Fixed on Flexible

Rethinking Exchange Rate Regimes after the Great Recession

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Abstract

The zero lower bound problem during the Great Recession has exposed the limits of monetary autonomy, prompting a re-evaluation of the relative benefits of currency pegs and monetary unions (see e.g. Cook and Devereux, 2016). We revisit this issue from the perspective of a small open economy. While a peg can be beneficial when the recession originates domestically, we show that a float dominates in the face of deflationary demand shocks abroad. When the rest of the world is in a liquidity trap, the domestic currency depreciates in nominal and real terms even in the absence of domestic monetary stimulus (if domestic rates are also at the zero lower bound)—enhancing the country's competitiveness and insulating to some extent the domestic economy from foreign deflationary pressure.

Keywords: External shock, Great Recession, Exchange rate, Zero lower bound, Exchange rate peg, Currency union, Fiscal Multiplier, Benign coincidence

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1 Introduction

The classical case for flexible exchange rates, going back at least to Friedman (1953), rests on two main arguments. Without the constraint of a currency target, first, policymakers are free to adjust the domestic monetary stance efficiently in response to business cycle disturbances; second, they can pursue their preferred rate of inflation. In a world of high capital mobility, a country foregoes these options if it commits to an exchange rate peg or joins a monetary union. Yet, during the Great Recession, a number of countries ran into the problem of the zero lower bound (ZLB) on interest rates. The ZLB de facto constrains the policymakers' ability to respond to adverse cyclical developments (at some level, just like currency pegs do), and forced them to accept inefficient deflation. In light of the ZLB problem, then, would (constrained) monetary autonomy still remain preferable to a fixed exchange rate?

In this paper, we revisit this new dimension in the debate on exchange rate regimes motivated by the Great Recession. In a noted contribution, Cook and Devereux (2016) have argued that the nominal anchor implied by a fixed exchange rate regime may be particularly beneficial in countries exposed to the risk of a liquidity trap, whereas flexible exchange rates may fail to deliver efficient stabilization. We reconsider the argument from the vantage point of small open economies facing either a world-wide Great Recession, or a large domestic demand shock. We show that while a peg can be beneficial when the recession originates from a domestic shock, the ranking of the two regimes reverses when the recessionary impulse comes from abroad. Facing low external demand in a deflationary environment, the benefits from floating rates as a shock absorber remain large—even if monetary policy is constrained by the ZLB. A peg, instead, can actually make things substantially worse. Moreover, in general, at the ZLB fiscal policy is an effective substitute for monetary policy amid flexible exchange rates (much less so under a peg) regardless of the origin of the shock. We conclude that the ZLB problem does not generally undermine the classical case for monetary autonomy in small open economies.

We carry out our analysis using a standard New Keynesian two-country model, but focus on the domestic economy which we assume to be small.[1] The model is deliberately stylized such that we are able to derive all our results in closed form (based on a linear approximation of the equilibrium conditions). This, in our view, is one valuable contribution of our analysis. However, we also perform a numerical analysis in order to gauge the relevance of our results from both a quantitative and a welfare point of view.

[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) who, in turn, build on the New Open Economy Macroeconomics literature (Obstfeld and Rogoff, 1996).

Our goal is to reassess the ability of the exchange rate to play the role of a shock absorber when monetary policy is constrained because policy rates are at the ZLB (and forward guidance and other instruments may not be available or not produce efficient stabilization). Consistent with this goal, we contrast three alternative regimes: an unconstrained float, where monetary policy can always pursue a conventional Taylor-type rule targeting the natural rate; a float where monetary policy pursues a Taylor rule in normal times but is unable to adjust interest rates for an extended period; and a (credible) exchange rate peg. For each regime, we distinguish along another dimension, namely, between domestic and foreign demand shocks as the source of the recession—a distinction that turns out to be crucial for the relative performance of the alternative monetary and exchange rate regimes.

Our main results are as follows. For the case of a small open economy facing a Great Recession abroad, we first provide an analytical illustration of the role of floating rates as a shock absorber. We assume that the recession abroad is due to an adverse demand shock which is not cushioned by monetary policy, possibly because foreign rates abroad are at their ZLB, while domestic policy rates remain unconstrained. In this context, the benefits of exchange rate flexibility are fully in line with the classical view. From the perspective of the domestic economy, upfront depreciation stabilizes the demand, both external and domestic, for domestically produced goods. In addition, sustained depreciation decouples domestic prices from any deflationary crawl that may haunt the rest of the world.

Second, and this is what we consider the most novel aspect of our analysis, we establish that flexible exchange rates continue to operate as a shock absorber vis-à-vis a demand-driven worldwide recession, even when domestic monetary policy is also constrained by the ZLB. We show that, when the rest of the world is in a liquidity trap, the domestic currency depreciates in nominal and real terms despite no change in domestic policy instruments. An upfront weakening of the currency allows the country to enjoy both the benefits from enhanced competitiveness and some insulation from the deflationary drift prevailing abroad, although to a lesser extent than in case monetary policy is unconstrained. It is worth stressing that this result is specific to a world-wide liquidity trap: if foreign rates are not at the ZLB, foreign monetary authorities would respond to adverse cyclical development with an expansion, resulting in domestic appreciation.[2]

Third, much in contrast, we show that a currency peg performs poorly vis-à-vis a world-wide recession. Not only does the country give up the benefits from monetary autonomy in

[2]The Great Recession has also triggered new research on the desirability of capital controls and, more in general, macro prudential policies. While we abstract from these issues, it is clear that additional policy instruments may help addressing the ZLB problem or, more in general, the limits of monetary policy, see Benigno et al. (2016) and the literature on policy dilemma after Rey (2016).

stabilizing current demand. This regime also implies a commitment to anchor Home prices at the Foreign price level and hence imports the deflationary drift (the liquidity trap) in the rest of the world. Worse, it does so to such an extent that the exchange rate actually appreciates in real terms. Rising real interest rates depress Home consumption demand, compounding the negative effects of a falling external demand and competitiveness losses.

Results change radically when the recessionary shock has a domestic origin. Our fourth contribution consists of revisiting Cook and Devereux (2016) for a small open economy, using our tractable model specification. When the adverse demand shock originates in the domestic economy (and does not impact the rest of the world), the exchange rate peg easily outperforms regimes of constrained monetary autonomy. Key to this finding is that, under a peg, a stable foreign price level anchors long-run price level expectations, preventing adverse deflationary developments from large shocks. Instead, such deflationary developments are unavoidable with floating rates if monetary policy is constrained by the ZLB and lacks a credible long-run target for the price level.[3]

We close our analysis by bringing into the picture the role of fiscal policy as an alternative stabilization tool. As established in earlier work of ours (Corsetti et al., 2013a), fiscal policy is rather ineffective under a peg because, by anchoring long-run expectations of the price level, an exchange rate target limits the inflationary impact of public spending. However, a strong inflationary impact of fiscal policy is precisely what magnifies the size of the multiplier at the ZLB (see also Erceg and Lindé, 2012; Fahri and Werning, 2016; Woodford, 2011), independently of the (domestic or external) origin of the shock. This result can be seen as one more reason to hold that the ZLB problem does not necessarily weaken the case for flexible rates in small open economies: precisely in situations in which the ZLB can have adverse effects on economic activity, there is a "benign coincidence", that is, fiscal policy can be expected to become a much more effective tool of stabilization. Of course, the recourse to fiscal policy may be limited by economic or institutional constraints. Indeed, our overall conclusions are best framed using the logic of the classic work of Poole (1970): the choice between a float or a peg vis-à-vis the risk of a ZLB problem is ultimately informed by the type of shocks an economy is mostly vulnerable to, in relation to the policy instruments available to domestic policymakers.[4]

[3] See also Groll and Monacelli (2016). They stress that in the absence of commitment by the central bank, an exchange rate peg may dominate a flexible exchange rate regime quite independently of the ZLB. They focus on cost push shocks.

[4] A potentially important factor in this choice is nominal rigidities in the export market. In our paper we consider the case of "producer currency pricing" or PCP: product prices are sticky in the currency of the exporters. In the literature, the case of "local currency pricing" or LCP (prices are sticky in the currency of the destination market) gave rise to a debate on the desirability of fixed exchange rate (see Devereux and Engel, 2003; Duarte and Obstfeld, 2008, among others). It is now clear that the optimal policy under LCP does not

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. As do Schmitt-Grohé and Uribe (2016), we show that macroeconomic adjustment can be particularly painful under a currency peg, although for different reason than nominal wage rigidities. Our analysis also abstracts from a number of issues and considerations which are likely to have a bearing on the costs and benefits of flexible exchange rates. One such issue is sovereign risk, as highlighted by Krugman (2014) and discussed in previous work of ours.[5] Another is international policy coordination in a ZLB environment as in Cook and Devereux (2013).[6]

A recent body of literature has addressed similar questions in a model where the global economy is in a secular stagnation steady state, whereby inefficiently low economic activity at the ZLB is a permanent, rather than temporary condition (Caballero et al., 2015; Eggertsson et al., 2016). This literature is focused on the possibility of negative spillovers from inward-looking policies and the risk of "currency wars," issues that we abstract from in our study. 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 permanent stagnation and reach a full-employment steady state. There is a notable common conclusion: vis-à-vis a worldwide recession, exchange rate flexibility is required to ensure that domestic inflation rises enough to overcome the ZLB problem. Exchange rate flexibility appears once more a pre-condition for maintaining stability when the world economy suffers from a slump, independently of whether this slump is temporary or permanent.

The text is organized as follows. Section 2 outlines the model, while Section 3 provides a summary of the linear approximations to the equilibrium conditions. Section 4 provides closed form results based on the linearized model, while Section 5 illustrates the quantitative relevance of these results through model simulations. It also provides a welfare assessment. Section 6 discusses the fiscal implications. Section 7 concludes. An extensive appendix provides derivations and proofs for results in the paper.

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generally support fixed rates (with the exception of a few notable cases), and can easily imply a variance of the nominal exchange rate higher than in the case of PCP (Corsetti et al., 2010). An additional, important case is that of "Dollar pricing" or DP, where exports prices are sticky in a vehicle currency (Burstein and Gopinath, 2014; Casas et al., 2016). In our context, depending on the strength of nominal rigidities, LCP or DP could reduce the benefit from floating rates at the ZLB, without however necessarily changing the result. We leave an exploration of these cases to future research.

[5] In previous work of ours, we have extensively analyzed the consequences of sovereign risk when monetary policy is constrained by the ZLB as well as in currency unions. For a discussion see also the early version of this paper, Corsetti et al., 2013b.

[6] Amador et al. (2016), instead, consider how to overcome the ZLB problem with exchange rate and international reserve policies in a world with segmented financial markets. Their analysis is motivated by the recent Swiss experience of large capital inflows.

2 A New Keynesian two-country model

We consider a tractable, if stylized version of the model laid out in Corsetti et al. (2012). There are two countries, Home and Foreign, that have identical structures. They differ, though, in terms of size, fiscal and monetary policies, and the shocks that they are exposed to. A small fraction of firms and households are located in Home. In case $n \to 0$ Home operates like a small open economy (see also De Paoli, 2009). The remaining fraction $1-n$ of households and firms are located in Foreign. For the purpose of our analysis it is important to explicitly model the structure of both Home and Foreign, because the specific developments in Foreign impact Home through both trade and financial markets.[7] The main building blocks of the model are standard. In the following, we thus provide a compact exposition of the model while focusing on Home. When necessary, we refer to Foreign variables by means of an asterisk. Readers familiar with the model may directly move to Section 3, which spells out the linearized equilibrium conditions.

2.1 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 to maximize expected life-time utility

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

$\beta \in (0,1)$ is the discount factor and ξ_t is a unit-mean shock to the time-discount factor, a "demand shock" for short. $\varphi > 0$ is the inverse of the Frisch elasticity of labor supply, and E_t is the expectations operator.

In our baseline, the household trades a complete set of state-contingent securities with the rest of the world.[8] 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

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

[7] This explicit consideration of Foreign sets apart our exercise from the typical treatment of a small open economy. Apart from this, Home is identical to the small open economy of Galí and Monacelli (2005), except that we allow for government consumption, and for tractability we restrict preferences to log-utility and assume that the trade-price elasticity is unity throughout (Cobb-Douglas case).

[8] We assume complete markets to ensure analytical tractability. By means of numerical simulations we verify that the main results of our analysis are unchanged if we allow for international trade in non-contingent bonds only. Note that our setup implies unitary elasticities for intertemporal subsitution as well as for trade. Differences between complete and incomplete markets may become larger for elasticities sufficiently below unity, and/or in the presence of non-stationary shocks or "news shocks" (Corsetti et al., 2008).

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. T_t are lump-sum taxes. P_t is the price index for the final consumption basket. The components of the consumption baskets are traded across borders. The baskets consist of bundles $C_{H,t}$ and $C_{F,t}$ of, respectively, Home and Foreign-produced intermediate goods. The final consumption basket C_t (C_t^*) is produced using the following aggregation technology

$$C_t = \frac{C_{H,t}^{(1-(1-n)\upsilon)} C_{F,t}^{(1-n)\upsilon}}{(1-(1-n)\upsilon)^{1-(1-n)\upsilon}((1-n)\upsilon)^{(1-n)\upsilon}}, \tag{2}$$

$$C_t^* = \frac{{C_{H,t}^*}^{n\upsilon} {C_{F,t}^*}^{(1-n\upsilon)}}{(n\upsilon)^{n\upsilon}(1-n\upsilon)^{1-n\upsilon}}. \tag{3}$$

Here $\upsilon \in [0,1]$ measures the home bias in consumption.[9]

The bundles of Home- and Foreign-produced goods are defined as follows

$$C_{H,t} = \left[\left(\frac{1}{n}\right)^{\frac{1}{\epsilon}} \int_0^n C_{H,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj\right]^{\frac{\epsilon}{\epsilon-1}}, \quad C_{F,t} = \left[\left(\frac{1}{1-n}\right)^{\frac{1}{\epsilon}} \int_n^1 C_{F,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj\right]^{\frac{\epsilon}{\epsilon-1}}, \tag{4}$$

where $C_{H,t}(j)$ and $C_{F,t}(j)$ denote differentiated intermediate goods produced in Home and Foreign, respectively, and $\epsilon > 1$ measures the elasticity of substitution between intermediate goods produced within the same country.

