International Monetary Policy Spillovers at the Zero Lower Bound [*]

Alex Haberis[†]and Anna Lipińska[‡]

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Abstract

In this paper, we consider the spillover effects from monetary policy in economies in which nominal interest rates have been driven to the zero lower bound (ZLB) onto their trading partners. We analyse these effects using a model comprising a small open economy ('home') that is affected by (but does not affect) developments in a large ('foreign') economy. We find that looser foreign monetary policy worsens significantly the policy trade-off at home economy only when both economies are at ZLB. This is because, when home and foreign goods are close substitutes, looser foreign monetary policy is associated with a more appreciated home real exchange rate. This tilts demand away from home goods at a time when demand is already depressed on account of the shock and home monetary policy is constrained by ZLB.

Keywords: Small open economy, Policy trade-offs, Trade structure

JEL codes: E58, F41, F42

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1 Introduction

The global nature of the 2007-08 financial crisis and subsequent Great Recession, which saw central banks across the major economies cut policy rates to zero (or thereabouts), has renewed interest in the international aspects of optimal monetary policy at the zero lower bound (ZLB). A key feature of the policy debate during the Great Recession has been policymakers' concerns about the potential for adverse spillover effects from monetary policy in individual economies at the ZLB on their trading partners. Monetary policy in one economy can have spillover effects onto another through its influence over the exchange rate between the economies. Moreover, foreign monetary policy can affect the demand for another economy's goods (at a given exchange rate) directly through trade linkages.

In our analysis of monetary-policy spillovers at the ZLB, two findings stand out. First, depending on the structure of international trade, a foreign monetary strategy that improves the trade-off between stabilising the output gap and inflation in the foreign economy can actually *worsen* the trade-off for domestic monetary policy. Second, the extent of this worsening in the trade-off is more substantial when domestic monetary policy is also constrained by the ZLB. These considerations recall classical concerns about *competitive devaluations* and *beggar-thy-neighbour*-type policies. Indeed, in their Spring 2013 Communiqué, the G20 Finance Ministers and Central Bank Governors stated their intention to "refrain from competitive devaluations" and to be "mindful of unintended negative side effects stemming from extended periods of monetary easing."[1]

The issue of international spillovers from monetary policy at the ZLB – the so-called "unintended negative side effects" – has received relatively little attention in the literature. We shed light on the source and nature of the spillovers using a modern, small open economy framework. This framework has been used to investigate fruitfully questions about optimal monetary policy away from the zero bound (De Paoli, 2009; Lipinska et al., 2011). An advantage of the small open economy framework is that it allows us to abstract from issues of policy co-ordination and highlight the effects of the policy spillovers more easily. Policy co-ordination at the ZLB has been considered by Fujiwara et al. (2010, 2013), as will be discussed below in more detail.

In our analysis, we examine the impact of monetary policy at the ZLB in a large ('foreign') economy on the trade-off facing monetary policy in a small open economy ('home'). We focus on two experiments which we think are empirically relevant. First, we consider a large negative demand shock in the foreign economy that drives only foreign nominal rates to the ZLB. In this case, the small open

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[1]See G20 (2013).

economy is affected by both a real spillover from the foreign demand shock (which would be present absent nominal frictions and hence monetary-policy actions), and the spillover from foreign monetary policy (which can be summarized by the size of the foreign output gap). The combined impact of these is insufficient to push home nominal rates to the ZLB. Hence, home monetary policy is unconstrained. This is motivated by the observation that during the Great Recession some countries, which may have been affected by policy actions elsewhere, were not themselves forced to the ZLB. Second, we consider a large, global shock that drives the small open economy to the ZLB alongside the foreign economy, reflecting the fact that the Great Recession saw many economies driven to the ZLB at the same time. In this case, the spillover from foreign policy is the same as in the first case, but its impact on the home economy is different since the response of home monetary policy is constrained by the ZLB. Comparing these two cases allows us to examine how the ZLB at home alters the home economy's response to the "unintended negative side effects" from foreign policy at the ZLB.

To shed light on the spillovers from foreign policy at the ZLB, we consider two alternative foreign monetary strategies: optimal policy under commitment and discretion. Home policy is also assumed to be set optimally.[2] In particular, policymakers minimise welfare-based loss functions subject to the structural equations representing their respective economies, and the ZLB. Considering foreign commitment and discretion allows us to compare the spillover effects on the home economy of a foreign policy strategy that gives rise to a looser monetary stance in the foreign economy (in the sense of bigger cuts in ex-ante real rates, as is the case under optimal commitment) to a tighter foreign policy strategy (i.e. optimal discretion).[3]

We show that the inability of foreign monetary policy to stabilise the foreign economy at ZLB, both under commitment and discretion, creates a spillover that affects the home policymaker's ability to stabilise its own economy. In our baseline calibration, which assumes home and foreign goods are close substitutes for home consumers, we find that foreign commitment policy, which improves the foreign policymaker's trade-off between output gap and inflation stabilisation, *worsens* the home policymaker's trade-off. [4] In particular, consumption-equivalent welfare losses are bigger for the home economy when foreign policy follows a commitment strategy compared to discretion. This is true both

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[2]Our main results assume home policy is set under commitment. The results are qualitatively similar for home discretion.

[3]In an absolute sense, however, the overall stance of policy in the foreign economy is tight under both strategies because the ZLB prevents the foreign central bank from lowering the ex-ante real rate in line with the fall in the natural rate.

[4]These findings are consistent with Lipinska et al. (2011), who study international policy spillovers in case of global cost-push shocks and show that more dovish foreign policy worsens the trade-off facing home policy.

when the home policy is unconstrained by the ZLB (as in the foreign-shock-only case) and when it is constrained (global-shock case). However, the difference in home losses for alternative foreign policies is substantial only in the global-shock case.

Foreign commitment policy worsens home welfare when goods are close substitutes because it is associated with a more appreciated home real exchange rate. This tilts expenditure away from domestic goods at a time when demand for home goods is depressed by the negative demand shock – there is a large "expenditure switching effect", to use the terminology of Corsetti and Pesenti (2001). While there is a boost to demand for home goods resulting from the higher level of foreign demand under looser foreign policy – the "aggregate demand effect"– this is dominated by the expenditure switching effect. The overall effect is to destabilise the home economy, resulting in greater welfare losses. In this sense, our simulation results are analogous with the notion of *beggar-thy-neighbour*, or *competitive devaluation*-like, effects from looser foreign monetary policy.[5]

The worsening in home losses for looser foreign policy is larger in the case of the global shock (compared for the foreign-shock-only case) because, in response to the global shock, home nominal rates are pushed to the ZLB. Looser foreign policy continues to exert the same destabilising influence on the home economy. But when the home central bank is also forced to the ZLB by the global shock, it is constrained from being able to loosen policy sufficiently to offset the effects of the foreign policy spillover on the home economy. The welfare losses for the home economy are thus made more severe.

By contrast, when goods are complements, looser foreign policy improves the trade-off for home policy and results in better stabilisation performance in terms of consumption-equivalent welfare. In this case, the aggregate demand effect dominates the expenditure switching effect. Therefore, looser foreign policy boosts demand for home goods overall, offsetting somewhat the downward pressure on demand from the effects of the shock. This improves the stabilisation of the home output gap and inflation, reducing the size of welfare losses.

Our analysis is related to previous work on competitive devaluations as well as the literature on optimal monetary policy at the zero lower bound in open economies.

In their analysis of competitive devaluations, Corsetti and Pesenti (2001) consider effects of a home monetary expansion in a two country model and argue that this improves welfare in the foreign economy (when goods are substitutes). In their model, steady-state output is inefficiently low on

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[5]We use these phrases analogously because, in contrast to the classical literature on *competitive devaluations*, the exchange rate is not an instrument of monetary policy in our model, but rather responds endogenously to monetary conditions.

account of monopoly distortions so a monetary expansion raises output towards its efficient level. However, the expansion also induces a depreciation of the home real exchange rate. As a result, households in the home economy can enjoy fewer imports. Therefore, the disutility from working harder is not offset sufficiently by utility from consuming extra goods. Indeed, "the benefits from the domestic monetary expansion accrue primarily to foreigners."Similar findings are reported in Corsetti et al. (2000). By contrast, we find that looser foreign monetary policy worsens home welfare for comparable assumptions about trade structure.

A number of factors account for these differences. First, in our model, when the home economy starts in steady state, any spillovers from a foreign monetary expansion (or contraction) will be de-stabilising for the home economy and hence welfare-reducing, or *beggar-thy-neighbour*. This is because we assume the steady state is efficient.[6] In addition, the nature of the experiment we examine is somewhat different. Rather than a foreign monetary policy shock, we consider negative demand shocks that are imperfectly stabilised because of the zero bound. By considering alternative foreign policy strategies we can assess the impact on the home economy of looser or tighter foreign policy (even if the absolute stance of policy is tight, as discussed above). But this is, nevertheless, conceptually distinct from considering an expansionary *policy shock*. In our simulations, it is the fact that looser foreign policy weighs more greatly on demand for home goods at the same time there is a demand short-fall in the home economy due to the demand shock itself that gives rise to the bigger home welfare losses.

Turning to past work on monetary policy at the ZLB in open economies, Svensson (2001, 2003) focuses on the case where only one country is pushed to the zero bound by an adverse shock, and argues that a currency depreciation formed part of the "Foolproof Way" for an open economy to escape a liquidity trap. This is because the depreciation helps to raise the private sector's expectations about the future price level, providing stimulus to the economy today. In the analysis of Svensson (2001, 2003), the policymaker is allowed to peg the exchange rate at a depreciated level. However, while a similar mechanism is at work in our analysis, in our model the policymaker does not directly control, or intervene to influence, the exchange rate; rather, the exchange rate responds endogenously to support the policymaker's optimal plan. McCallum (2000) and Coenen and Wieland (2003) report similar findings.

