1} y_{t-1}} & \text{otherwise.} \end{cases} \tag{19}$$

Proof. This follows directly from the downward wage rigidity together with the first order condition (4). Indeed, using the first-order condition when $L_{t-1} = 1$, the com-

Figure 1. Liquidity Shock: Increase in λ^*



(a) Foreign



(b) Home

plementary slackness condition associated to the downward wage rigidity becomes $(\theta p_t y_t / L_t - \gamma p_{t-1} y_{t-1})(1 - L_t) = 0$, $\theta p_t y_t / L_t \geq \gamma p_{t-1} y_{t-1}$, $L_t \leq 1$. □

As the lemma shows, for a shock just large enough to bring the economy to the ZLB, where nominal GDP does not decline much, the economy stays at full employment and short-run adjustment comes from the price level only. For larger shocks, as will be the case in the simulations of the next section, nominal GDP declines more, the downward wage rigidity binds and employment declines. In that case, adjustment comes from output, not just from prices.[10]

To summarize, the main short-run impact of an increase in λ^* on Foreign is an increase in its nominal interest rate i^*. In contrast, if Home reaches the ZLB, it faces a domestic currency appreciation (price decrease) and may suffer a decline in output in the short run.

[10]In Appendix A.5, we use a log-linear approximation around the initial steady state to study in more details the full dynamics of adjustment to a shock on λ^* at the ZLB. We show that, over time, as the nominal wage gradually declines, the price level declines as well and employment gradually increases back towards full employment.

Spillbacks In describing Figure 1a, we have assumed that the domestic real interest rate $i_t p_t / p_{t+1}$ was given. However, spillovers to the Home economy generate an adjustment in the real interest rate, either through a decrease in the nominal rate i_t outside the ZLB, or through a decrease in inflation p_{t+1}/p_t at the ZLB. These adjustments generate spillbacks of different nature. Outside the ZLB, there is a decrease in the Home real rate that shifts (PF) back to the left in Figure 1a. These spillbacks mitigate the increase in interest rate i^*. At the ZLB, there is an increase in the Home real rate, that shifts (PF) further to the right. These spillbacks amplify the increase in interest rate i^*: the increase in domestic real interest rate attracts further capital inflows into the Home economy, amplifying the impact of the shock in both Foreign and Home.

Expectations While Figure 1 represents a temporary equilibrium conditional on expectations, these expectations do matter. As apparent from the (IS) curve, a lower expectation of next period nominal output, by decreasing the available collateral to issue bonds, further decreases current nominal output in the ZLB. This is a dynamic multiplier similar to that of Kiyotaki and Moore (1997). If the borrowing constraint depended on the current value of the capital stock, instead of its future total return, this dynamic intertemporal multiplier would collapse into a static within-period multiplier.

Other shocks Other asset market shocks that increase net capital flows to Home include a decline in the supply of Foreign government bonds, b^{F*}. This shifts the (IS*) curve to the right in Figure 1a, resulting in a lower Foreign rate i^* and a higher net Foreign position $x^* - x$. The latter shifts the (PF) schedule to the right in Figure 1b, as previously. Economically, the lower supply of Foreign government bonds results in higher net saving in Foreign, which must be redirected to Home in equilibrium. This happens through a decrease in the Foreign interest rate, which makes Home bonds more attractive to savers and leads to an increase in x^* and a decline in x. The excess demand for assets in Foreign is then exported to Home. To accommodate these higher net capital inflows, the Home economy then requires either a decrease in the interest rate or a fall of the Home price, as above.

Our framework also accommodates temporary monetary shocks. Consider a monetary expansion in Foreign which leads to a permanent increase in the price level p^*. This shifts the (IS*) schedule to the right in Figure 1a, similarly to a decline in the supply of government bonds, which provides the decline in i^* needed to implement the monetary expansion. Transmission to the Home economy is the same as before.

Finally, in the more general case with $\eta, \eta^* \leq 1$, a decline in the investment opportunities η generates similar effects as it also increases net saving in Foreign, which again would shift the (IS*) to the right in Figure 1a.

4 Simulations

In this section we analyze the dynamic response to unexpected shocks in a calibrated model with $\delta < 1$ and $\eta, \eta^* < 1$. We also assume that Assumption 2 holds so that Foreign has a higher nominal interest rate and is never at the ZLB, while Home may or may not be at the ZLB. In the previous analytical section, we have focused on a financial shock to the liquidity of Foreign bonds, λ^*. In this section, we consider three different types of shocks: a real shock to Foreign investment opportunities η^*, the financial shock to λ^* considered before, and a monetary shock to the Foreign price level $\bar{P}^*$. While these shocks are of different nature, they all affect the supply of or the demand for assets and will share a similar spillover mechanism through capital flows.

4.1 Calibration

Our calibration of the model is designed to simulate the scenario of two countries whose sole difference is in their steady-state inflation rate. The time period is set to a year. In the baseline, we set the pair θ, θ^* to 1.00 and 1.02, which pins down the difference in nominal interest rates to two percentage points. As explained in the preceding section, when Foreign trend inflation is larger than Home, Home is the country with the lowest nominal interest rate. The ZLB on interest rates might therefore bind for Home but not for Foreign. This allows us to distinguish the spillovers from Foreign asset market shocks depending on whether or not Home is in a liquidity trap.

The parameters α, β, and δ have standard values for yearly models. The financial frictions are selected based on Gabaix and Maggiori (2015): in our framework, the sum of λ, λ^*, and κ correspond to the inverse elasticity of cross-border holdings to the currency excess return, and coincides with their Γ parameter, which they set to 0.1. The individual values of λ, λ^*, and κ are selected to target portfolio shares of cross-border bonds held by savers, x and x^*, of about 20% while maintaining $\lambda + \lambda^* + \kappa = 0.1$. This is in line with the steady-state fraction invested abroad of 17% documented by Bacchetta and van Wincoop (2021).

Collateral requirements ϕ and ϕ^* are set so that global investor debt to capital $(d^H/p + d^{F*}/p^*)/(K + K^*)$ is equal to 90%, which corresponds approximately to the ratio of total liabilities to non-financial assets in the US nonfinancial corporate sector in 2022, which is equal to 87%.[11] We then set the government debt b^H and b^{F*} so that the global real debt-to-GDP ratios $(b^H/p + b^{F*}/p^*)/(y + y^*)$ is approximately 25 percent. The sum

[11]We use thee balance-sheet table for Nonfinancial Corporate Business (B.103) from the Financial Accounts of the US. This figure corresponds to $FL104190005/LM102010005$.

Table 1. Baseline calibration

	Parameter	Value
α	Capital share of output	0.33
β	Factor of time preference	0.95
γ	Minimum wage growth rate	0.98
δ	Rate of depreciation of capital	0.1
η	Prob. of investment opportunity	0.1
θ	Home trend inflation	1.00
θ^*	Foreign trend inflation	1.02
κ	Cost of holding foreign bonds	0.06
λ	Liquidation cost	0.02
ϕ	Collateral requirement	0.839
b	Government debt	0.15
$\bar{P}$	Price level target	1
Z	Productivity	1

of govermment and investor debt worldwide constitutes the global supply of bonds to investors, and should be equal to global corporate saving. These parameters generate a ratio of global investors' saving to capital $(A + A^*)/(K + K^*)$ approximately equal to 102%. This ratio is consistent with the ratio of total financial assets to nonfinancial assets in the US nonfinancial corporate sector, which is equal to 111% in 2022.[12]

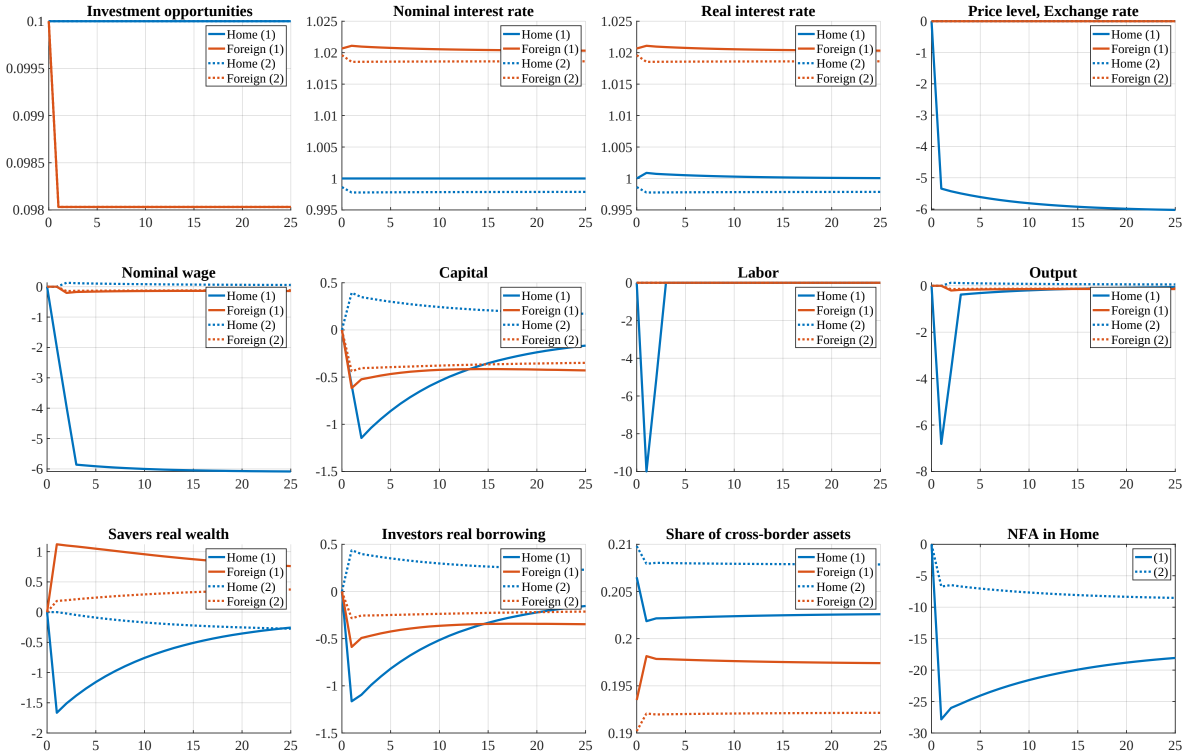
We calibrate to 10% the probabilities η and η^* that investors obtain an investment opportunity, corresponding to an average of 10 years between two investments and allowing us to target an asset-scarce equilibrium real interest rate of 0%. Given trend inflation rates $\theta = 1$ and $\theta^* = 1.02$, the corresponding nominal interest rates are $i = 1$ and $i^* = 1.02$ (in the baseline).

We fix minimum wage growth rates γ and γ^* to 0.98, as in Schmitt-Grohé and Uríbe (2017).[13] Note that because the minimum wage growth rate is smaller than the steady-state inflation rate of each country, full employment obtains globally in a steady-state equilibrium. Finally, the price level target $\bar{P}$ and the productivity parameter Z are both set to 1 without loss of generality. Table 1 summarizes the baseline calibration. Recall that units of time are expressed in years.