In maximizing utility, the household takes prices as given. Let $P_t(j)$ denote the price that the producer of good j charges in Home, denoted in Home's currency. Let $P_t^*(j)$ denote the price that the producer charges for the same good in Foreign, expressed in Foreign's currency. We assume that the law of one price holds at the level of each intermediate good, so that

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

$\mathcal{E}_t$ is the nominal exchange rate measured as the price of foreign currency in terms of domestic currency. A rise in $\mathcal{E}_t$, thus, marks a nominal depreciation from Home's perspective.

The price indices for the bundle of domestically produced goods and for imported goods, respectively, are given by

$$P_{H,t} = \left[\frac{1}{n} \int_0^n P_t(j)^{1-\epsilon} dj\right]^{\frac{1}{1-\epsilon}}, \quad P_{F,t} = \left[\frac{1}{1-n} \int_n^1 P_t(j)^{1-\epsilon} dj\right]^{\frac{1}{1-\epsilon}}. \tag{6}$$

[9]This specification of home bias 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, Home's consumption basket contains a share n of Home-produced goods, and a share of $1-n$ of imported goods. 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.

The consumer price indexes in Home and Foreign are given by

$$P_t = P_{H,t}^{1-(1-n)\upsilon} \, P_{F,t}^{(1-n)\upsilon}, \tag{7}$$

$$P_t^* = P_{H,t}^{*\ n\upsilon} \, P_{F,t}^{*\ 1-n\upsilon}. \tag{8}$$

We define the Home terms of trade, S_t, as the price of imports in Home relative to the price of exports:

$$S_t = \frac{P_{F,t}}{P_{H,t}}. \tag{9}$$

A rise in S_t marks a depreciation of the Home terms of trade (Home goods becoming relatively cheaper).

The household's problem defines the households's demand function for Foreign-produced and Home-produced goods. Demand for government consumption, G_t, is assumed to be isomorphic to the Home households' demand for domestically produced goods. That is Home government consumption falls on Home-produced goods only. Global demand for a generic intermediate good produced in Home and Foreign is, respectively:

$$Y_t^D(j) = \left(\frac{P_t(j)}{P_{H,t}}\right)^{-\epsilon} \left\{ \left(\frac{P_{H,t}}{P_t}\right)^{-1} \begin{bmatrix} (1-(1-n)\upsilon)C_t \\ +(1-n)\upsilon S_t^{1-\upsilon} C_t^* \end{bmatrix} + G_t \right\}, \tag{10}$$

$$Y_t^D(j)^* = \left(\frac{P_t^*(j)}{P_{F,t}^*}\right)^{-1} \left\{ \left(\frac{P_{F,t}^*}{P_t^*}\right)^{-1} \left[n\upsilon S_t^{-(1-\upsilon)} C_t + (1-n\upsilon)C_t^* \right] \right\}. \tag{11}$$

2.2 Firms

Intermediate goods producers sell under monopolistic competition, facing the demand function (10). The production function is linear in labor:

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

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 their price. When firm j has the opportunity, it sets $\tilde{P}_t(j)$ to maximize the expected discounted value of net profits:

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

subject to the demand function (10) and the production function (12). Domestic households own the firms, so profits are discounted with the domestic households' stochastic discount factor.

2.3 Fiscal policy and monetary policy

We assume that the government budget is balanced in each period by means of lump-sum taxes T_t. Monetary policy is conducted by adjusting the short-term nominal interest rate:

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

The monetary regime will be defined further below.

2.4 Market clearing and 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 $Y_t(j) = Y_t^D(j)$. Defining an index for aggregate output as $Y_t = \left(\int_0^1 Y_t^{\frac{\epsilon-1}{\epsilon}}(j)dj\right)^{\frac{\epsilon}{\epsilon-1}}$, we obtain

$$Y_t = \left(\frac{P_{H,t}}{P_t}\right)^{-1} \left[(1-(1-n)\upsilon)C_t + (1-n)\upsilon S_t^{1-\upsilon} C_t^*\right] + G_t. \tag{13}$$

Labor markets clear if

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

Finally, the markets for all securities have to clear in equilibrium.

From here onward, we will focus only on the limiting case $n \to 0$. The Foreign consumption basket will almost exclusively contain Foreign-produced goods. Consumer and producer price level in Foreign, therefore, will coincide. Effectively, the Foreign economy operates like a closed economy. From the perspective of the small open Home economy, Foreign can be an important source of shocks, transmitted across borders via financial markets and trade.

2.5 Transmission channels: financial markets and trade

Before delving into our analysis, we find it useful to spell out how shocks propagate across borders, distinguishing between a financial and a trade channel.

As regards the financial channel, under complete markets, the residents in the two countries can optimally insure against key risks such as productivity, income, preference shocks, and policies. Financial contracts and assets are optimally traded up to ensure that, at the margin, the utility value of a unit of currency is equalized across borders in any contingency—adjusting for possible differences in initial wealth. With log utility, and assuming identical initial wealth in Home and Foreign, the international condition for perfect risk-sharing implies

$$C_t/\xi_t = S_t^{1-\upsilon} C_t^*/\xi_t^*. \tag{15}$$

Absent movements in the terms of trade (or home bias), and without demand preference shocks, equation (15) implies a perfect correlation of Home and Foreign consumption in equilibrium. More generally, however, consumption levels will typically not be equalized perfectly. The reason why the terms of trade are part of (15) is that the same unit of currency may have a different real value when the composition of consumption baskets is not identical across the border. To the extent that there is home bias in consumption ($\upsilon < 1$), when the terms of trade depreciate the price of the Home consumption basket declines relative to Foreign's. In this case, efficient risk sharing implies that domestic consumption rises relative to consumption in the rest of the world. In other words, the terms of trade can insulate Home consumption and, thereby, output (partly) also from a fall in Foreign demand. By the same token, the reason why preference shocks are part of the risk-sharing condition is that the same real unit of income can have different utility value, when the stochastic discount factor is subject to exogenous variations in the utility that households derive from present, as opposed to future, consumption.

Specifically, preference shocks, ξ_t and ξ_t^*, make Home or Foreign households, respectively, appreciate present-period felicity more than future felicity. A low value of ξ_t, therefore, makes Home households postpone consumption and save more, with a commensurate effect on international risk sharing. Following the literature, we will assume that these saving shocks will be the driver of sharp fluctuations in demand, driving down the natural rate of interest, and potentially giving rise to the zero lower bound problem.

The trade channel of international transmission can instead by illustrated using the following equilibrium relation between Home output and its demand that follows from (13) (as $n \to 0$).

$$Y_t = (1-\upsilon)C_t S_t^{\upsilon} + \upsilon C_t^* S_t + G_t,$$

Next to the financial transmission to domestic output (which works through C_t), Foreign shocks can transmit through trade. The term S_t^{υ} on the first summand on the right-hand side captures "expenditure switching" effects of terms of trade movements on the demand for local goods by domestic consumers. All else equal, a change in the terms of trade will have a larger effect on domestic production if there is little home bias (that is, if υ is close to one). The second summand gives the direct effect of Foreign demand on Home output. Again, movements in the terms of trade imply expenditure switching by Foreign consumers. The final term is Home demand for government consumption.

Observe that international relative price (terms of trade) movements are centerstage in both the financial and trade channels. In order to characterize these channels fully, we have to spell out price determination in both Home and Foreign. We turn to this in detail next, in the linearized version of the model.

3 Linear approximation

This section presents linear approximations of the equilibrium conditions of the model around a deterministic and symmetric zero-inflation steady state (more details are provided in the appendix). As before, Foreign variables are indexed with an asterisk. Small letters generally refer to log deviations of the variable from its steady-state value. The exception is $\widehat{g}_t$, which denotes deviations of government consumption from the steady state in levels. In what follows, we focus on demand shocks which are the result of shocks to the effective discount factor. They may originate in Foreign or Home. In Section 6, we consider shocks to government spending.

3.1 Foreign

Since Foreign operates like a closed economy, we can study the equilibrium dynamics of its variables in isolation. The only shock that affects Foreign is the Foreign demand shock ξ_t^*, the law of motion of which will be specified later.

The consumption Euler equation of the Foreign household gives rise to the dynamic IS equation:

$$y_t^* \quad = \quad E_t y_{t+1}^* - (r_t^* - E_t \pi_{t+1}^* + E_t \Delta \xi_{t+1}^*). \tag{16}$$

where r_t^* is the Foreign nominal interest rate, π_t^* the Foreign inflation rate and Δ marks the difference operator—the Foreign demand shock is additive to the real rate of interest. According to this equation, Foreign output, y_t^*, is increasing in expected output, and decreasing in the real interest rate, reflecting the fact that residents optimally smooth consumption over time. All else equal, a lower realization of ξ_t^* (a lower preference for consumption today in Foreign) raises $E_t \Delta \xi_{t+1}^* := E_t \xi_{t+1}^* - \xi_t^*$, which means that Foreign output falls.

The evolution of Foreign prices is determined by the New Keynesian Phillips curve

$$\pi_t^* = \beta E_t \pi_{t+1}^* + \kappa \left(1 + \varphi\right) y_t^*. \tag{17}$$

$\kappa := (1-\alpha)(1-\alpha\beta)/\alpha$ measures the slope of the Phillips curve. The larger α, the more rigid are prices and the less will a change in Foreign marginal costs transmit to Foreign inflation. We abstract from productivity shocks, so marginal costs are given by the wage. The larger φ, the less elastic the labor supply and the more wages (and, thus, marginal costs) rise with a rise in production. Inflation is defined as the change in the price level, p_t^*,

$$\pi_t^* = p_t^* - p_{t-1}^*. \tag{18}$$

The last equation for Foreign is an instrument rule for the foreign central bank that describes the behavior of Foreign monetary policy in "normal times":

$$r_t^* = \phi_\pi \pi_t^* - E_t \Delta \xi_{t+1}^*. \tag{19}$$

Here, $\phi_\pi > 1$ is the response of the interest rate to inflation. We nonetheless allow for monetary policy in Foreign to be temporarily constrained, in which case it keeps the interest rate at the steady-state value. Note that, in order to ensure that this constraint is economically binding, we abstract from issues related to forward guidance, the effectiveness of which requires some degree of credibility of policy announcements. By the same token, we also abstract from non-conventional balance sheet policies, such as Quantitative Easing.

Observe that, in our model specification, as long as the Foreign central bank can pursue rule (19), the demand shock in Foreign has no effect on foreign inflation or output. When monetary policy is constrained, instead, the foreign demand shock will affect foreign output and inflation.

3.2 Home

Given Foreign variables, the laws of motion for the domestic demand shock, ξ_t, and the government spending shock in Home, a description of the Home economy rests on the same three equations of the canonical New-Keynesian model spelled out for Foreign: a dynamic IS-relationship, a Home Phillips curve, and a specification of monetary policy. In addition, a characterization of equilibrium will also require equations capturing asset pricing and the determination of the terms of trade.

The dynamic IS-relation in Home is derived by combining the first-order condition for consumption and saving of Home households with the Home goods-market clearing condition, the risk-sharing condition and the definition of the Home consumer-price index:

$$y_t \;=\; E_t y_{t+1} - \big(r_t - E_t \pi_{H,t+1} + (1-\upsilon) E_t \Delta \xi_{t+1} + \upsilon E_t \Delta \xi_{t+1}^*\big) - E_t \Delta \widehat{g}_{t+1}. \tag{20}$$

y_t, is Home output, r_t the nominal interest rate in Home, and $\pi_{H,t}$ Home producer-price inflation. The term in government spending has a negative sign since, holding constant output, higher government spending means lower consumption. The terms involving the Home and Foreign demand shocks are additive to the Home real rate of interest (defined using Home producer price inflation). All else equal, a lower realization of either ξ_t or ξ_t^* (a stronger preference for postponing consumption to the future in Home or Foreign) is recessionary. Note that openness (υ) plays an important role here. If the Home economy does not exhibit home bias in consumption, $\upsilon = 1$, the Home demand shock will not appear, and only the

Foreign demand shock matters. With home bias, instead, both Home and Foreign demand shocks have a bearing on the IS relation.