More recently, the literature has considered the optimal policy co-ordination in response to a global

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[6]In line with Benigno and Benigno (2008) we eliminate monopolistic distortion from the steady state by implementing a tax subsidy.

shock that pushes more than one country to the ZLB. Using a two-country model, Fujiwara et al. (2010, 2013) find that the nature of co-ordination policy depends on substitutability of traded goods, since this governs the size of international spillovers, consistent with our analysis. The key difference between the work of Fujiwara et al. (2010) and our work is they consider policy co-ordination, whereas we study unco-ordinated policies. In addition, they consider a two-country model, while we focus on a small open economy (i.e. the limiting case of a two-country model). As mentioned above, this allows us to abstract from the effects of strategic interaction between policymakers and highlight the effects of the policy spillover from the large to the small economy more precisely. Related to Fujiwara et al. (2010), a recent Brookings Report on Rethinking Central Banking (Eichengreen et al., 2011) argues that monetary spillovers at the ZLB should be internalised in a co-ordinated global monetary policy.

Bodenstein et al. (2009) and Erceg and Linde (2010) study the effects of foreign shocks in an open economy when it is at the ZLB. Both papers find that, in this situation, the effects of foreign shocks are usually amplified. This is because, at the ZLB, monetary policy is constrained and cannot provide the necessary stimulus to its economy. Interestingly, Bodenstein et al. (2009) also show that the spillover effects of foreign shocks do not seem to be much affected by foreign monetary policy. They argue that, although the ZLB makes foreign output fall by more in response to a negative shock, it also reduces the associated home appreciation. Thus the ultimate effect on home output is little changed when compared to the case of no ZLB. This result, as Bodenstein et al. (2009) acknowledge, however, depends on the assumed trade price elasticity. In our framework, as alluded to above, we show how foreign policy can alter the nature of home policy at the zero bound and the losses suffered, and how these depend on the trade elasticity.

The paper is organised as follows. In section 2 we outline the model we use to conduct the analysis; in section 3 we describe the source and nature of international spillovers; in section 4 we analyse international spillovers at the ZLB quantitatively; in section 5 we discuss alternative modelling assumptions that could have an impact on the nature of international spillovers; section 6 concludes.

2 Model

To investigate the issue of how foreign policy at the zero bound affects a small open economy we use a standard New Keynesian model along the lines of De Paoli (2009) and Gali and Monacelli (2005). The relative simplicity of the model is an advantage insofar as it allows the spillover effects due to the presence of the ZLB to be disentangled easily. The model has two countries: 'home' (indexed by H) and

'foreign' (indexed by F). Representative households in each country supply labour to monopolistically competitive firms producing differentiated goods, and consume goods produced in both the home and foreign economies. Wages are assumed to be fully flexible, but prices are assumed to be sticky as in Calvo (1983). We adopt the approach of De Paoli (2009), who first solves for the equilibrium of the two-country model, and then takes the limit of the size of the home economy to zero. As a result, the home economy becomes a small open economy, whereas the foreign economy behaves like a closed economy: although developments in foreign variables affect the home economy, the opposite is not true. This is because the share of home goods in the consumption basket of foreign households is infinitesimal. In addition, we assume that the steady state in each economy is undistorted; i.e. the steady-state mark-up is equal to unity (in line with Benigno and Benigno (2008)). The model is in the class of cashless-limit economies, see e.g. Woodford (2003). Furthermore, we assume both the home and foreign economies are subject to demand-type shocks which are summarised by consumption preference shocks.

2.1 Foreign Economy

The foreign economy we consider is the same as the one used to analyse optimal policy at the ZLB in a closed economy setting (Jung et al., 2005; Levin et al., 2010). The non-policy block of the model is represented by two equations: an *IS* curve and a New Keynesian Phillips curve, which are both derived from the optimising behaviour of households and firms:

$$\widehat{x}_{F,t}^{W} = \mathbb{E}_t\widehat{x}_{F,t+1}^{W} - \frac{1}{\rho}(i_{F,t} - \mathbb{E}_t\widehat{\pi}_{F,t+1} - r_{F,t}^{n}), \tag{1}$$

$$\widehat{\pi}_{F,t} = \beta\mathbb{E}_t\widehat{\pi}_{F,t+1} + \kappa(\rho+\eta)\widehat{x}_{F,t}^{W}, \tag{2}$$

where $\widehat{\pi}_{F,t}$ is the foreign inflation rate, $i_{F,t}$ is the foreign short-term nominal interest rate, $r_{F,t}^{n}$ is the foreign natural interest rate.[7] The parameter ρ is the inverse of the intertemporal elasticity of substitution, η is the inverse of the elasticity of labour supply, and we define the parameter $\kappa \equiv \frac{(1-\alpha\beta)(1-\alpha)}{\alpha(1+\sigma\eta)}$, where α denotes the per-period probability that foreign firms can change the price of their goods, β is the household's discount factor, and σ represents the elasticity of substitution between differentiated foreign goods. The variable $\widehat{x}_{F,t}^{W}$ is the foreign welfare-relevant output gap, which is the difference between the level of output and its efficient counterpart. Since we assume that there

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[7]The natural rate is defined as the real rate in the flexible-price equilibrium, or, equivalently, the real rate consistent with zero inflation.

are no mark-up shocks and the steady state is efficient, sticky prices are the only distortion in the foreign economy. As a result, the efficient and flexible-price levels of output will be equal, and the welfare-relevant output gap is simply the flexible-price output gap. The foreign natural interest rate depends on the foreign consumption preference shock, $\widehat{b}_{F,t}$:

$$r_{F,t}^n = -\frac{\rho\eta}{\rho+\eta}\Delta\mathbb{E}_t\widehat{b}_{F,t+1} + \frac{1-\beta}{\beta}, \tag{3}$$

where $\frac{1-\beta}{\beta}$ is the real interest rate in the steady state.

2.2 Home Economy

The home economy can be represented by the following set of equations:[8]

$$\widehat{\pi}_{H,t}^{PPI} = \beta\mathbb{E}_t\widehat{\pi}_{H,t+1}^{PPI} + \kappa\left(\rho\widehat{c}_{H,t} - \rho\widehat{b}_{H,t} + \eta\widehat{y}_{H,t} + \frac{\lambda}{1-\lambda}\widehat{q}_t\right) \tag{4}$$

$$\widehat{y}_{H,t} = (1-\lambda)\,\widehat{c}_{H,t} + \lambda\widehat{y}_{F,t} + \gamma\widehat{q}_t \tag{5}$$

$$\widehat{c}_{H,t} = \mathbb{E}_t\widehat{c}_{H,t+1} - \frac{1}{\rho}\left(i_{H,t} - \mathbb{E}_t\widehat{\pi}_{H,t+1}^{CPI} - r_{H,t}^{n,CPI}\right) - \left(\mathbb{E}_t\widehat{b}_{H,t+1} - \widehat{b}_{H,t}\right) \tag{6}$$

$$\widehat{c}_{H,t} - \widehat{b}_{H,t} = \widehat{y}_{F,t} - \widehat{b}_{F,t} + \frac{1}{\rho}\widehat{q}_t \tag{7}$$

$$\widehat{\pi}_{H,t}^{CPI} = \widehat{\pi}_{H,t}^{PPI} + \frac{\lambda}{1-\lambda}\left(\widehat{q}_t - \widehat{q}_{t-1}\right) \tag{8}$$

$$r_{H,t}^{n,CPI} = r_{F,t}^n - \frac{\rho\lambda\eta}{(\rho\lambda + \eta\,(1-\lambda))}\,(1-\lambda)\,\Delta\left(\widehat{b}_{H,t+1} - \widehat{b}_{F,t+1}\right) - \frac{\lambda}{1-\lambda}\left(q_t^f - q_{t-1}^f\right) \tag{9}$$

where $\widehat{\pi}_{H,t}^{PPI}$ denotes producer price inflation (PPI) (i.e. domestic, or GDP deflator, inflation), $\widehat{c}_{H,t}$ is home consumption, $\widehat{y}_{H,t}$ is home output, $\widehat{q}_t$ is the home real exchange rate, $i_{H,t}$ is the home nominal interest rate, $\widehat{\pi}_{H,t}^{CPI}$ is home consumer price inflation (CPI), $r_{H,t}^{n,CPI}$ is the natural rate of interest in terms of CPI, $\widehat{y}_{F,t}$ is foreign output and q_t^f is the real exchange rate that would prevail under flexible prices. We denote a home consumption preference shock by $\widehat{b}_{H,t}$. The parameter λ denotes the share of foreign goods in the home consumption basket. We define the parameter $\gamma \equiv \frac{\theta\lambda(2-\lambda)}{1-\lambda}$, where θ is the

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[8]For a more detailed derivation of the model, see the Appendix in De Paoli (2009).

intratemporal elasticity of substitution between home and foreign goods, and we define the parameter $\rho_\lambda \equiv \frac{\rho(1-\lambda)}{(\rho\theta-1)\lambda(2-\lambda)+1}$.

The model of the home economy has parallels with the canonical closed-economy New Keynesian model, although with clear differences on account of its openness. As in the closed economy, the home economy has a Phillips curve for PPI inflation (4). This relates current inflation to expected inflation and real marginal cost (the terms in parentheses). But for the home economy, real marginal cost also depends directly on the real exchange rate. The goods market clearing condition (5) shows that there is both domestic and foreign demand for home output. Equation (6) is the representative agent's consumption Euler equation. Equation (7) is the international risk-sharing condition derived under the assumption of complete international financial markets; it equates the marginal utility of consumption in the home and foreign economies in purchasing power parity terms. Note that since there are preference shocks, relative consumption across countries will not necessarily be proportional to the real exchange rate. Finally, there are some definitions: equation (8) defines CPI in terms of PPI and the change in the real exchange rate; equation (9) defines the natural rate of interest for the home economy.

2.3 Monetary Policy Specification

In our simulation results below, we assume monetary policy in both the home and foreign economies is set optimally. Specifically, the home and foreign central banks each minimise a loss function derived from the utility functions of households in their respective economies, subject to the constraints imposed by the structure of the economies, including the zero lower bound. This sub-section sets out the welfare-based loss function in each economy; the details of the optimisation (such as the first-order conditions), under both commitment and discretion, are included in Appendix A.

