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# Jump-Starting the Euro Area Recovery: Would a Rise in Core Fiscal Spending Help the Periphery?\*

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## Abstract

We show that a fiscal expansion by the core economies of the euro area would have a large and positive impact on periphery GDP assuming that policy rates remain low for a prolonged period. Under our preferred model specification, an expansion of core government spending equal to one percent of euro area GDP would boost periphery GDP around 1 percent in a liquidity trap lasting three years, about half as large as the effect on core GDP. Accordingly, under a standard ad hoc loss function involving output and inflation gaps, increasing core spending would generate substantial welfare improvements, especially in the periphery. The benefits are considerably smaller under a utility-based welfare measure, reflecting in part that higher net exports play a material role in raising periphery GDP.

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## 1. Introduction

There are many calls for Europe’s core economies to expand fiscal spending to help the periphery. The hope is that such a policy would help boost the GDP of periphery economies, improve their external positions, and make them less vulnerable to swings in confidence.

But would fiscal expansion in the core in fact be likely to raise periphery output? And, if so, would the effects be regarded as desirable by both the core and periphery?

Higher government spending in the core would affect the periphery partly through aggregate channels, including the reaction of monetary policy. Higher core spending would boost euro area output and inflation. Outside of a liquidity trap, the ECB would raise interest rates in real terms, which would tend to reduce periphery GDP. But in a liquidity trap – at least of sufficient duration – real interest rates could conceivably fall enough to provide a significant boost to periphery (as well as core) GDP.

The effects on periphery GDP also depend on how the core fiscal spending affects the composition of euro area demand. Higher core government spending has the direct effect of raising aggregate demand in the core. However, stronger core demand should push up inflation in the core relative to the periphery, and the implied depreciation of the periphery’s terms of trade – by boosting periphery real net exports – should rechannel some of the demand stimulus towards the periphery. This “rebalancing” should be stronger to the extent that a larger fraction of core government spending is comprised of imports of periphery goods and services.

In this paper, we attempt to gauge the likely effects of a fiscal expansion by core euro area countries using a two country New Keynesian model, and then consider welfare implications. Our benchmark model is particularly helpful in pinpointing how the various aggregate and compositional

channels shape the response of periphery output.<sup>1</sup> Even so, we also use a larger-scale DGSE model – which includes endogenous investment, nominal wage and price rigidities, and allows for non-Ricardian consumption behavior – to refine our quantitative assessments in a more empirically-realistic setting.

Outside of a liquidity trap, we find that the effects of higher core government spending on periphery GDP tend to be small and even negative (assuming that the import content of core government spending is low). The small response of periphery GDP reflects that the central bank raises real interest rates immediately, more than offsetting the stimulus arising from a depreciation of the periphery’s terms of trade.<sup>2</sup> The limited role for rebalancing through terms of trade adjustment seems consistent with Europe’s experience since the Great Recession. As seen in Figure 1, relative prices in Spain have only fallen modestly compared with the euro area average despite Spain’s much higher unemployment rate, and relative prices in Italy have actually risen slightly.

The spillovers to periphery GDP are markedly different in a liquidity trap: periphery GDP tends to rise, reflecting that the interest rate response is weaker, and the other channels tend to dominate. The size of the periphery GDP response to a core spending hike increases with the expected duration of the liquidity trap, with the import content of core government spending, and with the responsiveness of inflation. In a relatively short-lived trap lasting only a few quarters, the GDP stimulus to the periphery is fairly small (unless a sizeable fraction of core spending is imported), so that most of the expansionary effects of the fiscal stimulus is confined to the core.

However, higher core spending can provide a fairly potent source of stimulus to the periphery if

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<sup>1</sup> Our analysis is related to a large literature which has shown that the spending multiplier tends to be considerably larger in a liquidity trap than in normal times (Eggertsson (2008), Christiano, Eichenbaum, and Rebelo (2011), and Woodford (2011)). However, our analysis differs from this literature insofar as it focuses on how fiscal expansion that is concentrated in only one part of a currency union affects all member states. While our specific attention is on fiscal expansion in the core euro area countries, our analysis is equally applicable to e.g., fiscal expansion in a subset of U.S. states or Canadian provinces.