The Home New Keynesian Phillips curve links Home producer-price inflation to expected inflation and marginal costs:

$$\pi_{H,t} \quad = \quad \beta E_t \pi_{H,t+1} + \kappa \left[(1+\varphi)\, y_t - \widehat{g}_t + \upsilon(\xi_t - \xi_t^*) \right] \tag{21}$$

As for Foreign, Home marginal costs depend on the Home wage. The wage rises with demand for the domestic good. Hence it is increasing in output. It is decreasing in government consumption because, for given output, public spending reduces domestic consumption. In addition, the wage will depend on preference shocks affecting the relative desire of Home and Foreign households to consume in the current period.[10]

From (9), linearizing the Home terms of trade we have:

$$s_t = e_t + p_t^* - p_{H,t}. \tag{22}$$

Foreign being large, the Foreign consumer price level equals the Foreign producer price. Holding the law of one price, the price for imports in Home is $e_t + p_t^*$ (recall that e_t, the nominal exchange rate, is defined as the price of foreign currency in units of domestic currency, and $p_{H,t}$ is the producer price level in Home). Note that, by definition,

$$\pi_{H,t} = p_{H,t} - p_{H,t-1}. \tag{23}$$

We can write risk sharing condition (15) as follows

$$c_t - \xi_t = (1-\upsilon)s_t + c_t^* - \xi_t^*. \tag{24}$$

Combining good market clearing (13) with (24), we obtain

$$y_t = s_t + y_t^* + \widehat{g}_t + (1-\upsilon)\left(\xi_t - \xi_t^*\right). \tag{25}$$

In equilibrium, Home output relates positively to the terms of trade, Foreign output, Home government consumption and the demand shock in relative terms.

3.2.1 Monetary regimes in Home

Since we are interested in understanding the role of the exchange rate as a shock absorber in relation to constraints on monetary policy, we solve the model under alternative monetary

[10] One reason is that the relative preference shocks move Home consumption; recall (15). If the Home preference for current consumption rises (ξ_t rises), all else equal, Home consumption rises, which pushes up the wage. Conversely, the wage falls in shocks that raise the desire to consume today in Foreign.

and exchange rate regimes for Home, focusing on three scenarios.

Flexible exchange rate – natural rate rule.

In our first scenario, monetary policy in Home operates under a flexible exchange rate regime and follows a standard interest rate rule. Specifically, monetary policy in Home aims to track the natural rate of interest, r_t^n, and sets the nominal interest rate so as to stabilize Home producer-price inflation. This implies that, in nominal terms, the policy rate is set according to:

$$r_t = \phi_\pi \pi_{H,t} + r_t^n, \text{ with } \phi_\pi > 1. \tag{26}$$

This simple rule commands the central bank to stabilize inflation.[11] The natural rate of interest in Home (that would prevail under flexible prices in Home) is given by

$$r_t^n = -\frac{\varphi}{1+\varphi} E_t \Delta \widehat{g}_{t+1} - \frac{1+\varphi(1-\upsilon)}{1+\varphi} E_t \Delta \xi_{t+1} - \frac{\upsilon\varphi}{1+\varphi} E_t \Delta \xi_{t+1}^*. \tag{27}$$

The corresponding natural levels of output and the terms of trade are

$$y_t^n = \frac{1}{1+\varphi}\widehat{g}_t - \frac{\upsilon}{1+\varphi}\left(\xi_t - \xi_t^*\right), \tag{28}$$

$$s_t^n = -y_t^* - \frac{\varphi}{1+\varphi}\widehat{g}_t - \frac{1+\varphi(1-\upsilon)}{1+\varphi}(\xi_t - \xi_t^*). \tag{29}$$

Flexible exchange rate – rule constrained by the zero lower bound on interest rates.

In our second scenario, we allow for the fact that, under the regime specified above, monetary policy can become constrained further if shocks cause the natural rate to become too low to be matched by short-term policy (nominal) rates (given inflation expectations). In order to capture this scenario, we will assume that for some time Home nominal interest rates do not react to shocks. Thereafter, Home monetary policy reverts to policy rule (26). It is worth stressing that this way of conducting monetary policy is not optimal given this zero lower bound-type constraint. Optimal policy would require commitment—in particular, forward guidance. This choice of suboptimal policy is intentional, as we are interested in reconsidering the classic notion of flexible exchange rates providing insulation against shocks when monetary policy is not necessarily efficient.

Fixed exchange rate

In our third and last scenario we consider a regime of permanently (hence credibly) fixed exchange rates for Home. As far as macroeconomic stabilization is concerned, this credible

[11] We focus on a simple rule rule here for both realism and tractability. Rules like (26) need not be optimal, but tend to approximate the optimal policy quite well.

peg is equivalent to membership in a currency union—we can refer to the two regimes interchangeably. Formally, Home monetary policy adjusts interest rates so as to make sure that for all periods

$$e_t = 0. \tag{30}$$

In doing so, it gives up monetary autonomy. In equilibrium, by uncovered interest parity, when the nominal exchange rate is fixed, Home's interest rate follows the Foreign rate one-to-one.

The model is closed by assuming that tax policy is Ricardian and relies on lump-sum taxes. We specify fiscal policy, $\widehat{g}_t$ and the law of motion for the Home savings shocks below.

3.2.2 Exchange rate dynamics

For future reference we also note that the uncovered parity condition will be satisfied in equilibrium:[12]

$$r_t - r_t^* = E_t \Delta e_{t+1}. \tag{31}$$

Below, we derive the equilibrium exchange rate as a function of policy rates and inflation by expanding the uncovered interest rate parity condition (31) as follows:

$$e_t - (p_{H,t-1} - p_{t-1}^*) = E_t(e_{t+1} - p_{H,t} - p_t^*) + (r_t^* - r_t + \pi_{H,t} - \pi_t^*).$$

This expression can be iterated forward, using the fact that, under our assumptions, the terms of trade, interest rates, and inflation rates are all stationary.[13] Rearranging terms as in Engel (2014), we have that

$$e_t = E_t \sum_{k=0}^{\infty} (r_{t+k}^* - r_{t+k} + \pi_{H,t+k} - \pi_{t+k}^*) + (p_{H,t-1} - p_{t-1}^*). \tag{32}$$

That is, in equilibrium, today's nominal exchange rate depends on two terms: the sum of future gaps in real interest rates (first part) and the lagged terms of trade (second part).

3.3 Equilibrium

Given initial conditions for foreign prices, (p_{-1}^*), and a law of motion for the foreign demand shock (ξ_t^*), the foreign variables $(y_t^*, \pi_t^*, p_t^*, r_t^*)$ are determined by equations (16) – (18) and a specification for Foreign monetary policy such as (19).

[12]The condition can be derived combining equations (16), (20), (22), and (25).

[13]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.

Given initial conditions for Home producer prices and the terms of trade, $(p_{H,-1}, s_{t-1})$, a law of motion for the domestic demand shock (ξ_t), and of fiscal policy $(\widehat{g}_t)$, as well as the equilibrium law of motions $(y_t^*, \pi_t^*, p_t^*, r_t^*, \xi_t^*)$ for Foreign, the Home variables $(y_t, \pi_{H,t}, p_{H,t}, s_t, e_t, r_t, r_t^n)$ are determined by equations (20)–(25), and a specification of monetary policy such as (26) or (30).

4 Exchange rates and stabilization policy in a great recession

We can now start our reconsideration of the properties of exchange rate regimes in economies facing large recessionary shocks. In a first subsection, we will study the transmission of a negative Foreign demand shock, $\xi_t^* < 0$. In the following subsection, we will study the transmission of a negative demand shock that originates in Home, $\xi_t < 0$. In either case, we will analyze the transmission to the Home economy under different assumptions on the Home monetary policy and exchange rate regime.

To provide an analytical and intuitive account of the transmission mechanisms, we will derive tractable expressions under the assumptions that shocks follow a Markov structure: in the initial period, the shock of interest, $x_t \in \{\xi_t, \xi_t^*\}$, takes on a value $x_L < 0$—"L" standing for low. Each period thereafter, with probability $\mu \in (0, 1)$, x_t will remain at this level x_L for another period. Otherwise, the shock permanently reverts to the steady-state level of $x_t = 0$ and there are no other shocks in the future. To model the "zero lower bound-scenario," we assume that the respective interest rate(s) in Home and/or Foreign stay/stays at the steady-state level while the shock lasts. That is, $r_t = 0$ and/or $r_t^* = 0$ while $x_t = x_L$. Thereafter, policy is assumed to resume rule-based behavior.[14] In the current section, we keep Home government spending constant at zero: $\widehat{g}_t = 0$ for all t. We look into fiscal policy as a stabilization tool in Section 6 below.

We will exclusively focus on fundamental equilibria. That is, we exclude equilibria that arise from self-fulfilling beliefs. Therefore, we assume throughout that parameters of the model are such that the economy satisfies the conditions for local determinacy.

4.1 A great recession in the rest of the world

In this subsection, we focus on the transmission to our small open economy of a large contractionary shock in Foreign—recall that, from the perspective of Home, Foreign is "the rest of the world." We posit that this shock is large enough to create a liquidity trap in Foreign. Absent a monetary response because of the ZLB problem, this shock will induce a demand-

[14] The reason for invoking constant interest rates rather than modeling the ZLB explicitly is purely expositional. The assumption saves a constant term in many of the equations that follow.

determined recession in Foreign. While our ultimate goal is to learn what the shock means for the Home economy, we reiterate the importance of modelling explicitly the Foreign economy. If we want to know how Home responds to a shock in Foreign, we need to know how Foreign macroeconomic aggregates are influenced by the same shock, and how the recession is transmitted through financial markets and trade, conditional on the Foreign policy response. To with, a key novel result of our study—the real depreciation in the small open economy at the ZLB—occurs specifically when the recession abroad brings about a global liquidity trap (it would not occur if policy rates are not constrained).

As already stated, we model a "world recession" as a consequence of a contractionary demand shock in Foreign, $\xi_t^* < 0$. This shock makes Foreign residents value current-period consumption less than future consumption, translating into a negative Foreign demand shock driven by a rising desire to save by Foreign households. To model a liquidity trap in Foreign, we posit that Foreign monetary policy is constrained while the Foreign shock lasts (a ZLB scenario in Foreign). Namely, as long as $\xi_t^* = \xi_L^*$, Foreign monetary policy is assumed not to be able to adjust the nominal interest rate. It can, therefore, not cushion the effect of the shock on Foreign output and prices.

In a ZLB scenario, Foreign evolves just like the closed economy in Woodford (2011). Output and inflation in Foreign inherit the Markov property of the Foreign shock. That is, they will take on the same values as long as the shock lasts and they will revert to zero once the shock ends. The impact of the shock on output in Foreign is given by

$$y_L^* = \underbrace{\frac{(1-\beta\mu)(1-\mu)}{(1-\beta\mu)(1-\mu) - \mu\kappa(1+\varphi)}}_{:=1/\chi} \xi_L^*. \tag{33}$$

The expression in the denominator is positive as we only consider determinate equilibria. It is important to note here that the coefficient multiplying the shock, $\frac{1}{\chi}$ is larger than one, and is increasing in the persistence of the shock μ. In words, because the ZLB constrains monetary policy, output falls disproportionately in the shock (recall that we assume $\xi_L^* < 0$). The effect tends to be stronger, the more persistent the shock is and the longer Foreign monetary policy, thus, remains constrained.

Foreign inflation correspondingly becomes negative in response to the shock:

$$\pi_L^* = \frac{\kappa(1+\varphi)(1-\mu)}{\underbrace{(1-\beta\mu)(1-\mu) - \mu\kappa(1+\varphi)}_{>0}} \xi_L^*. \tag{34}$$

Again, the more so, the more persistent the shock is. As the Foreign nominal interest rate remains fixed because of the ZLB problem, this persistent fall in Foreign inflation raises real interest rates in Foreign, short and long.

For Home, these developments in Foreign mean depressed foreign demand as well as high global real interest rates. The extent to which the Foreign developments translate into losses of Home output, then, will crucially depend on Home monetary policy. We will consider the adjustment under the three types of Home monetary policy environments specified in Section 3.2.1, in turn.

4.1.1 Home: flexible exchange rate and unconstrained natural rate policy

According to the received wisdom, under flexible exchange rates monetary policy in Home is unconstrained and the exchange rate insulates the domestic economy from the recession in the rest of the world. To revisit this received wisdom within our framework, in what follows we assume that Home monetary policy adjusts the Home interest rate in response to inflation and the natural rate of interest as in equation (26).

Recalling that $E_t \Delta \xi^*_{t+1} = (\mu - 1)\xi^*_L$, equation (27) implies that the Foreign recession ($\xi^*_L < 0$) causes the Home natural rate of interest to decline:

$$r^n_L = \frac{\upsilon \varphi}{1+\varphi}(1-\mu)\xi^*_L. \tag{35}$$

Home natural output also falls, from equation (28):

$$y^n_L = \frac{\upsilon}{1+\varphi}\xi^*_L. \tag{36}$$

A familiar result, notably in New Keynesian closed-economy models (see, for instance, Galí, 2015, chapter 4), is that a monetary policy that follows the natural rate of interest stabilizes the price level and induces output to equal its natural level. The same result obtains here because of the well-established isomorphism of open and closed-economy New Keynesian settings (Clarida et al., 2001). That is, the equilibrium will have complete price stability in Home ($\pi_{H,t} = 0$ for all t, and especially $\pi_{H,L} = 0$). And Home output will be at its natural level,[15] so that

$$y_L = \frac{\upsilon}{1+\varphi}\xi^*_L.$$

Hence, under flexible exchange rates there is considerable insulation from the Foreign shock. Home output falls much less than Foreign output. This is so even if, perhaps unsurprisingly, insulation is not complete: expression (36) shows that the negative impact of the Foreign shock on Home output increases in openness, measured by υ. The pass-through of the Foreign shock to Home output will also be the larger, the more elastic Home labor supply is (the smaller

[15] It is straightforward to verify that equation (20) and (21) are satisfied at these values, as is (26).

φ).[16] Still, Home output will always fall less than one-for-one with the Foreign shock.

