The Case for Flexible Exchange Rates in a Great Recession

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Abstract

We analyze macroeconomic stabilization in a small open economy which faces a large recession in the rest of the world. We show that for the economy to remain isolated from the shock, the exchange rate must depreciate not only to offset the collapse in external demand, but also to decouple domestic prices from deflation in the rest of the world. If monetary policy becomes constrained by the zero lower bound, the scope of exchange rate depreciation is limited. Still, in this case there is a "benign coincidence": fiscal policy is particularly effective in stabilizing economic activity. Under fixed exchange rates, instead, the impact of the external shock is particularly severe and the effectiveness of fiscal policy reduced.

Keywords: External shock, Great Recession, Exchange rate, Zero lower bound, Fiscal Multiplier, External-demand multiplier, Benign coincidence

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1 Introduction

The case for flexible exchange rates rests on the ability of monetary policy to adjust its stance. Hence, even economies with floating exchange rates may suffer as a consequence of large external shocks, if monetary policy becomes constrained by the the zero lower bound (ZLB) on interest rates. Although the nature of the ZLB constraint is quite different from that implied by an exchange rate peg or participation in a currency union, the implications for macroeconomic resilience in the face of external shocks are potentially severe.

This has been illustrated forcefully during the Great Recession. Figure 1 shows the evolution of output and exchange rates in four Scandinavian countries after 2007. Two of these countries have given up exchange rate flexibility: Finland is a member of the euro area; Denmark operates an independent currency, but maintains a narrow peg to the euro. The other two, Sweden and Norway, pursue inflation targeting, but only in Sweden did policy rates fall to the ZLB in 2009–10. The left panel shows a sizeable output contraction for Finland and Denmark, but not for Norway. The contraction in Sweden, in turn, is much larger than in Norway and, in fact, as strong as in Denmark and Finland. The right panel shows that the Norwegian Krone and the Swedish Krona both depreciated sharply during the first year of the crisis, but initially the depreciation was stronger in Norway.

In this paper, we reassess the ability of the exchange rate to act as shock absorber. We do so from the vantage point of a small open economy facing a great recession, during which demand and inflation in the rest of the world collapse. We provide a comparative analysis of stabilization policy across exchange rate regimes, explicitly accounting for constraints on monetary policy—be it the ZLB or an exchange rate peg—as well as for the monetary-fiscal policy mix. Indeed, it is well understood that an effective fiscal policy requires an adequate degree of monetary accommodation (see, e.g, Woodford, 2011). This may be jeopardized in the absence of exchange rate flexibility or with policy rates at the zero lower bound.

We find that during a global great recession the case for flexible exchange rates in a small open economy is actually stronger still than classic arguments suggest (for the classic case, see Friedman, 1953). Provided that the central bank is not constrained in pursuing its inflation objective, the role of floating rates as a shock absorber vis-à-vis an adverse shock to global demand is twofold. First, upfront real depreciation counteracts the fall in net exports driven by the contraction of external demand. Second, further, sustained depreciation decouples domestic prices from the deflationary crawl in the rest of the world.

Importantly, floating rates continue to be beneficial even if the external shock is so large that domestic policy rates become constrained by the ZLB. Anticipating a future monetary expansion, the exchange rate still depreciates (although less than in the unconstrained case),

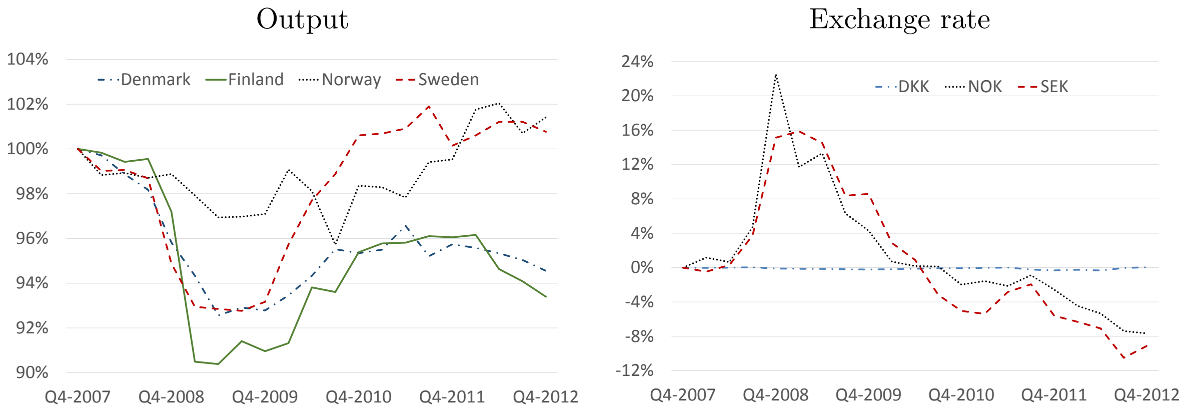

Figure 1: Real GDP (left) and change of exchange rate (end of quarter price of euro, in local currency) in four Scandinavian countries. Sample period: 2007Q4–2012Q4. GDP is normalized to 100 Percent in 2007Q4, the exchange rate is expressed in percentage changes relative to 2007Q4. Source: OECD Economic Outlook 98 and Bundesbank.

thereby providing some isolation from the adverse developments in the rest of the world. In addition, floating exchange rates allow fiscal stimulus to become more effective precisely when monetary policy can deliver less stabilization—a "benign coincidence."

The opposite holds in case of a fixed exchange rate regime. Lack of exchange rate flexibility not only exposes the economy fully to the adverse consequences of the external demand shock. It also amplifies the transmission of a global great recession. This is so because fixed exchange rates anchor the domestic price level to the foreign deflationary crawl. Anticipated domestic deflation, in turn, pushes up domestic real interest rates and induces a collapse of internal demand. Last but not least, as the external nominal anchor keeps it tied to inflation abroad, an exchange rate peg also prevents fiscal policy from having a significant and persistent effect on domestic inflation. Very much at odds with the received wisdom, fiscal policy is not necessarily more effective in a fixed exchange rate. Rather, the benign coincidence breaks down.

We establish these results analytically in a stylized framework as well as through model simulations. To state our results as clearly as possible, we build on the workhorse monetary model of a small open economy in its standard New Keynesian specification.[1] Throughout our analysis, we posit a large rise in world preferences for current savings. This shock cannot be fully offset by appropriate monetary policy measures in the rest of the world and, thus, causes a sustained drop in rest-of-the world demand, as well as rest-of-the world deflation.

[1]In the New Keynesian specification, the small open economy takes the global equilibrium as given but maintains some monopoly power on its terms of trade—see, for instance, Galí and Monacelli (2005) and De Paoli (2009) which, in turn, build on the New Open Economy Macroeconomics literature (Obstfeld and Rogoff, 1996).

The exchange rate regime entertained by the small open economy that is faced with these developments is essential for the extent to which the domestic economy remains insulated from both the real drag of global demand and the global deflationary pressure.
To verify the robustness of our findings to varying the degree of capital market integration and financial frictions, we consider model extensions which capture financial imperfections. Building on previous work of ours we consider economies in which there is limited risk sharing and vulnerability to sovereign risk crises, which may spill over to borrowing costs and conditions faced by the private sector—a mechanism that we dub "sovereign-risk channel" (Corsetti et al., 2013b). We find that this modification has little bearing on the transmission of the external shock to the small open economy under consideration. Yet, the "sovereign risk channel" causes fiscal policy to become much less effective in stabilizing economic activity exactly when monetary policy is constrained. This is so particularly under a peg.
Our paper relates to an emerging literature which has begun to reassess the costs and benefits of flexible exchange rates in light of recent developments. In line with Schmitt-Grohé and Uribe (2015), we show that macroeconomic adjustment is indeed particularly painful under a currency peg. The mechanisms that they and we highlight differ, though. Whereas we highlight the lack of effectiveness of both monetary and fiscal stabilization policy, they see wage-setting frictions as the central element. In any case, empirical evidence suggests that exchange-rate flexibility has mitigated the adverse impact of the Great Recession (Berkmen et al., 2012). Krugman (2014), however, emphasizes the benefits of flexible exchange rates in the face of sovereign risk.
The paper in the literature closest to ours is Cook and Devereux (2016). They show within a two-country model that a flexible exchange rate regime can make an economy more, rather than less, vulnerable to a large shock. The main difference to our work is the focus and main scenario of the analysis. Whereas we focus on the transmission of a large adverse external shock to a small open economy, they focus on the domestic stabilization of a large domestic demand shock. Cook and Devereux (2013) study the case for international policy coordination if in one of two countries monetary policy becomes constrained by the zero lower bound. Amador et al. (2016) instead consider how to overcome the ZLB problem via exchange rate and international reserve policies in a world with segmented financial markets. Their analysis is motivated by the the recent Swiss experience of large capital inflows.
A number of recent studies have emphasized that fiscal policy is particularly effective in stabilizing open economies once monetary policy becomes constrained by the ZLB (Cook and Devereux, 2011; Erceg and Lindé, 2012), while other studies have highlighted that the effectiveness of fiscal policy is limited under an exchange rate peg has been (Corsetti et al.,

2013a; Erceg and Lindé, 2012; Fahri and Werning, 2016). In the present paper we reconsider those findings in circumstances where a need for effective stabilization arises from a large external shock.

Finally, a recent body of literature has reconsidered macroeconomic and stabilization issues when the global economy is in a secular stagnation steady state, whereby inefficiently low economic activity at the ZLB is a permanent, rather than a temporary, condition as in the present paper (Caballero et al., 2015; Eggertsson et al., 2016). Taking the vantage point of a small open economy, exactly as in the present paper, Corsetti et al. (2016) study the conditions under which a single country can escape stagnation and reach a full-employment steady state. While the escape path and policies are not strictly comparable with the dynamic response to the external shock studied in this paper, there is a notable common conclusion: exchange rate flexibility is required to ensure that domestic inflation rises enough and to overcome the ZLB problem, while the country's net foreign asset absorbs its excess saving. Exchange rate flexibility appears once more a pre-condition for maintaining full employment when the world suffer a slump, independently of whether this is temporary or permanent.

The text is organised as follows. Section 2 outlines the model by focusing on a log-linear approximation of the equilibrium conditions. Section 3 provides a number of closed-form results on the transmission and stabilization of a great recession under alternative policy scenarios in the small open economy. Section 4 illustrates the quantitative relevance of these results through model simulations. It also provides results for a modified environment with financial friction and sovereign risk. Section 5 concludes.

2 A New Keynesian small open-economy model

We conduct our analysis in a standard New Keynesian framework, using a version of the two-country model put forward in Corsetti et al. (2012). Both countries produce a variety of country-specific intermediate goods, with the number of intermediate good producers in the world normalized to unity. Goods market integration is incomplete due to home bias. Hence, while we assume that the law of one price holds at the level of intermediate goods, purchasing power parity fails in the short run. The countries have isomorphic structures, but may differ in terms of size, policies, and shocks.

We build a scenario in which a small open economy faces a great recession in the rest of the world. For this purpose we make the following assumptions. First, the size of the domestic economy ("Home") in the world economy approaches zero, while the rest of the world is consolidated in "Foreign". As a result, Home behaves like a small open economy, while

Foreign behaves like a closed economy.[2] Second, the only source of variation at the world level is a foreign "saving shock." This shock effectively alters the time-discount factor. Such preference shocks are frequently used to model an exogenous variation of the intertemporal allocation of private expenditures (for a textbook treatment see Galí, 2015). In order to determine the effect of the shock on Home, one needs to know the effect of the shock on foreign demand and prices. We shall, third, assume that the shock in Foreign occurs when monetary policy in Foreign is unable to contain its effect.

Importantly, while our focus is on Home, we are explicit about the dynamics in Foreign so that the external shock which impacts Home is fully micro-founded. As a result we may account for the cross-equation restrictions of the model along two dimensions. First, the saving shock in Foreign impacts Home not only via goods markets, but also via financial markets.[3] Second, the model restricts the joint dynamics of output and inflation in Foreign during a great recession thus modelled. As we shall see, the dynamics of both of these matter for Home.

The structure of the model is well known. We give a detailed description in Appendix A. In the following, instead, we provide a compact exposition, based on a log-linear approximation of the equilibrium conditions around a deterministic and symmetric zero-inflation steady state.[4] Output is normalized to one. In both the appendix and the text, foreign variables are indexed with a star. Variables carry a time-subscript, t. Variables without a hat refer to log deviations from the steady state. Variables that carry a hat refer to deviations in levels. We begin with Foreign and discuss the equilibrium conditions in Home afterwards.