<sup>2</sup> In the same spirit, Wieland (1996) used a multi-country model to show that a fiscal expansion in Germany would cause the GDP of other countries pegging their exchange rate to Germany (in the context of the European Monetary System) to contract, reflecting the increase in German interest rates; and Kollmann et al (2014) derived similar conclusions in a model of the euro area.

monetary policy is expected to be constrained from raising interest rates for a couple of years or more. Not only is the fiscal multiplier substantially higher than normal times from the perspective of the currency union as a whole, but the stimulative effects are also more balanced across the periphery and core as higher inflation depresses real interest rates in both regions. The larger scale model implies that the effects of higher core fiscal spending are about half as large on periphery GDP as on core GDP in a three year liquidity trap.<sup>3</sup>

We next consider fiscal expansion from a more normative perspective. A fiscal stimulus program which boosts core government spending exclusively has the shortcoming that it delivers considerably more stimulus to the core, where it is “needed least” insofar as resource slack is much smaller than in the periphery. If the euro area countries were part of a fiscal union, more of the expansion could be targeted to the periphery, which would allow comparatively larger welfare gains.<sup>4</sup> Even so, we show that a moderate-sized expansion of core fiscal spending would be likely to improve both periphery and core welfare in a protracted liquidity trap, and could potentially achieve a good part of the benefits that would accrue under fiscal union.<sup>5</sup>

Some hedging in characterizing our welfare results is necessary, because the alternative welfare measures we consider differ somewhat in their implications, especially for how higher core spending is likely to affect periphery welfare. Our preferred measure is based on an ad hoc loss function in which welfare depends inversely on squared output and inflation gaps in each member state.

Given that the periphery output and inflation gaps appear large – and that higher core spending

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<sup>3</sup> Several recent papers have analyzed fiscal spillovers in a liquidity trap, including Fahri and Werning (2012), Devereux and Cook (2011), and Fujiwara and Ueda (2013). The qualitative analysis of Fahri and Werning (2012) shows that the pattern of spillovers flips sign – from negative in normal times when the currency union monetary authority raises interest rates – to positive in a liquidity trap. The other papers focus on an environment with flexible exchange rates, and argue that a country expanding fiscal spending is likely to cause its currency to depreciate enough to generate negative spillovers to its trading partners.

<sup>4</sup> While our discussion here focuses on the desirability of fiscal expansion in a prolonged liquidity trap, it bears emphasizing that a core fiscal expansion could potentially be counterproductive if monetary policy had latitude to cut interest rates sufficiently. Indeed, the analysis of both Gali and Monacelli (2008) and Pappa (2007) suggests that it might be desirable to respond to a contraction in periphery demand by cutting core fiscal spending – thus better aligning business cycles within the CU – and then cutting interest rates aggressively. While the implication that core consolidation is desirable is perhaps somewhat model-specific, the more general message that core fiscal expansion would not be desirable if monetary policy could do the lifting seems very reasonable.

<sup>5</sup> Here we are assuming that fiscal union would allow the same-sized spending hike to be distributed evenly on a per capita basis across the currency union.

is likely to boost periphery output and inflation substantially in a long-lived liquidity trap – this measure implies that the periphery would derive large benefits from an expansion in core spending. Core welfare would also improve, though by much less than for the periphery welfare given the core’s more favorable underlying conditions. Moreover, this welfare metric regards a higher import content of core spending as desirable: core fiscal expansion gives a larger boost periphery net exports, implying more balanced output effects across regions.

An alternative “utility-based” welfare measure – derived as a population weighted average of the utility functions of households in our model – suggests less scope for welfare improvement from an expansion of core government spending. Higher core government spending raises core welfare, reflecting that the cost in foregone leisure of producing government services is low, and also boosts the utility of periphery households in the near-term.<sup>6</sup> However, periphery household utility tends to be adversely affected at horizons beyond a year or two. While the adverse effects may seem surprising given the periphery’s large output gap, the utility-based measure cares about whether the fiscal stimulus boosts periphery consumption enough - and in a front-loaded manner – to justify the utility cost of the increased employment. Accordingly, the utility-based measure sees less benefit from core fiscal expansion than the simple ad hoc measure because net exports play a substantive role in reducing the periphery’s output gap, and because the consumption rise in the periphery is very drawn out (so that much of it occurs when the economy has recovered enough that the gap between the marginal utility of consumption and disutility of work is close to normal). Our sense is that the utility-based analysis is useful for highlighting that a focus on reducing output and inflation gaps is probably too narrow in assessing the merits of fiscal expansion. However, as we argue below, the utility-based measure probably understates considerably the benefits of reducing

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<sup>6</sup> As in Woodford (2011), we assume that households derive some direct utility from an expansion in government services in their home economy. Woodford shows in a simple workhorse New Keynesian model that a government spending expansion improves welfare in a liquidity trap. Using a similar one-country model, Bilbié, Monacelli, and Perotti (2015) corroborate how higher government spending can boost welfare in a moderate recession provided that government services yield direct utility, but may cause welfare to deteriorate if government spending provides no utility benefits.

the output gap and unemployment in economies facing high resource slack.