Key to this insulation result are the movements in the terms of trade and the nominal exchange rate. The terms of trade in Home unambiguously weaken (s_t increases) as ξ_L^* drops. To see this evaluate (29) for the scenario under consideration while using the solution for Foreign output (33) to obtain

$$s_L \quad = \quad \underbrace{-\left[\frac{1}{\chi} - \frac{1+\varphi(1-\upsilon)}{1+\varphi}\right]}_{<0} \xi_L^*. \tag{37}$$

Hence, Home-produced goods become cheaper.[17]

This terms-of-trade adjustment reflects the ability of Home policymakers to stabilize domestic output at the natural level. To see this, consider equation (25): in equilibrium, the demand for domestic goods increases one-for-one with the depreciation of the terms of trade. This reflects two effects. First, on the trade side: There is expenditure switching towards domestic goods when their relative price declines. Second, on the financial side: to the extent that there is home bias in consumption, as the terms of trade depreciate, the price of the Home consumption basket declines relative to Foreign's. Efficient risk sharing implies that domestic consumption rises relative to consumption in the rest of the world in this case.

The depreciation of the terms of trade, in turn, is the result of the movements of the nominal exchange rate, e_t. Taking first-difference of (22) and rearranging, we obtain

$$\Delta e_t = \Delta s_t - \pi_t^*, \tag{38}$$

since, as long as monetary policy can and does pursue price stability in Home, $\pi_{H,t} = 0$. We know that the terms of trade jump on impact in response to the shock and then take on a constant value (from equation (37)), while Foreign inflation is negative as long as the shock lasts. The above expression provides a clear illustration of the dual role of the nominal exchange rate as a shock absorber. First, the movement in the nominal exchange rate perfectly insulates the domestic economy from the Foreign deflationary crawl induced by the savings shock ($\pi_L^* < 0$). The nominal exchange rate depreciates (rises) one-for-one with the continuing fall in Foreign's price level, and precisely at the rate of Foreign disinflation $\pi_L^* < 0$. Second, when the shock hits, the nominal exchange rate depreciates in excess of the Foreign deflationary crawl, so as to bring about the depreciation of the terms of trade required to sustain the natural level of output.

[16] A policy targeting the natural rate in response to the demand shock is optimal under complete markets when pursued by both countries. When monetary policy in Foreign is constrained, however, there could be more efficient rules for Home, which may deliver higher welfare. For our purpose, however, a natural rate rule provides a suitable benchmark.

[17] The inequality stated in expression (37) follows from a comparison of the two terms in square brackets. From the definition in (33) $1/\chi > 1$. At the same time $(1 + \varphi(1 - \upsilon))/(1 + \varphi) < 1$, establishing the claim.

Further insight on the exchange rate as a shock absorber can be gained by deriving a closed-form expression for the exchange rate in Home. Starting from the expanded uncovered interest rate parity condition (32), as long as Foreign remains at the ZLB while Home is unconstrained, we have that $r_t^* = 0$, $r_t = r_L^n$ and $\pi_{H,L} = 0$. Hence, expression (32) implies that for any period k in which the shock lasts:

$$e_k^{unconstrained} = -\frac{r_L^n + \mu\pi_L^*}{1-\mu} - (k+1)\cdot\pi_L^*, \tag{39}$$

with $k = 0, 1, 2\ldots$ indexing the periods since the start of the recession in period $t = 0$ ($k = 0$, thus marking the first period of the recession).[18] Given our shock scenario, both r_L^n and π_L^* are negative. Thus, e_k is unambiguously positive: there is nominal depreciation.

Equation (39) decomposes the equilibrium Home depreciation into a temporary and a permanent effect of the shock (see Appendix C for details). The first term in (39) captures the temporary element of the depreciation that improves competitiveness. The second term captures the permanent cumulative depreciation required to insulate Home inflation from the deflationary drift abroad. This effect accumulates as the crisis lasts: for as long as the Foreign shock 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).

4.1.2 Home: ZLB scenario

What if, under the floating regime, Home monetary policy runs into the ZLB problem precisely at the time when the the rest of the world experiences the recession? We now revisit our results assuming that Home policy rates remain constant at their steady-state level as long as $\xi_t^* = \xi_L$. So, temporarily, the monetary authority in Home is unable to cushion the Home economy from the Foreign shock. In this scenario, not surprisingly, domestic output falls by more than in the previous case:

$$y_L = \frac{(1-\mu)(1-\beta\mu) - \mu\kappa}{(1-\mu)(1-\beta\mu) - \mu\kappa(1+\varphi)}\upsilon\xi_L^*. \tag{40}$$

Again, we focus on parameters that imply a locally unique equilibrium—the parameters are such that both the numerator and the denominator in (40) are positive. By comparing (40) to the solution in the unconstrained case, given by equation (36), one can easily verify that the Home contraction will become much more pronounced at the ZLB. The output loss in Home will be the larger, the more exposed Home is to Foreign due to openness (the larger υ).

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

Moreover, at the ZLB, the Home monetary authorities no longer control inflation. The solution for Home producer-price inflation is given by:

$$\pi_{H,L} \quad = \quad \frac{\kappa\varphi(1-\mu)}{(1-\mu)(1-\beta\mu)-\mu\kappa(1+\varphi)}\upsilon\xi_L^*. \tag{41}$$

Domestic producer price inflation (zero in the previous scenario) now falls in response to the recession in the rest of the world; the more so, the more open the economy is. The temporary constraint on Home monetary policy means that Home is no longer insulated from Foreign's deflationary crawl. The contractionary implications of the ZLB have been extensively explored in the context of fiscal policy for the closed economy (e.g., Woodford, 2011). The fall in (external and domestic) demand drives down inflation and inflation expectations in a significant and sustained way, causing a rise in (long-term) real interest rates.

Yet, on the positive side, observe that in response to the Foreign demand shock, Home output will always fall by less than Foreign output (compare equations (40) and (33)). By the same token, the rate of deflation will be lower in Home than in Foreign ($\pi_L^* < \pi_{H,L} < 0$, compare (34) and (41)). This is where the specific role of a floating exchange rate comes into play, to deliver some degree of insulation, even as the ZLB binds. Specifically, using (40) and (25), the solution for the terms of trade is:

$$s_L = \frac{-\mu\kappa\left[1+\varphi(1-\upsilon)\right]}{(1-\mu)(1-\beta\mu)-\mu\kappa(1+\varphi)}\xi_L^*. \tag{42}$$

Similar to the case in which monetary policy is not constrained, the Home terms of trade unambiguously depreciate in response a drop in ξ_t^* (s_L increases). This result is remarkable, given the strong fall in foreign output and inflation—indeed, there the result would be opposite if the Foreign rates were not constrained and Foreign authorities could respond to the shock with an appropriate degree of monetary expansion.

Of course, with domestic rate at the ZLB, the rate of depreciation is lower (compare the term multiplying ξ_L^* in (42) to the same term in (37), using the definition of χ from (33)). The weaker response of the terms of trade relative to the unconstrained case rationalizes why the drop of domestic output is larger in the ZLB scenario (there is less expenditure switching towards domestic goods and home consumption is less insulated from the financial transmission of the shock), and the country suffers a deflationary drift. Yet, it is by virtue of terms of trade adjustment, that the consequences of a world-wide great recession in the domestic economy are cushioned at least somewhat.

Nominal exchange rate flexibility is pivotal for this result. Using expression (32), the nominal exchange rate (assuming, as above, that the shock strikes first in period 0) is:

$$e_k^{ZLB} = \frac{\mu(\pi_{H,L}-\pi_L^*)}{1-\mu} + (k+1)\cdot(\pi_{H,L}-\pi_L^*)\,, \tag{43}$$

where, as before, the above expression holds for any period k in which the shock is still active ($k = 0, 1, 2\dots$ indexes the time since the start of the crisis). Since the deflationary drift in Home is always smaller than abroad, the nominal exchange rate unambigously depreciates, $e_k^{ZLB} > 0$; but the depreciation is less than absent the ZLB in Home. Equation (43) again decomposes the equilibrium Home depreciation into a temporary and a permanent effect of the shock (see Appendix C for details). The first term in (43) captures the temporary element of the depreciation that improves competitiveness. Comparing the first terms in (39) and (43), one can see that in absolute terms the adjustment is unambiguously smaller in case the ZLB binds. The reason is that the nominal interest rate in Home cannot mimic the falling natural rate. Still, there is some temporary competitiveness-increasing devaluation in Home under the ZLB. In addition, the second term in equation (43) shows that the exchange rate partially insulates Home against the effect of the deflationary crawl relative to Foreign—an important benefit of flexible exchange rates, as we will see next.

4.1.3 Home: an exchange-rate peg

Our results above have formalized analytically the notion that the nominal exchange rate fulfils a role as a shock absorber under flexible exchange rates even if domestic monetary policy is constrained by the ZLB. In our third, and final, scenario, Home monetary policy maintains an exchange rate peg. As monetary policy ensures that $e_t = 0$ in all periods, uncovered interest parity (see equation (31)) implies that in equilibrium the Home nominal interest rate has to move one-to-one with Foreign's, $r_t = r_t^*$.[19]

Above, we have argued that the movement in the terms of trade is central to explaining the degree of insulation from the Foreign shock. Therefore, as a starting point, we find it appropriate to show how the terms of trade evolve under a peg. Given equation (22) and assuming a fixed exchange rate, the terms of trade evolve as follows

$$s_t - s_{t-1} = \pi_t^* - \pi_{H,t}. \tag{44}$$

We may then subtract from the Phillips curve in Foreign (17) its counterpart in Home (21) and substitute for y_t using equation (25). This gives an expression for the right-hand side of (44), namely,

$$\pi_t^* - \pi_{H,t} = \beta E_t(\pi_{t+1}^* - \pi_{H,t+1}) + \kappa\big([1 + \varphi(1 - \upsilon)]\,(\xi_t^* - \xi_t) - (1 + \varphi)s_t\big). \tag{45}$$

Using (44) to substitute for $\pi_t^* - \pi_{H,t}$ in (45), and rearranging, we have that

$$s_t = \psi s_{t-1} + \beta\psi E_t s_{t+1} + \kappa\psi\big([1 + \varphi(1 - \upsilon)](\xi_t^* - \xi_t)\big), \tag{46}$$

[19]Note that under our scenario Home can always implement this.

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

$$s_t = \delta s_{t-1} + \underbrace{\frac{\kappa\psi\,[1 + \varphi(1 - \upsilon)]}{1 - \beta\psi[\delta + \mu]}}_{:=\Phi} \xi_L^*. \tag{47}$$

Here $\delta := \frac{1-\sqrt{1-4\beta\psi^2}}{2\psi\beta}$, with $0 < \delta < 1$, and $\Phi \in (0, 1)$.[20] The expression above shows that an exchange-rate peg gives a fundamentally different response to the recessionary shock in Foreign. Namely, if the exchange rate is fixed, the terms of trade unambiguously *appreciate* in response to the Foreign demand shock ($s_t < 0$). Home loses competitiveness, as Home-produced goods become relative more expensive than Foreign-produced goods.[21] This is in stark contrast with the results for flexible exchange rates, when there was always scope for the terms of trade to depreciate. With the nominal exchange rate fixed, the adjustment of the terms of trade depends on the relative adjustment of prices in Home and Foreign only. Foreign prices decline more than prices in Home—hence, the real appreciation of Home.
To trace the effect of the shock on Home's output, note that, in expression (25) the terms of trade are the only variable which depend on Home's policy. As the terms of trade appreciate, we obtain the following

Proposition 1. *Suppose the source of the shock is in Foreign, and $\xi_t^* = \xi_L^* < 0$. The output loss that Home experiences due to the shock is larger under the peg than under floating exchange rates. This is so regardless of whether in the latter case the ZLB in Home binds or not.*

The equilibrium allocation differs across exchange rate regimes in a number of key dimensions. First, if the shock persists, and so $\xi_L^* < 0$ for some time, under fixed exchange rates the terms of trade will not only appreciate on impact, but will continue to appreciate in any period that the shock lasts. That is Home will continue to lose competitiveness over time. Second, under flexible exchange rates, the terms of trade automatically reset once the Foreign shock ceases to exist. This means that the Home economy immediately returns to steady state. With fixed exchange rates, instead, the Home's terms of trade will remain appreciated for an extended period after the shock has stopped, curbing domestic output and inflation even once Foreign no longer is in a recession.

[20] See Appendix B for details.

[21] At the same time, the appreciation of the terms of trade depresses domestic consumption relative to the level of consumption in the rest of the world.

4.2 A contractionary demand shock in Home

The benefits of alternative monetary and exchange rate arrangements are quite sensitive to the shock underlying a Great Recession. To show this point, we briefly analyze the transmission of a negative demand shock which originates in Home: $\xi_L < 0$, instead of abroad. This is the same experiment studied by Cook and Devereux (2016), who however consider a model with two countries of equal size.

Home being small, all Foreign variables will remain at their steady-state value of zero. In what follows we will, therefore, focus on the evolution of the Home economy only.

4.2.1 Home: flexible exchange rate and unconstrained monetary policy

As for the case of the Foreign shock, we start from the benchmark of a flexible exchange rate regime, where monetary policy is able to follow rule (26) and implement the flex-price allocation, with $\pi_{H,t} = 0$. Given (27) and the Markov structure of the domestic shock, the interest rate drops in response to the domestic demand shock:

$$r_L = \frac{1 + \varphi(1 - \upsilon)}{1 + \varphi}(1 - \mu)\xi_L$$

and remains low as long the shock lasts. Afterwards the interest rate reverts to zero.