In order to simplify the exposition and derive tractable pencil-and-paper solutions, we initially posit that financial markets are complete across borders, and make some simplifying assumptions. These assumptions will be relaxed later, when we resort to numerical simulations, with little effect as to the qualitative conclusions of our analysis.

2.1 Foreign

Under our assumptions, Foreign operates like a closed economy. The equilibrium dynamics of output, y_t^*, inflation, π_t^*, and nominal interest rates, r_t^*, are driven by the dynamics of the saving shock in Foreign, ξ_t^*. We will specify a law of motion for the shock later. The evolution of the foreign economy is captured by the following three equations. The first is the dynamic

[2] In this case Home is identical to the small open economy of Galí and Monacelli (2005), except for the fact that we allow for government consumption and restrict preferences to log-utility.

[3] The global fall in demand (including the demand for the Home output), the adjustment in the world interest rate and the price of foreign exports are all taken as given by the small open economy. Because of the fluctuation in the relative price of Home to foreign consumption, however, full insurance via complete markets does not insulate Home consumption from the external shock.

[4] See appendix B for more details on the approximated model.

IS-equation:

$$y_t^* \quad = \quad E_t y_{t+1}^* - (r_t^* - E_t \pi_{t+1}^* + E_t \Delta \xi_{t+1}^*). \tag{1}$$

Here E_t is the expectations operator and Δ marks the difference operator. We abstract from government consumption in Foreign. Next, there is the New Keynesian Phillips curve:

$$\pi_t^* = \beta E_t \pi_{t+1}^* + \kappa (\varphi + 1) y_t^*. \tag{2}$$

Here, β is the steady-state time-discount factor. $\kappa := (1-\alpha)(1-\beta\alpha)/\alpha$ measures the slope of the Phillips curve, with $\alpha \in [0,1)$ measuring the degree of price stickiness. $\varphi > 0$ is the inverse of the Frisch elasticity of labor supply. The next (and last) equation for Foreign is an instrument rule for the foreign central bank that describes the behavior of monetary policy.[5] We assume that

$$r_t^* = \max\{\phi_\pi \pi_t^* - E_t \Delta \xi_{t+1}^*, -(1-\beta)\}. \tag{3}$$

Here, $\phi_\pi > 1$ is the response to inflation in normal times. Foreign monetary policy can become constrained by the ZLB, however, explaining the max operator. As long as the foreign central bank can pursue rule (3) without being constrained by the ZLB, the time-discount factor shock does not have an effect on foreign inflation or output. In this case, foreign monetary policy implements the flexible price allocation under which the saving shock is fully absorbed by changes in the real rate of interest. If, instead, policy becomes constrained, the flexible-price allocation can no longer be implemented by monetary policy (alone). In this case eqs. (1)–(2) restrict the joint dynamics of output and inflation in Foreign.

2.2 Home

While the dynamics in Foreign are independent of what happens in Home, Foreign does matter for Home. The following set of equations describes the equilibrium dynamics in Home, given the realization of Foreign variables. The dynamic IS-relation in Home is:

$$y_t \quad = \quad E_t y_{t+1} - (1-\varpi) E_t \Delta y_{t+1}^* - E_t \Delta \hat{g}_{t+1} + [1 - \upsilon - \varpi] \Delta \xi_{t+1}^* - \varpi (r_t - E_t \pi_{H,t+1}). \tag{4}$$

Here $\hat{g}_t$ denotes government expenditure (in units of output). In the steady state, government consumption is zero. We allow for positive government consumption shocks in Home. Government spending is financed through lump-sum taxes and falls exclusively on domestically

[5] We abstract, both in Foreign and in Home, from issues related to forward guidance, the effectiveness of which requires some degree of credibility of policy announcements, and its puzzling effectiveness in theoretical models (Giannoni et al., 2016). By the same token, we also abstract from non-conventional balance sheet policies, such as Quantitative Easing. Given the results of Gertler and Karadi (2011), the latter can have a strong effect in the model extension studied in section 4.3 below, but its study is beyond the scope of our paper.

produced goods. The term $(1-\varpi)y_t^*$ captures external demand for domestically produced goods (as a function of foreign output), where $\varpi := 1-\upsilon(2-\upsilon)(1-\sigma)$. Here, $\upsilon \in (0,1)$ measures the degree of openness, with a low value of υ implying a strong home bias (little openness), and $\sigma > 0$ measures the trade-price elasticity of international demand.[6] In deriving the above equation, we have substituted for Home consumer-price inflation rates. Thus, what remains in the IS-equation is producer-price inflation, $\pi_{H,t}$.

The New Keynesian Phillips curve links inflation to expected inflation, as well as a number of variables that determine the evolution of marginal costs in our small open economy

$$\pi_{Ht} = \beta E_t \pi_{Ht+1} + \kappa \left\{ \left(\varphi + \varpi^{-1}\right) y_t - \tilde{\varpi}^{-1}[(1-\varpi)\hat{y}_t^* + \hat{g}_t] + \frac{1-\upsilon-\varpi}{\varpi} \xi_t^* \right\}. \tag{5}$$

Note that both the dynamic IS-relation and the New Keynesian Phillips curve in Home are a function of foreign output (that is the same as foreign consumption) as well as the foreign saving shock, which enter the equations as separate arguments. This is because a foreign saving shock spills over internationally through two channels. The first is a direct demand channel: given prices, a saving shock leads to less foreign demand for domestic goods—this is the key effect of a global recession that we wish to focus on in our analysis. The second channel works through prices: because of home bias in consumption, for given relative prices the fall in Foreign demand falls disproportionately on foreign-produced goods. In equilibrium, the relative price of foreign-produced goods must fall, which in turn crowds out demand for domestic goods.

Our aim is to provide tractable analytical expressions for the impact of the demand shock and fiscal spending. Therefore, we make the following

Parametric assumption: *The parameters governing openness (υ) and the trade elasticity (σ) are related as* $1-\sigma = (2-\upsilon)^{-1}$.

The above constraint implies $1-\upsilon-\varpi = 0$, so that the foreign savings shock disappears from equations (4) and (5) and we can focus on the demand channel. Note also that in this case external demand for domestically produced goods is simply given by υy_t^*. The assumption greatly simplifies the readability of the analytical expressions that we derive below. However, it turns out it is not consequential for our main results. Namely, for the numerical solutions of the model (shown in Section 4) we will not impose this assumption and still find the results fully bear out the main implications that we derive analytically.

The terms of trade in Home, s_t, are defined as the price of imports relative to the price of exports. Foreign being large, the foreign consumer price level equals the foreign producer

[6]External demand for domestically produced goods thus increases with foreign output as long as $\sigma < 1$.

price level. With the law of one price assumed to hold and producer currency pricing, we have that

$$s_t = e_t + p_t^* - p_{H,t}. \tag{6}$$

Here, e_t is the nominal exchange rate, defined as the price of foreign currency in units of domestic currency, p_t^* is the (consumer and producer) price level in Foreign and $p_{H,t}$ is the producer price level in Home. Note that $\pi_{H,t} = p_{H,t} - p_{H,t-1}$ and $\pi_t^* = p_t^* - p_{t-1}^*$.

In equilibrium, demand for domestically-produced goods satisfies

$$y_t = (1-\upsilon)s_t + \hat{g}_t + y_t^* - (1-\upsilon)\xi_t^*. \tag{7}$$

This is derived from goods market clearing for domestically-produced goods using the risk sharing condition under complete international financial markets.[7] All else equal, Home output depends positively on foreign demand, the terms of trade and Home government consumption.

The model is closed by specifying the monetary policy regime in Home. We will, in the next section, consider three different scenarios: an independent monetary policy in Home that follows the analog of rule (3), with and without being constrained by the ZLB, as well as the case of a currency peg.

In equilibrium, eqs. (4)–(7) determine a sequence of Home variables $\{y_t, \pi_{H,t}, p_{H,t}, s_t, e_t, r_t, \hat{g}_t\}_{t=0}^{\infty}$, given a specification of (i) monetary policy in Home, (ii) fiscal policy in Home, (iii) $\pi_{H,t} = p_{H,t} - p_{H,t-1}$, (iv) the sequence $\{y_t^*, \pi_t^*, p_t^*, \xi_t^*\}_{t=0}^{\infty}$, as well as initial conditions $(p_{-1}^*, p_{H,-1})$.

Below we will also refer to the natural output and the natural rate of interest in Home. They are given by:

$$y_t^n = \underbrace{\frac{1}{1+\varphi(1-\upsilon)}}_{<1}(\upsilon y_t^* + \hat{g}_t) \tag{8}$$

and

$$r_t^n = -\frac{\varphi}{1+\varphi(1-\upsilon)}\left(\upsilon E_t \Delta y_{t+1}^* + E_t \Delta \hat{g}_{t+1}\right), \tag{9}$$

respectively.

3 The impact of a global recession

In this section, we provide analytical insight on the transmission of a large external demand shock to Home—a small open economy specialized in the production of country-specific varieties. We study, in particular, how the effects of the shock vary with the extent to which

[7] Again, in our setup complete financial markets do not imply equal consumption in Home and Foreign because of home bias. Moreover, the saving shock will affect consumption-risk sharing, as it impacts the marginal utility in Foreign.

monetary instruments in Home are constrained, either by the zero lower bound or by a commitment to an exchange rate peg. Then, we analyze how effectively fiscal instruments can substitute for monetary ones in each regime.

Throughout, we focus on the effect of the saving shock in Foreign that directly affects only foreign households. The effect of this shock on global demand and production, the world interest rate and the prices of goods produced abroad are endogenous to the world economy. From the vantage point of the (small) domestic economy, however, they are exogenous. And so is the decline of world demand for domestically-produced goods and the price drift in foreign exports denoted in foreign currency.

More in detail, we model the great recession scenario as follows: in the initial period ($t = 0$), foreign households become more patient, so that ξ_t^* drops to $\xi_L^* < 0$. Each period afterwards, with probability $\mu \in (0, 1)$, ξ_t^* will remain at that same low level for another period, or otherwise permanently revert to the level of $\xi_t^* = 0$. Having the Great Recession in mind, we will—in addition—assume that the shock hits the foreign economy when foreign monetary policy does not respond to the shock, for example, because the foreign economy was at its ZLB to start with. That is, the foreign interest rate, r_t^*, does not react to the shock while it lasts. Government spending in Home follows the same stochastic structure as the savings shock in Foreign. Throughout the paper, we shall focus on those cases only in which the equilibrium is determinate both in Foreign and in Home. Parameters of the model are restricted to satisfy the determinacy conditions in each scenario.

3.1 The impact on Foreign

With these assumptions, we obtain a unique representation of the dynamics of foreign output and foreign prices. Output and inflation in Foreign inherit the Markov property of the saving shock, that is, they will look the same in any period in which the shock lasts. We use the subscript "L" to indicate the value that endogenous variables take during the shock period (for "Low"). The impact of the shock on output in Foreign is given by

$$y_L^* = \underbrace{\frac{(1-\beta\mu)(1-\mu)}{(1-\beta\mu)(1-\mu) - \mu\kappa(1+\varphi)}}_{:=1/\chi>1} \xi_L^*. \tag{10}$$

It is important to note here that $\chi < 1$ and decreasing in the persistence of the shock μ. In words, due to the ZLB constraint binding in Foreign, the discount-factor shock has a disproportionate effect on Foreign's output. This effect tends to be stronger the more persistent the shock is and the longer foreign monetary policy remains constrained.

Foreign inflation also falls in response to the negative shock:

$$\pi_L^* = \underbrace{\frac{\kappa(1+\varphi)(1-\mu)}{(1-\beta\mu)(1-\mu) - \mu\kappa(1+\varphi)}}_{>0} \xi_L^*. \tag{11}$$

3.2 The impact on Home

Having characterized the evolution of foreign demand (output) and foreign inflation, we now take the perspective of the small open economy (Home). We will consider three types of policy environments. In turn, we will assume that the Home monetary policy either (i) permits floating exchange rates and is unconstrained by the ZLB; (ii) is constrained by the ZLB for some time amid a floating exchange rate; (iii) is constrained by a credible (and permanent) currency peg.