Home policymaker's loss function Following De Paoli (2009), the loss function for the policy-maker in the small open economy can be expressed as:

$$L_{H,t_0} = \frac{1}{2}\overline{C}^{1-\rho}\mathbb{E}_{t_0}\sum_{t=t_0}^{\infty}\beta^{t-t_0}\left[\omega_y^H\left(\widehat{x}_{H,t}^W\right)^2 + \omega_\pi^H\left(\widehat{\pi}_{H,t}^{PPI}\right)^2\right] + sotip \tag{10}$$

where $\overline{C}$ is the steady state consumption and *sotip* means second-order terms independent of policy. The weights the central bank assigns to the welfare-relevant output gap and PPI inflation (ω_y^H and

ω_π^H, respectively) are functions of the structural parameters of the model.[9]

Given our assumptions about the efficiency of the steady state and the absence of mark-up shocks, the home economy is affected by two distortions: sticky prices and the terms-of-trade externality. Optimal policy in the home economy, therefore, aims to minimise the influence of these two distortions.

Foreign policymaker's loss function   In the foreign economy, the central bank's loss function can be expressed as:

$$L_{F,t_0} = \frac{1}{2}\overline{C}^{1-\rho}\mathbb{E}_{t_0}\sum_{t=t_0}^{\infty}\beta^{t-t_0}\left[\omega_y^F\left(\widehat{x}_{F,t}^W\right)^2 + \omega_\pi^F\left(\widehat{\pi}_{F,t}\right)^2\right] + sotip \tag{11}$$

As discussed above, sticky prices represent the sole source of distortions in the foreign economy. These give rise to the welfare losses that the policymaker aims to minimise.

Zero lower bound, credibility, and the absence of quantitative policies   Nominal interest rates cannot be negative; there is a zero lower bound:

$$i_t^j \geqslant 0. \tag{12}$$

for $j = H, F$. Furthermore, the central banks are assumed to be able to adopt perfectly credible policies. They are also assumed not to have access to quantitative measures such as asset purchases when nominal interest rates are zero.

3   International Spillover Effects

It is possible to shed light on the spillovers from the foreign economy to the home economy by re-writing the set of equations (4)–(8) as an *IS* curve and a Phillips curve for the home economy, and the home natural rate in terms of PPI inflation, equations (13), (14), and (15) respectively:

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[9]The expression for the loss function in De Paoli (2009) includes the welfare-relevant real exchange rate gap. The reason for this is that, in addition to the distortion introduced by sticky prices, there is an external distortion in the small open economy that leads to inefficient fluctuations in the terms of trade – known as the 'terms-of-trade externality'. This externality arises when home and foreign goods are not perfect substitutes for home consumers. In this case, a social planner in the home economy may be able to take advantage of a degree of monopoly power in the supply of home goods on world markets to improve home welfare. Although we have eliminated the real exchange rate gap term, our formulation is equivalent. This implies that the target output level will differ in our formulation compared to if we had written the problem in terms of the real exchange rate gap also. The optimal paths for nominal interest rates, inflation and output remain unchanged, however.

$$\widehat{x}_{H,t}^{W} = \mathbb{E}_t \widehat{x}_{H,t+1}^{W} - \frac{1-\lambda}{\rho\lambda}\left(i_{H,t} - \mathbb{E}_t\widehat{\pi}_{H,t+1}^{PPI} - r_{H,t}^{n,PPI}\right) \tag{13}$$

$$+ \frac{\rho(1-\lambda) - \rho\lambda}{\rho\lambda}\Delta\mathbb{E}_t\widehat{x}_{F,t+1} + \Delta\mathbb{E}_t\widehat{\chi}_{H,t+1}^{Y}$$

$$\widehat{\pi}_{H,t}^{PPI} = \kappa\left(\frac{\eta(1-\lambda) + \rho\lambda}{1-\lambda}\right)\widehat{x}_{H,t}^{W} + \kappa\left(\frac{\rho(1-\lambda) - \rho\lambda}{1-\lambda}\right)\widehat{x}_{F,t} \tag{14}$$

$$+ \kappa\left(\frac{\eta(1-\lambda) + \rho\lambda}{1-\lambda}\right)\widehat{\chi}_{H,t}^{Y} + \beta\mathbb{E}_t\widehat{\pi}_{H,t+1}^{PPI}$$

$$r_{H,t}^{n,PPI} = r_{F,t}^{n} - \frac{\rho\lambda\eta(1-\lambda)}{\rho\lambda + \eta(1-\lambda)}\Delta\mathbb{E}_t\left(\widehat{b}_{H,t+1} - \widehat{b}_{F,t+1}\right) \tag{15}$$

where $\widehat{x}_{H,t}^{W}$ is the home welfare-relevant output gap, which is the difference between the actual level of output and its welfare-relevant target level, and $r_{H,t}^{n,PPI}$ is the home natural rate in terms of PPI inflation. We define the variable $\widehat{\chi}_{H,t}^{Y} \equiv \widehat{y}_{H,t}^{T} - \widehat{y}_{H,t}^{f}$ where $\widehat{y}_{H,t}^{f}$ is the flexible-price level of output and $\widehat{y}_{H,t}^{T}$ is the welfare-relevant target level of output.[10]

Developments in the foreign economy affect the home economy through two channels. First, there is a spillover from foreign monetary policy, which is the focus of this paper. Equations (13) and (14) are written to show that the home output gap and inflation are functions of the foreign output gap. Since the foreign central bank determines the size and time path of the foreign output gap, the influence of the foreign output gap on the home output gap and inflation entirely reflects foreign monetary policy. Second, there is a real spillover, which is independent of foreign policy. This arises since the natural real interest rate in the home economy is affected by shocks in the foreign economy, reflecting the assumption that a proportion of total demand for home goods is from foreign consumers and that home consumers consume both home and foreign goods. It also reflects the impact of $\widehat{\chi}_{H,t}^{Y}$ in the home economy's Phillips curve, which, as described above, depends on the foreign preference shock.

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[10]The presence of the $\widehat{\chi}_{H,t}^{Y}$ term in the Phillips curve indicates that, in general, it will not be possible to close the welfare-relevant output gap and stabilise producer price inflation at the same time, even if the foreign output gap is closed and the shocks are small enough for the ZLB not to bind. This reflects the existence of the 'terms-of-trade' externality. Therefore, unlike the standard closed-economy New Keynesian model, there is not 'Divine Coincidence' for natural-rate shocks in the small open economy when the steady state is undistorted (De Paoli, 2009).

3.1 Foreign policy spillover effects

3.1.1 Transmission of foreign policy spillover effects

Both the home economy's demand and supply sides are affected by spillovers from changes in foreign monetary policy. In line with the literature on the international transmission of shocks, the nature of the spillover from foreign monetary policy – i.e. its sign – depends on the structure of trade.[11] In particular, the substitutability of home and foreign goods for home households plays a key role. Home and foreign goods are substitutes (complements) – i.e. the marginal utility of one good decreases (increases) with the increase in consumption of another good – when the intratemporal elasticity of substitution is higher (lower) than the intertemporal elasticity of substitution (analytically, when $\rho\theta > 1(\rho\theta < 1)$).

To shed light on the nature of the spillover from foreign monetary policy, it is helpful to consider a thought experiment in which there is a monetary contraction in the foreign economy. This induces two effects that are of interest. First, the contraction in foreign monetary policy reduces foreign aggregate demand. Since the natural level of foreign output is unchanged, a negative output gap opens up in the foreign economy. At the same time, the tightening in foreign monetary policy leads the foreign exchange rate to *appreciate* (in both real and nominal terms); or, equivalently, the home exchange rate *depreciates*.

The sign of the impact on home demand (for a given home real interest rate) will depend on the foreign-output-gap coefficient in the *IS* curve. When home and foreign goods are substitutes (complements), $\rho(1 - \lambda) - \rho_\lambda > 0 \ (< 0)$, which implies home demand is decreasing in the foreign output gap.[12] Two opposing effects determine the impact on home demand: an *aggregate demand effect* and an *expenditure switching effect*. On the one hand, the aggregate demand effect of the foreign monetary contraction pushes down on home output; at a given real exchange rate, the decrease in foreign demand induced by the tightening in foreign monetary policy directly reduces demand for home output. On the other hand, the expenditure switching effect pushes up demand for home output; the real depreciation of the home exchange rate induced by the foreign monetary contraction leads to expenditure switching towards home goods, which raises demand for home output. When home and foreign goods are substitutes (complements), the expenditure switching effect dominates (is dominated

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[11]Including, among others, Corsetti et al. (2000), Corsetti and Pesenti (2001), Corsetti et al. (2008), and De Paoli (2009).

[12]This is because the foreign output gap enters the home *IS* curve contemporaneously with a negative sign; it is the lagged term in the expected change term.

by) the aggregate demand effect. Overall demand for home output, therefore, rises (falls), which leads to a positive (negative) home output gap.

On the supply side, the sign of the foreign monetary contraction's impact on home inflation (for a given level of home demand) will also depend on the relative significance of two opposing effects. These effects work through the home economy's labour market, affecting home real wages and, hence (given unchanged productivity), home real marginal cost. On the one hand, at a given real exchange rate, the fall in foreign output reduces home consumption on account of international risk sharing – home households own foreign assets and are made poorer when foreign output falls. This raises the marginal utility of consumption in the home economy. For a given level of labour demand, in order to restore the ratio of the marginal utilities of consumption and leisure, households reduce the amount of time spent as leisure. That is, they increase their labour supply, which pushes down real wages and hence real marginal cost. On the other hand, other things equal, the real depreciation raises the value of the payoff of home households' holdings of foreign assets in terms of home goods. This allows households to consume more at a given level of labour supply. Households respond to this by reducing their labour supply somewhat, which pushes up on real wages and hence real marginal costs. When home and foreign goods are substitutes (complements), the real exchange rate adjustment is smaller (bigger). This implies the negative foreign output gap has a negative (positive) effect on home real marginal costs and hence inflation.