The policymakers' response to the shock keeps Home output in line with the natural level of output, which actually rises in response to the contraction in domestic demand:

$$y_L = y_L^n = -\frac{\upsilon}{1 + \varphi}\xi_L. \tag{48}$$

Output rises because the terms of trade depreciate unambiguously:

$$s_L = e_L = -\frac{1 + \varphi(1 - \upsilon)}{1 + \varphi}\xi_L. \tag{49}$$

To derive this equation, we combine the equilibrium condition (25) with the definition of the terms of trade (22), bearing in mind that Home inflation is perfectly stabilized. Since prices in Home are constant and the foreign price level is not affected by the Home shock either, the nominal exchange rate moves one-for-one with the terms of trade.

In sum, if exchange rates are truly flexible and if monetary policy is not constrained, flexible exchange rates can serve their classic purpose of insulating the Home economy against both Home and Foreign shocks.

4.2.2 Home: ZLB scenario

Next, we consider the ZLB scenario for monetary policy in Home. A first key implication is that domestic output drops with the domestic demand shock, rather than rising as it would absent the ZLB constraint:

$$y_L = \frac{\mu\upsilon\kappa + (1-\mu)(1-\beta\mu)(1-\upsilon)}{(1-\mu)(1-\beta\mu) - \mu\kappa(1+\varphi)}\xi_L. \tag{50}$$

As the drop in the demand is not cushioned by monetary policy, the output loss in response to a domestic demand shock can be severe when the ZLB binds. Key is the deflationary impact of the shock. Formally, the response of inflation in our model is given by

$$\pi_{H,L} \quad = \quad \frac{[1+(1-\upsilon)\varphi]\kappa(1-\mu)}{(1-\mu)(1-\beta\mu) - \mu\kappa(1+\varphi)}\xi_L. \tag{51}$$

The loss in output mirrors a "perverse" response of the terms of trade. Rearrange equation (25) and drop variables that remain at their steady-state value. Then:

$$s_L = y_L - (1-\upsilon)\xi_L. \tag{52}$$

Using (50), one can establish that output moves by more than $(1-\upsilon)\xi_L$, meaning that the terms of trade unambiguously *appreciate* ($s_L < 0$) in response to an adverse shock to domestic demand ($\xi_L < 0$). This is in sharp contrast to the depreciation observed absent the ZLB constraint, a point stressed by Cook and Devereux (2016).

The response of the nominal exchange rate can be inferred from expression (32). If Home is the source of the shock and the Home ZLB binds, the persistent deflation in Home raises the long-term real interest rate in Home. With Foreign's real rate unaffected, the real interest rate differential rises, leading to an appreciation of the nominal exchange rate (e_t falls). For any period k in which the shock lasts:

$$e_k = \frac{\mu\pi_L}{1-\mu} + (k+1)\cdot\pi_L, \tag{53}$$

with $k = 0, 1, 2\ldots$ indexing the periods since the start of the recession in period $t = 0$ ($k = 0$, thus marking the first period of the recession). That is, the nominal exchange rate anticipates the expected future fall in the Home price level (the shock may last, the first term) and, in addition, shows an appreciation that exactly offsets the fall in the price level since the onset of the shock (the second term).

It is important to emphasize that this seemingly "perverse" response of the nominal exchange rate is driven by the monetary policy rule. Once the shock ceases, Home monetary policy will immediately revert to the natural rate rule (26). Home producer-price inflation will revert to zero forever (in terms of price level, bygones are bygones). At the time the shock ceases, the exchange rate jumps once to restore long-run international purchasing power parity. Now, while the shock lasts and the ZLB binds, the cross border interest differential is constant, implying that, in expectations, the exchange rate must neither appreciate nor depreciate, compare (31)). Market expectations of appreciation in case the shock lasts can be consistent with international capital-market clearing only if the exchange rate is also expected to *depreciate* once the shock ceases. In turn, for the final depreciation to be consistent with long-run goods-market equilibrium (PPP), on impact, the nominal exchange rate must *appreciate* in excess of the initial disinflation in Home—an instance of overshooting just like in Dornbusch (1976).

4.2.3 Home: an exchange-rate peg

Under fixed exchange rates, the transmission of the Home shock differs starkly from the transmission of the Foreign shock. Following the same line of derivation that lead to (47), the solution for the terms of trade is given by

$$s_t = \delta s_{t-1} - \Phi \xi_t, \tag{54}$$

where Φ was defined in (47). Since $\Phi \in (0,1)$, upon the recessionary domestic shock ($\xi_L < 0$), the terms of trade unambiguously *depreciate* under fixed exchange rates (s_L rises). That is, the terms of trade work toward making Home more competitive.
Iterating backwards equation (54) and inserting in equation (25) above, one obtains that t periods after the shock first hit, Home output is given by:

$$y_t = (1-\upsilon)\xi_t - \left[\sum_{k=0}^{t} \delta^{t-k}\Phi\xi_k\right]. \tag{55}$$

Leaving a formal proof to the appendix, we summarize our results regarding the dynamic effect of the domestic demand shock on Home economic activity in the following proposition.

Proposition 2. *Suppose the source of the shock is in Home, and $\xi_t = \xi_L < 0$. The output loss that Home experiences due to the shock is larger under the ZLB scenario with floating exchange rates than under the peg.*

Intuitively, the terms of trade depreciation mitigates the impact of the shock, relative to the ZLB case. When Home demand is hit by a negative demand disturbance in Home, the Home price level falls.[22] Under a peg (since the Foreign price level will not move), Home gains competitiveness in the short run. In addition, the (constant) Foreign price level serves as an external anchor on inflation expectations for Home: A credible peg implicitly comes with a commitment to reflate the Home economy in the long-run (when goods-market equilibrium requires purchasing power parity to be restored), see Corsetti et al. (2013a). Such a reflation is to be achieved through higher inflation and output in the future (compare the Phillips

[22]The response of Home producer prices can be derived from (21). Prices fall after the shock.

curve (21) and the term in square brackets in (55)). This stabilizes domestic demand already as the shock lasts, since consumption smoothing in Home brings that expansion forward.

5 Quantitative assessment and welfare

We now turn to model simulations in order to illustrate the quantitative relevance of our results. 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. Home is assumed to be relatively open, corresponding to $\upsilon = 0.4$. The average price duration is assumed to be four quarters, requiring the Calvo parameter to be set equal to 0.75. Finally, we set the Taylor-rule coefficient to $\phi_\pi = 1.5$. In what follows, we first consider the dynamic adjustment to adverse demand shocks and assess their welfare costs under alternative policy regimes afterwards.

5.1 The quantitative impact of recessionary shocks

Regarding the Foreign demand shock, just like in our analysis above, we assume that it is not stabilized by foreign monetary policy because of a ZLB scenario in Foreign. Specifically, we assume that the foreign policy interest rate is fixed for 10 periods. Afterwards monetary policy follows rule (19). For the simulations, we relax the Markov assumption and instead assume that the shock follows an AR(1) process with persistence parameter 0.8. This assumption ensures that the ZLB in Foreign remains a binding constraint for as long as the shock has a significant impact. We assume that ξ_t^* falls by 3 percent in the initial period. We make the same assumptions for the domestic demand shock ξ_t. In all instances, we contrast the adjustment under the three policy scenarios analyzed above: an interest rate rule under flexible exchange rates; the case with flexible exchange rates in which monetary policy does not respond for 10 quarters; and the case of a currency peg.

Figure 1 shows the impulse responses for both shocks. The upper panel shows the transmission of the Foreign saving shock, which causes a sharp and persistent contraction in Foreign output and inflation (not shown). In each figure the 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). Contrasting the three scenarios for monetary policy in Home, we find that differences are large—notably, in terms of the response of Home output. Initially, Home output falls by some 8 percent under a peg (dash-dotted line), about 2.5 percent if policy rates are fixed for 10 quarters (solid line), and by less than one percent if monetary policy can follow the Taylor rule throughout (dashed line).

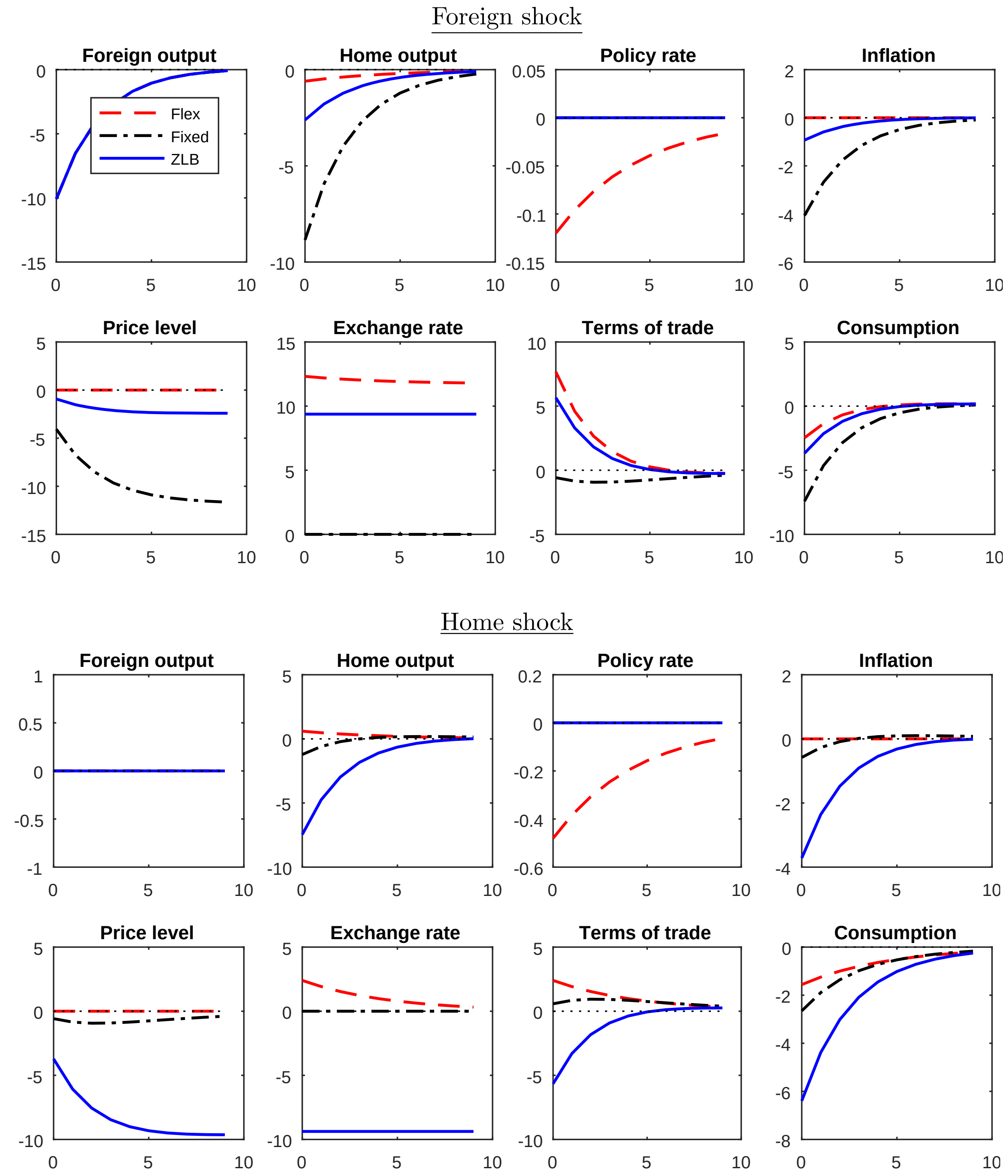

Figure 1: Effect of adverse demand preference shock originating in Foreign (top panel) vs Home (bottom panel). Monetary policy under the Taylor rule in Home (dashed line) vs constant-interest-rate period of 10 quarters (solid line) vs fixed exchange rate (dash-dotted line). Horizontal axes measure time 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).

Several aspects of the transmission mechanism are noteworthy. When monetary policy can follow the natural rate rule, policymakers respond to the shock with an upfront cut of the Home interest rate, causing a large depreciation of the nominal exchange rate (by about 12.5 percent) and the terms of trade. As a result, demand for domestic goods remains insulated from the full fall-out of the external shock and domestic prices are fully stabilized. Exchange rate flexibility however plays a significant role also when monetary policy in Home is constrained by the ZLB. The overall economic outlook worsens, since short-term monetary stimulus is insufficient and domestic demand remains inefficiently low. The fall of domestic output is more than twice as large compared to the case when monetary policy is unconstrained by the ZLB. Nevertheless, 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, but not as much as in Foreign (the latter is not shown in the figure). The terms of trade depreciation (while lower than in case monetary policy is unconstrained by the ZLB) cushions somewhat the fall in domestic output. The regime that performs worst in response to the Foreign shock, however, is the currency peg. This is not only because the deflation in Foreign induces the domestic terms of trade to appreciate in the short run. Crucially, the implicit domestic commitment that a pegging country makes to follow the unstable foreign price level generates expectations of sustained domestic deflation, which in turn amplifies the domestic downturn over and above any loss of "competitiveness" from real appreciation.

Results are fundamentally different when we look at the adjustment to the adverse demand shock which originates in Home, shown in the lower panel of Figure 1. Again, contrasting the three scenarios for monetary policy in Home, differences are large—notably in terms of the response of domestic output. However, the ordering of the output response across the ZLB and the peg changes compared to the effects of the Foreign shock. Home output now drops most strongly in the ZLB scenario, namely by about 7 percent. It drops only by about 1 percent under the peg (it actually rises in case monetary policy is unconstrained). Hence, in response to the Home shock, the peg is superior to the ZLB scenario (in terms of output loss).