[12]We use thee balance-sheet table for Nonfinancial Corporate Business (B.103) from the Financial Accounts of the US as well. This figure corresponds to $FL104090005/LM102010005$.

[13]In the quarterly model from Schmitt-Grohé and Uríbe (2011), our calibration corresponds to a downward wage rigidity parameter of $0.98^{1/4} = 0.995$, which is close to their baseline value 0.99.

Figure 2. Drop in Foreign Investment Opportunities η^*



Notes: The solid red and blue lines labeled (1) correspond to the path for Home and Foreign when Home is at the ZLB, while the dashed lines labeled (2) correspond to the path when Home is not at the ZLB. Variables are expressed in percentage-point deviation from their initial steady-state level, except for interest rates and shares of cross-border assets. On the x-axis, 0 is the initial steady-state, and 1 is the year of the shock.

4.2 Results

We now turn to the results of our simulation exercise for the three shocks we consider.

Results are shown in Figures 2 to 4. Each subplot in the figures displays the transition dynamics of the Home and Foreign economies to the shock under two alternative specifications. The solid red and blue lines labeled (1) correspond to the case where Home is at the ZLB, while the dashed lines labeled (2) correspond to the dynamics that would have prevailed in the absence of the ZLB constraint on Home monetary policy.

Variables are expressed in percentage-point deviation from their initial steady-state level, except for interest rates and portfolio shares of cross-border assets. Period 0 corresponds to the initial steady-state, and period 1 to the year of the shock.

Decline in Foreign Investment Opportunities.—The real shock under study in this first simulation exercise is a permanent decline in Foreign investment opportunities, whereby a lower fraction of savers is presented with an investment opportunity in Foreign, starting from period 1.

As can be seen from the dotted red lines in Figure 2, absent a ZLB, the negative shock to η^* implies a decline in Foreign investment, as investment opportunities are reduced, followed by a drop in output. The supply of Foreign private assets then declines. Because the number of savers increases, the demand for saving instruments increases. The resulting imbalance on the Foreign asset market creates a downward pressure on the Foreign price level, prompting the Foreign monetary authority to decrease the interest rate in order to keep inflation on target.

This triggers a net capital outflow towards Home. Outside the ZLB, the Home central bank decreases its interest rate to accommodate the increase in the demand for Home assets due to capital inflows. This keeps the price level on target but has a positive impact on investment and output.

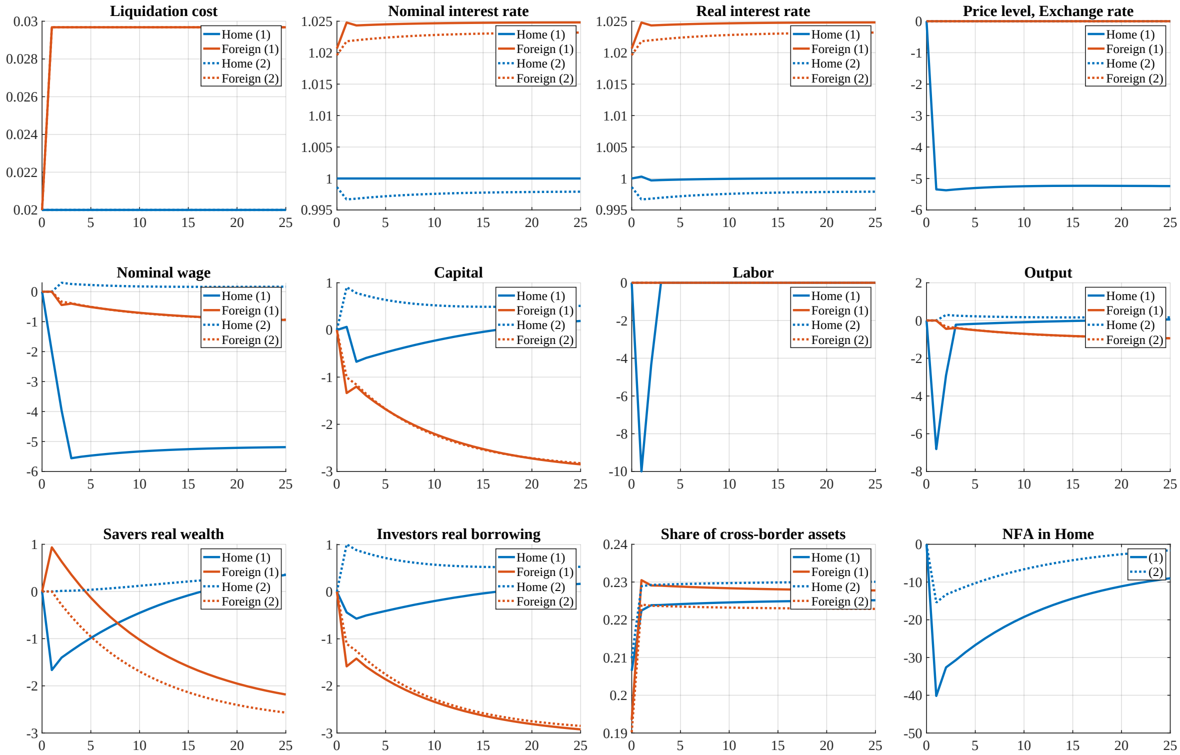
At the ZLB (solid blue lines), the sign of the spillovers is reversed. This is because the increase in demand for Home bonds is now accommodated by a decrease in the Home price, which, in the presence of downward wage rigidity, triggers an increase in unemployment. Additionally, because nominal wages only gradually adjust, the decrease in the Home price level is expected to continue. This leads to an increase in the real interest rate, which tightens the I-investors' borrowing constraints and triggers an investment slump. The decline in both labor and capital contribute to a strong recession.

Interestingly, at the ZLB, the shock spills back to Foreign as the net capital outflows from Foreign are amplified (solid red lines). Indeed, the Home currency appreciates for a few periods, which temporarily increases the Home currency excess return in Home. This drives capital away from Foreign even more in the short term. As a response to this stronger capital flight, the Foreign real interest rate temporarily increases, generating a stronger reduction in capital accumulation and output than in the absence of ZLB.

Adverse Foreign Liquidity Shocks.— We now turn to a financial shock, characterized by a permanent increase in the liquidation cost of Foreign bonds starting from period 1. As shown in Figure 3, an increase in λ^* decreases the demand for Foreign bonds, which pushes the Foreign real interest rate up. The increase in the cost of borrowing results in a decrease in Foreign investment and output, both in the short and long run.

Overall, the reaction of the Home economy is qualitatively similar to that of a decline in the supply of assets in Foreign described above, as both situations result in a capital inflow to Home. Thus, at the ZLB (solid lines), this shock generates deflation, an exchange rate appreciation, and transitory unemployment in Home. We also see similar spillbacks as the interest rate in Foreign has to increase more than in the absence of ZLB because of the strong increase in the Home currency return, which also exacerbates

Figure 3. Increase in Foreign Bonds Liquidity Cost λ^*



Notes: See Figure 2.

the net capital outflow from Foreign.

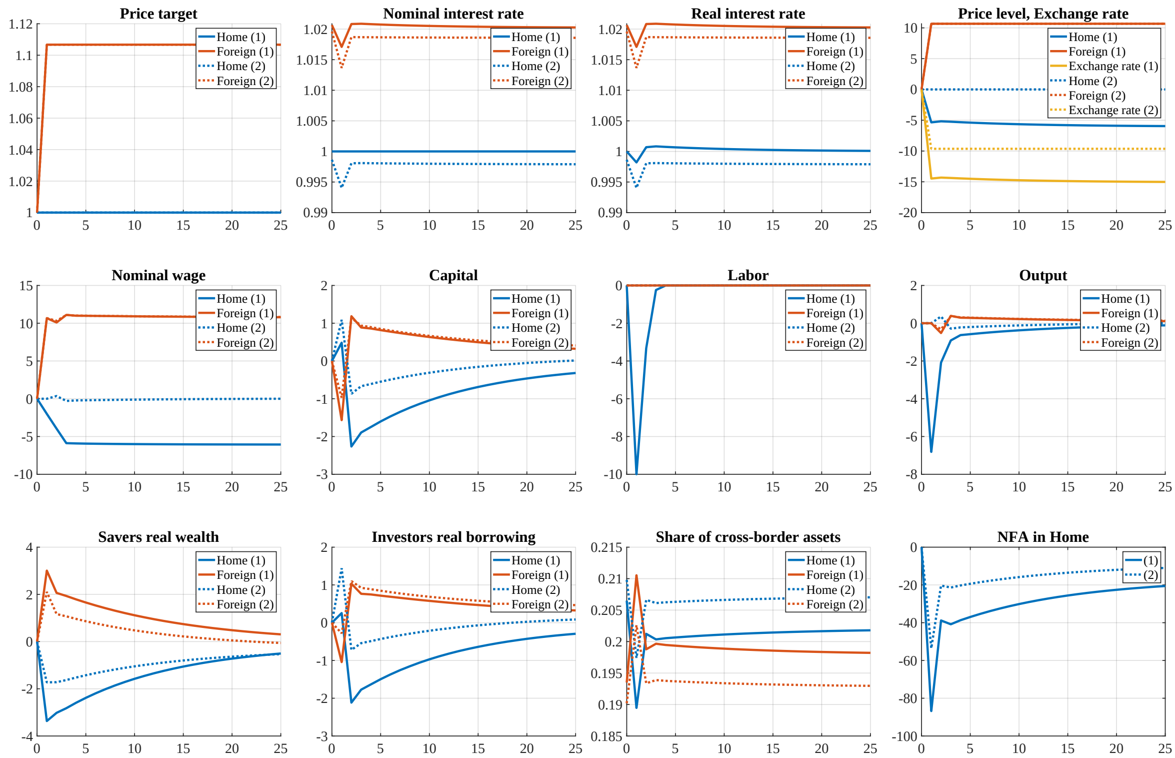
Interestingly, the real wealth of Foreign savers initially increases as they benefit from the unexpected appreciation of Home currency, but it settles at a lower equilibrium level than initially, due to the decline in economic activity.

Increase in the Foreign Price Level.— The third shock that we simulate is a monetary expansion, originating from a permanent increase in the price level $\bar{P}^*$ that the Foreign central bank targets starting from period 1. This corresponds to a one-period rise in Foreign inflation.

The price increase is implemented by the Foreign central bank through a temporary decline in the nominal interest rate. Since the central bank's objective is to perform a once-and-for-all increase in the price level, expected inflation goes immediately back to 2%. Therefore, the decline in the nominal rate generates a decline in the real rate, as shown in Figure 4. This decline in the real rate increases the collateral of Foreign borrowers, leading, other things equal, to a larger supply of Foreign private assets. It also provokes a net capital outflow from Foreign.