3.2.1 Unconstrained monetary policy in Home

We begin by revisiting, analytically, a classic result: under flexible exchange rates a small open economy has the ability to stabilize the output gap and inflation in response to a large external-demand shock. It can do so through its own monetary policy, as long as this policy remains unconstrained. To show this, we postulate that the monetary authority in Home is able to implement a rule akin to that in Foreign, but unconstrained by the ZLB:

$$r_t = \phi\pi_{H,t} + r_t^n, \text{ with } \phi > 1. \tag{12}$$

Under our shock scenario, r_t^n will be zero after the shock has ceased. Otherwise,

$$r_L^n = \frac{(1-\mu)\varphi}{1+\varphi(1-\upsilon)} \left(\upsilon y_L^* + \hat{g}_L\right).$$

Here $\hat{g}_L$ is the value that government consumption in Home is assumed to take during the shock episode. By following rule (12), Home monetary policy targets producer-price inflation and adjusts policy rates to changes in the natural rate of interest. Combining the interest rate rule specified above with equations (4) and (5), we can determine the equilibrium interest rate, inflation and output in Home. The model shows the well-established isomorphism between open and closed-economy settings, as is common in New Keynesian models (Clarida et al., 2001). This is not to say that openness is irrelevant for Home. It matters for Home through openness parameter υ. In addition, openness matters here by opening the door to external shocks.

Moreover, provided that the central bank follows the rule above, we obtain the other well-known result (see, for instance, Galí, 2015, chapter 4): with complete markets and in the absence of markup shocks, rule (12) above supports the flexible-price allocation. In particular, there is no inflation ($\pi_{H,t} = 0$) and output equals its natural level given in (8). This expression shows that domestic output, y_L, falls by less than external demand, υy_L^*, meaning that the external-demand multiplier, $\frac{dy_t}{d(\upsilon y_t^*)}$, is smaller than unity. Under flexible exchange rates the isolation from the shock in terms of output is thus not complete. Rather, monetary policy stabilizes Home output at the natural level. Under the assumptions made above, the natural level of output declines in response to the external shock. Another way to read equation (8) is that a one percent fall in foreign output will translate into less than a υ-percent fall in Home output. Naturally, the impact of the foreign shock increases in the openness parameter υ (which determines the exports-to-GDP ratio in steady state).

It is instructive to analyze the accompanying movements in the terms of trade and the nominal exchange rate. The following expression for the terms of trade can be derived by combining the solution for output (8) with the market-clearing condition equation (7):

$$s_L = \underbrace{-\left[1 - \chi + \frac{\upsilon\varphi}{1+\varphi(1-\upsilon)}\right]}_{<0} y_L^* - \frac{\varphi}{1+\varphi(1-\upsilon)} \hat{g}_L^*. \tag{13}$$

We observe that the terms of trade in Home automatically and unambiguously depreciate if foreign output—and hence external demand—declines. Expansionary government spending in Home, all else equal, appreciates the Home terms of trade.

The following expressions illustrate how exactly the nominal exchange rate operates as a shock absorber in our environment, as long as monetary policy is unconstrained. From (6), the nominal exchange rate, e_t, is given by

$$e_t = s_t + p_{H,t} - p_t^*, \tag{14}$$

As long as monetary policy can and does pursue price stability in Home, we have $p_{H,t} = 0$. In this case, taking first differences of equation (14) implies

$$\Delta e_t = \Delta s_t - \pi_t^*. \tag{15}$$

Two observations are in order. First, the movement in the nominal exchange rate perfectly insulates the domestic economy from movements in foreign inflation. In our shock scenario, the nominal exchange rate will depreciate one-to-one with the continuing fall in Foreign's price level, at the disinflation rate $\pi_L^* < 0$. Second, the nominal exchange rate will depreciate in excess of the foreign deflationary crawl, so as to bring about the depreciation of the terms of trade required to sustain full employment.[8]

[8] Note that Foreign's exchange rate appreciates even though it is exposed to an adverse demand shock—just like in scenario studied by Cook and Devereux (2016). As emphasized in that paper, it is the ZLB which induces a "perverse" adjustment of exchange rates: a country which suffers from an adverse shocks sees its exchange rate appreciating.

We now solve formally for the exchange rate in Home, starting from the uncovered interest rate parity (UIP) condition:[9]

$$r_t - r_t^* = E_t e_{t+1} - e_t.$$

We iterate this equation forward as in Engel (2014) and rearrange terms:

$$e_t = E_t \sum_{k=0}^{\infty} (r_{t+k}^* - r_{t+k} + \pi_{H,t+k} + \pi_{t+k}^*) + (p_{H,t-1} - p_{t-1}^*). \tag{16}$$

Here, we used the expression for the nominal exchange rate (14) and $\lim_{t\to\infty} s_{t+k} = 0$. The terms of trade converge back to the steady state in the long run because of complete financial markets and the assumption that the shock is temporary.

We now evaluate expression (16) for our crisis scenario. As long as Foreign remains at the ZLB while Home is unconstrained, we have $r_t^* = 0$, $r_t = r_L^n$ and $\pi_{H,L} = 0$. Hence, expression (16) implies—for as long as the shock lasts:

$$e_k^{unconstrained} = -\frac{r_L^n + \pi_L^*}{1-\mu} - k \cdot \pi_L^* > 0, \tag{17}$$

with $k = 0, 1, 2 \ldots$ indexing the periods since the start of the crisis in period $t = 0$.[10]

The inequality in (17) follows from our solution for r_L^n and π_L^*: both are negative in our recession scenario. We thus see that there is nominal depreciation in response to a global recession which is currently under way expected to last for some time. This restores competitiveness (the first term captures the monetary policy response which aligns the policy rate with the natural rate) and isolates Home from deflation abroad. The second effect becomes stronger, as the crisis lasts: foreign prices are on a downward trajectory and the Home currency depreciates in order to shield domestic prices from the downward pressure (recall that PPP holds in the long run). Hence, for as long as the crisis goes on, the exchange rate continues to depreciate.

3.2.2 The ZLB constraint under flexible exchange rates in Home

In our second scenario the exchange rate regime in Home is still a float, but now also the monetary policy in Home is assumed to be constrained when the adverse shock in Foreign materializes. Specially, we impose that domestic policy rates are constant as long as the foreign economy is in the shock state—for example, because Home had been at its ZLB already. So, at least temporarily, the monetary authority in Home is unable to cushion the foreign shock.

[9] We obtain the UIP condition by combining the linearized Euler equations in Home and Foreign, see appendix B and by substituting for CPI inflation using the first difference of relation (6).

[10] Here we use that prior to when the shock hits the economy is in steady state ($p_{-1}^* = 0$).

In this case, the solution for domestic output is given by:

$$y_L = \underbrace{\left(1 + \frac{\mu\kappa\varphi(1-\upsilon)}{(1-\mu)(1-\beta\mu) - \mu\kappa(1+\varphi(1-\upsilon))}\right)}_{:=\Xi} (\upsilon y_L^* + \hat{g}_L). \tag{18}$$

One can show that

$$1 < \Xi < \frac{1}{\upsilon}.$$

In other words, the external-demand multiplier is unambiguously larger than unity and thus larger than when the ZLB constraint in Home is not binding, compare (18) with (8). Exchange rate flexibility alone is not sufficient to insulate the Home economy from the Foreign demand shock.

While the drop in domestic output will never exceed the drop of output in Foreign, the output loss due to an external-demand shock can be larger. The reason for why the multiplier is large at the ZLB (and larger than absent the ZLB) has been extensively explored in the context of fiscal policy (e.g., Woodford, 2011). The fall in external demand drives down inflation and inflation expectations in a significant and sustained way, causing a rise in (long-term) real interest rates. Specifically, the solution for inflation is given by:

$$\pi_{H,L} = \underbrace{\frac{(1-\mu)\kappa\varphi}{(1-\beta\mu)(1-\mu) - \mu\kappa(1+\varphi(1-\upsilon))}}_{>0} (\upsilon y_L^* + \hat{g}_L), \tag{19}$$

so that Home inflation will fall along with foreign demand.

Next, we turn to the accompanying movements of the terms of trade and the nominal exchange rate. The solution for the terms of trade is given by:

$$s_L = -\frac{1}{(1-\upsilon)}\left[1 - (1-\upsilon)\chi - \Xi\upsilon\right] y_L^* - \underbrace{\frac{1-\Xi}{(1-\upsilon)}}_{>0} \hat{g}_L. \tag{20}$$

It is instructive to compare this to the solution for the terms of trade when monetary policy follows rule (12) in an unconstrained way, that is, to the expression in equation (13) above. A close inspection of the terms multiplying foreign output reveals that the terms of trade depreciate to a lesser extent in response to a drop of external demand when the ZLB binds in Home.[11]

We can now turn to expression (16) to solve again for the nominal exchange rate (assuming, as above, that the shock strikes first in period t):

$$e_k^{ZLB} = \frac{\pi_{H,L} - \pi_L^*}{1-\mu} + k\left(\pi_{H,L} - \pi_L^*\right) > 0, \tag{21}$$

[11] While it is difficult to formally establish the sign of the terms of trade response to the external shock, we consistently find in our numerical experiments the terms of trade to depreciate even when the ZLB binds in Home.

where, as before, $k = 0, 1, 2 \ldots$ indexes the period since the start of the crisis. In the expression above, the inequality follows because while both inflation rates drop below zero, foreign inflation falls more. Moreover, as $\pi_{H,L} < 0$ the depreciation is muted relative to the unconstrained case, see (17), that is:

$$e_k^{unconstrained} > e_k^{ZLB}.$$

This formalizes the notion that the nominal exchange rate cannot fully fulfil its role as a shock absorber, once monetary policy is constrained by the ZLB. Still, Home does not fully import Foreign's deflationary crawl.

With monetary policy unable to cushion the shock, the question naturally arises if Home may nonetheless stabilize the economy through fiscal policy. The expressions above directly speak to this question (see expressions (18) and (19)). In fact, assuming that government spending is raised by $\hat{g}_L$ for as long as the economy is in the shock state, we observe that fiscal policy is quite effective in raising output: The fiscal multiplier is just as large as the external-demand multiplier. We think of this result as highlighting a "benign coincidence": if the conditions are such that, due to the ZLB, the effect of an external demand shock is strongly amplified, domestic fiscal policy is also particularly effective in stabilizing economic activity.[12]

The mechanism underlying the power of fiscal policy at the ZLB is well understood: higher government spending lowers real interest rates to the extent that fiscal spending raises expected inflation and provided that its inflationary impact is not met by higher policy rates (Christiano et al., 2011; Woodford, 2011). Relative to analyses conducted in a closed-economy setting, our analysis sheds light on the contribution to stabilization of the exchange rate. Indeed, flexible exchange rates are an important element for the effectiveness of fiscal policy in the ZLB scenario. The next section will make this clear.

3.2.3 An exchange-rate peg in Home

We turn to our third, and final, scenario for monetary policy in Home. Namely, we now assume that monetary policy adjusts interest rates so as to ensure the following target for the log exchange rate:

$$e_t = 0. \tag{22}$$

[12]Note, however, that while government spending may be used to effectively isolate Home from the external-demand shock, this also alters the flexible-price allocation. As a result, at the ZLB it is not feasible to restore the allocation which obtains in the unconstrained case through government spending. To see this, note that if domestic inflation is fully stabilized, domestic output will not be at the natural level, but at the steady state level.

Here we abstract from issues pertaining to implementation and from other possible constraints on monetary policy.[13]

To understand the implications of an exchange rate peg for the macroeconomic stabilization in a small open economy, we derive an expression for the evolution of the terms of trade. Home's terms of trade are given by the expression in equation (6). With permanently fixed exchange rates, the terms of trade then evolve as

$$s_t - s_{t-1} = \pi_t^* - \pi_{H,t}. \tag{23}$$

We may then subtract from the Phillips curve in Foreign (2) its counterpart in Home (5). This gives

$$\pi_t^* - \pi_{H,t} = \beta E_t(\pi_{t+1}^* - \pi_{H,t+1}) + \kappa\big(\chi[1+\varphi(1-\upsilon)]\hat{y}_t^* - \varphi\hat{g}_t - [1+\varphi(1-\upsilon)]s_t\big). \tag{24}$$

Organizing terms leads to the following second-order difference equation in the terms of trade:

$$s_t = \psi s_{t-1} + \beta\psi E_t s_{t+1} + \kappa\psi\big[\chi[1+\varphi(1-\upsilon)]y_t^* - \varphi\hat{g}_t\big], \tag{25}$$

where $\psi = [1+\beta+\kappa(1+\varphi(1-\upsilon))]^{-1}$. Under our assumptions on the structure of the shock, one can solve this difference equation using the method of undetermined coefficients. We obtain as a stable solution

$$s_t = \delta s_{t-1} + \underbrace{\frac{\kappa\psi\chi[1+\varphi(1-\upsilon)]}{1-\beta\psi[\delta+\mu]}}_{:=\Phi} y_t^* - \underbrace{\frac{\kappa\psi}{1-\beta\psi[\delta+\mu]}\varphi}_{:=\Gamma}\,\hat{g}_t, \tag{26}$$

where $\delta := \frac{1-\sqrt{1-4\beta\psi^2}}{2\psi\beta}$, with $0<\delta<1$, and $\Phi \in (0,\chi)$, and $\Gamma > 0$. Expression (26) shows that the terms of trade unambiguously *appreciate* in response to a drop of external demand. This is in stark contrast with results for flexible exchange rates, when there was scope for the terms of trade to depreciate. Intuitively, with the nominal exchange rate fixed, the adjustment of the terms of trade depends on the relative adjustment of prices in Home and Foreign. It turns out that in response to the Foreign saving shock, Foreign prices decline more than in Home—hence, the real appreciation.