3.1.2 Implications for home monetary policy of foreign policy spillover effects

Home monetary policy will not generally be able to offset the effects on the home economy of imperfect stabilisation by monetary policy in the foreign economy. If foreign monetary policy fails to stabilise the foreign economy perfectly in response to shocks (or if there are destabilising monetary policy shocks), this introduces a stabilisation problem for home monetary policy. This can been understood by recognising that since the foreign output gap has a tendency to push the output gap and inflation in opposite directions in the home economy, its effects on the home economy are similar to those of a home mark-up shock. And, as is well known in the literature, mark-up shocks induce trade-offs for monetary policy. In the context of this paper, foreign monetary policy is unable to stabilise the foreign economy on account of the zero bound. But the mark-up shock-like effects on the home economy of imperfect stabilisation in the foreign economy also exist in other contexts (Lipinska et al., 2011).

3.2 Real spillover effects

Real spillover effects emerge irrespective of foreign policy actions. In the absence of the ZLB, whether home monetary policy can stabilise the home output gap and inflation in response to these spillovers depends on the underlying shock. When the shock is global and symmetric – that is, equally sized shocks affect both the home and foreign economies at the same time – home monetary policy will be able to keep the home output gap closed and inflation at target. In this special case, absent the ZLB, so-called 'Divine Coincidence' holds in the home economy. This reflects the fact that for global shocks the real exchange rate would not need to adjust. In this case, the home policymaker does not face a trade-off between stabilising the output gap and inflation (i.e $.\widehat{\chi}_{H,t}^{Y} = 0$). Optimal policy at home would simply involve adjusting the nominal rate in line with the natural rate. This is consistent with Benigno and Benigno (2006), who show that there are no gains from co-ordination in response to symmetric shocks when policy is set optimally. However, if the shock occurs only in the foreign economy, the $\widehat{\chi}_{H,t}^{Y}$ variable will no longer necessarily be zero as the welfare-relevant target and flexible-price levels of output will no longer necessarily coincide. From the home Phillips curve, equation (14), it is clear that, in general, it is not possible to stabilise home inflation and the welfare-relevant output gap at the same time.

4 Simulation Results

In this section we show how foreign monetary policy at the ZLB affects the home economy in simulations of stylised large demand shocks. In our first simulation, we consider a large demand (i.e. preference) shock in the foreign economy that causes the foreign natural rate to fall by around 7 percentage points on impact, driving foreign nominal interest rates to the lower bound. The size of this shock matches the "Great Recession" shock considered by Levin et al. (2010). The home natural rate also falls since it too depends on the foreign preference shock (see equation (15)). However, it does not fall sufficiently far for the ZLB to bind in the home economy. In the second simulation, we consider a global demand shock that leads the ZLB to bind in both the home and foreign economies. Specifically, we consider symmetric, simultaneous preference shocks that induce a 7-percentage-point fall in the natural rate on impact in both economies.

We focus on consumption preference shocks because they induce a pattern of responses that we think capture, in a stylised way, some key features of the Great Recession. Specifically, negative preference shocks lead the natural rate to fall, a negative output gap to open up, and, at the same

time, the level of output to fall. We associate the shocks we consider with a narrative in which consumers' desire to save increases, perhaps related to a generalised increase in risk premia, which is consistent with many accounts of the Great Recession.

To illustrate the impact of the foreign monetary-policy spillover we consider each shock under two different specifications for foreign policy: commitment and discretion. For our main results we assume home policy is always set under commitment. Results for home policy under discretion are reported in Appendix B. We contrast foreign policy under commitment and discretion because it allows us to consider policies that give rise to a looser monetary stance (in the sense that the gap between the ex-ante real rate and the natural rate is smaller, i.e. commitment) versus those that result in a tighter stance (discretion). Rather than having a specific interest in the distinction between foreign commitment and discretionary policies *per se*, considering the alternative policies allows us to analyse policy spillovers of differing magnitudes.

4.1 Solution Approach

For our simulation results we use a piece-wise linear perfect-foresight algorithm for solving models with inequality constraints that has been widely used in the literature.[13] Although it is an approximation to the full non-linear model at the ZLB, Carlstrom et al. (2013) and Christiano and Eichenbaum (2013) argue the approximation is reasonable.[14] Furthermore, to the extent that in the non-linear model, foreign policy is constrained at the ZLB and a negative foreign output gap opens up, there will be a spillover to the home economy. The direction of that spillover will continue to depend on the relative importance of the aggregate demand versus expenditure effects, as shown by Corsetti and Pesenti (2001), who consider a non-linear model.

Much of the existing literature focuses on models with a single inequality constraint: the zero lower bound on nominal interest rates. In our model, by contrast, we have two inequality constraints: the ZLB in the home and foreign economies. While generalisations of the standard approach exist for models with multiple inequality constraints (e.g. Dennis (2007), and Ha (2012)), it is not necessary

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[13]Including by Jung et al. (2005) and Levin et al. (2010). More recently, it has been used to investigate the issue of the size of the fiscal multiplier at the ZLB, by Eggertsson (2011), Christiano et al. (2011), Carlstrom et al. (2013), and by Eggertsson and Krugman (2012).

[14]Braun et al. (2012) question the validity of using a linear approximation to the full non-linear model at the ZLB, arguing that the size of the fiscal multiplier is materially different in the non-linear model compared to its linearised counterpart. That said, in critiquing these results, Christiano and Eichenbaum (2013) nevertheless find that using linear approximations appears to be robust.

Parameter	Value
Intertemporal elasticity of substitution (ρ^{-1})	1
Intratemporal elasticity of substitution (θ)	3
Frisch elasticity of labour supply (η^{-1})	4^{-1}
Degree of openness (λ)	0.2
Subjective discount factor (β)	0.99
Elasticity of substitution across the differentiated products (σ)	10
Probability of not being able to reset price (α)	0.66
$\kappa = (1 - \alpha\beta)(1 - \alpha)/\alpha(1 + \sigma\eta)$	

Table 1: Model parameters

to use these given the structure of our model. In particular, since the home economy is small, the dynamics of the foreign economy can be solved for independently. This allows us to use a two step procedure. First, we compute the dynamics of the foreign economy. Second, we compute the dynamics of the endogenous variables in the small open economy, feeding in the paths of the relevant foreign variables (such as the foreign output gap) as exogenous variables.

4.2 Benchmark Calibration: Home and Foreign Goods are Substitutes

Our benchmark case is characterised by home and foreign goods that are substitutes for home consumers. Ultimately, whether home and foreign goods are substitutes or complements, and whether this changes depending on the horizon considered, is an empirical question that remains somewhat unresolved. That said, the literature survey of Obstfeld and Rogoff (2000b) finds an intratemporal elasticity of substitution between home and foreign goods that is quite high (in the neighbourhood of 5 or 6), consistent with their being substitutes. Given this finding, we focus on the case of substitutes in explaining the impact of the foreign policy spillover on the home economy. However, we also present findings under the alternative assumption that home and foreign goods are complements. The calibration of the rest of the parameters is reported in Table 1.

4.2.1 Large Foreign Demand Shock

Before turning to the spillover of foreign policy to the home economy, it is worth describing what happens in the foreign economy in response to the large demand shock, and why we associate foreign commitment policy with a looser monetary stance. Figure 1 plots the response of the foreign variables

to the foreign demand shock under the alternative assumptions of commitment and discretionary policy. These results are essentially the same as those in Jung et al. (2005) and Levin et al. (2010). The fall in the natural rate leads to the zero bound to bind on impact for both commitment and discretionary policy. Under discretion, nominal rates are held at the ZLB until the natural rate becomes positive. From that point onwards, the nominal rate is set equal to the natural rate, and the foreign output gap is closed. However, under discretion, there is a large recession and period of deep disinflation. Under commitment, nominal interest rates are held lower for longer than under discretion, with policy exiting the zero bound several quarters after the natural rate has turned positive. This policy inertia creates expectations of lower future real rates, consistent with a looser stance of monetary policy. Since demand is forward looking, these expectations of lower real rates bring forward spending to the earlier periods, reducing the size of the recession and decline in inflation on impact. Indeed, both inflation and the output gap eventually overshoot their steady state levels. Overall, commitment policy imparts greater monetary stimulus in response to the demand shock, improving the stabilisation performance and welfare.
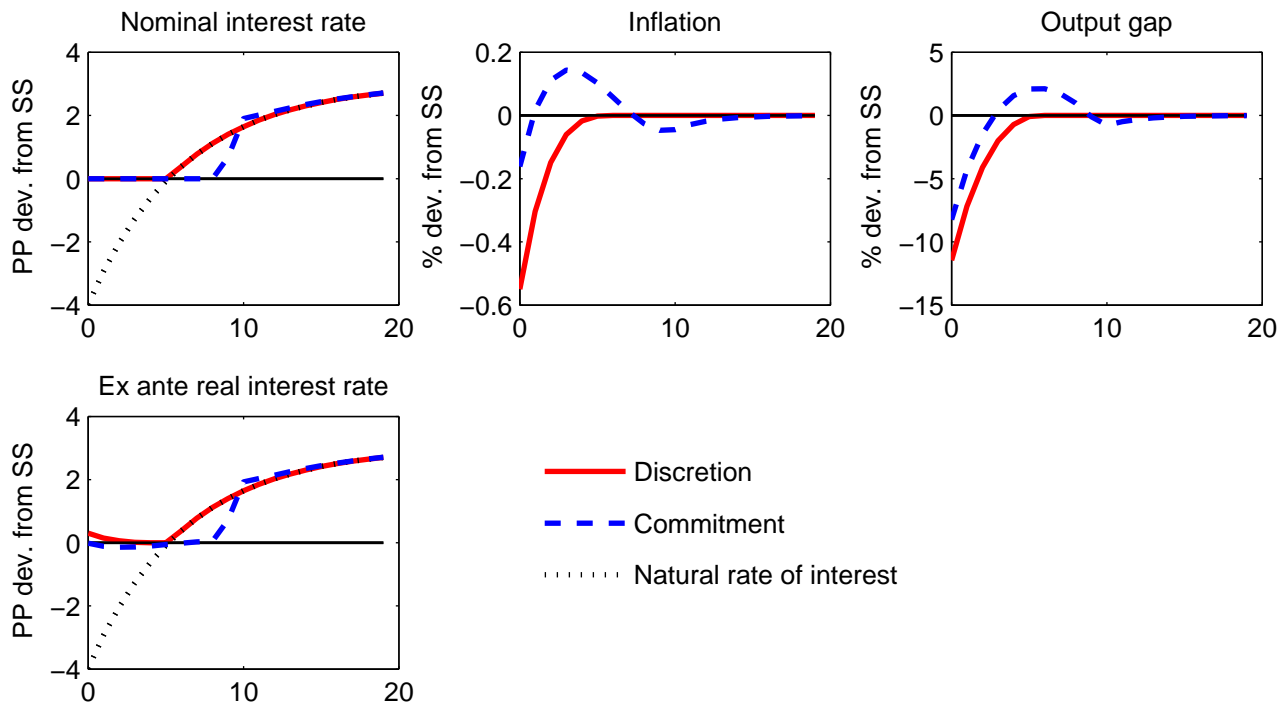