Together, the two effects result in a lower net demand for assets in Foreign. This leads to the price increase desired by the central bank, as the supply of real Foreign bonds

Figure 4. Increase in the Foreign Price Target



Notes: See Figure 2. In addition, the solid (dashed) yellow line in the top-right subplot is the exchange rate prevailing at (outside) the ZLB.

must adjust to the lower net demand. Despite the fact that, all else equal, the fall in the real interest rate alleviates I-investors' borrowing constraint, Foreign capital initially decreases as I-investors' nominal wealth is hit by the unexpectedly higher price level, leaving them with less funds to finance investment.

This negative effect is exclusively due to the open dimension of the economy. Indeed, in a closed economy, this shock would generate an increase in Foreign capital. The reason is the following. The unexpected price increase also lowers the real debt of past I-investors, leading to a windfall profit. In a closed economy, this windfall would have to be reinvested locally, which would be possible thanks to a lower interest rate. Overall, investment would increase. In the open economy, the windfall profit is instead invested abroad, in the Home economy. This results in a funding dry-up which leaves Foreign investors with less resources to finance capital.

In the absence of ZLB, the capital flight would stimulate Home's investment and output through a decline in the nominal and real interest rate. But with the ZLB, prices must decrease in Home to generate the amount of real bonds that accommodate the Foreign demand for assets. This, again, generates a decline in labor and output. Similar spillbacks are at work as with the two previous shocks.[14]

4.3 Synthesis

The simulations outlined above reveal that the nature of shocks, whether real, financial, or monetary, gives rise to both similarities and differences in their spillovers and spillbacks.

First, the transmission mechanism is consistent across shocks. Indeed, all three shocks lead to an increase in asset scarcity in the Foreign economy. This arises from savers reallocating their portfolios towards Home bonds, resulting in capital inflows into the Home economy and creating an excess demand for Home assets. This mechanism is common to all shocks, highlighting its importance in transmitting the impact of shocks across economies.

Second, the ZLB plays a critical role in shaping the responses to these shocks. In particular, when the Home economy is outside the ZLB, the central bank can adjust the nominal interest rate to reequilibrate the Home asset market and mitigate the impact of shocks. However, in a liquidity trap, the central bank's inability to decrease the interest rate further leads to deflation and currency appreciation in Home. This constraint is significant in shaping the world economy's response to shocks.

Third, the spillovers from these shocks are significant. Under some level of nominal rigidities, the deflation caused by shocks leads to unemployment and recession in Home. The constraints imposed by the ZLB magnify the negative impact of these shocks, making the economy more susceptible to spillover effects from external shocks.

Finally, the presence of the ZLB triggers spillbacks in all three shocks. Capital inflows driven by the shocks cause the Home currency to appreciate temporarily, making Home assets more attractive to investors. As a result, capital flows away from Foreign, leading to a temporary increase in the Foreign real interest rate. This causes a more pronounced reduction in capital accumulation and output in the Foreign economy compared to scenarios without ZLB constraints.

Despite the similarities in transmission mechanisms and spillovers, differences arise in international portfolio allocation. Notably, the financial shock drives Home investors to hold more Foreign bonds, despite higher liquidation costs. As noted earlier, cross border flows are decreasing in international financial frictions κ, and increasing in Home

[14] In Appendix C, we present an analysis investigating how the impact of Foreign asset market shocks on the Home economy is potentially heightened when Home has a relatively low real debt-to-GDP ratio. This is conducted through similar simulations. We calibrate nominal government debt in Home to be half of that in Foreign, while keeping global nominal debt constant for comparison across specifications. Our findings, as depicted in Figures C1, C2, and C3, indicate that the spillovers from these shocks to Home are significantly exacerbated when it has a relatively smaller debt-to-GDP ratio.

financial frictions $\lambda + \lambda^*$ whenever $\kappa > 0$. When λ^* rises, the increase in costs associated with the Foreign asset has a greater effect on Foreign savers in comparison to Home savers. This discrepancy can be attributed to the convex nature of these costs. The main reason for this phenomenon is that Foreign savers hold a larger share of Foreign assets compared to Home savers ($1 - x^* > x$), which precisely occurs because $\kappa > 0$. As the returns on Foreign assets increase to offset this shock, the overall effect for Home savers is an enhanced attractiveness of Foreign assets.

Furthermore, the monetary shock stands out as the only shock that stimulates Foreign investment in the medium run. Indeed, due to the unanticipated decline in prices, the real interest rate for borrowers decreases, constituting a positive income shock. Consequently, there is a medium-term increase in saving and capital (when borrowers transition into savers). Incidentally, this is the sole shock where the real interest rate in the Foreign economy declines. Conversely, the initial reduction in capital is explained by a negative income shock for savers (who transform into investors), as the returns on saving undergo an unforeseen decrease.

Finally, while the size of each shock is chosen to generate a 10% decrease in employment in Home, it is important to note that the amount of capital flows required for that level of unemployment to obtain varies across shocks. Specifically, the monetary shock leads to the strongest decrease in Home NFA, followed by the financial shock and the real shock. However, despite these differences, the persistence of the effects outlined above is roughly similar across shocks.

5 Policy implications

Can macroeconomic policy mitigate asset market spillovers at the ZLB? We discuss four policies: increasing the steady-state inflation θ, forward guidance (decreasing future interest rates), fiscal expansion and sterilized foreign exchange reserve policies.

Higher steady-state inflation The ZLB has implications on the desirable steady-state inflation rate. Raising the steady-state inflation rate allows the nominal interest rate to stay further above zero in normal times, increasing the central bank's policy space during downturns. Importantly, in our setup with downward-wage rigidity, for a given minimal nominal wage inflation γ, a higher steady-state inflation rate θ reduces the likelihood of experiencing a drop in employment and the negative impact on output when the downward wage rigidity is binding (see Lemma 1).

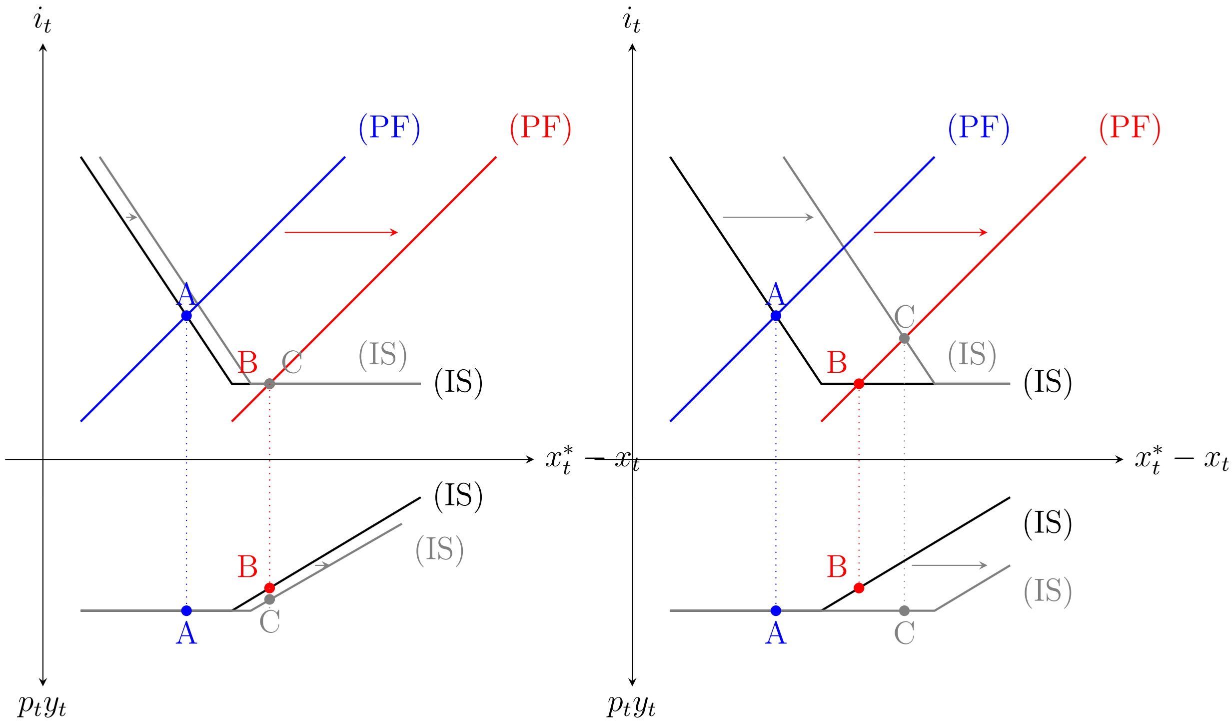
Forward guidance A key insight from the literature on optimal monetary policy at the zero lower bound is that the ZLB introduces a nonlinearity in the policy problem, making traditional Taylor-rule frameworks suboptimal in such settings. Eggertsson and Woodford (2003) have shown that credible promises to keep future nominal interest rates low—forward guidance—can stimulate current output and inflation by lowering real long-term interest rates.[15] This channel is at play in our framework because the generalized IS curves are forward-looking, due to the forward-looking borrowing constraints. However, the effectiveness of forward guidance is mitigated in models with financial frictions, because these models feature a discounting of future aggregate demand. In our case, the borrowing constraints generate a similar discounting (see Equations (27) and (28) in Appendix A.3), which will mitigate the impact of forward guidance. In addition, forward guidance is only effective in the presence of temporary shocks that ensure the economy will eventually exit the ZLB. Standard representative-agent models cannot accomodate permanent shocks that keep the economy at the ZLB indefinitely. Our framework, through its non-Ricardian features, allows us to model this situation in which forward guidance becomes ineffective.

A debt-fuelled fiscal expansion Consider a fiscal expansion (an increase in real transfers T/P) financed through an increase in normalized government debt b^H. This increase in the supply of domestic assets mitigates the impact of asset market shocks by accommodating the excess demand of foreigners for domestic assets. This mitigates spillovers both outside the ZLB (the domestic interest rate does not need to fall as much) and at the ZLB (nominal output does not need to fall as much). The literature has emphasized that inflationary fiscal expansions have a positive effect on output, especially at the ZLB (Woodford, 2011, Christiano et al., 2011). However, the channel is different: driven by an increase in inflation, the real interest rate drops and stimulates aggregate demand. In our framework, it is an asset supply channel that hinges crucially on the fact that the fiscal expansion is financed through debt.

Figure 5 represents how a weak and a strong fiscal expansion affect the Home economy, when it is undergoing the spillovers from a liquidity shock in Foreign. After a liquidity shock in Foreign, the economy moves from equilibrium A to equilibrium B, as in Figure 1. The economy falls in the ZLB and nominal output drops. Both a weak and a strong fiscal expasion shift the IS curves to the right (panels (a) and (b)). In both cases, the impact on nominal output is reduced as the supply of domestic debt fulfills part of the excess demand for domestic assets (equilibrium C). With a strong fiscal expansion, the debt expansion is strong enough to lift the interest rate above the ZLB and completely immunize the nominal domestic output from the foreign shock (panel

[15] See Haberis and Lipinska (2020) for an analysis of forward guidance in a two-country setting.