Two other dimensions set the fixed exchange rate regime apart from the flexible exchange rate regime. First, if the shock persists, and so $y_L^* < 0$ for some time, the terms of trade will not only appreciate in the first period of the shock but will continue to do so going forward. Second, the terms of trade will not automatically reset once the shock ceases to exist. Rather, Home's terms of trade will remain appreciated for an extended period, with

[13]See, for instance, Benigno et al. (2007). In the event of a binding ZLB constraint, one may think of an appropriate commitment to future policy rates as a way to ensure the exchange rate peg. Recall that one scenario we have in mind is the membership of a small open economy within a currency union.

detrimental results on domestic output and inflation even once Foreign no longer suffers from the shock and foreign demand has reverted to $y_t^* = 0$. This can be best seen by iterating the expression for the terms of trade backward in time, assuming that prior to the first period the terms of trade were at their steady-state value ($s_{-1} = 0$):

$$s_t = \sum_{k=0}^{t} \delta^{t-k} \left(\Phi y_k^* - \Gamma \hat{g}_k \right). \tag{27}$$

In other words, fixed exchange rates not only mean reduced competitiveness upon a negative foreign demand shock. Worse, fixed exchange rates can mean that these effects keep lingering after the rest of the world has already recovered from the shock. Similarly, the effect of reduced competitiveness that goes in hand with higher fiscal spending in Home will be felt after the fiscal stimulus is no longer provided.

Last, we turn to the effect of the shock on Home's output. By equation (7), we have that

$$y_t = (1-\upsilon)s_t + \frac{1-\chi(1-\upsilon)}{\upsilon}\upsilon y_t^* + \hat{g}_t.$$

Inserting the expression for the terms of trade under fixed exchange rates, we obtain:

$$y_t = \frac{1-\chi(1-\upsilon)}{\upsilon}\upsilon y_t^* + (1-\upsilon)\sum_{k=0}^{t}\delta^{t-k}\Phi y_k^* + \hat{g}_t - (1-\upsilon)\Gamma\sum_{k=0}^{t}\delta^{t-k}\hat{g}_k. \tag{28}$$

The impact of the shock on Home's output will tend to be large in absolute terms. Indeed, one can show that on impact output in Home will fall more in response to the foreign demand shock under the peg than in the ZLB scenario discussed earlier. As discussed above, under floating exchange rates, the terms of trade do change on impact. They are constant thereafter for as long as the negative demand shock persists. Under the peg, instead, not only is the adverse effect of the shock on Home output larger on impact, but also do the terms of trade continue to appreciate, and remain appreciated even after the external demand disturbance is over. Thus, domestic output will be lower under the peg than under the float (with or without ZLB). Since the demand shock persistently appreciates the terms of trade, output remains lower under the peg than under floating exchange rates.

At the same time, the government spending multiplier is always smaller than one, and thereby smaller than under the ZLB. The government will need to commit more resources, on a more than one-to-one basis, to compensate for any given fall in output due to the external demand shock. As analyzed in our previous work, a credible exchange rate target amounts to a credible commitment to anchoring the domestic price level to that of Foreign in the medium and long run (Corsetti et al., 2013a). In our scenario above, Foreign suffers from a deep deflationary downturn. Hence, as Home pegs its own currency to Foreign, it anchors domestic expectations to a *falling* price level, causing domestic real interest rates to rise substantially in tandem with the foreign ones.

Not only does the anchor to the foreign price level implicit in a peg exacerbate the transmission of the world recession. It is also the reason why fiscal stabilization is not particularly effective under the peg. This is because any inflationary effects that government spending has in the short run are offset, over time, by a rebalancing of demand in the goods market, causing enough (relative) deflation in Home to re-establish purchasing power parity.

4 Quantitative relevance

We now turn to model simulations in order to illustrate the quantitative relevance of our results. In doing so, we also assess to what extent our results are robust to relaxing the simplifying assumptions required to carry out our analytical derivations. For our numerical experiments we adopt the following parameter values (identical in Home and Foreign). Since a period in the model corresponds to one quarter, the discount factor β is set to 0.99. We assume that the inverse of the Frisch elasticity of labor supply, φ, takes the value of one. The trade-price elasticity σ is set equal to 2/3. Home is assumed to be relatively open, corresponding to $\upsilon = 0.3$.[14] The average price duration is assumed to be four quarters, requiring the Calvo parameter to be set equal to 0.75. Finally, we assume that the government-spending-to-GDP ratio is 20 percent in steady state.

For the sake of clarity, we consider the dynamic adjustment to the foreign shock separately from the dynamic adjustment to an increase in government spending. In the first experiment, we look at a saving shock in Foreign that cannot be stabilized by foreign monetary policy because of a zero-lower-bound problem in Foreign. More specifically, we assume that the foreign policy interest rate is fixed for 10 periods. Afterwards monetary policy in Foreign targets price stability ($\pi_t^* = 0$). We assume that the shock follows an AR(1) process with persistence parameter 0.5. This assumption ensures that the ZLB in Foreign remains a binding constraint for as long as the shock has a significant impact. We normalize the size of the shock so that initially external demand drops by 1 percent of GDP.

In the second experiment, we consider an increase of government consumption in Home, also equal to 1 percent of GDP, assuming again an AR(1) process, and set the persistence parameter to 0.9. In all instances, we contrast the adjustment under the three policy scenarios analyzed above: the case in which an unconstrained monetary policy targets price stability

[14] These assumptions imply that the restriction imposed on σ and υ imposed in our analytical derivations is not satisfied. Yet it turns out that our simulation results are fully in line with our analytical results. This holds true also for a wide range of alternative values for σ and υ.

($\pi_{H,t} = 0$); the case in which monetary policy does not respond to the shock for 10 periods (and targets price stability afterwards); and the case of a currency peg.

4.1 Domestic implications of a global recession

In Figure 2, we look at the transmission of the Foreign saving shock, which causes a sharp and persistent contraction in Foreign consumption and inflation (not shown). In each panel vertical axes measure deviations from the pre-shock path, in percent of steady-state output (in case of quantities) or percent (in case of prices). From the perspective of the small open economy, the shock generates a drop of external demand (upper-left panel). In equilibrium, the shock generates financial inflows corresponding to an external deficit in the trade balance (depicted in lower-right panel). Contrasting the three scenarios for monetary policy in Home, we find large differences—notably in terms of the response of domestic output (upper row, middle panel). Initially, output falls by about four percent under a peg (dash-dotted line), about two percent if policy rates are fixed for 10 quarters (solid line), and by about one percent if monetary policy is unconstrained (dashed line).

Several aspects of the transmission mechanism are noteworthy. In case monetary policy is unconstrained, there is a large upfront cut of interest rates (2nd row, left panel), associated with a large depreciation of the nominal exchange rate (2nd row, right panel). As a result, internal demand remains insulated from the full fall-out of the external shock (3rd row, middle panel). In fact, it actually rises at the margin, since a regime of price stability means that expectations of inflation remain firmly anchored and the long-term real rate, which is relevant for the consumption decision, falls with the current and anticipated monetary stance. Despite nominal depreciation and a weakening of the terms of trade (3rd row, left panel), the contraction in external demand causes a trade deficit. By pursuing price stability, monetary policy effectively tilts aggregate demand towards domestic consumption.

Exchange rate flexibility plays a crucial role also when monetary policy in Home is constrained by the ZLB. The economic outlook worsens relative to that under an unconstrained monetary policy, since insufficient short-term monetary stimulus means that domestic demand remains inefficiently low. But the depth of the foreign contraction and deflation translates into a permanent depreciation of Home's nominal exchange rate. This weakens the link with the deflationary drift in Foreign: dynamically, the Home price level falls somewhat (2nd row, middle panel), but not as much as in Foreign (the latter is not shown in the figure). The terms of trade depreciate, although by less than in case monetary policy is unconstrained—net exports deteriorate by more. Overall, the contraction in both internal and external demand causes a fall of domestic output which is about twice as large as in case monetary policy is

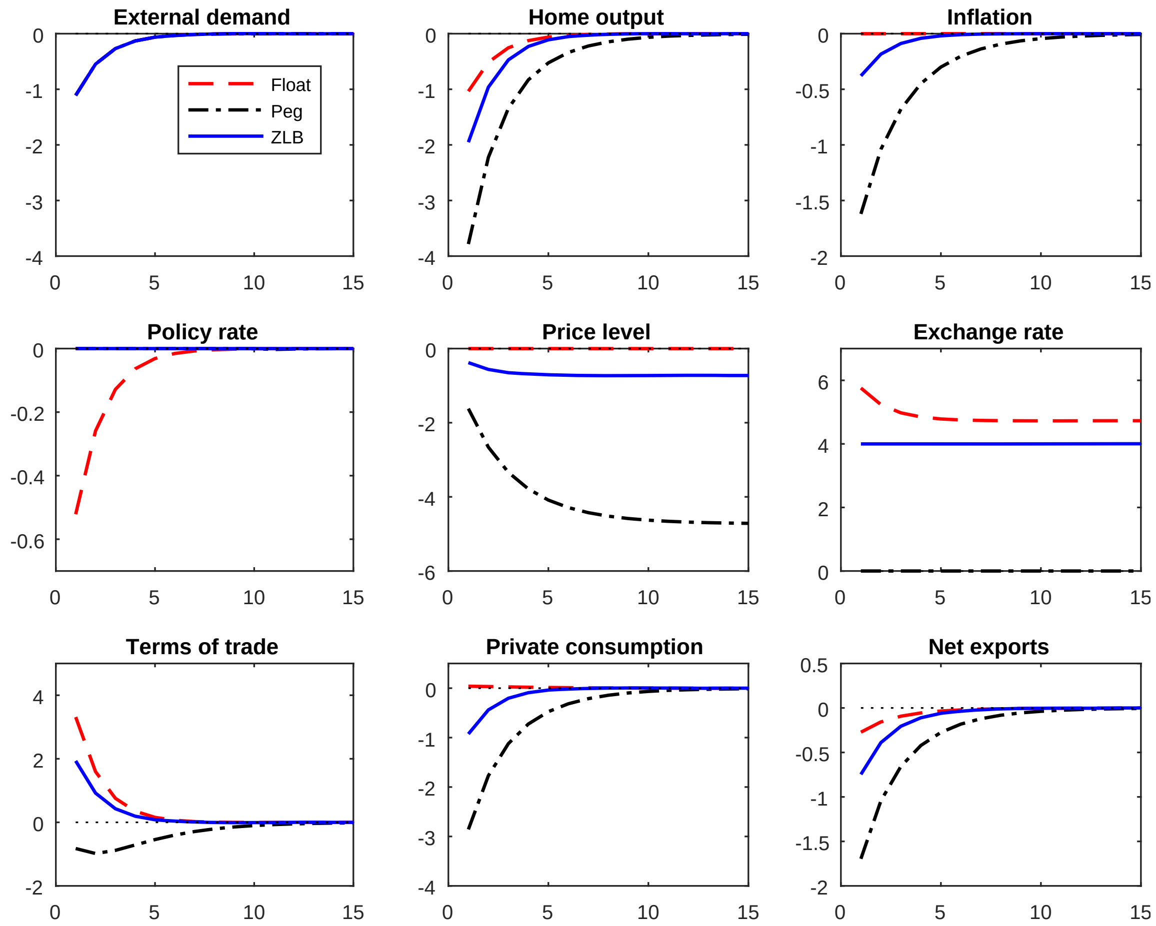

Figure 2: Adjustment to one-percent drop of external demand: unconstrained monetary policy in Home (dashed line) vs constant-interest-rate period of 10 quarters (solid line) and exchange rate peg (dash-dotted line). Horizontal axes measure time in quarters. Vertical axes measure deviations from the pre-shock path, in percent of steady state output (in case of quantities) or percent (in case of prices).

unconstrained.