Figure 1: Response in the foreign economy to a large demand shock in the foreign economy

Figure 2 shows the response of key variables in the home economy to the foreign shock under the

alternative assumptions about foreign policy.[15] The difference in the response of the home economy under the alternative assumptions about foreign monetary strategy is fairly small. Home nominal rates fall as home monetary policy loosens in response to the decline in the natural rate (i.e. the real spillover effect). However, while the home monetary loosening also induces a fall in home ex-ante real rates, the fall in ex-ante real rates in the foreign economy is larger under both assumptions about foreign policy (albeit, as discussed above, insufficient to stabilise the foreign economy). Consistent with this, there is an appreciation of the home real exchange rate (equivalently, a depreciation of the foreign real exchange rate). The appreciation of the home real exchange rate means home consumers can consume more at a given labour supply. Home consumers, therefore, optimally choose to reduce their labour supply, increasing the amount of leisure they enjoy, which raises real wages and hence marginal costs. As a result, home PPI inflation rises.[16] A negative welfare-relevant output gap also opens up in the home economy in response to the shock for both foreign monetary strategies.

Although the difference in the response of the home economy under the alternative assumptions about foreign policy is small, there is nevertheless a *beggar-thy-neighbour* effect in evidence here. When foreign monetary policy is looser (under commitment), foreign losses are smaller. At the same time, home losses are bigger, as reported in Table 2. In particular, losses in the home economy are around 4 percent higher when foreign policy is set under commitment compared to discretion. In other words, a policy strategy that makes the foreign economy better off makes the home economy worse off. In the hypothetical case in which the foreign policymaker is completely unconstrained by the zero bound and able to loosen monetary policy much more, home losses would be larger still (while, of course, foreign losses would be zero).[17]

What is behind these results? In essence, they follow from the influence of the foreign policy spillover on the home economy, as represented by the appearance of the foreign output gap in the home *IS* and Phillips curves, and the tendency for the dynamics of the foreign output gap to dampen the effects of the shock on the home output gap and inflation. In Section 3.1 we discussed how a negative foreign output gap is similar to a negative mark-up shock, tending to put downward pressure on home PPI inflation and upward pressure on home output under the assumption that home and foreign

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[15]The equivalent results for home policy under discretion are reported in Figure B.2.

[16]This can be understood with reference to equation (4). In terms of the reduced form representation of the Phillips curve, equation (14), since both the home and foreign output gap terms push down on inflation, the increase in home inflation reflects a positive value for $\widehat{\chi}^Y_{H,t}$, the difference between the target level of output and its flexible price counterpart.

[17]This is clear from Figure B.1, which plots the response of the home economy for foreign commitment, foreign discretion, and unconstrained foreign policy (under the assumption home policy is set under commitment).
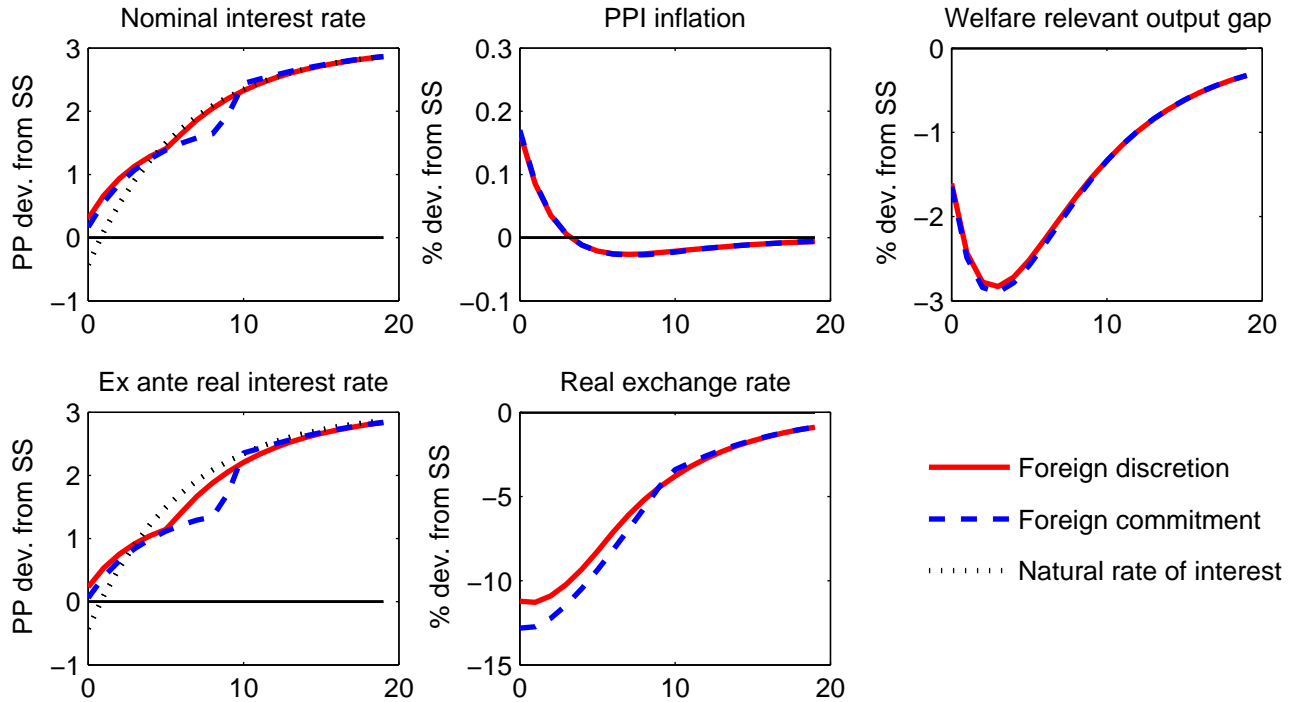
Figure 2: Response in the home economy to a large demand shock in the foreign economy for alternative assumptions about foreign policy when home monetary policy is set under commitment

Notes: The definition of the real exchange rate is such than an increase (decrease) is consistent with a depreciation (appreciation).

goods are substitutes, as considered here. In our simulation, the inability of foreign monetary policy to loosen sufficiently in response to the large negative demand shock on account of the ZLB implies a negative foreign output gap opens up. At the same time, in response to the shock, home output is depressed and inflationary pressure is increased (on account of the home labour market response, as discussed above). Therefore, the negative foreign output gap actually acts to dampen the responses of the home output gap and inflation to the shock. That is, the mark-up shock-like properties of the foreign output gap are favourable to stabilisation in this scenario since they countervail the underlying impact on the home economy of the foreign preference shock. Moreover, these dynamics are consistent with there being a *beggar-thy-neighour* effect since, when foreign policy is looser (i.e. as is the case under commitment policy compared to discretion), the size of the negative output gap in the foreign economy is smaller. And hence its dampening effects on the home economy are smaller, worsening the trade-off for the home economy.

These effects can also be understood with reference to the dynamics of the real exchange rate, which relates our simulation results to the notion of the home economy being made worse off by a