This paper is organized as follows. Section 2 presents the benchmark log-linearized model and benchmark calibration. Section 3 shows impulse responses to a core fiscal expansion with a focus on factors determining spillovers to the periphery. Section 4 considers both the positive and normative effects of alternative fiscal expansion packages against a baseline for the euro area. Section 5 examines robustness in the larger scale model, while Section 6 concludes. As the model discussion in Section 2 is somewhat technical, we have tried to make the discussion in Sections 4 and 5 sufficiently self-contained that readers should be able to understand many of the key results without delving into the details of our particular model.

## **2. The Benchmark Open Economy Model**

Our benchmark model is comprised of two countries that may differ in population size. Similar to Gali and Monacelli (2008), our model assumes that financial markets are complete both domestically and internationally, that producers set the same price in both the home and foreign market (producer currency pricing), and that monopolistically competitive firms are subject to Calvo-style nominal price frictions. We generalize the Gali and Monacelli model by allowing for habit persistence in consumption, and by assuming that some fraction of government consumption may be imported. Given the symmetric structure across countries, our discussion below focuses mainly on the home country.

Our formulation below highlights how the model can be decomposed into two parts. The first part, which determines the equilibrium for the currency union (CU) as a whole, is completely standard. The familiar three equations – the New Keynesian IS curve, the AS curve, and the policy reaction function – determine aggregate CU output, inflation, and policy rates, respectively; and per usual, a core fiscal expansion boosts CU output and inflation. The second part involves

characterizing the difference between the response of periphery and core variables. These differences depend exclusively on the terms of trade and exogenous shocks, including to fiscal policy. Importantly, monetary policy only affects the core and periphery through its effects on the CU as a whole, but does not influence the terms of trade, or the differences between the responses of periphery and core variables.

Our discussion below focuses on the log-linearized equations of the model; a full description of the underlying model structure is provided in Appendix A.

### 2.1. The Log-Linearized Benchmark Model

Consumption demand in each economy is determined by the consumption Euler equation condition, which for the home economy is given by:

$$\lambda_{ct} = \lambda_{ct+1|t} + i_t^{CU} - \pi_{ct+1|t}, \quad (1)$$

where  $i_t^{CU}$  is the policy rate of the central bank in the currency union (CU),  $\pi_{ct}$  is consumer price inflation in the home economy, and  $\lambda_{ct}$  is the marginal utility of consumption:

$$\lambda_{ct} = -\frac{1}{\hat{\sigma}}(c_t - \varkappa c_{t-1} - \nu \nu_t). \quad (2)$$

The marginal utility of consumption varies inversely with current consumption  $c_t$ , but rises both with past consumption due to habit persistence. Taken together, these equations imply that consumption falls in response to higher real interest rates, with the sensitivity depending on intertemporal elasticity in substitution parameter  $\hat{\sigma} = \sigma(1 - \varkappa - \nu)$ . The preference shock  $\nu_t$  boosts consumption demand at any given interest rate.<sup>7</sup>

Consumption demand in the CU as a whole is determined as a population-weighted average of the demand of the home and foreign economies (with weights  $\zeta$  and  $\zeta^*$ , respectively). Imposing the

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<sup>7</sup> While our model also allows for the discount factor shocks  $\zeta_t$  and  $\zeta_t^*$ , these shocks have been omitted from the description of the log-linearized equations. The discount factor shock boosts consumption demand, but has no effect on potential output or labor supply.