Figure 5. Liquidity Shock: Increase in λ^* – With a Debt-Fuelled Fiscal Expansion



(a) Home – Weak Fiscal Expansion (b) Home – Strong Fiscal Expansion

(b)).[16]

Sterilized foreign exchange interventions Sterilized foreign exchange interventions by central banks change the economy's net supply of domestic assets. For instance, the central bank can issue domestic bonds in order to buy foreign assets. Could this policy then accommodate international asset market shocks by increasing the supply of domestic assets, as the debt-fuelled fiscal expansion? We show that this policy in fact does not alleviate the asset market shock, because it also increases the demand for foreign assets. The resulting impact is thus neutral. Appendix E shows this precisely.

6 Conclusions

In a globally integrated financial system, it is essential to understand how shocks affecting the supply and demand for assets are transmitted internationally. These financial ties, bolstered by monetary policy constraints such as the ELB, influence not only how

[16]In Appendix D, we simulate the impact on the Home economy of an adverse liquidity shock in Foreign when Home follows a debt policy rule of the form $b_t^H = \bar{b}^H e^{\iota \lambda_t^*}$ with $\iota > 0$. The experiment is identical to that of Figure 3, except that Home government debt increase in response to the shock. Our findings confirm that spillovers from these shocks to the domestic economy are significantly alleviated by debt-fuelled fiscal expansions (cf. Figure D4).

economies respond to shocks, but also how these responses ripple across economies.

We construct a two-country model with heterogeneous agents and segmented international capital markets in order to investigate the spillovers of real, monetary, and financial shocks. We extend the conventional New Keynesian IS curve to capture the effects of gross capital flows and variations in the real supply of domestic assets by incorporating financial frictions and a mechanism for alternating savers and investors. This extension is particularly valuable when considering a world in which asset availability plays a significant role in international finance.

This extended IS-curve offers interesting analytical insights. In particular, when shocks that discourage foreign bonds holdings happen abroad, portfolio reallocations from foreign to domestic assets occur, causing the domestic currency to appreciate. While the domestic central bank could normally offset this by lowering its nominal interest rate—resulting in positive spillover effects—the ELB prevents this action, causing deflation with a contractionary effect, and thus negative spillovers.

We demonstrate the spillovers from various categories of shocks, namely real, financial, and monetary shocks, both analytically and through a series of perfect-foresight simulations. We show how the presence of the ELB can alter the sign and magnitude of these spillovers, resulting in profound effects on economic activity, prices, and exchange rates. Notably, we discover that ELB can have repercussions on the domestic economy due to changes in exchange rates and capital flows.

Our simulation results reveal that while a permanent decline in foreign investment opportunities stimulates capital inflows and boosts domestic output under normal conditions, the presence of ELB can reverse these effects, causing deflation and unemployment. The same pattern of ELB-induced reversal of spillovers is also observed for financial and monetary shocks, which we characterize as increases in the liquidation cost of foreign assets and increases in the foreign monetary authority's price level target. These results highlight the importance of the monetary policy response in determining the sign and magnitude of spillovers in a globally integrated financial system.

In addition, our model reveals the existence of spillbacks at the ELB. We find that the shocks in the foreign economy trigger a temporary appreciation of the domestic currency and an associated increase in excess returns. This phenomenon drives capital away from the foreign economy, leading to a temporary surge in foreign real interest rates and a more substantial decrease in capital accumulation and output compared to situations not constrained by the ELB.

One key insight from our research is the importance of considering the specific context of the ELB in shaping policy responses. With Home constrained by the ELB, traditional monetary policy tools may not be fully effective in stabilizing the economy and may even lead to unintended consequences. This highlights the need for alternative policy measures to complement the nominal interest rate adjustments. While results are striking at the ELB, these conclusions would carry over to less extreme situations where monetary policy does not respond enough to fully stabilize prices, perhaps due to a gradual approach to interest rate changes or to a focus on shocks originating in the domestic economy. The way monetary policy is conducted strongly shapes spillovers and spillbacks of international asset market shocks.

Our study opens interesting avenues for future research. Investigating alternative policy measures beyond nominal interest rate adjustments could be valuable. For instance, increasing the supply of Home government bonds to absorb additional asset demand from abroad mitigates the asset shortage, and potentially alleviates ELB-induced spillover impacts. However, this approach may raise fiscal solvency concerns and lead to a risk premium on government debt. Investigating this aspect further could shed light on the potential challenges faced by the world economy in a liquidity trap as well as its possible escape routes.

References

Amador, M., J. Bianchi, L. Bocola, and F. Perri (2020). Exchange rate policies at the zero lower bound. *The Review of Economic Studies 87*(4), 1605–1645.

Auerbach, A. J. and M. Obstfeld (2005). The case for open-market purchases in a liquidity trap. *American Economic Review 95*(1), 110–137.

Bacchetta, P. and K. Benhima (2015). The demand for liquid assets, corporate saving, and international capital flows. *Journal of the European Economic Association 13*(6), 1101–1135.

Bacchetta, P., K. Benhima, and Y. Kalantzis (2019). Money and capital in a persistent liquidity trap. *Journal of Monetary Economics*.

Bacchetta, P. and E. van Wincoop (2021). Puzzling exchange rate dynamics and delayed portfolio adjustment. *Journal of International Economics 131*, 103460.

Bianchi, J. and L. Coulibaly (2022). Liquidity traps, prudential policies, and international spillovers. Technical report, National Bureau of Economic Research.

Blanchard, O. J. (1985). Debt, deficits, and finite horizons. *Journal of Political Economy 93*(2), 223–247.

Broner, F. and J. Ventura (2011, 01). Globalization and risk sharing. *The Review of Economic Studies 78*(1), 49–82.

Buera, F. J. and J. P. Nicolini (2020). Liquidity traps and monetary policy: Managing a credit crunch. *American Economic Journal: Macroeconomics 12*(3), 110–38.

Caballero, R. and E. Farhi (2018). The safety trap. *The Review of Economic Studies 85*(1), 223–274.

Caballero, R. J., E. Farhi, and P.-O. Gourinchas (2021). Global imbalances and policy wars at the zero lower bound. *The Review of Economic Studies 88*(6), 2570–2621.

Christiano, L., M. Eichenbaum, and S. Rebelo (2011). When is the government spending multiplier large? *Journal of Political Economy 119*(1), 78–121.

Cook, D. and M. B. Devereux (2011). Cooperative fiscal policy at the zero lower bound. *Journal of the Japanese and international Economies 25*(4), 465–486.

Cook, D. and M. B. Devereux (2013). Sharing the burden: monetary and fiscal responses to a world liquidity trap. *American economic Journal: macroeconomics 5*(3), 190–228.

Corsetti, G., K. Kuester, and G. J. Müller (2017). Fixed on flexible: Rethinking exchange rate regimes after the great recession. *IMF Economic Review 65*, 586–632.

Corsetti, G., E. Mavroeidi, G. Thwaites, and M. Wolf (2019). Step away from the zero lower bound: Small open economies in a world of secular stagnation. *Journal of International Economics 116*, 88–102.

Devereux, M. B. and J. Yetman (2014). Capital controls, global liquidity traps, and the international policy trilemma. *The Scandinavian Journal of Economics 116*(1), 158–189.

Di Giorgio, G. and S. Nisticò (2007). Monetary policy and stock prices in an open economy. *Journal of Money, Credit and Banking 39*(8), 1947–1985.

Di Giorgio, G., S. Nisticò, and G. Traficante (2018). Government spending and the exchange rate. *International Review of Economics & Finance 54*, 55–73.

Di Giorgio, G. and G. Traficante (2018). Fiscal shocks and helicopter money in open economy. *Economic Modelling 74*, 77–87.

Eggertsson, G. B. and P. Krugman (2012). Debt, deleveraging, and the liquidity trap: A fisher-minsky-koo approach. *The Quarterly Journal of Economics 127*(3), 1469–1513.

Eggertsson, G. B. and M. Woodford (2003). The zero bound on interest rates and optimal monetary policy. *Brookings Papers on Economic Activity 2003*(1), 139–233.

Fornaro, L. (2021, 09). A theory of monetary union and financial integration. *The Review of Economic Studies 89*(4), 1911–1947.

Fornaro, L. and F. Romei (2019). The paradox of global thrift. *American Economic Review 109*(11), 3745–79.

Fujiwara, I., T. Nakajima, N. Sudo, and Y. Teranishi (2013). Global liquidity trap. *Journal of Monetary Economics 60*(8), 936–949.

Gabaix, X. and M. Maggiori (2015). International liquidity and exchange rate dynamics. *The Quarterly Journal of Economics 130*(3), 1369–1420.

Guerrieri, V. and G. Lorenzoni (2017). Credit crises, precautionary savings, and the liquidity trap. *The Quarterly Journal of Economics 132*(3), 1427–1467.

Haberis, A. and A. Lipinska (2020). A welfare-based analysis of international monetary policy spillovers at the zero lower bound. *Journal of Money, Credit and Banking 52*(5), 1107–1145.

Jeanne, O. (2009). The global liquidity trap. *Unpublished Manuscript*.

Kiyotaki, N. and J. Moore (1997, April). Credit cycles. *Journal of Political Economy 105*(2), 211–248.

Kolasa, M. and G. Wesołowski (2020). International spillovers of quantitative easing. *Journal of International Economics 126*, 103330.

Kollmann, R. (2021). Liquidity traps in a world economy. *Journal of Economic Dynamics and Control 132*, 104206.

Krugman, P. (1998). It's baaack: Japan's slump and the return of the liquidity trap. *Brookings Papers on Economic Activity 1998*(2), 137–205.

Maggiori, M., B. Neiman, and J. Schreger (2020). International currencies and capital allocation. *Journal of Political Economy 128*(6), 2019–2066.

Michau, J.-B. (2018). Secular stagnation: Theory and remedies. *Journal of Economic Theory 176*, 552–618.

Nistico, S. (2016). Optimal monetary policy and financial stability in a non-ricardian economy. *Journal of the European Economic Association 14*(5), 1225–1252.

Ragot, X. (2023). Optimal monetary policy in a liquidity trap with heterogeneous agents. *Annals of Economics and Statistics* (149), 97–124.

Schmitt-Grohé, S. and M. Uríbe (2011, March). Pegs and pain. Working Paper 16847, National Bureau of Economic Research.

Schmitt-Grohé, S. and M. Uribe (2016). Downward nominal wage rigidity, currency pegs, and involuntary unemployment. *Journal of Political Economy 124*(5), 1466–1514.

Schmitt-Grohé, S. and M. Uríbe (2017). Liquidity traps and jobless recoveries. *American Economic Journal: Macroeconomics 9*(1), 165–204.

Tirole, J. (2003, December). Inefficient foreign borrowing: A dual- and common-agency perspective. *American Economic Review 93*(5), 1678–1702.

Werning, I. (2011). Managing a liquidity trap: Monetary and fiscal policy. Technical report, National Bureau of Economic Research.