Overall, our numerical simulations thus point toward a quantitatively important role of the monetary policy regime when it comes to the adjustment to a great recession. They, thus, underscore the message of our analytical results: the performance of alternative monetary and exchange rate regimes depends fundamentally on the source of the shock. In our scenarios, only in case the demand preference shock originates in Home is the peg superior to the ZLB scenario. If the shock originates in Foreign, instead, the peg is more contractionary than the

Foreign shock: incomplete international financial markets

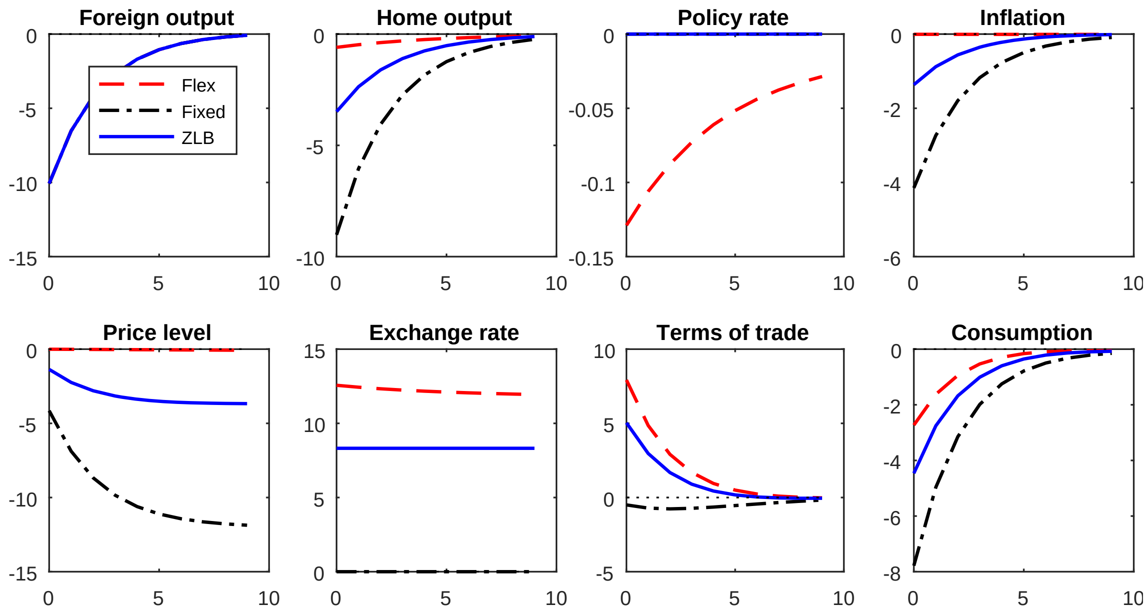

Figure 2: Effect of adverse demand shock originating in Foreign, assuming incomplete international financial markets. Unconstrained monetary policy in Home (dashed line) vs constant-interest-rate period of 10 quarters (solid line) vs exchange rate peg (dash-dotted line). Horizontal axes measure time 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).

ZLB scenario.

Finally, it is worth stressing that our assumption of complete financial markets is not essential for our results. To show this we compute impulse response functions for an alternative model specification which allows for international trade in non-contingent debt only. We show results for the Foreign shock in Figure 2. The dynamic adjustment to the shock under all three policy regimes is very similar to what we obtain under the assumption of complete international financial markets (see again Figure 1, upper panel).

5.2 Welfare

So far, the analysis was purely positive. We have discussed the effect that the shocks have on output, inflation, and other variables of interest. And we have discussed how these effects in turn depend on the exchange rate regime. That said, a contraction in output or consumption will only be an incomplete guide to welfare. One reason is that output has to be produced and, by way of our specification of the households' utility function, a contraction in output comes with a reduction in the disutility of work. We, therefore, examine briefly the welfare

Table 1: Welfare effect of shocks

	Flex	ZLB	Fixed
Foreign shock	0.0169	0.0123	-0.0327
Home shock	-0.0116	-0.0541	-0.0133

Notes: shock size is 3 percent; welfare measured in consumption units; entry of -0.0327 means, for example, that the Home household would be willing to permanently give up 0.0327 percent of steady-state consumption in order not to suffer the shock.

implications for Home of the Home and Foreign shock under the different exchange-rate regimes.

Table 1 summarizes the results for the same scenarios for which we have shown the adjustment dynamics in Figure 1 above. We now report the welfare costs of the Foreign and Home demand shock in terms of the equivalent of permanent consumption which the representative household is willing to forego if there would be no shock.[23] The performance of the policy regime in terms of welfare depends again on the shock under consideration, but is unchanged relative to the ranking based on the output performance. Namely, if the recessionary shock originates in Foreign, flexible exchange rates are preferred. While Home output falls even under flexible exchange rates, the Home consumer gains (an equivalent welfare gain of 0.0169 percent of life-time consumption for the Home consumer). Welfare still improves if Home is temporarily constrained by the ZLB (a welfare gain of 0.0123 percent of life-time consumption). Under fixed exchange rates, instead, the Home country imports the Foreign deflationary crawl, and welfare falls an order of magnitude more than under the ZLB scenario (a welfare loss of 0.0327 percent of life-time consumption). When faced with the Foreign shock, fixed exchange rates in Home, therefore, are a terrible idea.

Table 1 also shows, however, that the costs of fixed exchange rates are very different if the source of the shock is in Home. If the Home government can always apply the Taylor rule, flexible exchange rates perform well. Under the ZLB scenario, the welfare loss from the shock is 0.0541 percent of life-time consumption, notably larger than under fixed exchange rates. Indeed, in our simulations, for the domestic shock fixed exchange rates result in almost the same welfare loss as flexible exchange rates.

It is important, though, to stress that the policy under the flexible exchange rate with the

[23] In order to compute welfare, we solve the model globally under perfect foresight, and assume a constant subsidy on wages that makes the steady state efficient following Galí and Monacelli (2005), see Appendix D for details.

ZLB is not optimal. In our simulations, once it can do so the central bank implements the zero inflation policy. An optimal policy response to this domestic shock would, instead, ask the central bank to reflate the economy once it is no longer constrained by the ZLB. This is precisely what fixed exchange rates do. The law of one price combined with fixed exchange rates gives an implicit commitment to reflate the economy in the future. It is precisely this feature which leads to the relatively good performance of the regime of fixed exchange rates if the source of the shock is in Home.

6 Fiscal stabilization and the "benign coincidence"

Fiscal policy has traditionally been considered a substitute for monetary policy in case the latter is constrained, be it by the ZLB or by an exchange rate peg. An important question is, thus, whether fiscal policy is particularly effective in stabilizing domestic economic activity precisely when the monetary regime is not able to keep output at the natural level. This section briefly discusses the effects of Home government spending on Home output in the three regimes, thereby revisiting some of the earlier results of Corsetti et al. (2013a) and Fahri and Werning (2016). We proceed first as in Section 4 and we assume that Home government spending follows the same Markov structure as the demand shocks. We briefly discuss how the effects of a government spending shock $\widehat{g}_L > 0$ vary across monetary and exchange rate regimes.

If monetary policy is not constrained, under a flexible exchange rate, there is little need for fiscal intervention. Monetary stabilization is enough to keep output at the natural level, and producer-price inflation at zero. In this regime, an increase in government spending (however motivated) still raises output. But the multiplier is strictly less then unity, and output rises less than one-for-one with public demand, compare (28). The natural rate of interest rises and the natural terms of trade appreciate, see expressions (27) and (29). With monetary policy maintaining Home and Foreign inflation at their steady state level of zero, the nominal exchange rate appreciates one-for-one with the terms of trade.

Against this benchmark, the fiscal multiplier is much larger in the ZLB scenario under flexible rates. When monetary policy is temporarily constrained, the effect of government spending on output is given by

$$y_L = \frac{(1-\mu)(1-\beta\mu) - \mu\kappa}{(1-\mu)(1-\beta\mu) - \mu\kappa(1+\varphi)} \hat{g}_L. \tag{56}$$

The fraction is larger than unity (our assumption of determinacy means the denominator is positive). This means that output rises more than one-to-one with spending (recall that $\widehat{g}_L$ is measured in units of domestic output). The mechanism underlying the power of fiscal policy at the ZLB is well understood in a closed-economy context: higher fiscal spending raises expected inflation (see appendix). Provided that its inflationary impact is not met by higher policy rates, this reduces real rates and stimulates private demand (Christiano et al., 2011; Woodford, 2011). In the open economy, the transmission mechanism has an additional dimension. At the ZLB, government spending also results in a *depreciation* of the terms of the trade. To see this, observe that (32) implies that the nominal exchange rate depreciates by more than the domestic price level rises. Real depreciations in turn reinforces the overall expansionary effect of public spending—(see also Fahri and Werning, 2016; Fujiwara and Ueda, 2013). At the ZLB we thus have "benign coincidence": precisely when output could be most adversely affected by an adverse demand shock, government spending is particularly effective in raising output.

This is in sharp contrast with fiscal transmission in the peg scenario, where government spending appreciates the terms of trade. Formally, we have

$$s_t = \delta s_{t-1} - \underbrace{\frac{\kappa\psi}{1-\beta\psi[\delta+\mu]}}_{:=\Gamma}\varphi\,\hat{g}_t, \tag{57}$$

where $\Gamma \in (0,1)$. Because of the adverse effects of government spending on competitiveness, from equation (25) it follows that the multiplier under the peg is necessarily smaller than unity. As discussed in our earlier work, the predictions of the New Keynesian model are at odds with the conventional wisdom according to which fiscal policy is particularly effective under a peg (Corsetti et al., 2013a). The government spending multiplier remains smaller than one under a fixed exchange rate, close to the unconstrained case—and much smaller relative to the case of the ZLB. This is because the peg anchors the price level to the Foreign price level such that any inflationary effects that government spending has in the short run are offset, over time, by deflation. Hence, under the peg there is no "benign coincidence."

The following proposition summarizes the results as to the fiscal multiplier.

Proposition 3. *The government spending multiplier on output is positive under the three monetary regimes. It is larger than one under floating exchange rates with the ZLB constraint, but smaller than one in the other two regimes.*

For completeness, Appendix E also presents numerical simulations to illustrate the quantitative relevance of these results.

7 Conclusions

According to the received wisdom going back at least to Friedman (1953), floating exchange rates best allow monetary policy to stabilize the economy at the natural level. What the Great

Recession has shown, however, is that monetary policy frameworks that build on flexible exchange rates may not be sufficiently robust to rule out that policy instruments become unduly constrained when the economy is under severe stress. Since this undermines the ability of policymakers to stabilize the output gap and inflation, the literature has started to reconsider whether exchange rate regimes that help anchor inflation expectations may be preferable over floats, even if they under-deliver output gap stabilization in the short run.

The current paper has revisited the case for flexible exchange rates in a micro-founded, yet analytically tractable two-country New Keynesian model. It has studied the stabilization properties of flexible and fixed exchange rate regimes. We took the view point of a small open economy that is exposed to demand-driven recessions originating abroad (in the rest of the world) or at home (in the small open economy). Doing so, we have explicitly allowed for the ZLB problem.

A key message from our analysis is that, for a small open economy predominantly exposed to demand shocks originating in the rest of the world, a flexible exchange rate regime remains the most desirable option – even if the ZLB may bind for some time. For the exchange rate to insulate the small open economy from the external shock, it needs to both cushion the fall in external demand, and decouple domestic inflation from the deflationary crawl that may afflict the world economy. With policy rates at the ZLB, exchange rate flexibility helps in both dimensions. The importance of this result cannot be over-emphasized. A decade after the outburst of the global financial crisis, the world economy remains vulnerable to the risk that large global shocks once again cause a great recession. This is a challenge to policymaking in small open economies, which by their very openness are particularly vulnerable to external developments.

The view questioning the case for flexible exchange rates, instead, rests on the assumption that the recessionary demand shock originates in the domestic economy, Cook and Devereux (2016). In this context, the adoption of a fixed exchange rate will deliver stabilization results that are superior to a flexible exchange rate amid the ZLB. The reason is that a peg provides an implicit commitment to reflate the economy toward a foreign price level which itself is not affected by the shock. Our paper highlights that this result rests strongly on the source of the shock. Namely, if the demand recession originates in the rest of the world, a peg performs very poorly, for it would make the domestic economy import fully the foreign deflationary crawl, and offer no cushion against the fall in external demand. Once accounting for the fact that floating rates can also enhance the effectiveness of fiscal policy (by allowing monetary policy to accommodate the effects of current and prospective public spending on inflation), we conclude that the ZLB alone is not a good reason to abandon the conventional wisdom on flexible exchange rates.

The paper contributes tractable analytical solutions that allow to revisit a classic topic in a modern guise, and a powerful reminder that there is no such thing as an exchange-rate regime that provides for reasonable stabilization regardless of the source of shock and the fiscal/monetary instrument mix. The institutional or economic constraints on monetary and fiscal policy shape which exchange rate regime is desirable as do the nature and origin of business cycle disturbances. This is an important lesson for the ongoing discussion as to the desirability of currency pegs, not least in the context of the European Monetary Union.

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A Linearized model equations

In what follows we briefly outline the approximations of the equilibrium conditions around a deterministic steady state. For this steady state we assume that there is zero inflation. As explained in the main text, small-case letters denote log deviations of variables from their steady-state value. 'Hats' measure deviations from steady state in percentage points of output. We focus on the case $n \to 0$.