aggregate resource constraints which equate CU consumption to CU output  $y_t^{CU}$  less government spending  $g_t^{CU}$  (i.e.,  $c_y c_t^{CU} = y_t^{CU} - g_y g_t^{CU}$ ) and average CPI inflation in each country to CU inflation ( $\zeta \pi_{Ct} + \zeta^* \pi_{Ct}^* = \pi_t^{CU}$ ), aggregate demand in the CU may be expressed in terms of a familiar New Keynesian IS curve:

$$x_t^{CU} = \frac{1}{1 + \varkappa} x_{t+1|t}^{CU} + \frac{\varkappa}{1 + \varkappa} x_{t-1}^{CU} - c_y \widehat{\sigma} (i_t^{CU} - \pi_{t+1|t}^{CU} - r_t^{CU,pot}), \quad (3)$$

where  $c_y$  denotes the consumption-output ratio in steady state, and  $g_y$  is the government spending share. As seen from eq. (3), the CU output gap  $x_t^{CU}$  depends both on past and future output gaps, and inversely on the difference between the real policy rate in the CU  $i_t^{CU} - \pi_{t+1|t}^{CU}$  and its potential or “natural” rate of  $r_t^{CU,pot}$ .

On the aggregate supply side, the inflation rate of domestically-produced goods in each country is determined by a New Keynesian Phillips Curve. Thus, the home inflation rate  $\pi_{Dt}$  depends both on the current marginal cost of production  $m_{ct}$  and future expected inflation:

$$\pi_{Dt} = \beta \pi_{Dt+1|t} + \kappa_{mc} m_{ct}. \quad (4)$$

The subscript "D" on inflation is used to distinguish the inflation rate on domestically-produced goods  $\pi_{Dt}$  from the consumer price inflation rate  $\pi_{Ct}$ . Given our assumption of monopolistically competitive producers and Calvo-style staggered price contracts, the parameter  $\kappa_{mc}$  determining the sensitivity of inflation to marginal cost  $m_{ct}$  depends on the mean price contract duration  $\frac{1}{1-\xi_P}$  according to  $\kappa_{mc} = \frac{(1-\xi_P)(1-\beta\xi_P)}{\xi_P}$ . Thus, longer-lived price contracts flatten the slope of the Phillips Curve. Marginal cost in turn depends on the gap between the product real wage  $w_t^r$  and the marginal product of labor  $mpl_t$ :

$$m_{ct} = w_t^r - mpl_t = [\chi n_t - \lambda_{ct} + \omega_c \tau_t] + \alpha n_t - (1 - \alpha) z_t. \quad (5)$$

The effects on marginal cost associated with fluctuations in the product real wage are captured by the term in brackets. Because wages are fully flexible, the product real wages rises in response to

an increase in work hours  $n_t$  ( $\chi$  is the inverse Frisch elasticity), a fall in the marginal utility of consumption  $\lambda_{ct}$  (reflecting a wealth effect), or to a depreciation of the terms of trade  $\tau_t$ . Marginal costs also rise in response to factors which reduce the marginal product of labor, including a rise in hours work (with sensitivity  $\alpha$ ), or decline in technology  $z_t$ .

Aggregate CU inflation is determined as a population-weighted average of equation (4):

$$\pi_t^{CU} = \beta\pi_{t+1|t}^{CU} + \kappa_{mc}mc_t^{CU}. \quad (6)$$

Using the production function to substitute for hours in terms of output, CU marginal cost can be expressed solely in terms of the CU output gap and its lag (with the latter reflecting the effect of habit persistence in consumption on labor supply). Thus, the New Keynesian Phillips Curve for CU inflation is given by:

$$\pi_t^{CU} = \beta\pi_{t+1|t}^{CU} + \kappa_{mc}[\phi_x x_t^{CU} + \frac{1}{c_y \widehat{\sigma}}(x_t^{CU} - \varkappa x_{t-1}^{CU})], \quad (7)$$

where the composite parameter  $\phi_x = \frac{\alpha + \chi}{1 - \alpha}$  captures the influence of diminishing returns and the disutility of working, and  $\frac{1}{c_y \widehat{\sigma}}$  the wealth effect on labor supply.