Woodford, M. (1990). Public debt as private liquidity. *The American Economic Review 80*(2), 382–388.

Woodford, M. (2011). Simple analytics of the government expenditure multiplier. In D. Acemoglu and M. Woodford (Eds.), *NBER Macroeconomics Annual 2010, Volume 25*, pp. 1–45. University of Chicago Press.

Appendix

A Steady states and log-linearization

This appendix provides further analytical details to Section 3. As in that section, we make the simplifying assumptions of full capital depreciation ($\delta = 1$) and deterministic alternating investment opportunities ($\eta = 1$). We start by studying almost-symmetric steady states, before log-linearizing the model around them.

A.1 Capital accumulation

In addition to the optimal portfolio choice given by Equations (14) and (15), and the generalized IS curves (16) and (17), the model dynamics is also driven by capital accumulation. For Home, we can aggregate the budget constraints of both groups of investors in each country, use the fact that they save a fraction β of their beginning-of-period wealth, together with the market-clearing conditions for bonds (11) and the generalized IS curve to get:

$$k_t = (1-\phi)\beta\alpha y_{t-1}\frac{\beta i_{t-1}p_{t-1}}{\theta p_t} + \phi\beta\alpha y_{t+1}\frac{\theta p_{t+1}}{\beta i_t p_t} - (1-\phi)\beta^2\alpha y_{t-1}\left[\frac{\lambda - (\lambda+\lambda^*+\kappa)x_{t-1}^2}{2}\right]. \quad (20)$$

A similar equation holds for foreign. Capital accumulation has two sources. The first term captures cumulated savings. In the limit of alternating investment opportunities, it takes a simple form and only depends positively on the real interest rate of the previous period. The second term captures debt issuance by I-investors, using future production as collateral: it is decreasing in the real interest rate of the current period. The third term is a resource cost due to bond liquidation costs.

A.2 Almost-symmetric steady states

Steady states are then easy to characterize. Consider an almost-symmetric steady state, where both countries have the same parameters except for $\theta < \theta^*$. Then, they have the same real interest rates $R = i/\theta = i^*\theta^*$. We also assume that λ is small enough so that we can neglect cross-border bond holdings x and x^* in this steady state, an assumption that we relax in the quantitative analysis of Section 4. Steady states can be indexed by a parameter Ψ:

$$\bar{x} = \frac{\lambda}{2\lambda + \kappa}, \tag{21}$$

$$\beta\bar{R} = \frac{\phi}{1 - \phi - \Psi}, \tag{22}$$

$$\frac{\bar{k}}{\beta\alpha\bar{y}} = (1-\phi)\beta\bar{R} + \frac{\phi}{\beta\bar{R}} - \beta(1-\phi)\lambda(1-\bar{x})/2, \tag{23}$$

$$\bar{y} = Z^{\frac{1}{1-\alpha}} \left[\frac{\bar{k}}{\bar{y}}\right]^{\frac{\alpha}{1-\alpha}}, \tag{24}$$

$$\Psi = \frac{b}{\beta\alpha\bar{p}\bar{y}}, \tag{25}$$

where steady-state variables are denoted with a bar.

Note first that the last term in the capital-output Equation (23), which represents the resource cost of bond liquidation, can be neglected under our assumption of a small λ.

The parameter Ψ represents the real provision of public liquidity by governments. As the steady-state version of the generalized IS curve (22) shows, the real interest rate is increasing in both public liquidity Ψ and private liquidity, which is determined by the collateral share ϕ. Then, the capital-output ratio $\bar{k}/(\beta\alpha\bar{y})$ is a U-shaped function of $\beta\bar{R}$, equal to 1 at $\beta\bar{R} = \phi/(1-\phi)$ and 1, with a minimum at $\beta\bar{R} = \sqrt{\phi/(1-\phi)}$. The lower bound of this range corresponds to the absence of public liquidity ($\Psi = b = 0$). At the upper bound ($\beta\bar{R} = 1$), borrowing constraints stop binding and the steady state exits the domain of asset-scarce equilibria. Assume that Ψ is low enough so that the capital-output ratio is on the decreasing branch of this U-shape function. This is a crowding-out regime, where more public liquidity leads to a higher real rate and a lower capital-output ratio.

To see how the economy adapt to asset scarcity, consider first a steady state outside the ZLB. Then, the central bank targets a path of constant inflation, which sets the (normalized) price level $\bar{p}$. The lower the nominal supply of government bonds b, the lower Ψ, the lower the real rate $\bar{R}$, the higher the capital-output ratio and the steady state level of output. On the contrary, at the ZLB, the real rate $\bar{R}$ becomes exogenous (at $1/\theta$ for a zero-lower bound) and cannot depend on the nominal supply of bonds b. Neither do the capital-output ratio and steady-state output. Then, adjustment comes from the price level. The lower the nominal supply of bonds b, the lower the price level $\bar{p}$, to restore the real supply of bonds consistent with the ZLB real rate of interest.

A.3 Log-linearization

We now derive a log-linearized version of the model. This will allow us to provide more rigourous foundations to the graphical analysis of Section 3.4.

Suppose that the liquidity parameter in the Foreign economy λ^* is slightly higher than in the Home economy. We can log-linearize the model for small deviations of $\lambda^* - \lambda$. More precisely, let $\zeta_t = \bar{x}\frac{\lambda_t^* - \lambda_t}{\lambda_t}$ and consider small positive values of ζ_t. Then, denoting log-deviation with a tilde (except for the share $\tilde{x}$ which is an absolute deviation), we have:

$$\tilde{x}_t - \tilde{x}_t^* = -\zeta_t + \frac{2\bar{R}\Delta_t}{2\lambda + \kappa} \tag{26}$$

$$\tilde{p}_t + \tilde{y}_t = \Omega(\tilde{p}_{t+1} + \tilde{y}_{t+1} - \tilde{i}_t) + (\tilde{x}_t - \tilde{x}_t^*) + \bar{x}(\tilde{y}_t - \tilde{y}_t^*) \tag{27}$$

$$\tilde{p}_t^* + \tilde{y}_t^* = \Omega(\tilde{p}_{t+1}^* + \tilde{y}_{t+1}^* - \tilde{i}_t^*) + (\tilde{x}_t^* - \tilde{x}_t) + \bar{x}(\tilde{y}_t^* - \tilde{y}_t) \tag{28}$$

$$\tilde{k}_t = \tilde{y}_t + \Gamma[\tilde{p}_{t-1} + \tilde{y}_{t-1} - \tilde{p}_t - \tilde{y}_t + \tilde{i}_{t-1}] + (1-\Gamma)[\tilde{p}_{t+1} + \tilde{y}_{t+1} - \tilde{p}_t - \tilde{y}_t - \tilde{i}_t] \tag{29}$$

$$\tilde{y}_t = \alpha\tilde{k}_{t-1} + (1-\alpha)\tilde{L}_t \tag{30}$$

with $\Omega = \phi/[(1-\phi)\beta\bar{R}] < 1$, $\Gamma = (\beta\bar{R})/(\beta\bar{R} + \Omega] < 1$, and where $\Delta_t = \tilde{i}_t^* + \tilde{p}_t^* - \tilde{p}_{t+1}^* - \tilde{i}_t - \tilde{p}_t + \tilde{p}_{t+1}$ is the log-linearized UIP-wedge.

The crowding-out regime where the capital-output ratio is declining in the real interest rate corresponds to $\Gamma \leq 1/2$. Equation (26) corresponds to the optimal portfolio choices (14) and (15), Equations (27) and (28) to the generalized IS curves (16) and (17), and Equation (29) to the capital accumulation equation (20) (a similar equation holds for Foreign). Compared to the textbook IS curve, the linearized version of the generalized IS curve (27) features both discounting (with $\Omega < 1$) due to the non-Ricardian nature of the model, and a role for the relative cross-border bond holdings $\tilde{x}_t - \tilde{x}_t^*$. As the latter is scaled by the relative size of the Home economy, there is also a third term $\tilde{y}_t - \tilde{y}_t^*$. Under our assumption of a small λ and small cross-border bond holdings $\bar{x}$, the terms in $\bar{x}$ can be neglected in (27) and (28): then, the IS curves of Home and Foreign are only coupled by the relative bond holdings $\tilde{x}_t - \tilde{x}_t^*$, which simplifies the analytics.

A.4 Dynamics out of the ZLB

Suppose the economy is initially in the almost-symmetric steady state corresponding to $\zeta = 0$. At $t = 1$, the liquidity cost ζ permanently increases to a positive value. If Home and Foreign are both out of the ZLB, price levels stay on their targeted path $\tilde{p}_t = \tilde{p}_t^* = 0$ and the economy stay at full employment $\tilde{L}_t = \tilde{L}_t^* = 0$. The symmetry of the linearized equations imply that $\tilde{i}_t + \tilde{i}_t^* = 0$, and similarly for $\tilde{k}_t$ and $\tilde{y}_t$. Therefore, we have $\tilde{i}_t^* = \Delta_t/2 = -\tilde{i}_t$, and $\tilde{y}_t = -\tilde{y}_t^*$. There are positive spillovers to the Home economy. We can compute the response of the interest rate and capital at impact and in the new steady state:

$$\tilde{i}_1^* = \frac{\zeta}{\dfrac{\Omega}{1-\alpha(1-\Gamma)} + \dfrac{4\bar{R}}{2\lambda+\kappa}}, \qquad \tilde{k}_1 = -\frac{(1-\Gamma)}{1-\alpha(1-\Gamma)}\tilde{i}_1^*, \tag{31}$$

$$\tilde{i}_\infty^* = \frac{\zeta}{\Omega - \nu(1-\Omega) + \dfrac{4\bar{R}}{2\lambda+\kappa}}, \qquad \tilde{k}_\infty = -\frac{\nu}{\alpha}\tilde{i}_\infty^*, \tag{32}$$

where $\nu = \frac{\alpha}{1-\alpha}(1-2\Gamma)$ is the interest-rate elasticity of steady state output ($\tilde{y} = -\nu\tilde{i}$). To get a well-defined equilibrium, we need to assume that $\frac{\Omega}{1-\Omega} > \frac{\alpha}{1-\alpha}(1-2\Gamma)$, a condition that requires Ω close enough to 1. In other words, the generalized IS curve must not feature too much discounting with respect to the standard IS curve. Economically, this requires not too much amplification between output and the interest rate. Indeed, suppose the interest rate $\tilde{i}^*$ increases by some amount due to a higher $\tilde{x}^* - \tilde{x}$: this decreases output $\tilde{y}^*$ by a factor ν. A lower level of output decreases saving, which requires an even higher interest rate (by a factor $\frac{1-\Omega}{\Omega}$), and so on. For this process to converge, the total factor $\nu\frac{1-\Omega}{\Omega}$ must be smaller than 1. This condition is equivalent to having a positively sloped steady-state (IS*) curve in the $(x^* - x, i^*)$, a feature that we will use in the graphical analysis of Section B.