competitive devaluation by its trading partners. When foreign policy is looser, the home real exchange rate is relatively more appreciated. This is clear from Figure 2, which shows the home real exchange rate appreciates by more when foreign policy is set under commitment. Under the assumption that home and foreign goods are substitutes, the more appreciated home real exchange rate is consistent with weaker demand for home output through the expenditure switching effect – global demand is tilted away from the now more expensive home goods. It is also consistent with greater upward pressure on home PPI inflation as a result of home households' decision to reduce labour supply. Therefore, the home economy is worse off when its real exchange rate is more appreciated, as it is in the case when the foreign monetary policymaker is able to set a looser policy stance (i.e. as it is under commitment).
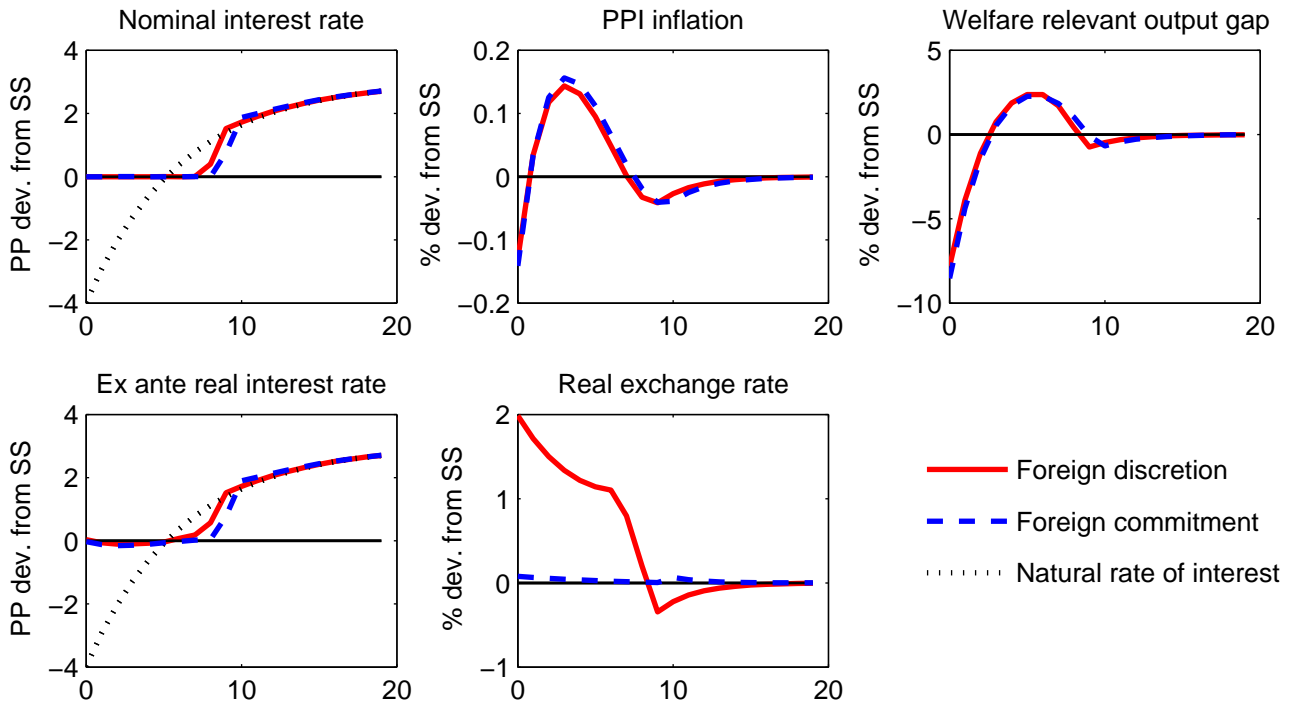
4.2.2   Large Global Demand Shock

Figure 3: Response in the home economy to a large global demand shock for alternative assumptions about foreign policy when home monetary policy is set under commitment

Notes: The definition of the real exchange rate is such than an increase (decrease) is consistent with a depreciation (appreciation).

Figure 3 shows the response of the home economy in the global-demand shock scenario. [18] The

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[18]The fact that the home economy experiences a large shock does not change the behaviour of the foreign economy –

decline in the home natural rate is sufficient to drive the home economy to the lower bound. This is true whether foreign policy is set under discretion or commitment. For each of the alternative specifications of foreign policy, the shock leads to a negative welfare-relevant output gap to open up and PPI inflation to fall on impact in the home economy.

Under commitment policy at home, nominal interest rates are held at the zero bound for several quarters after the natural rate has become positive. This strategy of policy inertia is qualitatively similar to findings for closed economies. As in the closed-economy case, the lower-for-longer policy induces declines in expected real rates, which reduce the extent of the negative output gap and the fall in inflation on impact compared to when home policy is set under discretion (see Figure B.4 in Appendix B). An additional channel through which commitment policy creates stimulus in the home economy is through a depreciation of the home real exchange rate. Since home and foreign goods are assumed to be substitutes, the home depreciation induces large expenditure-switching effects that boost demand for home goods. Inflation is also increased. This finding is consistent with the proposal of Svensson (2001, 2003) that an exchange-rate depreciation can help a small open economy to escape a liquidity trap.

However, while a depreciation is associated with optimal policy in the small open economy, the *beggar-thy-neighbour* effect remains a feature of the global-shock scenario. Figure 3 shows that the extent of the depreciation is smaller when foreign policy is set under commitment compared to discretion. As in the foreign-shock-only case, when foreign policy is looser (i.e. when foreign policy is set under commitment), the home real exchange rate is stronger than in the case when foreign policy is tighter (foreign policy under discretion). In this case, however, for looser foreign policy, the home real exchange rate is *less depreciated*, whereas in the foreign shock only case considered in Section 4.2.1 it is *more appreciated*. In other words, in both the foreign-only-shock and global-shock scenarios, the home real exchange rate is stronger when foreign policy is looser.[19]

Furthermore, when the home economy is at the ZLB, the actions of the foreign policymaker at the ZLB have more material consequences for home welfare compared to when home policy is unconstrained. From Table 2 it is clear that home losses are around 18 percent higher when foreign policy is set under commitment compared to discretion. That is, the worsening in the home policymaker's trade-off imposed by the spillover from looser foreign policy – the so-called "unintended negative side

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it is effectively closed. The dynamics of the foreign economy in the global shock scenario are simply those in Figure 1.

[19]In the hypothetical case in which the foreign policymaker is unconstrained by the ZLB, foreign policy is set sufficiently loosely that the home economy experiences a real appreciation in the global-shock scenario – see Figure B.3 in Appendix B.

	Foreign policy under commitment	Foreign policy under discretion
Large foreign demand shock		
Home policy under commitment	0.10	0.099
Home policy under discretion	0.32	0.31
Large global demand shock		
Home policy under commitment	0.21	0.18
Home policy under discretion	0.62	0.55

Table 2: Home losses when home and foreign goods are substitutes (% of steady state consumption).

effects" – is exacerbated by the constraint of the zero bound.

Why is this the case? In Section 4.2.1, we saw that, in the foreign-shock-only case, looser foreign monetary policy worsens the trade-off for home policy since it increases the extent of the home real appreciation and the associated expenditure switching away from home goods. In that case, however, home monetary policy is able to partially offset these effects by loosening. In the global-shock scenario we consider here, looser foreign policy continues to induce expenditure switching away from home goods by strengthening the home real exchange rate. But, unlike for the foreign-shock-only case, in the global-shock scenario, the home economy is also pushed to the zero lower bound. Home monetary policy is, therefore, constrained in its attempts to loosen to offset the drag on home demand associated with looser foreign policy.

Our results show that the inability of home monetary policy to loosen due to the zero bound implies the expenditure switching effects of the strengthening in the home real exchange rate associated with looser foreign policy are larger. In part this reflects the fact that the strengthening in the home real exchange rate for foreign commitment versus discretionary policy is slightly bigger when the home economy is at the ZLB. But this difference is fairly small. Instead, our quantitative results suggest that the ZLB amplifies the expenditure switching channel. In turn, this widens the home output gap and increases home losses.

4.3   Home and Foreign Goods are Complements

When home and foreign goods are complements for home consumers, our findings are reversed: home losses are smaller when the foreign central bank follows commitment policy. This finding is clear from Table 3, which shows welfare losses assuming the intratemporal elasticity of substitution between home

	Foreign policy under commitment	Foreign policy under discretion
Large foreign demand shock		
Home policy under commitment	0.0035	0.0043
Home policy under discretion	0.0099	0.0119
Large global demand shock		
Home policy under commitment	0.44	0.46
Home policy under discretion	1.16	1.18

Table 3: Home losses when home and foreign goods are complements (% of steady state consumption).

and foreign goods (θ) is 0.5 (consistent with $\rho\theta < 1$). This finding reflects the difference in the impact of a looser foreign monetary policy under this assumption: the aggregate demand effect dominates the expenditure switching effect. Although the home economy still suffers from expenditure switching away from its goods as a result of the more appreciated real exchange rate associated with a period of looser foreign monetary policy, this is outweighed by the benefit in terms of higher overall demand it enjoys due to the higher level of aggregate demand in the foreign economy. Therefore, a foreign commitment strategy, by providing the foreign economy with greater stimulus, in turn provides a bigger boost to home demand. This leads to smaller losses compared to when foreign policy is set with discretion.

5   Discussion

In the analysis above, for the purposes of clarity of exposition, we consider a highly stylised model. We discuss the effect of the degree of substitutability between home and foreign goods on the nature of the foreign policy spillover. But a number of alternative modelling assumptions would also affect the impact of foreign developments on the home economy. Among other things, the spillover effect would be different were we to assume imperfect pass-through of exchange-rate changes to consumer prices, limited risk sharing among countries, or labour-market frictions, such as sticky wages. In this section, we will briefly outline how these alternative assumptions might affect our results.

First, given the assumption of producer-currency pricing in our model, there is full pass-through from exchange-rate movements to consumer prices. This implies that the expenditure switching effect induced by foreign policy dominates the aggregate demand effect when home and foreign goods are

substitutes. However, under the alternative assumption of local-currency pricing,[20] exchange-rate pass-through would be incomplete and the expenditure switching effect reduced.[21] As a result, the sign of international spillovers would be reversed. Empirical evidence suggests pass-through in the short run is somewhat limited, in contrast to the model of producer-currency pricing. In the long run, however, there is (almost) full pass-through. That said, empirically there appears to be a strong correlation between the exchange rate and the terms of trade, which is not the case in models with local-currency pricing.[22] Ultimately, therefore, these findings point to inadequacies in the model of price setting in the New Keynesian framework we consider in this paper.

Second, our model assumes that there is full risk sharing among countries. A lower degree of financial integration would reduce the extent of the trade linkages between countries and hence the size of international spillovers. Corsetti et al. (2008) show, however, that a model with incomplete international financial markets is characterised by dynamics very similar to the complete-market model unless the assumed trade elasticity is very low and/or the shocks driving economic dynamics are very persistent.

Finally, our model assumes a frictionless labour market. As discussed in Section 3.1, the labour market is central to the transmission of the foreign policy spillover to the home economy, particularly through its influence over real wages. However, under alternative labour-market assumptions, the transmission would be different. For example, if wages were sticky, the effect the foreign policy spillover has on home real wages would be much more limited. And thus home real marginal cost and inflation would be less affected by foreign policy.