The regime that performs worst, however, is the currency peg. This is because of deflation in Foreign. If Foreign were not at the ZLB and, hence, would not have suffered a deflationary drift, a peg would in fact have desirable features. Indeed, to the extent that a credible peg is an implicit commitment to a stable price level, the transmission of *domestic* adverse demand shocks would be muted by the peg. The reason is that any short-run fall in domestic prices associated with such domestic demand shocks would in the medium or long run be offset by positive domestic inflation (Cook and Devereux, 2016; Corsetti et al., 2013a). When the foreign country is at the ZLB and the shock is a demand shock that originates in Foreign, instead, this conclusion is turned on its head. The implicit domestic commitment that a pegging country makes to follow the unstable foreign price level works against the country.

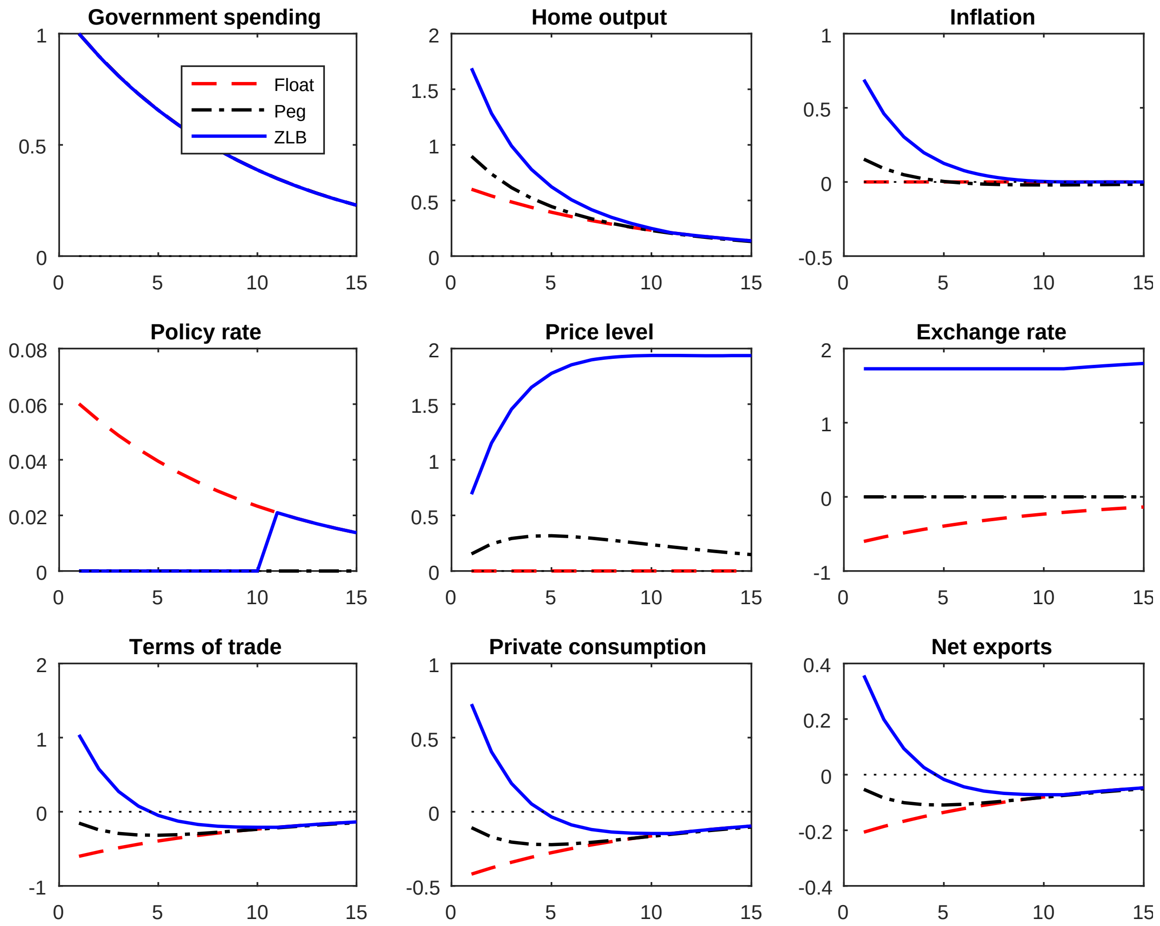

Figure 3: Effect of domestic government spending increase: unconstrained monetary policy (dashed line) vs constant-interest-rate period of 10 quarters (solid line) and exchange rate peg (dash-dotted line). Horizontal axes measure time in quarters. Vertical axes measure deviations from the pre-shock path, in percent of steady state output (in case of quantities) or percent (in case of prices).

Namely, it amplifies the domestic downturn by generating expectations of sustained domestic deflation. The terms of trade actually appreciate, exacerbating the contraction of domestic net exports in response to the shock to foreign demand.

4.2 The scope for fiscal stabilization

Figure 3 traces the effect of an increase of government spending (itself depicted in the upper-left panel). In the case of a free float, as long as monetary policy is unconstrained, the fiscal expansion has moderate effects. With the monetary authority ensuring price stability, more government spending leads to a monetary contraction and real appreciation. It raises output, but only at the cost of crowding out domestic consumption and net exports. The multiplier is substantially below one. Conversely, fiscal policy is quite powerful when the domestic policy rates are temporarily constant at the ZLB. Persistently higher government spending raises expected inflation, thus lowering the long-term real rate: private consumption rises substantially. At the same time, the fall in long-term rates causes the nominal exchange rate to depreciate. Domestic consumption rises with domestic inflation. In addition, net exports rise on the back of the real depreciation. Comparing the ZLB case across Figures 2 and 3 illustrates the "benign coincidence" that we emphasized in Section 3: under those circumstances in which the external shocks become more damaging because of the ZLB, fiscal policy is a powerful substitute for monetary stabilization, if exchange rates are flexible.

This benign coincidence breaks down, however, when the country pursues a currency peg. Figure 3 shows that—contrary to conventional wisdom—fiscal policy is not particularly effective in a fixed exchange rate regime. Note that this is precisely the regime where the adverse external shock is most consequential for Home output and consumption—compare, again, Figures 2 and 3. The mechanism governing the transmission of fiscal policy, as discussed in Corsetti et al. (2013a), is illustrated by the panel in the middle of the figure: by the working of purchasing power parity in the medium and the long run, under a peg, the initial positive response of inflation to a government spending expansion will be offset over time: after a fiscal expansion the price level in Home eventually reverts back to the price level in Foreign. In the figure here, since Foreign did not receive any shocks, the Home price level reverts to its pre-shock level. This is in sharp contrast to the evolution of Home prices when Home monetary policy is constrained by the ZLB but pursues flexible exchange rates. There, the Home price level keeps increasing over the entire life of the fiscal expansion. Comparing the two scenarios, therefore, under a peg the overall monetary stance, measured by the rise in long-term real rates is less rather than more accommodative; and the fiscal multiplier is correspondingly lower.

4.3 Model extensions: financial frictions and sovereign risk

So far we have proceeded under the assumption of frictionless financial markets, both within a country and across borders. This assumption is necessary in order to obtain the closed-form results discussed in the previous section. Here we demonstrate that it is not particularly consequential for macroeconomic dynamics. In what follows, we perform a sensitivity analysis and relax the assumption of complete financial markets. We posit that cross-border asset trade is limited to non-contingent nominal bonds. In addition, we consider the possibility that Home is vulnerable to a deterioration in the markets' assessment of sovereign risk.[15]

[15] A full-fledged analysis of the role of financial frictions in designing exchange-rate policies is beyond the scope the present paper (for recent work on this issue see, for instance, Banerjee et al., 2016; Kolasa and Lombardo, 2014).

Drawing on our previous work (Corsetti et al., 2013b, 2014), we assume that sovereign risk in Home increases when public debt builds up. Higher sovereign risk, in turn, induces a rise of borrowing costs in the private sector (see also Bocola, forthcoming). This specification entails that sovereign risk premia result in a contraction of domestic demand and, therefore, a drop in current economic activity, independently of whether sovereign default actually takes place or not. We provide some details on the modified model in Appendix A.5. Throughout we continue to assume that Home is a small open economy.

Using the extended model, we first establish that, under our parameterization, the propagation of the external-demand shock (the source of this being, as before, a foreign saving shock) is not fundamentally different if we move from the complete-market economy to an economy where there is trade in nominally non-contingent bonds only. With cross-border trade in non-contingent assets only, whether or not markets price sovereign risk, the transmission of a foreign great recession remains least detrimental under a float and amid domestic price stability, and most damaging under a peg—the ZLB case with floating exchange rates being the intermediate case.

Figure 4 shows the dynamic adjustment in case of incomplete markets, but so far absent sovereign risk. Comparing Figures 4 and 2 suggests that differences between the complete and incomplete-market economy are marginal at best.[16] Intuitively, the global shock that we place at the core of our analysis is temporary. Self-insurance via intertemporal trade in bonds and the equilibrium response of the terms of trade and real interest rate at the global level allow a small open economy to achieve an allocation that is not too far from that with perfect risk sharing (see, for instance, Cole and Obstfeld, 1991).

Next, we allow in addition for sovereign risk. Accounting for the sovereign risk channel in the model results in a mild amplification of the adverse effects of the foreign shock. Namely, as output falls in Home in response to the external shock, government debt builds up due to the working of automatic stabilizers (that we introduce in the model through a constant tax rate which is proportional to income). The fiscal outlook worsens, affecting the probability of default. Markets, in turn, call for a higher sovereign risk premium which impacts private borrowing conditions in Home adversely. This reduces aggregate demand and activates an adverse loop: lower demand translates into lower activity, hence higher deficits and debt; higher debt raises sovereign risk and borrowing costs further.[17] Quantitatively, however, the

[16] A qualitative difference worth mentioning concerns the response of net exports and consumption under a float with an unconstrained monetary policy. In the complete markets model, the saving shock in the foreign country generates a larger financial inflow into the Home country. Correspondingly, Home consumption rises, if only at the margin, and the exchange rate depreciates. The capital inflow is less pronounced in the bond economy. Home consumption falls, while a more pronounced depreciation produces a small trade surplus over time.

[17] Under a float and an unconstrained monetary policy, sovereign risk causes more current and/or future

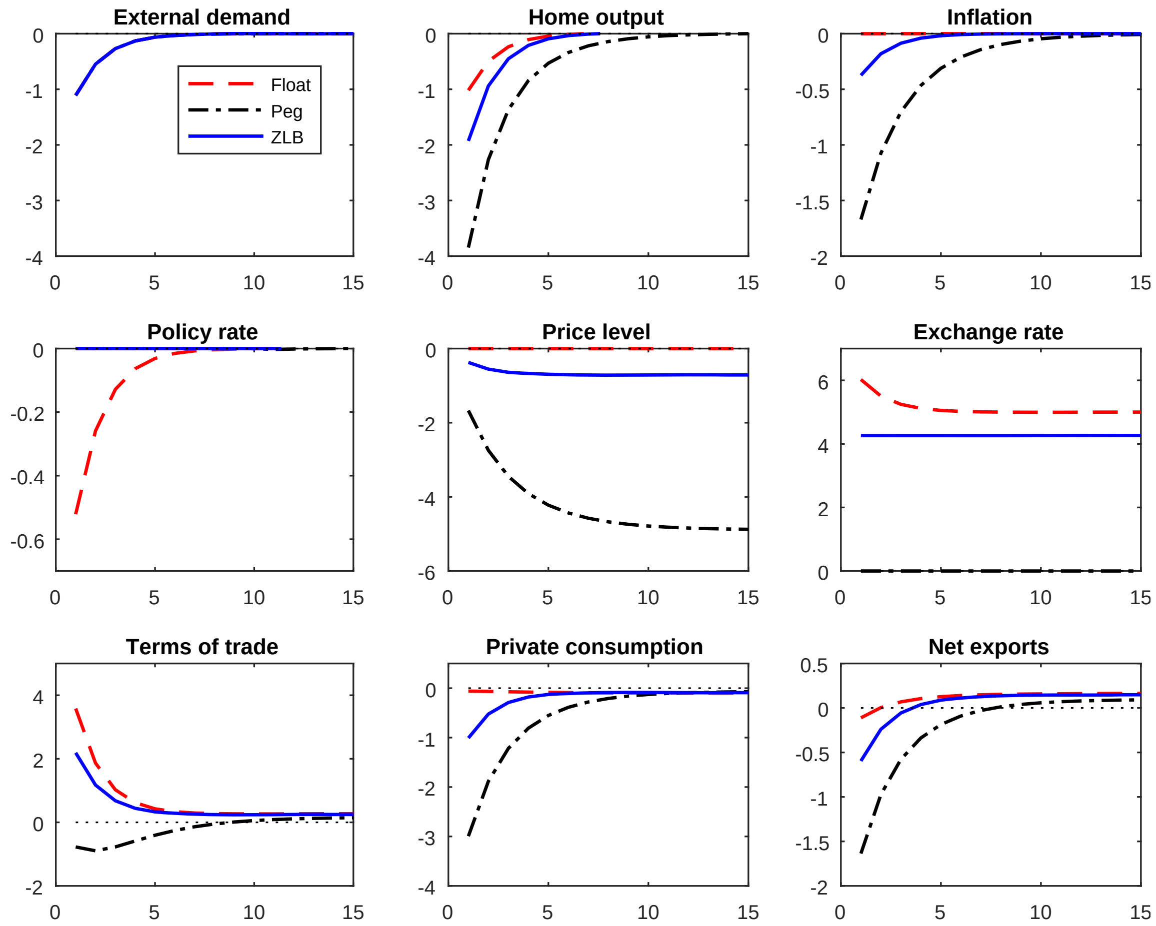

Figure 4: Adjustment to one-percent drop of external demand under incomplete international financial markets; unconstrained monetary policy in Home (dashed line) vs constant-interest-rate period of 10 quarters (solid line) and exchange rate peg (dash-dotted line); see Figure 2 for details.

change in transmission is only moderate. Since the numerical results remain quite similar to Figure 4, we omit a graph for this case.