The currency union central bank is assumed to adhere to a Taylor-type policy rule subject to the ZLB of the form:

$$i_t^{CU} = \max(-i, \psi_\pi \pi_t^{CU} + \psi_x x_t^{CU}), \quad (8)$$

Thus, outside of a liquidity trap, the policy rate  $i_t^{CU}$  rises in response to an increase in the CU inflation rate  $\pi_t^{CU}$  or expansion in the CU output gap  $x_t^{CU}$ . Because the policy rate is measured as a deviation from the steady state nominal interest rate  $i$  – the sum of the steady state interest rate  $r$  and inflation rate  $\pi$  – the zero bound constraint becomes binding only when the policy rate falls below  $-i$ . Currency union inflation  $\pi_t^{CU}$  is itself a population-weighted average of the inflation rate  $\pi_{Ct}$  in both the home and foreign country:

$$\pi_t^{CU} = \zeta \pi_{Ct} + \zeta^* \pi_{Ct}^*. \quad (9)$$

where each country inflation rate is simply the log percentage change in the respective consumption price index (i.e.,  $\pi_{Ct} = \ln(P_{Ct}/P_{Ct-1})$ ). The CU output gap  $x_t^{CU}$  is the difference between currency union output  $y_t^{CU}$  and its potential level  $y_t^{CU,pot}$ , with both variables again simply population-weighted averages of the respective country variables.

Both the potential output measure  $y_t^{CU,pot}$  relevant for the CU output gap ( $x_t^{CU} = y_t^{CU} - y_t^{CU,pot}$ ) and the potential real rate  $r_t^{CU,pot}$  depend only on population-weighted averages of the underlying shocks and lags of  $y_t^{CU,pot}$  (due to habit persistence). For example, abstracting from habit persistence for expositional simplicity, CU potential output is given by:

$$y_t^{CU,pot} = \Theta \left( g_y g_t^{CU} + \nu(1 - g_y) \nu_t^{CU} + (1 - g_y)(1 + \chi) z_t^{CU} \right), \quad (10)$$

where  $\Theta = \frac{1}{\hat{\sigma}(1-g_y)\phi_x+1} < 1$ , while the potential real interest rate may be expressed as:<sup>8</sup>

$$r_t^{CU,pot} = (1 - \rho) \left( \frac{(1 - \Theta)}{1 - g_y} g_y g_t^{CU} + \nu \nu_t^{CU} + (1 + \chi) z_t^{CU} \right), \quad (11)$$

A rise in average CU government spending  $g_t^{CU}$  has the same positive effect on currency union potential output and the potential real interest rate  $r_t^{CU,pot}$  irrespective of how it is distributed across the member states (as does the preference shock  $\nu_t^{CU}$  and technology shock  $z_t^{CU}$ ). This result rests on our assumption of a symmetric structure across the home and foreign economy, aside from population size and home bias in trade.

Our formulation highlights how a core fiscal expansion can be thought of as partly operating through aggregate channels – boosting euro area inflation, the output gap, and possibly the policy rate. Given the simple equation structure implied by the IS curve (3), the Phillips Curve (7), and the CU policy rule (8), the fiscal expansion has exactly the same effects on aggregate variables (including  $x_t^{CU}$ ,  $\pi_t^{CU}$ , and  $i_t^{CU}$ ) as in a similarly calibrated closed economy model. Of course, in

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<sup>8</sup> This expression assumes that the government spending, consumption taste, and technology shocks all follow AR(1) processes with common persistence parameter  $\rho$ .

addition to the aggregate impact, we are also interested in how the effects of core fiscal stimulus would be distributed between the periphery and core. Accordingly, we next solve for the differences in the responses between the home and foreign economy. This approach allows us to solve the model in a way that sheds light on compositional question of why the stimulus has a differential impact on each economy.

In this vein, the resource constraint implies that home output  $y_{Dt}$  may be expressed as a weighted average of consumption  $c_t$ , government spending  $g_t$ , and “net exports”  $nx_t$ , which are the the difference between exports  $m_t^*$  and imports  $m_t$  scaled by the trade share of GDP:

$$y_{Dt} = c_y c_t + g_y g_t + nx_t, \quad (12)$$

Net exports in turn depend on the percentage difference between exports and imports of each type of tradable good, including of private consumption goods (i.e.,  $m_{ct}^* - m_{ct}$ ) and government goods/services ( $m_{gt}^* - m_{gt}$ ):

$$nx_t = \omega_{cy}(m_{ct}^* - m_{ct}) + \omega_{gy}(m_{gt}^* - m_{gt}). \quad (13)$$

Each component is weighted by its respective GDP share (i.e.  $\omega_{cy} = \omega_C \times \frac{C}{Y}$  and  $\omega_{gy} = \omega_G \times \frac{G}{Y}$ ).