6   Conclusion

In this paper we show how the inability of foreign monetary policy to achieve full stabilisation at the zero lower bound creates a spillover effect on a small open economy it trades with. The nature of this spillover effect depends on factors that determine the structure of trade, such as the degree of substitutability between home and foreign goods for home consumers, the extent of exchange-rate pass-through, the degree of international risk sharing.

Using a small open economy model, we examine quantitatively how alternative monetary-policy strategies – commitment and discretion – in the foreign economy affect home welfare in two empirically

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[20]See e.g. Bacchetta and van Wincoop (2000).

[21]See e.g. Bacchetta and van Wincoop (2000).

[22]See e.g. Obstfeld and Rogoff (2000a).

relevant scenarios. First, a scenario where there is a negative demand shock in the foreign economy alone, driving only the foreign economy to the ZLB. Second, a scenario in which the home economy is driven to the ZLB by a negative demand shock at the same time.

Under our benchmark assumptions about trade structure, we show that looser monetary policy in the foreign economy at the ZLB – i.e. a commitment strategy – worsens the trade-off facing the monetary policymaker in the home economy. Furthermore, when the home economy is also at the ZLB, the worsening in the trade-off for home policy under looser foreign policy is more pronounced. Put another way, although the nature of the spillover from foreign monetary policy at the ZLB on the home economy is the same whether or not the home economy is at the ZLB, its impact on the home welfare is exacerbated when home monetary policy is also constrained by the ZLB. From the viewpoint of a simple small open economy New Keynesian model, therefore, G20 authorities are justified in their concerns about the need to be "mindful of unintended negative side effects stemming from extended periods of monetary easing."

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A Optimal Policy

Optimal policy under discretion The central bank in the home economy minimises (10) subject to the economy's structural equations, (13) and (14), and the non-negativity constraint on nominal interest rates (12). Under discretion, the central bank re-optimises each period. The optimisation can be represented by the following Lagrangian:

$$
\begin{aligned}
\mathcal{L} \; = \; & \frac{1}{2}\overline{C}^{1-\rho}E_{t_0}\left\{\sum_{t=t_0}^{\infty}\beta^{t-t_0}[\omega_y^H\left(\widehat{x}_{H,t}^W\right)^2+\omega_\pi^H\left(\widehat{\pi}_{H,t}^{PPI}\right)^2]+sotip\right. \\
& +2\phi_{1,t}\left[-\Delta\widehat{x}_{H,t+1}^W-\Delta\left(\widehat{Y}_{H,t}^T-\widehat{Y}_{H,t}^f\right)-\frac{\rho\left(1-\lambda\right)-\rho_\lambda}{\rho_\lambda}\Delta\widehat{x}_{F,t+1}+\frac{1-\lambda}{\rho_\lambda}\left(i_{H,t}-\widehat{\pi}_{H,t+1}^{PPI}-r_t^{n,PPI}\right)\right] \\
& \left.+2\phi_{2,t}\left[\widehat{\pi}_{H,t}^{PPI}-\beta\widehat{\pi}_{H,t+1}^{PPI}-k\left(\left(\frac{\eta\left(1-\lambda\right)+\rho_\lambda}{1-\lambda}\right)\widehat{x}_{H,t}^W+\left(\frac{\rho\left(1-\lambda\right)-\rho_\lambda}{1-\lambda}\right)\widehat{x}_{F,t}\right)-k\left(\frac{\eta\left(1-\lambda\right)+\rho_\lambda}{1-\lambda}\right)\widehat{\zeta}_{H,t}^Y\right]\right\}
\end{aligned}
\tag{A.1}
$$

The first order conditions with respect to $\widehat{\pi}_{H,t}^H$ $\widehat{x}_{H,t}^W$ and $i_{H,t}$ are as follows:

$$
\omega_y^H\widehat{x}_{H,t}^W+\phi_{1,t}-k\left(\frac{\eta\left(1-\lambda\right)+\rho_\lambda}{1-\lambda}\right)\phi_{2,t} \; = \; 0 \tag{A.2}
$$

$$
\omega_\pi^H\widehat{\pi}_{H,t}^{PPI}+\phi_{2,t} \; = \; 0 \tag{A.3}
$$

$$
\widehat{i}_{H,t}\phi_{1,t} \; = \; 0 \tag{A.4}
$$

$$
\widehat{i}_{H,t} \; \geq \; 0 \tag{A.5}
$$

$$
\phi_{1,t} \; \geq \; 0 \tag{A.6}
$$

where $\phi_{1,t}$ and $\phi_{2,t}$ are the Lagrange multipliers on the constraints. The form of the first order conditions (FOCs) is broadly thesame as for a closed economy. Equation (A.4) and inequalities (A.5) and (A.6) are the Kuhn-Tucker conditions for the non-negativity constraint on the nominal interest rate. When the nominal interest rate is zero, from and (A.6), it must be the case that $\phi_{1,t}$ is strictly positive (that is, (12) is binding). Similarly, when the nominal interest rate is positive, $\phi_{1,t}$ will be equal to zero.

Optimal policy under commitment Under commitment, the home central bank's optimisation problem can be represented by the same Lagrangian (A.1) as for discretion. But in contrast to the case of discretionary policy, under commitment the policymaker is assumed to be able to choose the entire paths of inflation and the output gap to minimise its loss. The first order conditions to the policymaker's problem with respect to $\widehat{\pi}_{H,t}^{PPI}$ $\widehat{x}_{H,t}^W$ and $i_{H,t}$ are as follows:

$$\omega_y^H \widehat{x}_{H,t}^W + \phi_{1,t} - \beta^{-1}\phi_{1,t-1} - k\left(\frac{\eta\left(1-\lambda\right)+\rho_\lambda}{1-\lambda}\right)\phi_{2,t} = 0 \tag{A.7}$$

$$\omega_\pi^H \widehat{\pi}_{H,t}^{PPI} - \frac{1-\lambda}{\rho_\lambda}\beta^{-1}\phi_{1,t-1} + \phi_{2,t} - \phi_{2,t-1} = 0 \tag{A.8}$$

$$\widehat{i}_t\phi_{1,t} = 0 \tag{A.9}$$

$$\widehat{i}_t \geq 0 \tag{A.10}$$

$$\phi_{1,t} \geq 0 \tag{A.11}$$

where $\phi_{1,t}$ and $\phi_{2,t}$ are the Lagrange multipliers on the constraints. The implications of the Kuhn-Tucker conditions (A.9), (A.10) and (A.11) for whether the nominal interest rate is positive or not are similar to those for discretionary policy.
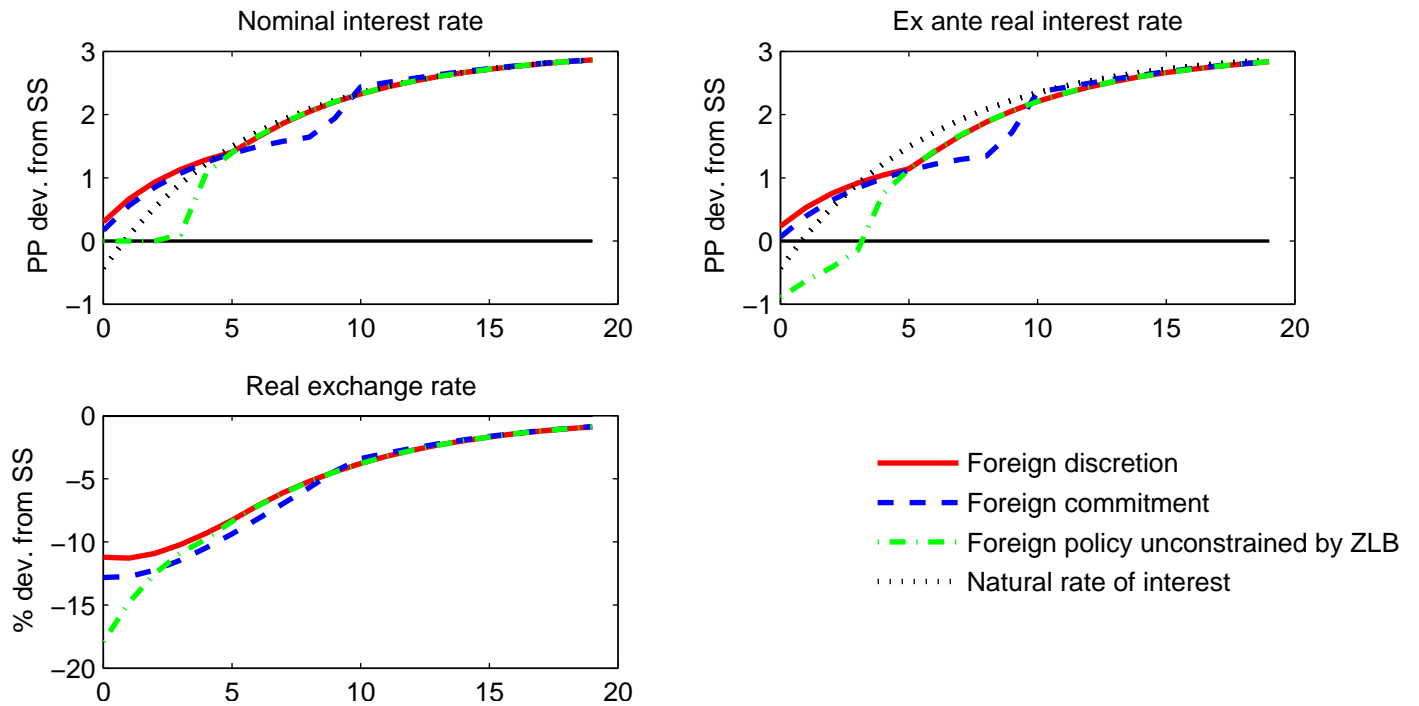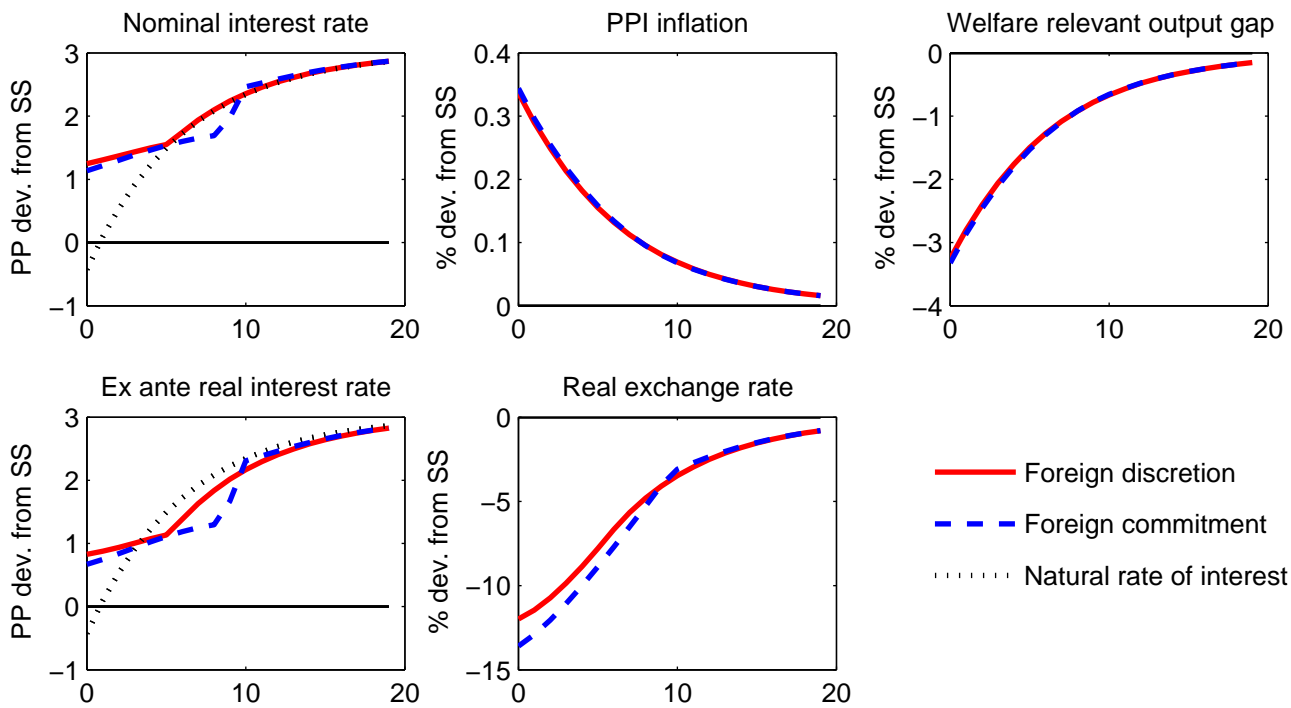
B   Figures