Rather, we emphasize the dimension in which sovereign risk matters a lot, namely, the effectiveness of fiscal stabilization policy. The effectiveness of fiscal stabilization may be eroded by a loss of confidence when the government pursues deficit-financed expansions in times of a poor fiscal outlook. Figure 5 shows the adjustment to an increase of domestic government consumption by one percent of GDP. The left column shows the response of the economy under the float and unconstrained monetary policy in Home. The middle column corresponds to

monetary accommodation, reflected by exchange rate depreciation upfront. Although consumption falls, it actually falls by less than in the absence of foreign risk—net exports are correspondingly lower. Monetary accommodation and upfront depreciation is instead lower in the ZLB case: the fall in consumption is now more pronounced than in the absence of sovereign risk, making room for a stronger net export dynamic. Under a peg, sovereign risk exacerbates and magnifies the effects under the ZLB scenario.

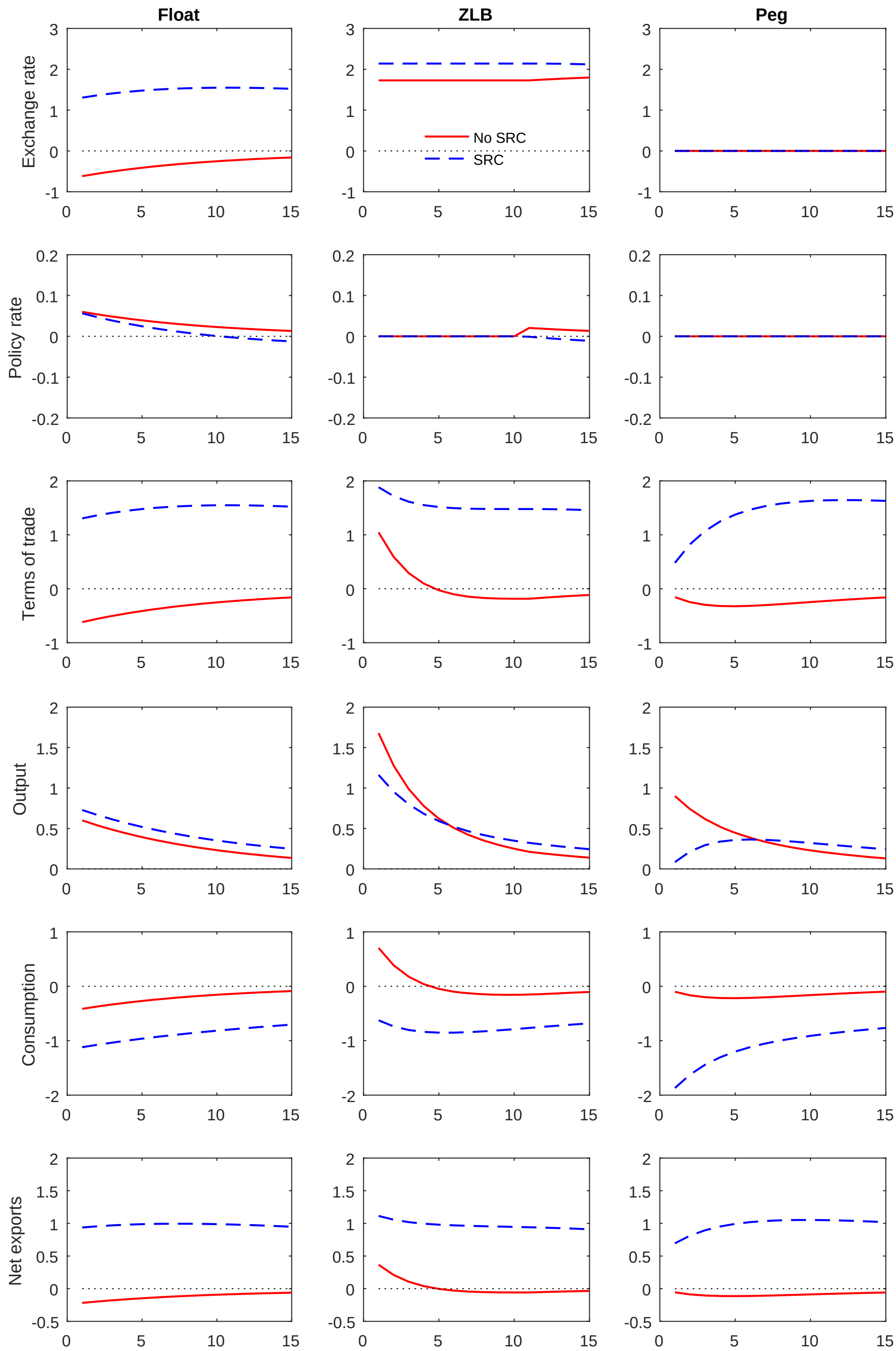

Figure 5: Effect of increase of government spending in Home w/ (dashed line) and w/o (solid line) sovereign risk: see Figure 3 for details; international financial markets assumed to be incomplete.

a float with the ZLB constraint binding in Home. The panels on the right show the responses under the permanent peg. In each of the panels, a solid line marks the responses that would prevail absent the sovereign risk channel. The dashed line marks the responses with sovereign risk.

Focus on the panels in the fifth row which depict the response of domestic consumption: it is much depressed by higher government spending in all three scenarios if the sovereign risk channel is operative (dashed lines). Even at the ZLB there is, in fact, crowding out. Without the sovereign risk channel, instead, government spending crowds in private consumption (solid lines). That said, in spite of the crowding out of domestic consumption and somewhat surprisingly, the effect of government spending on overall economic activity in Home is not necessarily weaker with sovereign risk (see the 4th row). Indeed, sovereign risk increases the spending multiplier under an unconstrained float (first column). For the other two scenarios, the medium-term effect of fiscal spending on output is larger when there is sovereign risk. This result is driven by the dynamics of net exports (bottom row), which record large surpluses in all cases, either on impact (if exchange rates are flexible) or over time (under a peg), clearly helped by a large real depreciation (3rd row). In the short-term, however, if monetary policy is constrained by either the ZLB or a peg, sovereign risk means that fiscal effectiveness is much reduced.

The consequence of sovereign risk for the exchange rate and economic dynamics is the subject of a small but significant debate. Based on the consequences of sovereign risk for the exchange rate, Krugman (2014) strongly argues that prospective sovereign risk should not be used as an argument against the use of countercyclical fiscal policy. If spreads rise with a fiscal expansion—Krugman argues—their negative effects on output will be offset by a large depreciation, which will boost external demand. Figure 5 substantiates but also qualifies Krugman's view.

Under a float, our results appear to lend support to Krugman (2014): the output multiplier of public spending actually is larger with sovereign risk. Nonetheless, it is worth stressing that the stronger expansion of output is accompanied by a sharp deterioration of domestic consumption. That is, fiscal spending causes a sharp change in the composition of aggregate demand, whereby a boom in exports more than offsets a contraction of internal demand. The output expansion is largest when the policy rate is not constrained by the ZLB, since the central bank can engineer a stronger response to the collapse in internal demand. It is less pronounced, however, when monetary policy is constrained. At the ZLB, the exchange rate still adjusts sharply upfront, favoring large external surpluses. This offsets the crowding out effect of government spending on domestic demand via the sovereign risk channel. Under a peg, instead, there is no depreciation, hence with sovereign risk the spending multiplier on impact becomes very small.

Our analysis makes clear that sovereign risk can make fiscal stabilization policy more effective, as Krugman has argued. There are several important provisos, however. First, all of this crucially hinges on the the exchange rate regime. This is so because the extent to which the exchange rate will depreciate amid sovereign risk reflects the degree of monetary accommodation. Second, while effective in preventing a contraction in economic activity, fiscal stimulus amid sovereign risk in the simulations above does not prevent (but rather amplifies) the contraction in internal demand. Our reading of this is that, in light of the above, and especially given the limits of our understanding of financial and fiscal crises, the arguments for dynamic budget correction and policies maintaining a stable fiscal outlook remain strong.[18]

In the previous section, we have entertained the notion that the stabilization of large external shocks under flexible exchange rates may benefit from a "benign coincidence", with fiscal policy becoming most effective at stabilizing domestic activity when the external shock is most detrimental. Earlier, we already qualified that the benign coincidence holds only under flexible exchange rates. The analysis above qualifies this further. The benign coincidence does not only require floating exchange rates, it also applies reliably only when sovereign risk is not an important consideration.

5 Conclusion

Almost a decade after the outburst of the global financial crisis, the world economy remains vulnerable. In particular, there is a risk that large global shocks once again cause the world economy to fall into a great recession. This is a challenge to policymaking in small open economies, which by their very openness to trade are particularly vulnerable to external shocks. In this paper we provide a stylized analysis of the effectiveness of different monetary and fiscal policies in a small open economy that faces a large external demand shock. Specifcally, we model a shock to the rest of the world's desire to save that occurs at a time when policy rates in the rest of the world are constrained, for example, due to the ZLB. The shock causes world aggregate demand to fall and a global deflationary crawl. We reassess the effect that fiscal and monetary policies (in particular, the exchange rate regime) have on the evolution of the small open economy in the wake of the shock. We explicitly account for potential constraints on either policy, in the form of a ZLB constraint on domestic monetary

[18] The strong response of net exports to a government-spending expansion is also noteworthy in light of the ongoing controversy on currency wars. Our model suggests that, in a sovereign risk crisis, even fiscal stabilization—typically targeted to sustain internal demand—tends to increase net saving in the economy, and require currency depreciation to be effective.

policy or an exchange-rate peg, or concerns with sovereign risk which may constrain fiscal policy.

We analyze in detail the specific way in which a flexible exchange rate can act as a shock absorber under circumstances which have been defining features of the great recession and which may re-occur in the near future. A central result of our analysis is that for the exchange rate to isolate the small open economy from the external shock, it needs to decouple domestic inflation from the deflationary crawl that afflicts the world economy. This requires domestic policymakers to manage a depreciation drift in the nominal exchange rate, over and above the nominal and real depreciation needed to buffer the Home economy from the collapse in external demand alone.

If monetary policy cannot manage that drift, fiscal policy—in principle—can be used to stabilize the small open economy. However, we find that fiscal policy will be an effective tool only when the monetary regime is such that it can accompany fiscal stimulus with enough monetary accommodation, and, again, the country pursues an exchange rate regime that insulates the evolution of the domestic price level from the price level abroad. If that is the case, fiscal policy turns out to be particularly effective when the effect of the external shock is largest, namely, when domestic monetary policy is temporarily constrained by the ZLB. The same does not hold under an exchange rate peg.

Modern monetary theory indeed questions the conventional wisdom from the textbook rendition of the Mundell-Fleming model, that fiscal policy is a reliable alternative to monetary policy in a currency peg or a monetary union. Furthermore we find that the conventional Mundell-Fleming logic is misleading if there is a loss of confidence in the sovereign debt market that risks affecting the domestic private sector's financial conditions. Indeed, whether sovereign risk reduces the effectiveness of spending stimulus greatly depends on the monetary regime as well. Sovereign risk greatly reduces the effectiveness of spending stimulus if the small open economy pursues a pegged exchange rate, and to a lesser extent if its monetary rates are constrained at the ZLB. The opposite is true when the small open economy has opted for floating exchange rates and its monetary policy is not constrained.