Net exports of either type of tradeable rise if home goods become relatively cheaper – that is, the terms of trade  $\tau_t$  depreciates – or if foreign demand rises relative to home demand. Thus:

$$m_{ct}^* - m_{ct} = c_t^* - c_t + \epsilon_c \tau_t, \quad (14)$$

$$m_{gt}^* - m_{gt} = g_t^* - g_t + \epsilon_g \tau_t. \quad (15)$$

The parameters  $\epsilon_c$  and  $\epsilon_g$  capture the sensitivity of each component of real net exports to the terms of trade and may differ between consumption and government goods.<sup>9</sup>

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<sup>9</sup> In terms of the model parameters, we have  $\epsilon_c = \left( \frac{(1+\rho_C)}{\rho_C} (2 - \omega_C^* - \omega_C) - 1 \right)$  and  $\epsilon_g = \left( \frac{(1+\rho_G)}{\rho_G} (2 - \omega_G^* - \omega_G) - 1 \right)$ .

Using the home resource constraint and its analogue for the foreign economy, the difference between home and foreign GDP may be expressed:

$$\begin{aligned} y_{Dt} - y_{Dt}^* &= g_y(g_t - g_t^*) + c_y(c_t - c_t^*) + (nx_t - nx_t^*) \\ &= g_y(1 - \omega_g - \omega_g^*)(g_t - g_t^*) + \epsilon\tau_t + c_y(1 - \omega_c - \omega_c^*)(c_t - c_t^*). \end{aligned} \quad (16a)$$

This equation says that home relative output  $y_{Dt} - y_{Dt}^*$  depends on three factors – home relative government spending, the terms of trade, and home relative consumption – and is very useful for considering how a rise in foreign government spending  $g_t^*$  (identified with higher core spending below) affects the composition of aggregate demand across the home and foreign economy. Specifically, the “direct” effect of a rise in foreign government spending of one percentage point of baseline GDP  $g_y g_t^*$  is to reduce home relative output by  $(1 - \omega_g - \omega_g^*)$  percent, with the smaller-than-unity response reflecting that some government spending may be imported. We call this the “direct” effect because it holds relative prices (i.e., the terms of trade) constant. The latter two terms capture the strength of the rebalancing channel, and both vary positively with the terms of trade. In particular, the term  $\epsilon\tau_t$  captures how the home country’s terms of trade depreciation – which would be expected following a rise in foreign government spending – shifts some demand toward the home country through a net exports channel. The responsiveness coefficient  $\epsilon$  is a weighted average of the import price sensitivity of private consumption and government services (i.e.,  $\epsilon = c_y(\omega_C + \omega_C^*)\epsilon_c + g_y(\omega_G + \omega_G^*)\epsilon_g$ ). Moreover, home relative consumption  $c_t - c_t^*$  also varies positively with the terms of trade through the complete markets risk-sharing condition (17) below, and thus also contributes to rebalancing:

$$c_t - c_t^* = \varkappa(c_{t-1} - c_{t-1}^*) + \widehat{\sigma}(1 - \omega_C - \omega_C^*)\tau_t + \frac{1}{\sigma}(\nu_t - \nu_t^*). \quad (17)$$

To provide more intuition for why home relative consumption increases in response to a foreign government spending shock, it is helpful to draw on the consumption Euler equations to link the

consumption differential to long-term real interest rate differentials in each economy:

$$c_t - c_t^* = \varkappa(c_{t-1} - c_{t-1}^*) - \hat{\sigma}(1 - \omega_C - \omega_C^*)(r_{Lt} - r_{Lt}^*) + \frac{1}{\sigma}(\nu_t - \nu_t^*). \quad (18)$$

where the long-term real interest rate differential ( $r_{Lt} - r_{Lt}^*$ ) may in turn be expressed either in terms of future short-term real interest rates, or in terms of expected inflation differentials:

$$r_{Lt} - r_{Lt}^* = \mathbb{E}_t \sum_{j=0}^{\infty} (r_{t+j} - r_{t+j}^*) = -\mathbb{E}_t \sum_{j=1}^{\infty} (\pi_{Dt+j} - \pi_{Dt+j}^*), \quad (19)$$

A foreign government spending hike initially causes foreign inflation to rise relative to home inflation, implying that the home terms of trade depreciates. But for relative prices to converge in the long-run – as they must given that the government spending shock is stationary – long-run expected inflation in the home country must *exceed* long-run expected inflation abroad (i.e.,  $\mathbb{E}_t \sum_{j=1}^{\infty} \pi_{Dt+j} > \mathbb{E}_t \sum_{j=1}^{\infty} \pi_{Dt+j}^*$  in equation (19)), implying that expected long-run real interest rates fall at home relative to abroad. Since it is the long-run real interest rate response that matters for consumption in the benchmark model, equation (18) implies that periphery relative consumption rises relative to foreign consumption (concurring with equation (17)).