Figure B.1: Response in the home economy to a large demand shock in the foreign economy for alternative assumptions about foreign policy when home monetary policy is set under commitment

Notes: The definition of the real exchange rate is such than an increase (decrease) is consistent with a depreciation (appreciation).

Figure B.2: Response in the home economy to a large demand shock in the foreign economy for alternative assumptions about foreign policy when home monetary policy is set under discretion

Notes: The definition of the real exchange rate is such than an increase (decrease) is consistent with a depreciation (appreciation).
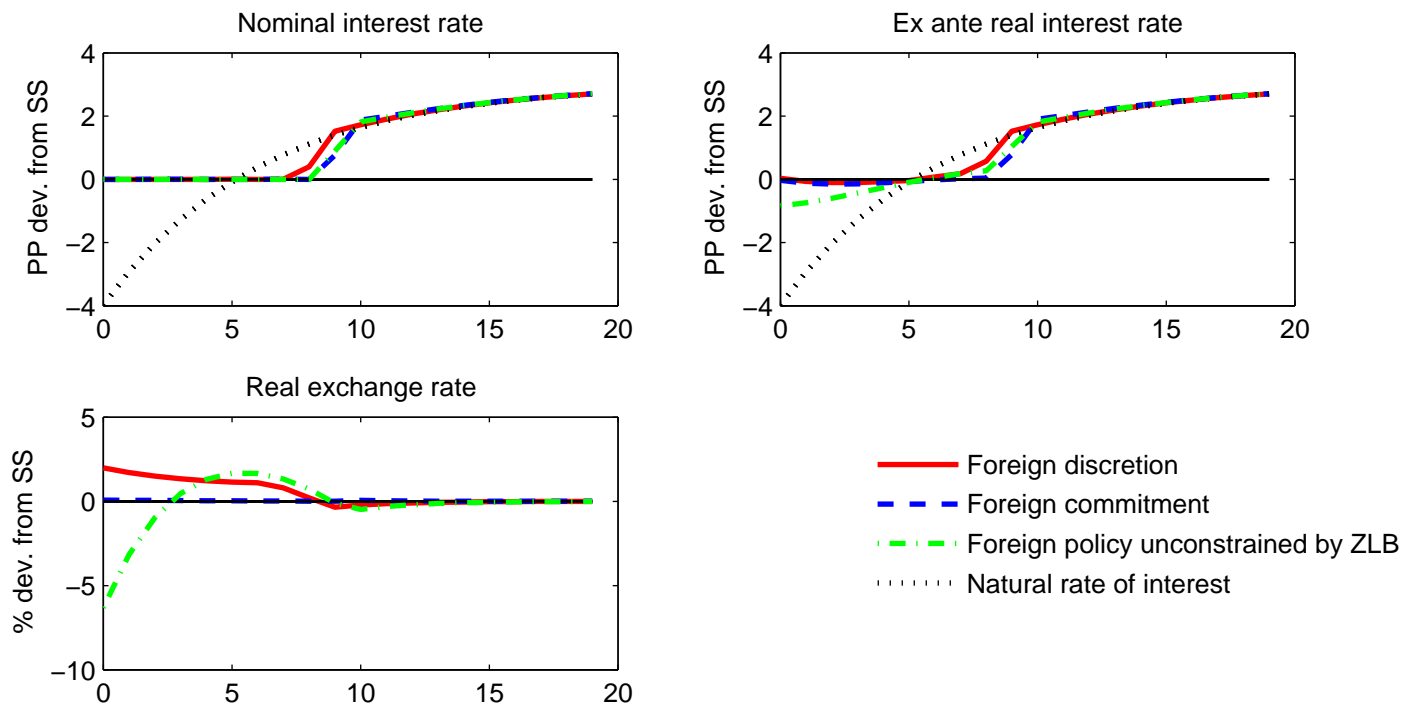
Figure B.3: Response in the home economy to a large global demand shock for alternative assumptions about foreign policy when home monetary policy is set under commitment

Notes: The definition of the real exchange rate is such than an increase (decrease) is consistent with a depreciation (appreciation).
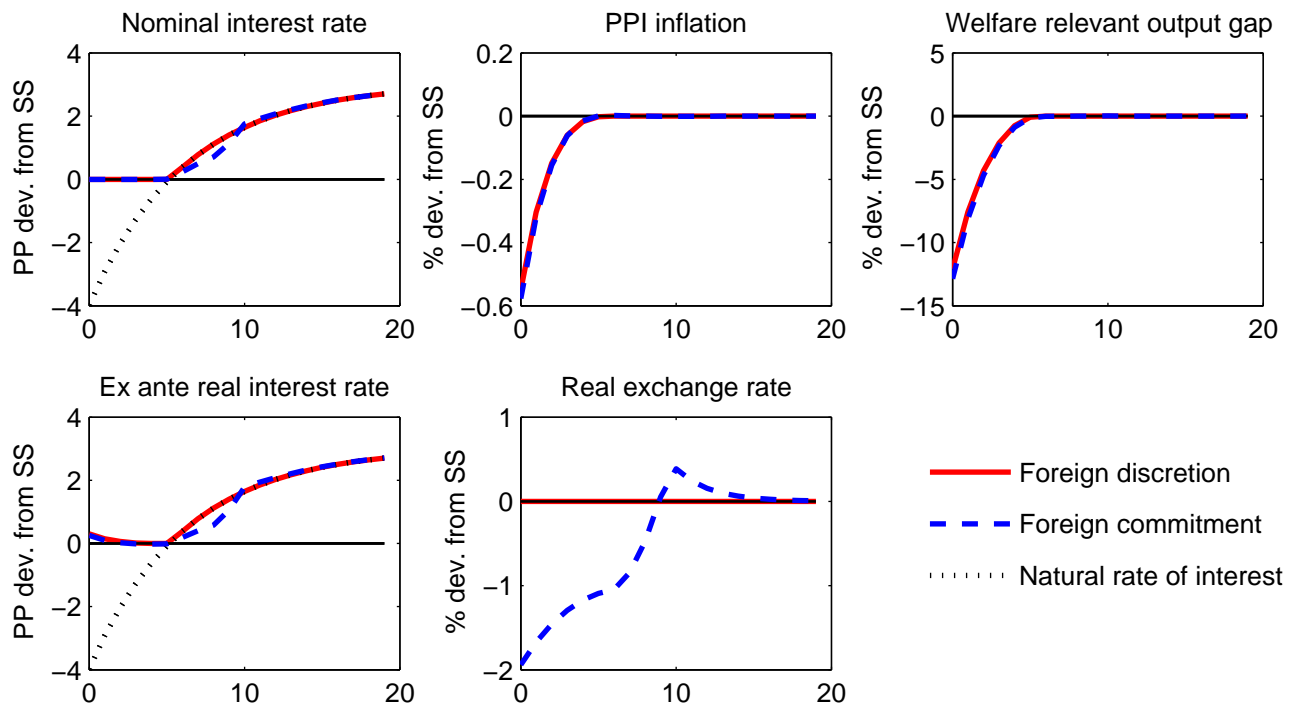
Figure B.4: Response in the home economy to a large global demand shock for alternative assumptions about foreign policy when home monetary policy is set under discretion

Notes: The definition of the real exchange rate is such than an increase (decrease) is consistent with a depreciation (appreciation).