In sum, we find that the risk of another great recession strengthens the case for flexible exchange rates.

References

Amador, Manuel, Javier Bianchi, Luigi Bocola, and Fabrizio Perri (2016). "Exchange rate policies at the zero lower bound". mimeo. Federal Reserve Bank of Minneapolis.

Banerjee, Ryan, Michael B. Devereux, and Giovanni Lombardo (2016). "Self-oriented monetary policy, global financial markets and excess volatility of international capital flows". *Journal of International Money and Finance*. forthcoming.

Benigno, Gianluca, Pierpaolo Benigno, and Fabio Ghironi (2007). "Interest rate rules for fixed exchange rate regimes". *Journal of Economic Dynamics and Control 31* (7), 2196–2211.

Berkmen, S. Pelin, Gaston Gelos, Robert Rennhack, and James P. Walsh (2012). "The global financial crisis: Explaining cross-country differences in the output impact". *Journal of International Money and Finance 31* (1), 42–59.

Bocola, Luigi (forthcoming). "The Pass-Through of Sovereign Risk". *Journal of Political Economy*.

Caballero, Ricardo J., Emmanuel Farhi, and Pierre-Olivier Gourinchas (2015). "Global Imbalances and Currency Wars at the ZLB". NBER Working Papers 21670. National Bureau of Economic Research, Inc.

Christiano, Lawrence, Martin Eichenbaum, and Sergio Rebelo (2011). "When is the government spending multiplier large?" *Journal of Political Economy 119* (1), 78 –121.

Clarida, Richard, Jordi Gali, and Mark Gertler (2001). "Optimal Monetary Policy in Open versus Closed Economies: An Integrated Approach". *American Economic Review 91* (2), 248–252.

Cole, Harold L. and Maurice Obstfeld (1991). "Commodity trade and international risk sharing : How much do financial markets matter?" *Journal of Monetary Economics 28* (1), 3–24.

Cook, David and Michael B. Devereux (2011). "Optimal fiscal policy in a world liquidity trap". *European Economic Review 55* (4), 443–462.

——— (2013). "Sharing the Burden: Monetary and Fiscal Responses to a World Liquidity Trap". *American Economic Journal: Macroeconomics 5* (3), 190–228.

——— (2016). "Exchange rate flexibility under the zero lower bound". *Journal of International Economics 101*, 52–69.

Corsetti, Giancarlo, André Meier, and Gernot J. Müller (2012). "What determines government spending multipliers?" *Economic Policy 27* (72), 521–565.

Corsetti, Giancarlo, Keith Kuester, and Gernot J. Müller (2013a). "Floats, Pegs and the Transmission of Fiscal Policy". *Fiscal Policy and Macroeconomic Performance*. Ed. by Luis Felipe Cespedes and Jordi Gali. Vol. 17. Central Banking, Analysis, and Economic Policies Book Series. Central Bank of Chile. Chap. 7, 235–281.

Corsetti, Giancarlo, Keith Kuester, André Meier, and Gernot J. Müller (2013b). "Sovereign risk, fiscal policy, and macroeconomic stability". *Economic Journal 123* (566), F99–F132.

Corsetti, Giancarlo, Keith Kuester, André Meier, and Gernot J Müller (2014). "Sovereign risk and belief-driven fluctuations in the euro area". *Journal of Monetary Economics 61*, 53–73.

Corsetti, Giancarlo, Eleonora Mavroeidi, Gregory Thwaites, and Martin Wolf (2016). "Step away from the zero lower bound: small open economies in a world of secular stagnation". mimeo. Cambridge University.

De Paoli, Bianca (2009). "Monetary policy and welfare in a small open economy". *Journal of International Economics 77*, 11–22.

Eggertsson, Gauti B., Neil R. Mehrotra, Sanjay R. Singh, and Lawrence H. Summers (2016). "A Contagious Malady? Open Economy Dimensions of Secular Stagnation". NBER Working Papers 22299. National Bureau of Economic Research, Inc.

Engel, Charles (2014). "Chapter 8 - exchange rates and interest parity". *Handbook of international economics*. Ed. by Elhanan Helpman Gita Gopinath and Kenneth Rogoff. Vol. 4. Handbook of International Economics. Elsevier, 453 –522.

Erceg, Christopher J. and Jesper Lindé (2012). "Fiscal Consolidation in an Open Economy". *American Economic Review 102* (3), 186–91.

Fahri, Emmanuel and Ivan Werning (2016). "Fiscal Multipliers: Liquidity Traps and Currency Unions". In preparation, *Handbook of Macroeconomics*.

Friedman, Milton (1953). "The case for flexible exchange rates". *In: essays in positive economics*. University of Chicago Press, 157–203.

Galí, Jordi (2015). *Monetary policy, inflation and the business cycle: an introduction to the new keynesian framework*. 2nd ed. Princeton University Press.

Galí, Jordi and Tommaso Monacelli (2005). "Monetary policy and exchange rate volatility in a small open economy". *Review of Economic Studies 72*, 707–734.

Gertler, Mark and Peter Karadi (2011). "A model of unconventional monetary policy". *Journal of Monetary Economics 58* (1), 17–34.

Giannoni, Marc, Christina Patterson, and Marco Del Negro (2016). "The Forward Guidance Puzzle". Mimeo.

Kolasa, Marcin and Giovanni Lombardo (2014). "Financial Frictions and Optimal Monetary Policy in an Open Economy". *International Journal of Central Banking 10* (1), 43–94.

Kriwoluzky, Alexander, Martin Wolf, and Gernot J. Müller (2015). "Exit expectations and debt crises in currency unions". CEPR Discussion paper 10817.

Krugman, Paul (2014). "Currency Regimes, Capital Flows, and Crises". *IMF Economic Review 62* (4), 470–493.

Obstfeld, Maurice and Kenneth S. Rogoff (1996). *Foundations of International Macroeconomics*. Vol. 1. MIT Press Books 0262150476. The MIT Press.

Schmitt-Grohé, Stephanie and Martin Uribe (2003). "Closing small open economy models". *Journal of International Economics 61* (1), 163–185.

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

Sutherland, Alan (2005). "Incomplete pass-through and the welfare effects of exchange rate variability". *Journal of International Economics 65* (2), 375–399.

Woodford, Michael (2011). "Simple analytics of the government expenditure multiplier". *American Economic Journal: Macroeconomics 3* (1), 1–35.

A A New Keynesian open-economy model

Our model is a simplified version of the two-country model put forward in Corsetti et al. (2012), as we abstract from investment and wage rigidities. Home trades with the rest of the world, consolidated in Foreign. Both countries produce a variety of country-specific intermediate goods, with the number of intermediate good producers normalized to unity. A fraction n of firms is located in Home, the remaining firms $(n, 1]$ are located in Foreign. Analogously, Home accounts for a fraction $n \in [0, 1]$ of the global population. Intermediate goods are traded across borders while final goods which are bundles of intermediate goods, are not. Prices of intermediate goods are sticky in producer-currency terms. Households supply labor services only within the country where they reside, but trade assets internationally. For the sake of analytical tractability, in our baseline, they will trade a complete set of state-contingent assets.

Many of the features of the model are standard, so we keep the exposition short. We focus our exposition on Home. When necessary, we refer to foreign variables by means of an asterisk.

A.1 Households

There is a representative household in each country. Letting C_t denote a consumption basket (defined below) and H_t labor supply, the objective of the household is

$$\max E_t \sum_{k=0}^{\infty} (e^{\xi_{t+k}} \beta^k) \left(\ln C_{t+k} - \frac{H_{t+k}^{1+\varphi}}{1+\varphi} \right), \tag{A.1}$$

where ξ_t is a zero-mean shock to the time-discount factor, $\beta \in (0, 1)$ is the discount factor, and $\varphi > 0$ is the inverse of the Frisch elasticity of labor supply.

In our baseline, the household trades a complete set of state-contingent securities with the rest of the world. Letting $\mathcal{X}_{t+1}$ denote the payoff in units of domestic currency in period $t+1$ of the portfolio held at the end of period t, the budget constraint of the household is given by

$$E_t \{\rho_{t,t+1} \mathcal{X}_{t+1}\} - \mathcal{X}_t = (1-\tau)(W_t H_t + \Upsilon_t) - T_t - P_t C_t.$$

Here $\rho_{t,t+1}$ is the nominal stochastic discount factor. W_t is the nominal wage. Υ_t are the domestic firms' nominal profits. τ is a constant tax rate, T_t are lump-sum taxes. P_t is the price index for the final consumption basket. The consumption baskets themselves are not traded across borders. Their components are, however. The baskets consist of bundles A_t and B_t of, respectively, domestically and foreign produced intermediate goods. The final consumption basket C_t (C_t^*) is produced using the following aggregation technology

$$C_t = \left\{ [(1-(1-n)\upsilon)]^{\frac{1}{\sigma}} A_t^{\frac{\sigma-1}{\sigma}} + [(1-n)\upsilon)]^{\frac{1}{\sigma}} B_t^{\frac{\sigma-1}{\sigma}} \right\}^{\frac{\sigma}{\sigma-1}}, \tag{A.2}$$

$$C_t^* = \left\{ [n\upsilon]^{\frac{1}{\sigma}} (A_t^*)^{\frac{\sigma-1}{\sigma}} + [(1-n\upsilon)]^{\frac{1}{\sigma}} (B_t^*)^{\frac{\sigma-1}{\sigma}} \right\}^{\frac{\sigma}{\sigma-1}}, \tag{A.3}$$

where σ measures the terms of trade elasticity of the relative demand for domestically produced goods and $\upsilon \in [0,1]$ measures the home bias.[19]
The bundles of domestically and imported intermediate goods are defined as follows

$$A_t = \left[\left(\frac{1}{n}\right)^{\frac{1}{\epsilon}} \int_0^n A_t(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}}, \quad B_t = \left[\left(\frac{1}{1-n}\right)^{\frac{1}{\epsilon}} \int_n^1 B_t(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}}, \tag{A.4}$$

where $A_t(j)$ and $B_t(j)$ denote intermediate goods produced in Home and Foreign, respectively, and ϵ measures the elasticity of substitution between intermediate goods produced within the same country.
The household minimizes expenditures subject to (A.2) and (A.4). Specifically, let $P_t(j)$ denote the price of an intermediate good expressed in domestic currency and $\mathcal{E}_t$ the nominal exchange rate (the price of foreign currency in terms of domestic currency). We assume that the law of one price holds, so that

$$\mathcal{E}_t P_t^*(j) = P_t(j). \tag{A.5}$$

The household's expenditure minimization implicitly defines a demand function for intermediate goods. Assuming that government consumption, G_t, is a bundle isomorphic to final goods, but consisting of domestically produced goods only, global demand for a generic intermediate good produced in Home and Foreign is, respectively:

$$Y_t^D(j) = \left(\frac{P_t(j)}{P_{Ht}}\right)^{-\epsilon} \left\{ \left(\frac{P_{Ht}}{P_t}\right)^{-\sigma} \begin{bmatrix} (1-(1-n)\upsilon)C_t \\ +(1-n)\upsilon Q_t^{\sigma} C_t^* \end{bmatrix} + G_t \right\}, \tag{A.6}$$

$$Y_t^D(j)^* = \left(\frac{P_t^*(j)}{P_{Ft}^*}\right)^{-\epsilon} \left\{ \left(\frac{P_{Ft}^*}{P_t^*}\right)^{-\sigma} \left[n\upsilon Q_t^{-\sigma} C_t + (1-n\upsilon) C_t^* \right] \right\}, \tag{A.7}$$

[19] This specification follows Sutherland (2005) and De Paoli (2009). With $\upsilon = 1$, there is no home bias: if the relative price of foreign and domestic goods is unity, the fraction of domestically produced goods which ends up in the production of final goods is equal to n, while imports account for a share of $1-n$. Importantly, final goods are identical across countries in this case. A lower value of υ implies that the fraction of domestically produced goods in final goods exceeds the share of domestic production in the world economy. If $\upsilon = 0$, there is full home bias and no trade across countries.

where price indices are given by

$$P_{Ht} = \left[\frac{1}{n}\int_0^n P_t(j)^{1-\epsilon}dj\right]^{\frac{1}{1-\epsilon}}, \quad P_{Ft} = \left[\frac{1}{1-n}\int_n^1 P_t(j)^{1-\epsilon}dj\right]^{\frac{1}{1-\epsilon}}, \tag{A.8}$$

$$P_t = \left[(1-(1-n)\upsilon)P_{Ht}^{1-\sigma} + ((1-n)\upsilon)P_{Ft}^{1-\sigma}\right]^{\frac{1}{1-\sigma}}, \tag{A.9}$$

$$P_t^* = \left[n\upsilon\left(P_{Ht}^*\right)^{1-\sigma} + (1-n\upsilon)\left(P_{Ft}^*\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}, \tag{A.10}$$

and

$$Q_t = \frac{\mathcal{E}_t P_t^*}{P_t} \tag{A.11}$$

measures the real exchange rate.