Under this assumption, the Foreign interest increases when the shock hits, and increases further over time until it settles a the new steady state value. The Home interest rate moves down symmetrically.

A.5 Dynamics at the ZLB

Suppose now that Home is at the ZLB and that $\tilde{i}_t = 0$ cannot adjust. Then, adjustment will come from the price level $\tilde{p}_t$ and employment $\tilde{L}_t$. In Foreign, we still have $\tilde{p}_t^* = \tilde{L}_t^* = 0$ and $\tilde{i}_t^* > 0$. To see how the economy adjusts, it is useful to proceed heuristically in three steps.

1. We start by making a simplifying approximation, which we will relax later. Let's assume that the UIP wedge Δ_t directly jumps at $t = 1$ to its final steady state value. That is, we start by neglecting transitory fluctuations in both $\tilde{i}_t^*$ and $\tilde{p}_{t+1} - \tilde{p}_t$. The steady state value of Δ_t is equal to that of $\tilde{i}^*$ and given by $\frac{\zeta}{\Omega - \nu(1-\Omega) + \frac{2\bar{R}}{2\lambda+\kappa}}$. Remark that this steady state increase in $\tilde{i}^*$ is larger when Home is at the ZLB, a case of spillback to the Foreign economy.

   Under this approximation, we can solve forward for nominal output in Equation (27): $\tilde{p}_t + \tilde{y}_t$ instantaneously jumps to a constant value

$$n = -\frac{\Omega - \nu(1-\Omega)}{\Omega - \nu(1-\Omega) + \frac{2\bar{R}}{2\lambda+\kappa}} \frac{\zeta}{1-\Omega} < 0$$

Let $\xi = -\log(\gamma/\theta)$ the (normalized) rate of wage deflation when the downward rigidity is binding. From Lemma 1, if $n \geq -\xi$, the shock is small enough for the downward wage rigidity not to bind. Then p directly jumps to n, its new steady state value. If $n < -\xi$, then let T be the smallest integer such that $\xi t \geq |n|$. The downward wage rigidity binds until period $T-1$ and Home dynamics follow:

$$\begin{aligned}
1 \leq t < T \qquad & \tilde{L}_t = n + \xi t \\
& \tilde{y}_t = \alpha \tilde{k}_{t-1} + (1-\alpha)\tilde{L}_t \\
& \tilde{p}_t = n - \tilde{y}_t \\
t = 1 \qquad & \tilde{k}_1 = (1-\alpha)\tilde{L}_1 - \Gamma n \\
2 \leq t < T \qquad & \tilde{k}_t = \tilde{y}_t
\end{aligned}$$

Then, for $t \geq T$, we have full employment ($\tilde{L}_t = 0$) and $\tilde{y}_t = \alpha \tilde{y}_{t-1}$ gradually recovers to its value in the initial state while $\tilde{p}_t = n - \tilde{y}_t$ gradually declines to its steady state value of n.

To sum it up, for a large enough shock, employment drops at period 1 before gradually recovering as nominal wages gradually decline. Output initially drops with employment and is further hurt by the decline in investment, before recovering as well. The recovery in output goes together with a slow decline in the price level.

2. Next, consider the dynamics of the Foreign interest rate $\tilde{i}^*$, while still neglecting Home inflation $\tilde{p}_{t+1} - \tilde{p}_t$. In the first period, the Foreign interest rate is given by $\tilde{i}_1^* = \frac{\zeta}{\frac{\Omega}{1-\alpha(1-\Gamma)} + \frac{2\bar{R}}{2\lambda+\kappa}}$, a value lower than its steady state level. This smoother response of $\tilde{i}^*$ translates into a smoother response of nominal output n.

3. Finally, consider the impact of Home deflation. The gradual decrease in Home prices implies a lower value of Δ_t at the begining of the transition dynamics. From (26), this decreases relative cross-border holdings $\tilde{x}_t - \tilde{x}_t^*$: deflation raises the return of Home assets and attracts further inflows into the Home economy. This has two consequences.

   First, from (28), it yields a larger initial increase in $\tilde{i}^*$ (26), other things equal. In our simulations of Figure 3, both effects, the smoother response of $\tilde{i}^*$ mentioned previously, and the stronger response of $\tilde{i}^*$ due to Home deflation roughly offset each other. Therefore, the Foreign interest rate has only limited fluctuations after its initial increase in $t = 1$.

Second, from (27), expected deflation in Home, by attracting further inflows for Home assets, amplifies the shock in Home and leads to an even lower nominal output n in the short run.

B Graphical Analysis

This appendix provides details on the graphical analysis presented in Section 3.4. The top panel of Figure 1a represents the equilibrium in the Foreign economy in the short run, within period t, for given expectations of future variables and for a given domestic real interest rate $i_t p_1/p_{t+1}$. We denote with a bar all the predetermined or given variables. (PF) is downward-sloping in the $(x^* - x, i^*)$ space:

$$x_t^* - x_t = \frac{\lambda^* - \lambda}{\lambda + \lambda^* + \kappa} - \frac{2}{\lambda + \lambda^* + \kappa}\left[\frac{i_t^*}{\theta^*} - \overline{\left(\frac{i_t p_t}{\theta p_{t+1}}\right)}\right]. \tag{PF}$$

Within period t, y_t^* is predetermined and p_t^* is set by monetary policy, so Foreign nominal output is exogenous in period t. Expected output y_{t+1}^* is a function of capital k_t^* installed in period t, which itself depends negatively on the interest rate i_t^*. All together, (IS*) is then an upward-sloping schedule between $x^* - x$ and i^*:

$$1 - (x_t^* - x_t) = \frac{\phi}{1-\phi}\frac{\theta^* y_{t+1}^*(i_t^*)}{\beta i_t^* \overline{y_t^*}} + \frac{1}{1-\phi}\frac{\overline{b_t^{F*}}}{\beta\alpha \overline{p_t^* y_t^*}}, \tag{IS*}$$

while in the $(x^* - x, p_t^* y_t^*)$ plane, it is simply horizontal, as in the bottom panel of Figure 1a, since Foreign nominal output is exogenous in period t.

Consider now the Home economy. Outside the ZLB, the (IS) curve is the same as in Foreign, up to a minus sign:

$$1 + (x_t^* - x_t) = \frac{\phi}{1-\phi}\frac{\theta y_{t+1}(i)}{\beta i_t \overline{y_t}} + \frac{1}{1-\phi}\frac{\overline{b_t^H}}{\beta\alpha \overline{p_t y_t}}. \tag{IS}$$

Therefore, the Home (IS) curve is downward-sloping in the $(x^* - x, i)$ space, until the ZLB binds. Then it becomes horizontal:

$$1 + (x_t^* - x_t) = \frac{\phi}{1-\phi}\frac{\theta \overline{p_{t+1} y_{t+1}(1)}}{\beta p_t y_t} + \frac{1}{1-\phi}\frac{\overline{b_t^H}}{\beta\alpha p_t y_t}, \tag{IS'}$$

This is represented in Figure 1b, where (IS) has a kink. At the ZLB, given expectations of future variables, the (IS) curve now determines nominal GDP $p_t y_t$, as shown in the bottom of Figure 1b.

A similar graphical analysis holds at the final steady state without the need to neglect expectations. Indeed, in the steady state, (PF) is a decreasing relationship between $x^* - x$ and $i^*/\theta^* - i/\theta$, so it is increasing (decreasing) in the $(x^* - x, i^*)$ space ($(x^* - x, i)$ space), exactly as in period $t = 1$. The steady state version of the (IS*) curve is also increasing in the $(x^* - x, i^*)$ space under an additional parametric assumption: as discussed in Section A.4, we need $\frac{\Omega}{1-\Omega} > \frac{\alpha}{1-\alpha}(1 - 2\Gamma)$, which makes sure that steady state output does not depend too much on the interest rate. Under the same condition, the steady state version of the (IS) curve is downward sloping in the $(x^* - x, i)$ space until it reaches the same kink as in Figure 1b. Similarly, we get similar bottom panels as in Figure 1 by replacing nominal output by the steady state price level on the vertical axis. The Foreign price level is set by monetary policy, so we get a horizontal line in Figure 1a. When Home is at the ZLB, its output converges back to its initial steady state, as shown in the log-linearized version of Section A.5, so nominal output can also be replaced by the price level in the bottom panel of Figure 1b.

C Relatively Low Home Debt

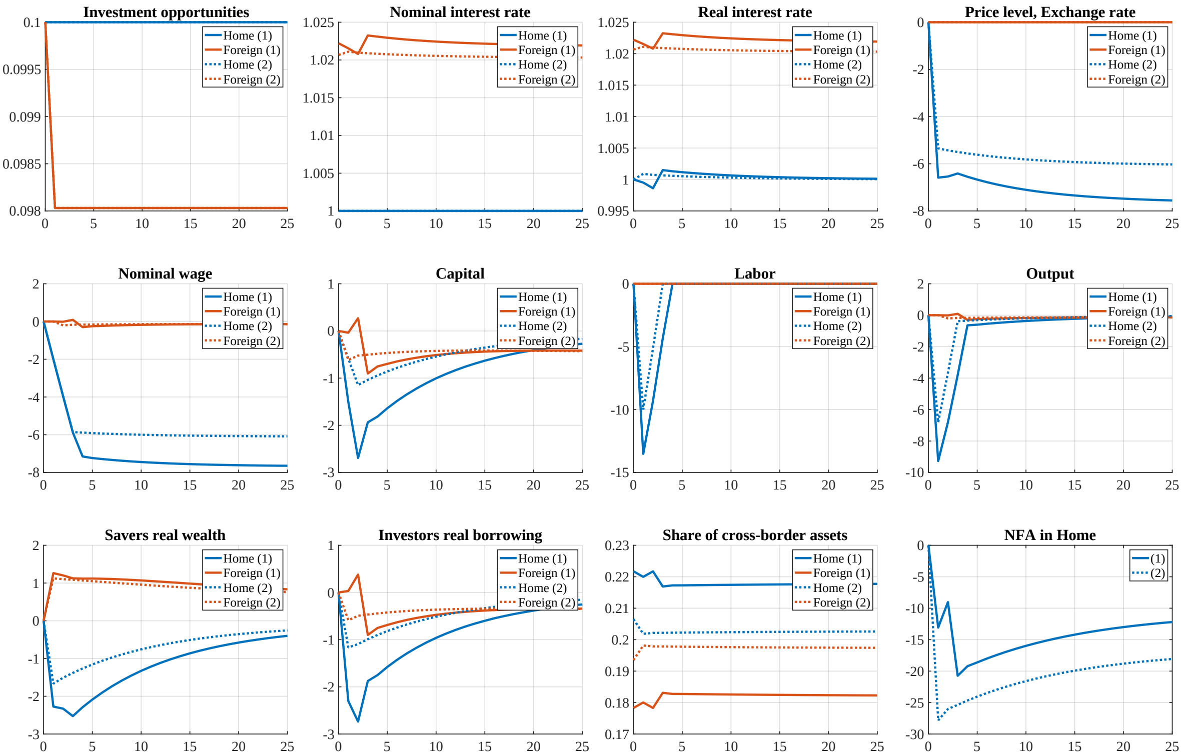
In this appendix we analyze the dynamic response to unexpected shocks to foreign investment opportunities η^*, to the liquidity of Foreign bonds, λ^* and to the Foreign central bank's price level target under alternative levels government debt b^H, b^F. The idea is to investigate whether the spillovers from asset market shocks occurring abroad to the domestic economy are exacerbated when Home has a relatively low real debt-to-GDP ratio.