A.1 Equilibrium conditions of approximate model

Households supply labor such that the following relation is satisfied:

$$\tilde{w}_t = \varphi h_t + c_t, \tag{A.1}$$

$$\tilde{w}_t^* = \varphi h_t^* + c_t^*, \tag{A.2}$$

where $\tilde{w}_t$ is the (consumption) real wage (the log-linearization of W_t/P_t). The optimal time path of consumption satisfies:

$$c_t - \xi_t = E_t(c_{t+1} - \xi_{t+1}) - (r_t - E_t\pi_{t+1}), \tag{A.3}$$

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

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

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

Intermediate good firms' price-setting behavior gives

$$\pi_{Ht} = \beta E_t \pi_{Ht+1} + \kappa(\tilde{w}_t + \upsilon s_t) \tag{A.6}$$

$$\pi_t^* = \beta E_t \pi_{t+1}^* + \kappa \tilde{w}_t^*. \tag{A.7}$$

The aggregate production function is given by

$$y_t = h_t, \tag{A.8}$$

$$y_t^* = h_t^*. \tag{A.9}$$

The terms of trade are given by

$$s_t = e_t + p_t^* - p_{H,t}, \tag{A.10}$$

with the change in the price levels defining

$$\pi_t^* \quad = \quad p_t - p_{t-1}, \tag{A.11}$$

$$\pi_{H,t} \quad = \quad p_{H,t} - p_{H,t-1}. \tag{A.12}$$

We also have

$$\pi_t = (1-\upsilon)\pi_{H,t} + \upsilon(\Delta e_t + \pi_t^*). \tag{A.13}$$

Finally, there is market clearing:

$$y_t = \upsilon s_t + (1-\upsilon)c_t + \upsilon c_t^* + \upsilon(1-\upsilon)s_t + \hat{g}_t. \tag{A.14}$$

$$y_t^* = c_t^*. \tag{A.15}$$

We omit the specification of monetary and fiscal policy which is provided in the main text.

Incomplete financial markets. In this case, instead of the risk-sharing condition (A.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 net foreign assets. Assuming that foreign-currency bonds are in zero net supply, we have:

$$\beta \hat{d}_t \quad = \quad \hat{d}_{t-1} + y_t - c_t - \upsilon s_t - \hat{g}_t.$$

In order to close the model under incomplete markets we assume that the interest rate in home increases very mildly in the net foreign asset position d_t (see also Schmitt-Grohé and Uribe, 2003).

A.2 Canonical representation

Foreign operates like a standard New Keynesian closed-economy model. Combining equations (A.4) and (A.15) gives the dynamic IS-equation stated in the main text, see equation (16). Combining equations (A.2), (A.7), (A.9) and (A.15) gives the Phillips curve stated in the main text, see equation (17).

Home is de facto a small open economy. In main text we rely on a number of equations to determine the equilibrium outcome, given the realization of Foreign variables and Home shocks. We now derive these equations starting from equations stated in the previous subsection. Substituting for Home consumption in the market clearing condition (A.14) using risk sharing (A.5) yields

$$y_t = s_t + c_t^* + (1-\upsilon)(\xi_t - \xi_t^*) + \hat{g}_t. \tag{A.16}$$

which is equation (25) in the main text.
Combining (A.3) and (A.5) gives

$$(c_t^* - \xi_t^*) + (1-\upsilon)s_t \quad = \quad E_t(c_{t+1}^* - \xi_{t+1}^*) + (1-\upsilon)E_t s_{t+1} - (r_t - E_t\pi_{t+1}).$$

Rearraging and substituting for c_t^* using (A.16) gives

$$y_t \quad = \quad E_t y_{t+1} - \upsilon E_t s_{t+1} - \upsilon E_t \Delta\xi_{t+1}^* - (1-\upsilon)E_t\Delta\xi_{t+1} - (r_t - E_t\pi_{t+1}) - E_t\Delta\hat{g}_{t+1}.$$

Noting from (A.13) and (A.10) that $\pi_t = \pi_{H,t} + \upsilon\Delta s_t$ and using this in the expression above, we obtain equation (20) stated in the main text:

$$y_t \quad = \quad E_t y_{t+1} - \left(r_t - E_t\pi_{H,t+1} + (1-\upsilon)E_t\Delta\xi_{t+1} + \upsilon E_t\Delta\xi_{t+1}^*\right) - E_t\Delta\hat{g}_{t+1}. \quad \text{(A.17)}$$

To obtain the Phillips curve for Home, we start from (A.6) and use (A.1) and (A.8). This gives

$$\pi_{H,t} = \beta E_t\pi_{H,t+1} + \kappa\left(\varphi y_t + c_t + \upsilon s_t\right).$$

Using, in turn, equation (A.5) to substitute for c_t and (A.16) to substitute for c_t^* gives

$$\pi_{H,t} \quad = \quad \beta E_t\pi_{H,t+1} + \kappa\left[(1+\varphi)\,y_t - \hat{g}_t - \upsilon(\xi_t^* - \xi_t)\right], \quad \text{(A.18)}$$

which is expression (21) in the main text.

A.3 Natural rates in Home

To determine the natural level of output we set $\pi_{H,t} = 0$ for all t in equation (A.18) and obtain

$$y_t^n = \frac{1}{1+\varphi}\hat{g}_t - \frac{\upsilon}{1+\varphi}\left(\xi_t - \xi_t^*\right). \quad \text{(A.19)}$$

Similarly, for the natural rate of interest, plug (A.19) into (A.17), with $\pi_{H,t} = 0$ for all t, and rearrange terms:

$$r_t^n \quad = \quad -\frac{\varphi}{1+\varphi}E_t\Delta\hat{g}_{t+1} - \frac{1+\varphi(1-\upsilon)}{1+\varphi}E_t\Delta\xi_{t+1} - \frac{\upsilon\varphi}{1+\varphi}E_t\Delta\xi_{t+1}^*,$$

which is expression (27) given in the main text. To obtain the natural terms of trade we substitute for output in equation (25). The result is shown in equation (29) in the main text.

B Solving the linearized model

Foreign variables only deviate from their steady-state values in case the demand shock originates in Foreign. Given our assumptions regarding the shock, equations (16) and (17) simplify to

$$\begin{aligned} y_L^* &= \mu y_L^* - (-\mu \pi_L^* + (\mu \xi_L^* - \xi_L^*)), \\ \pi_L^* &= \beta \mu \pi_L^* + \kappa(1+\varphi) y_L^*. \end{aligned}$$

Straightforward substitution yields (33) and (34) in the main text, and thus $y_L^* \chi = \xi_L^*$, using the definition of χ in the main text.

Determinacy. Note that, in order to satisfy our assumption that parameters are such that they guarantee a locally unique stable rational expectations equilibrium, we require (compare Woodford, 2011)

$$(1-\beta\mu)(1-\mu) - \mu\kappa(1+\varphi) > 0.$$

The response of **Home variables** to shocks depends on the policy regime in place. We solve the model under each policy regime.

B.1 Home: flexible exchange rate and unconstrained monetary policy

In this case, the flexible price allocation and the natural rates obtain. Domestic inflation is zero. In order to solve for the terms of trade, we consider equation (25) and substitute for Home output using natural output and for Foreign output using $y_L^* = \chi^{-1} \xi_L^*$. We obtain the following expression

$$\begin{aligned} s_L &= -\frac{\varphi}{1+\varphi} \hat{g}_L - \frac{1+\varphi(1-\upsilon)}{1+\varphi} \xi_L \\ &\quad - \frac{\upsilon \varphi}{1+\varphi} \xi_L^* - \frac{\mu\kappa(1+\varphi)}{(1-\mu)(1-\beta\mu) - \mu\kappa(1+\varphi)} \xi_L^*. \end{aligned} \tag{B.20}$$

B.2 Home: ZLB scenario

Starting from equations (20) and (21) and imposing the Markov structure on all three shocks, we get, after a bit of rearranging

$$
\begin{aligned}
y_L &= \frac{(1-\mu)(1-\beta\mu)-\mu\kappa}{(1-\mu)(1-\beta\mu)-\mu\kappa(1+\varphi)}\hat{g}_L + \frac{(1-\upsilon)(1-\mu)(1-\beta\mu)+\mu\kappa\upsilon}{(1-\mu)(1-\beta\mu)-\mu\kappa(1+\varphi)}\xi_L \qquad \text{(B.21)}\\
&\quad + \frac{\upsilon((1-\mu)(1-\beta\mu)-\mu\kappa)}{(1-\mu)(1-\beta\mu)-\mu\kappa(1+\varphi)}\xi_L^*.\\
\pi_L &= \frac{\kappa\varphi(1-\mu)}{(1-\mu)(1-\beta\mu)-\mu\kappa(1+\varphi)}\hat{g}_L + \frac{\kappa(1-\mu)(1+\varphi(1-\upsilon))}{(1-\mu)(1-\beta\mu)-\mu\kappa(1+\varphi)}\xi_L \qquad \text{(B.22)}\\
&\quad + \frac{\kappa\varphi\upsilon(1-\mu)}{(1-\mu)(1-\beta\mu)-\mu\kappa(1+\varphi)}\xi_L^*.
\end{aligned}
$$

To solve for the terms of trade in the ZLB scenario we use equations (33) and (B.21) as well as equation (25). We obtain

$$
\begin{aligned}
s_L = \frac{\mu\kappa\varphi}{(1-\mu)(1-\beta\mu)-\mu\kappa(1+\varphi)}\hat{g}_L &+ \frac{\mu\kappa[1+\varphi(1-\upsilon)]}{(1-\mu)(1-\beta\mu)-\mu\kappa(1+\varphi)}\xi_L \qquad \text{(B.23)}\\
&- \frac{\mu\kappa\,[1+\varphi(1-\upsilon)]}{(1-\mu)(1-\beta\mu)-\mu\kappa(1+\varphi)}\xi_L^*.
\end{aligned}
$$

B.3 Home: an exchange-rate peg

The following gives the solution to the terms of trade under an exchange-rate peg with all three shocks considered. First, rewrite the marginal cost term in the Home Phillips curve (A.18), using equation (A.16):

$$
\begin{aligned}
& \kappa\,(1+\varphi)\,y_t - \kappa\hat{g}_t - \kappa\upsilon(\xi_t^* - \xi_t),\\
= \; & \kappa\,(1+\varphi)\,(s_t + \hat{g}_t + y_t^* + (1-\upsilon)\,(\xi_t - \xi_t^*)) - \kappa\hat{g}_t - \kappa\upsilon(\xi_t^* - \xi_t),\\
= \; & \kappa\,(1+\varphi(1-\upsilon))\,(\xi_t - \xi_t^*) + \kappa(1+\varphi)s_t + \kappa\varphi\hat{g}_t + \kappa(1+\varphi)y_t^*.
\end{aligned}
$$

Subtracting Phillips curves (Foreign (17) minus Home (A.18))

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

Using the first difference of (A.10) and setting $\Delta e_t = 0$, we arrive at

$$
s_t = \psi s_{t-1} + \beta\psi E_t s_{t+1} + \kappa\psi\big([1+\varphi(1-\upsilon)](\xi_t^* - \xi_t) - \varphi\hat{g}_t\big), \qquad \text{(B.24)}
$$

where $\psi = [1+\beta+\kappa(1+\varphi)]^{-1}$, as given in the main text. Define

$$
u_t \equiv \kappa\big((1+\varphi(1-\upsilon))(\xi_t^* - \xi_t) - \varphi\hat{g}_t\big), \qquad \text{(B.25)}
$$

such that the equation (B.24) reads more compactly as

$$s_t = \psi s_{t-1} + \beta\psi E_t s_{t+1} + \psi u_t. \tag{B.26}$$

Using the method of undetermined coefficients, one can show that the only stable solution to (B.24) is

$$s_t = \delta s_{t-1} + \underbrace{\frac{\kappa\psi\left[1+\varphi(1-\upsilon)\right]}{1-\beta\psi[\delta+\mu]}}_{:=\Phi}(\xi_L^* - \xi_L) - \underbrace{\frac{\kappa\psi}{1-\beta\psi[\delta+\mu]}\varphi}_{:=\Gamma}\,\hat{g}_L, \tag{B.27}$$

with $\delta = \frac{1-\sqrt{1-4\beta\psi^2}}{2\beta\psi}$. Note that $\delta \in (0,1)$.
The sign of Φ can easily be determined. Rewriting the expression slightly

$$\Phi = \frac{\kappa(1+\varphi(1-\upsilon))}{1+\beta+\kappa(1+\varphi)-\beta(\delta+\mu)},$$

it becomes apparent that Φ is positive but always smaller than one. To see this, note that $1+\beta > \beta(\delta+\mu)$ (since $\beta, \delta \in (0,1)$ and $\mu \in [0,1)$), and $\kappa(1+\varphi(1-\upsilon)) < \kappa(1+\varphi)$ (recall $\kappa > 0$, $\varphi > 0$ and $\upsilon \in (0,1)$). Exactly the same reasoning shows that $\Gamma \in (0,1)$, as well:

$$\Gamma = \frac{\kappa\varphi}{1+\beta+\kappa(1+\varphi)-\beta(\delta+\mu)}.$$

To determine the output response under the peg, solving (B.27) backward (and recalling $s_{-1} = 0$), we get

$$s_t = \Phi\sum_{k=0}^{t}\delta^{t-k}(\xi_k^* - \xi_k) - \Gamma\sum_{k=0}^{t}\delta^{t-k}\hat{g}_k. \tag{B.28}$$

Plugging this into (25)

$$y_t = \hat{g}_t - \Gamma\sum_{k=0}^{t}\delta^{t-k}\hat{g}_k + (1-\upsilon)\xi_t - \Phi\sum_{k=0}^{t}\delta^{t-k}\xi_k - (1-\upsilon)\xi_t^* + \frac{1}{\chi}\xi_t^* + \Phi\sum_{k=0}^{t}\delta^{t-k}\xi_k^* \tag{B.29}$$

The inflation response can be recovered via (44), having derived earlier the solution to the terms of trade and foreign inflation (see (34)).