A.2 Firms

Intermediate good producers sell under monopolistic competition, facing the demand function (A.6). The production function is Cobb-Douglas:

$$Y_t(j) = H_t(j) \tag{A.12}$$

where $H_t(j)$ denotes labor services employed by firm $j \in [0,n]$ in period t.
We assume that prices are set in the currency of the producer and that price setting is constrained exogenously à la Calvo, so that in each period only a fraction of intermediate good producers $(1-\alpha)$ may adjust its price. When firm j has the opportunity, it sets $\tilde{P}_t(j)$ to maximize the expected discounted value of net profits:

$$\max_{\tilde{P}_t(j)} \sum_{k=0}^{\infty} \alpha^{t+k} E_t \rho_{t,t+k} \left\{\tilde{P}_t(j) Y_{t+k}^D(j) - \Psi\left[Y_{t+k}^D(j)\right]\right\}$$

subject to the demand function (A.6) and the production function (A.12); $\Psi\left[Y_{t+k}^D(j)\right]$ measures costs. Domestic households own the firms, so profits are discounted with the domestic households' stochastic discount factor.

A.3 Monetary and fiscal policy

We assume that monetary policy is conducted by adjusting the short-term nominal interest rate:

$$R_t \equiv 1/E_t \rho_{t,t+1}.$$

As regards fiscal and budget policy, we assume that Home government spending falls on an aggregate of domestic intermediate goods only. We also posit that intermediate goods are assembled so as to minimize costs. Thus the price index for government spending is given by $P_{H,t}$. In the first part of the paper, without loss of generality, we assume that the government budget is balanced in each period by means of lump-sum taxes T_t. In the second part of the paper, we will consider a richer specification, so as to account for the possibility of sovereign risk.

A.4 Equilibrium

In equilibrium, firms and households optimally choose prices and quantities subject to their respective constraints and initial conditions while markets clear. At the level of intermediate goods we have $Y_t(j) = Y_t(j)^D$. Defining an index for aggregate output $Y_t = \left(\int_0^1 Y_t^{\frac{\epsilon-1}{\epsilon}}(j)dj\right)^{\frac{\epsilon}{\epsilon-1}}$, we obtain

$$Y_t = \left(\frac{P_{Ht}}{P_t}\right)^{-\sigma}[(1-(1-n)\upsilon)C_t + (1-n)\upsilon Q_t^{\sigma}C_t^*] + G_t. \tag{A.13}$$

Labor markets clear if

$$H_t = \int_0^n H_t(j)dj \tag{A.14}$$

Finally, asset markets clear by Walras' law.
In our analysis we focus on the limiting case $n \to 0$ for the size of the domestic economy:

$$\begin{aligned} Y_t &= \left(\tfrac{P_{Ht}}{P_t}\right)^{-\sigma}[(1-\upsilon)C_t + \upsilon Q_t^{\sigma}C_t^*] + G_t, \\ Y_t^* &= C_t^*. \end{aligned}$$

This makes the Home economy de facto a small open economy. Foreign, instead, operates like a closed economy. But – importantly – it may be a source of shocks for Home.

A.5 Incomplete financial markets

We also consider a variant of the model where financial markets are incomplete. Specifically, in the modified model, we restrict asset trade to nominally non-contingent bonds only. Moreover, we relax the assumption that government debt is neutral and allow it to impact the economy through the sovereign risk channel. Denote with D_t the stock of nominal debt issued by the fiscal authorities, assumed to have a maturity of one period. The period budget constraint of the government reads as follows:

$$Q_{D,t}D_t = D_{t-1}[1 - \delta I(\text{default in } t+1)] + G_t - \tau Y_t - T_t, \tag{A.15}$$

where $\delta > 0$ is the fixed haircut that the government applies to private holders of its own debt in those states of the world in which it defaults. $I(\text{default in } t+1)$ is the indicator function that takes a value of one in case the government defaults and is zero otherwise. As in Corsetti et al. (2013b), the probability of default in period t, p_t, may increase in the level of debt relative to steady-state output according to the following random function:

$$p_t = F_{\text{beta}}\left(\frac{D_t}{4Y}\frac{1}{\overline{d}}; \alpha_{b^g}, \beta_{b^g}\right). \tag{A.16}$$

Here $\overline{d}$ denotes the upper end of the support for the debt-to-GDP ratio and F_{beta} marks the CDF of the beta distribution. That is, from an *ex ante* perspective, the government applies the haircut δ in the next period with probability p_{t+1}. With the opposite probability, the government will comply with its promises to pay.

Finally, we postulate that lump-sum taxes adjust to stabilize debt in the following way:

$$T_t = \phi_d D_t, \text{ with } \phi_d > 1 - \beta.$$

Households trade two discount bonds on international financial markets, one paying one unit of domestic currency in the next period, the other one unit of foreign currency. Specifically, letting B_t denote the domestic-currency bond and B_t^* the foreign-currency bond, traded at price $Q_{B,t}$ and $Q_{B^*,t}$, respectively, the budget constraint of a household in Home reads as follows

$$Q_{B,t}B_t + Q_{B^*,t}B_t^*\mathcal{E}_t + P_tC_t = (1-\tau)Y_t - T_t + B_{t-1} + B_{t-1}^*\mathcal{E}_t, \tag{A.17}$$

where τ is a constant tax rate.

For tractability, we assume that sovereign default is possible only in the Home country and that the marginal investor in sovereign bonds is a small mass of risk-neutral investors in Foreign. Since Home bonds are subject to both outright sovereign default (a haircut), and the risk of changes in the price of currencies, the bond price schedule is

$$Q_{D,t} = \beta E_t\left\{[1 - \delta I(\text{default in } t+1)]\, \mathcal{E}_t/\mathcal{E}_{t+1}\right\}. \tag{A.18}$$

Sovereign default risk in the Home country, in turn, is assumed to spill over to private-sector bond prices as follows

$$Q_{B,t} = R_t^{-1}E_t[1 - \eta\delta I(\text{default in } t+1)], \quad Q_{B^*,t} = \beta E_t[1 - \eta\delta I(\text{default in } t+1]. \tag{A.19}$$

where the parameter $\eta \geq 0$ captures the degree of spillover of sovereign risk into private borrowing. Following Corsetti et al. (2013b) we rationalize a value of η larger than zero by the observation that private-sector contracts may not be fully enforced in the event of a sovereign default.[20] Importantly, however, we assume that even though lenders may not be fully serviced in the event of sovereign default, borrowers may not retain resources either.

[20]Specification (A.19) follows Kriwoluzky et al. (2015).

Rather, resources are lost in the process.
We reconsider our earlier experiments in our modified model, based on simulations throughout. For this purpose, we rely on a first order approximation to the equilibrium conditions around a deterministic steady state. As before, there is no debt and inflation in steady state. The strength of the sovereign risk channel is captured by three parameters: the sensitivity of F_{beta} to the debt level (how steeply the default risk rises in debt), the size of the haircut in the event of default, δ, and the spillover parameter η. Eventually, our assumptions imply that an increase of sovereign debt by one percent of GDP, raises the interest rates faced by the private sector by half a basis point. This corresponds to a scenario of severe fiscal stress, according to our earlier work (Corsetti et al., 2013b). We ensure stationarity by assuming that the private-sector interest rate is also elastic in the net foreign asset position of the private sector (Schmitt-Grohé and Uribe, 2003).

B System of linear difference equations

A linear approximation to the equilibrium conditions of the complete markets model yields the following system of expectational difference equations. Small letters indicate the log deviation of a variable from its steady-state value. We first focus on the baseline model allowing for $n \in [0, 1]$.

B.1 Baseline

Households supply labor according to

$$\tilde{w}_t = \varphi h_t + c_t + \frac{\tau}{1-\tau}\tilde{\tau}_t \tag{B.1}$$

$$\tilde{w}_t^* = \varphi h_t^* + c_t^* + \frac{\tau}{1-\tau}\tilde{\tau}_t^*, \tag{B.2}$$

where $\tilde{w}_t$ is the (consumption) real wage. The optimal time path of consumption satisfies:

$$c_t = E_t(c_{t+1}) - (i_t - E_t\pi_{t+1}) \tag{B.3}$$

$$c_t^* - \xi_t^* = E_t(c_{t+1}^* - \xi_{t+1}^*) - (i_t^* - E_t\pi_{t+1}^*). \tag{B.4}$$

Under complete financial markets, we have the following risk-sharing condition:

$$(c_t - \xi_t) - (c_t^* - \xi_t^*) = q_t = (1-\upsilon)s_t. \tag{B.5}$$

Intermediate good firms' price-setting behavior is given by

$$\pi_{Ht} = \beta E_t \pi_{Ht+1} + \kappa mc_t \tag{B.6}$$
$$\pi_t^* = \beta E_t \pi_{t+1}^* + \kappa mc_t^*, \tag{B.7}$$

where marginal costs are given by

$$mc_t = \tilde{w}_t - q_{H,t} \tag{B.8}$$
$$mc_t^* = \tilde{w}_t^* - q_{F,t}^*. \tag{B.9}$$

The aggregate production function is given by

$$y_t = h_t \tag{B.10}$$
$$y_t^* = h_t^*. \tag{B.11}$$

Relative prices satisfy

$$\pi_{Ht} = q_{Ht} - q_{Ht-1} + \pi_t \tag{B.12}$$
$$\pi_{Ft}^* = q_{Ft}^* - q_{Ft-1}^* + \pi_t^*, \tag{B.13}$$

as well as

$$-q_t + q_{Ht} = q_{Ht}^* \tag{B.14}$$
$$-q_t + q_{Ft} = q_{Ft}^*. \tag{B.15}$$

From the definition of the real exchange rate we have

$$q_{Ft} - q_{Ft-1} = de_t + \pi_t^* - \pi_t + q_{Ft}^* - q_{Ft-1}^*. \tag{B.16}$$

Deflated price indices

$$0 = (1 - (1 - n)\omega)q_{Ht} + (1 - n)\omega q_{Ft} \tag{B.17}$$
$$0 = (1 - n\omega)q_{Ft}^* + n\omega q_{Ht}^*. \tag{B.18}$$

Finally, there is market clearing:

$$y_t = (1 - n)\upsilon(c_y c_t^* + \sigma c_y q_t) - \sigma c_y q_{Ht} + (1 - (1 - n)\upsilon)c_y c_t + (1 - c_y)g_t \tag{B.19}$$
$$y_t^* = n\upsilon(c_t - \sigma q_t) - \sigma q_{Ft}^* + (1 - n\upsilon)c_t^*. \tag{B.20}$$

B.2 Incomplete markets model

The incomplete markets model assumes $n \to 0$, that is, Home is small. Instead of the risk-sharing condition B.5, equilibrium requires the following UIP condition to hold:

$$r_t - r_t^* = E_t e_{t+1} - e_t.$$

Also, we need to keep track of private-sector bond holdings. Assuming that foreign-currency bonds are in zero net supply, we have:

$$\beta \hat{b}_t + \hat{c}_t \quad = \quad \hat{b}_{t-1} + (1-\tau) y_t - \hat{c}_t - c_y q_{H,t} - \hat{t}_t. \tag{B.21}$$

$$\tag{B.22}$$

If the sovereign risk-channel is operative, we need to keep track of government debt:

$$\beta \hat{d}^r_{t+1} \quad = \quad \hat{d}^r_t + \hat{g}_t - \hat{t}^r_t - \tau y_t \tag{B.23}$$

$$\hat{t}_t \quad = \quad \psi_d \hat{d}_t. \tag{B.24}$$

Here, the second equation determines the adjustment of taxes to debt. Eventually, the sovereign risk channel alters the Euler equation in Home

$$c_t = E_t c_{t+1} - (i_t - E_t \pi_{t+1} + \chi d_t + \gamma \hat{b}_t),$$

where χ captures the pass-through of sovereign risk (which rises in public debt) into private borrowing conditions; $\gamma > 0$ makes the effective interest rate dependent on the net foreign asset position.