Specifically, we set nominal government debt in Home b^H to be half that in Foreign b^F by holding global nominal debt $b^H + b^F$ constant. This corresponds to a respective calibration of b^H and b^F to 0.10 and 0.20, against the the symmetric value 0.15 used in the baseline. Holding global nominal debt constant ensures comparability across specifications.

Figures C1, C2 and C3 below enable us to assess the difference in spillovers that emerges from the difference in government debt levels. In particular, each figure overlays the path that Home and Foreign experience when their government debt level differs (solid lines labeled (1)) and when it does not (dashed lines labeled (2)). The size of the various shocks is held constant.

Decline in Foreign Investment Opportunities.—Figure C1 presents the impact of a permanent decrease in Foreign investment opportunities η^* in a scenario where Foreign has a higher debt-to-GDP ratio. Similarly to the symmetric case, this leads to an increase in savers, which in turn raises the demand for saving instruments. Consequently, deflationary pressures arise, which the central bank can counteract by lowering the nominal interest rate. Interestingly, Foreign seems to be partially insulated under this circumstance, managing to boost its investment owing to a decreased real interest rate and the value gains from Home bonds, effectively offsetting the initial loss of

Figure C1. Drop in Foreign Investment Opportunities η^*



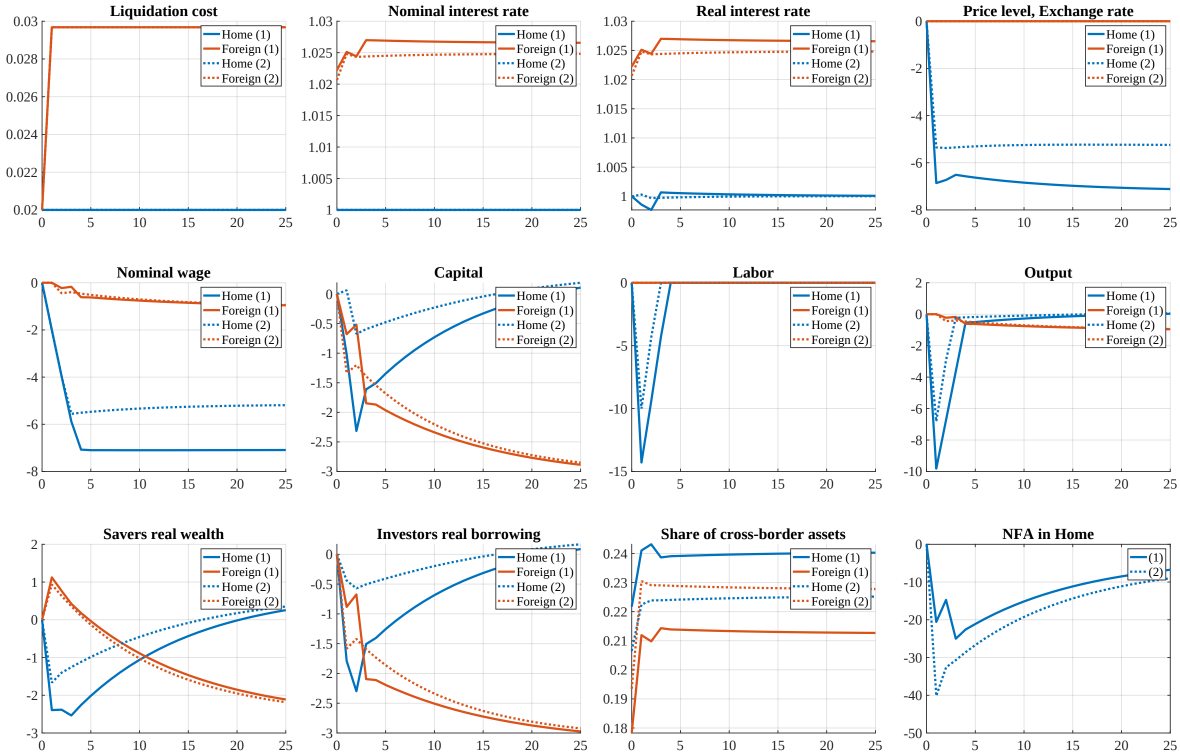
Notes: The solid red and blue lines labeled (1) correspond to the path for Home and Foreign when Home has a relatively smaller nominal government debt, while the dashed lines labeled (2) correspond to the path when Home and Foreign have identical levels of nominal government debt, as in the baseline calibration. Variables are expressed in percentage-point deviation from their initial steady-state level, except for interest rates and shares of cross-border assets. On the x-axis, 0 is the initial steady-state, and 1 is the year of the shock.

investment opportunities. However, by the second period, investment returns to lower long-term levels, aligning the economy back to its benchmark path.

On the flip side, the impact of this shock type is intensified in Home due to its smaller debt-to-GDP ratio, with a stronger capital outflow towards Home that ultimately leads to more intense deflation when the central bank is stuck at the ZLB, larger currency appreciation, and due to nominal rigidities, a more severe and prolonged recession.

Adverse Foreign Liquidity Shocks.—The outcomes revealed in Figure C2, which illustrates the response to a permanent increase in the liquidation cost of Foreign bonds $\lambda*$, are analogous to those seen in the previous shock scenario. When Foreign, acting as a larger government bond supplier, experiences a slight decrease in investment, this results in a slightly less intense economic downturn than under purely symmetrical conditions. Conversely, the repercussions for Home are magnified when it is smaller in terms of debt-to-GDP ratio: the negative impacts stemming from the increased foreign liquidation cost are more significant and persistent across all variables.

Figure C2. Increase in Foreign Bonds Liquidity Cost λ^*



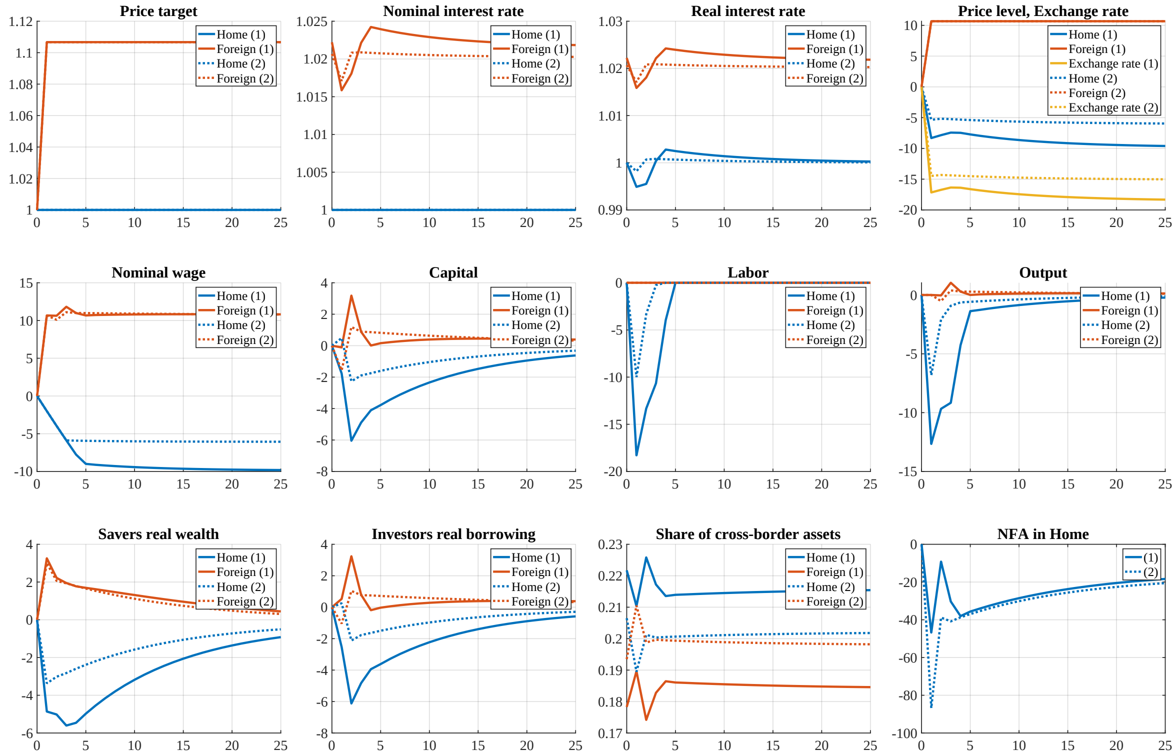
Notes: See Figure C1.

Increase in the Foreign Price Target.—Figure C3 showcases the outcomes from a monetary shock due to a permanent rise in the price level targeted by the Foreign central bank $\bar{P}^*$. The central bank induces temporary inflation to attain this new target, which is facilitated by a lower nominal interest rate. When Foreign has a larger debt-to-GDP ratio, this mechanism operates similarly as in the symmetric case.

However, a surprising consequence emerges due to the surge in economic activity triggered by increased investment, facilitated by a lower real interest rate. The central bank needs a subsequent larger increase in the nominal rate to keep prices on target, compared to what was required under symmetrical conditions.

This dynamic initiates an interesting transition phase during which capital temporarily flows back into Foreign before leaving it at a lower long-term level. This implies that the spillbacks are no longer potent enough to override the positive effect of inflation on output, allowing Foreign to enjoy a temporary economic boost. However, Home's situation worsens due to its smaller debt-to-GDP ratio, experiencing larger and longer-lasting spillover effects from the shock.

Figure C3. Increase in the Foreign Price Target



Notes: See Figure C1.