B.4 Proof of Propositions

Proof of Proposition 1. It is to show that when $\xi_t^* = \xi_L^* < 0$, under the peg the fall in output is larger than under a float (for both the unconstrained and the ZLB case). Equation (B.29) gives the coefficient for the peg in period t (assuming the shock started in $t = 0$), and equation (28) gives the coefficient for the unconstrained case. This gives the following condition

$$
\begin{aligned}
-(1-\upsilon)+\chi^{-1}+\Phi &> \frac{\upsilon}{1+\varphi} \\
\upsilon+(\chi^{-1}-1)+\Phi &> \frac{\upsilon}{1+\varphi},
\end{aligned}
$$

which holds since $\chi^{-1} > 1$, $\Phi > 0$ and $\varphi > 0$. The same can be shown for the ZLB scenario (equation (B.21) gives the coefficient for the ZLB case):

$$
\begin{aligned}
-(1-\upsilon)+\chi^{-1}+\Phi &> \frac{(1-\mu)(1-\beta\mu)-\mu\kappa}{(1-\mu)(1-\beta\mu)-\mu\kappa(1+\varphi)}\upsilon \\
(1-\upsilon)\mu\kappa(1+\varphi)+\Phi((1-\mu)(1-\beta\mu)-\mu\kappa(1+\varphi))+\mu\kappa\upsilon &> 0,
\end{aligned}
$$

which is true since every term on the left hand side is positive (recall, $(1-\mu)(1-\beta\mu)-\mu\kappa(1+\varphi) > 0$ by our assumption on determinacy). □

Proof of Proposition 2. To see that the drop in output due to $\xi_t = \xi_L < 0$ is smaller under the peg than under the ZLB, first consider the coefficient on ξ_L for the peg on impact (equation (B.29)): $(1-\upsilon)-\Phi$, with $\Phi \in (0,1)$. We can now show that output in the ZLB scenario falls by more than $1-\upsilon$. Consider the coefficient on ξ_L in (B.21):

$$
\begin{aligned}
(1-\upsilon) &< \frac{(1-\mu)(1-\beta\mu)(1-\upsilon)+\mu\upsilon\kappa}{(1-\mu)(1-\beta\mu)-\mu\kappa(1+\varphi)} \\
-\mu\kappa(1+\varphi)(1-\upsilon) &< \mu\upsilon\kappa.
\end{aligned}
$$

Therefore, the fall in output at the ZLB is always larger under the home savings shock than in the peg regime. □

Proof of Proposition 3. Considering the coefficient on $\hat{g}_t$ for output in equation (B.21), we can immediately see that it is larger than one. For the flexible exchange rate case, equation (28) gives a positive coefficient which is smaller than one. Lastly, the coefficient in the case of the peg (equation (B.29)) gives $1-\Gamma$ on impact, which is positive but smaller than one due to $\Gamma \in (0,1)$. □

C Exchange rate response to Foreign shock

The main text asserts that the two terms on the right-hand sides of (39) and (43), respectively, reflect a temporary and a permanent effect of the Foreign shock on the nominal exchange rate. This appendix lays out this argument in more detail.

Suppose that in period k the recession in Foreign persists (so that $\xi_k = \xi_L$). This means that the shock has persisted for a total of $k+1$ periods ($t = 0, 1, ..., k$). The uncovered interest parity condition (31) holds in all periods, so it also holds in $t = k$, reading

$$r_k - r_k^* = E_k e_{k+1} - e_k.$$

Let us introduce some notation. Call e_{k+1}^{shock} the nominal exchange rate that realizes (in period $k+1$) if the shock persists into the next period. The latter happens with probability μ. Note that, in this notation, $e_k = e_k^{\text{shock}}$ since by assumption the shock persists in period k. Call $e_{k+1}^{\text{no shock for the first time}}$ the nominal exchange rate that realizes if the shock does not persist into the next period. We wish to derive an expression for $e_{k+1}^{\text{no shock for the first time}}$. By way of the Markov assumption,

$$E_k e_{k+1} = \mu\, e_{k+1}^{\text{shock}} + (1-\mu) e_{k+1}^{\text{no shock for the first time}}.$$

Using this in the interest parity condition, we have

$$\begin{aligned} r_k - r_k^* &= \mu\, e_{k+1}^{\text{shock}} + (1-\mu) e_{k+1}^{\text{no shock for the first time}} - e_k \\ &= \mu\, e_{k+1}^{\text{shock}} + (1-\mu) e_{k+1}^{\text{no shock for the first time}} - e_k^{\text{shock}} \\ &= \mu(e_{k+1}^{\text{shock}} - e_k^{\text{shock}}) + (1-\mu)(e_{k+1}^{\text{no shock for the first time}} - e_k^{\text{shock}}). \end{aligned}$$

Since the shock is active in period k, the lower bound will bind in Foreign. This means $r_k^* = 0$. Therefore,

$$r_k = \mu(e_{k+1}^{\text{shock}} - e_k^{\text{shock}}) + (1-\mu)(e_{k+1}^{\text{no shock for the first time}} - e_k^{\text{shock}}). \tag{C.30}$$

C.1 Unconstrained monetary policy in Home

Consider first the case when Home monetary policy is unconstrained. For the terms e_{k+1}^{shock} and e_k^{shock} formula (39) (evolution of the exchange rate while the shock lasts) applies. With this, we have that

$$e_{k+1}^{\text{shock}} - e_k^{\text{shock}} = -\pi_L^*.$$

Using this in (C.30), we have

$$r_k = -\mu\pi_L^* + (1-\mu)(e_{k+1}^{\text{no shock for the first time}} - e_k^{\text{shock}}).$$

While the shock binds, $r_k = r_L^n$. Therefore, the above implies

$$r_L^n + \mu\pi_L^* = (1-\mu)(e_{k+1}^{\text{no shock for the first time}} - e_k^{\text{shock}}),$$

or, equivalently,

$$e_{k+1}^{\text{no shock for the first time}} = e_k^{\text{shock}} + \frac{r_L^n + \mu\pi_L^*}{1-\mu}.$$

In words, in the period in which the shock ceases to exist, the nominal exchange rate appreciates relative to the previous period ($r_L^n + \mu\pi_L^* < 0$). Using (39) to substitute for e_k^{shock}, we have that the nominal exchange rate in period $k+1$ (if the shock ceased to exist that period) is given by

$$e_{k+1}^{\text{no shock for the first time}} = -(k+1)\cdot\pi_L^*.$$

In words, once the shock ceases to exist, the exchange rate permanently reflects the depreciation that insulates Home from the Foreign deflationary crawl. That is, the second term in (39) is permanent. The first term in (39), instead, reflects a temporary depreciation.

C.2 ZLB in Home

For the ZLB scenario in Home (and still with the Foreign shock), one can follow steps analoguous to those above. Start from (C.30). Observe that under the ZLB in Home also $r_k = 0$. Otherwise apply the same steps used above (but using (43) to substitute for e_k^{shock} and e_{k+1}^{shock}). Then, in $k+1$ (if this is the first period in which the shock ceases to exist), the nominal exchange rate takes on the value

$$e_{k+1}^{\text{no shock for the first time}} = (k+1)\cdot\left(\pi_{H,L} - \pi_L^*\right),$$

highlighting that the first term in (43) reflects a temporary depreciation, while the second term is permanent.

D Efficient steady state

Our welfare comparisons build on a calibration with an efficient steady state. This appendix first derives the allocation that the social planner of a small open economy would choose. It, then, specifies a labor income tax that would decentralize this allocation. The derivations here follow closely Galí and Monacelli (2005), using the notation for our model.

D.1 Planner's allocation

Consider the problem of a planner of the small open Home economy ($n \to 0$). Consider the flex-price steady-state allocation without government spending. International risk sharing implies

$$C = C^* S^{1-\upsilon}.$$

Home output is given by

$$Y = \left(\frac{P_H}{P}\right)^{-1} \left[(1-\upsilon)C + \upsilon S^{1-\upsilon} C^*\right].$$

The Home price level is given by

$$P = P_H^{1-\upsilon} P_F^{\upsilon}.$$

The terms of trade are defined as

$$S = P_F / P_H,$$

Last, the production function is

$$Y = H.$$

Combining the risk sharing condition and the demand equation gives:

$$Y = \left(\frac{P_H}{P}\right)^{-1} C$$

Using this with the price aggregate and the terms of trade, we have

$$Y = S^{\upsilon} C.$$

Substituting the real exchange rate Q from the risk-sharing condition, and using $C^* = Y^*$, we have, after rearranging:

$$C = Y^{1-\upsilon} Y^{*\upsilon}.$$

Using the production function, the constraint that the small open economy's planner faces is

$$C = H^{1-\upsilon} Y^{*\upsilon}.$$

The small open economy's planner solves

$$\max_{C,H} \ln(C) - \frac{1}{1+\varphi} H^{1+\varphi} \text{ s.t. } C = H^{1-\upsilon} Y^{*\upsilon} \ ,$$

the first-order condition of which gives

$$H^{\varphi} = \frac{1}{C}(1-\upsilon) Y^* H^{-\upsilon}.$$

Using that $Y = H$ and substituting from $C = Y^{1-\upsilon} Y^{*\upsilon}$, we get

$$H^{1+\varphi} = \frac{1}{C} C (1-\upsilon) = (1-\upsilon)$$

That is, the allocation that is optimal from the perspective of the small open economy's planner is given by

$$H = (1-\upsilon)^{\frac{1}{1+\varphi}},$$

and

$$C = (1-\upsilon)^{\frac{1-\upsilon}{1+\varphi}} Y^{*\upsilon}.$$

D.2 Decentralization

This steady state can be decentralized through a distortionary tax on household's labor income (and a lump-sum transfer). Let labor income after taxes be $wH(1-\tau)$. Then the level of taxes that decentralizes the planner's allocation is $\tau = 1 - \frac{(1-\upsilon)\epsilon}{\epsilon - 1}$.[24]
We implement the same tax in Foreign in order to focus on a symmetric steady state.

E Fiscal simulations complementing Section 6

This appendix shows numerical simulations to illustrate the quantitative relevance of the results in Section 6. We proceed with the same parametrization of the model as in Section 5. We assume that the shock to government spending follows an AR(1) process and set the persistence parameter to 0.8. Figure 3 traces the effect of an increase of government spending by one percent of GDP (the shock itself depicted in the upper-left figure). In the case of a free float, as long as monetary policy is unconstrained, the fiscal expansion has moderate effects. As the monetary authority is ensuring price stability, more government spending leads to a monetary contraction and real appreciation. The increase in government spending raises output, but only at the expense of domestic consumption. 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. Comparing the ZLB case across Figure 1 in the main text and Figure 3 above illustrates the "benign coincidence" emphasized above: under those circumstances in which the demand shocks can 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 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, Figure 1 in the main text and Figure 3 here. The mechanism governing the transmission of fiscal policy operates via price level

[24] Galí and Monacelli (2005), instead of taxes implement a subsidy on labor to the firm. The efficient allocation in Home is not affected by this choice.

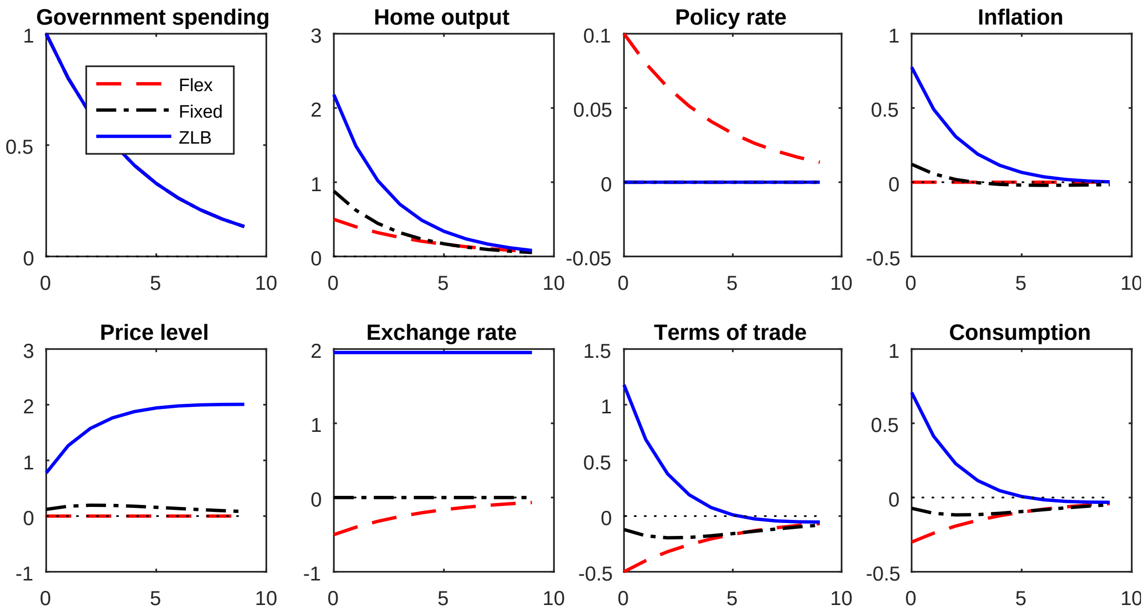

Figure 3: Effect of domestic government spending increase. Unconstrained monetary policy (dashed line) vs constant-interest-rate period of 10 quarters (solid line) and exchange rate peg (dash-dotted line). Horizontal axes measure time in quarters. Vertical axes measure deviations from the pre-shock path,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

dynamics: in order to restore 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. 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.