D A Debt-Fuelled Expansion

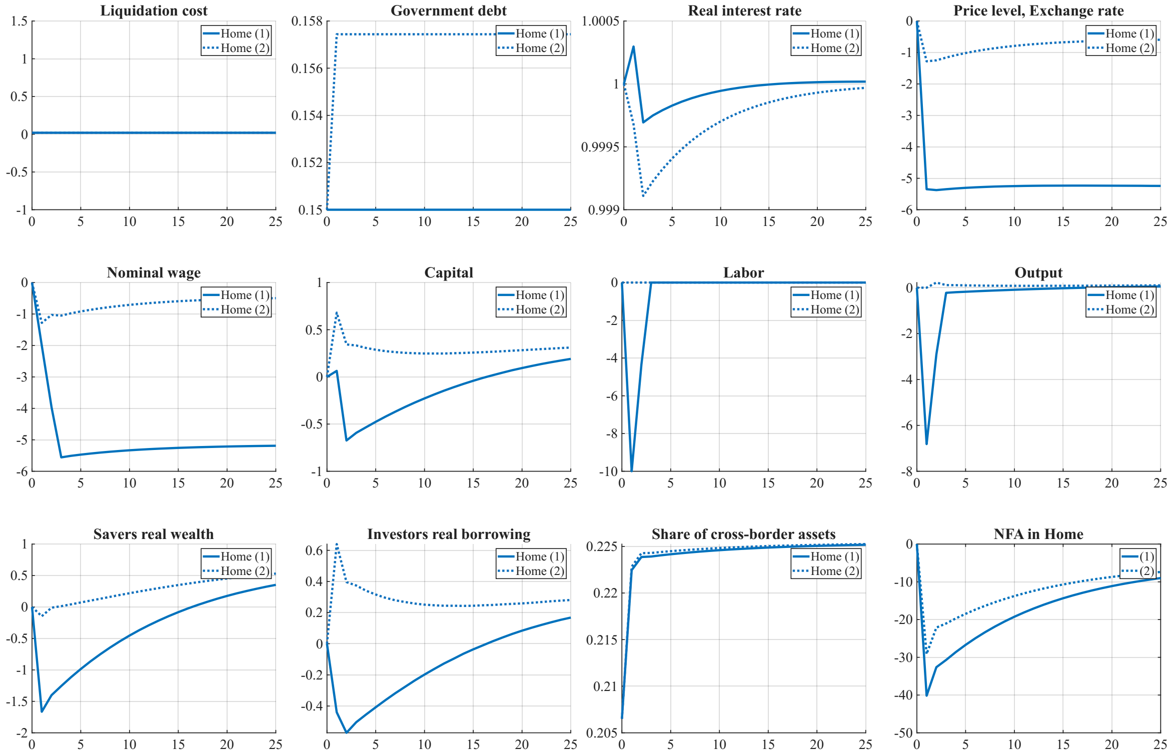
In this appendix, we analyze the dynamic response to unexpected shocks to the liquidity of Foreign bonds λ^* under an endogenous debt rule. The idea is to investigate whether a debt-fuelled domestic fiscal expansion can mitigate the spillovers from asset market shocks occurring abroad to the domestic economy.

We set an endogenous debt policy rule of the form $b_t^H = \bar{b}^H e^{\iota \lambda_t^*}$ with $\iota > 0$. The parameters $\bar{b}^H$ and ι are calibrated to 0.135726 and 5 respectively, such that the ex-ante government debt levels are identical to the baseline calibration (0.15). We then simulate the same adverse shock to Foreign liquidity λ^* as in Section 4.2.2 under this alternative specification.

Results are shown in Figure D4. The solid blue lines labeled (1) correspond to the cases where Home government debt does not change, i.e., the baseline calibration. They are thus identical to those in Figure 3. The dashed blue lines labeled (2) correspond to the dynamics that would prevail under the debt policy rule outlined above, ceteris paribus. Variables associated with the Foreign economy are omitted from the plots for parsimony.

The simulation confirms that, by increasing its debt in reaction to the adverse Foreign liquidity shock, the government in Home satisfies part of the excess demand for domestic assets. As a result, the decline in the Home price level is less severe. If home fiscal expansion is strong enough (as governed by the ι parameter), the deflation in Home may be small enough to prevent the downward wage rigidity to trigger unemployment.

Figure D4. Liquidity Shock: Increase in λ^* – Debt-Fuelled Expansion



Notes: The solid blue lines labeled (1) correspond to the cases where Home government debt does not change, i.e., the baseline calibration. They are thus identical to those in Figure 3. The dashed blue lines labeled (2) correspond to the dynamics that would prevail under the debt policy rule outlined above, ceteris paribus. Variables are expressed in percentage-point deviation from their initial steady-state level, except for interest rates and shares of cross-border assets. On the x-axis, 0 is the initial steady-state, and 1 is the year of the shock.

E Sterilized FX Intervention

Consider a central bank that can buy an amount of foreign bonds $\tilde{b}_t^{F*}$ (normalized by θ^{*t}) by issuing domestic bonds $\tilde{b}_t^H$ (normalized by θ^t). All profits earned or losses incurred from the central bank's balance sheet $i_{t-1}^* s_t b_{t-1}^F / p_t - i_{t-1} b_{t-1}^H / p_t$ are redistributed to workers. The resource constraint of the central bank then implies:

$$\frac{\tilde{b}_t^H}{p_t} = \frac{s_t \tilde{b}_t^F}{p_t} \tag{33}$$

Foreign exchange interventions modify the (IS) and (IS*) curves used for our graphial analysis as follows:

$$1 + (x_t^* - x_t) = \frac{\phi}{1-\phi}\frac{\theta p_{t+1} y_{t+1}}{\beta i_t p_t y_t} + \frac{1}{1-\phi}\frac{b_t^H + \tilde{b}_t^H}{\beta \alpha p_t y_t}, \tag{IS}$$

$$1 - (x_t^* - x_t) = \frac{\phi}{1-\phi}\frac{\theta^* y_{t+1}^*}{\beta i_t^* y_t^*} + \frac{1}{1-\phi}\frac{b_t^{F*} - \tilde{b}_t^{F*}}{\beta \alpha p_t^* y_t^*}, \tag{IS*}$$

Accumulating foreign assets $\tilde{b}_t^F$ by issuing domestic bonds $\tilde{b}_t^H$ has two effects on asset markets. For a given net capital inflow $x^* - x$, it increases the supply of domestic bonds and shifts (IS) on the right, mitigating the domestic spillovers. However, by limiting the net supply of foreign bonds to the foreign investors, it shifts (IS*) to the right, thus increasing the net capital inflows $x^* - x$. The combination of these two effects has an ambiguous impact on the domestic economy.

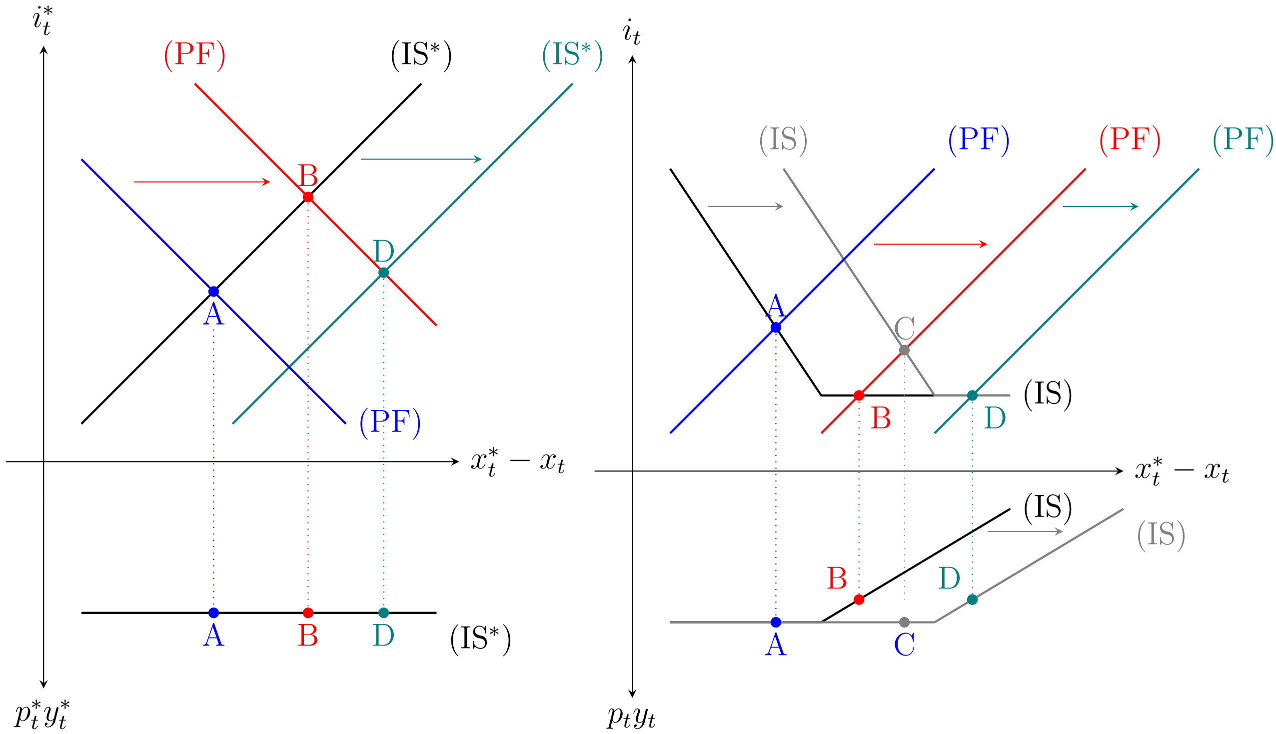
In fact, we can show that the impact of sterilized interventions is completely neutral. One can see this by writing the consolidated generalized IS curves (18) with sterilized interventions:

$$\beta(1-\phi)\left(1 + \frac{y_t^*}{y_t}\right) = \phi\left(\frac{\theta p_{t+1} y_{t+1}}{i_t p_t y_t} + \frac{\theta^* p_{t+1}^* y_{t+1}^*}{i_t^* p_t^* y_t^*}\frac{y_t^*}{y_t}\right) + \frac{1}{\alpha p_t y_t}\left(b_t^H + \tilde{b}_t^H + s_t(b_t^{F*} - \tilde{b}_t^{F*})\right) \tag{34}$$

Noting that the central bank's resource constraint imposes that $\tilde{b}_t^H - s_t\tilde{b}_t^F = 0$, this equation boils down to (18), the global asset market equilibrium without interventions. Sterilized interventions have a neutral effect on global asset markets, and hence they will not influence the nature of spillovers. Key to this result is that the spillover takes the form of a net capital inflow into the Home economy and that sterilized foreign exchange interventions do not affect net capital inflows.

Figure E5 represents the spillover of a liquidity shock in Foreign on the Home economy, when the Home economy engages in sterilized foreign exchange interventions. The liquidity shock shifts the equilibrium from A to B, and the Home economy hits the ZLB and experiences a drop in nominal output. With foreign exchange interventions, the central bank issues domestic bonds, which shifts the IS curve to the right. Here, the domestic debt issuance is strong enough to lift the economy out of the ZLB and prevent the drop in nominal output, as with a strong fiscal expansion (equilibrium C in Panel (b)). However, the intervention also impacts the Foreign economy by reducing the net supply of foreign assets, which shifts IS* to the right and generate a stronger capital inflow $x^* - x$ into the Home economy (equilibrium D in panel (a)). This provokes a shift of PF to the right in the Home economy (panel (b)). The economy falls back into the liquidity trap and nominal output drops to the same level as in the absence of intervention (equilibrium D in panel (b)).

Figure E5. Liquidity Shock: Increase in λ^* – Sterilized Foreign Exchange intervention



(a) Foreign

(b) Home