As we will illustrate in the next section, this process of relative price convergence turns out to be of central importance for generating large output spillovers to the periphery from an expansion of core spending in a liquidity trap. While it is well-recognized that higher fiscal spending boosts aggregate (here, CU) expected inflation in a liquidity trap more than in normal times, the analysis above indicates that home (periphery) expected inflation must rise *even more* than foreign (core) expected inflation, fueling at least a somewhat larger rise in home (periphery) consumption than in aggregate consumption.<sup>10</sup>

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<sup>10</sup> While the dependence of current consumption on the expected long-term real interest rate is a familiar implication of the consumption Euler equation, it is worth pointing out that home relative consumption could well decline if consumption depended instead on the short-term real interest rate, or on current income due to e.g., rule-of-thumb consumers (the latter is considered in Section 5). Even so, the key implications about spillovers that we develop in the next section do not hinge sensitively on the response of *relative* consumption; what matters instead is that core spending has a big enough effect on home inflation and real interest rates that home consumption is boosted significantly (even if less than foreign consumption).

Turning to the home price-setting equation (4) and its foreign counterpart, it follows inflation differentials between the home and foreign economy depend on the difference between home and foreign marginal costs:

$$\pi_{Dt} - \pi_{Dt}^* = \beta(\pi_{Dt+1|t} - \pi_{Dt+1|t}^*) + \kappa_{mc}(mc_t - mc_t^*). \quad (20)$$

Relative marginal costs – using equation (5) and its foreign analogue – may be expressed:

$$mc_t - mc_t^* = \frac{\alpha + \chi}{1 - \alpha}(y_{Dt} - y_{Dt}^*) + \tau_t - (1 + \chi)(z_t - z_t^*). \quad (21)$$

Relative marginal cost depends on relative output  $y_{Dt} - y_{Dt}^*$ , the terms of trade, and on exogenous productivity differentials between the home and foreign economy. A rise in home relative demand boosts home relative marginal costs as wages rise more at home, and because of diminishing marginal returns to production; conversely, the rise in foreign government spending we focus on below causes foreign relative marginal costs to increase. As noted above, relative demand can be expressed exclusively as a function of the terms of trade and exogenous shocks (given complete markets). There is also an additional role for the terms of trade to affect marginal costs – captured by the middle term of equation 21 – which reflects that a terms of trade depreciation, by increasing home relative consumption, raises home relative marginal costs through a wealth effect on wages.

Since inflation differences between the home and foreign economy vary inversely with terms of trade growth according to  $\pi_t - \pi_t^* = -(\tau_t - \tau_{t-1})$  (see equation A.19 in the Appendix), the solution for the inflation differential in eq. (20) implies that the terms of trade evolves according to:

$$(\tau_t - \tau_{t-1}) = \beta(\tau_{t+1|t} - \tau_t) - \kappa_{mc}(mc_t - mc_t^*). \quad (22)$$

From an intuitive perspective, a rise in foreign fiscal spending  $g_t^*$  initially increases aggregate demand by relatively more abroad (as seen from equation 16a). This boosts relative marginal production costs abroad, which causes the home terms of trade to depreciate (from equation 22,  $mc_t^* > mc_t$ ,

so that  $\tau_t$  rises). The terms of trade depreciation gradually shifts more of the aggregate demand increase to the home economy. This rebalancing continues until there is no further pressure for relative price adjustment. This upward pressure on the terms of trade diminishes as the gap between the terms of trade and the “potential” terms of trade  $\tau_t^{pot}$  closes, as can be seen by a reformulation of equation (22):

$$(\tau_t - \tau_{t-1}) = \beta(\tau_{t+1|t} - \tau_t) - \kappa_{mc}\phi_{mc}(\tau_t - \tau_t^{pot}), \quad (23)$$

which abstracts from habit persistence for expositional convenience.<sup>11</sup> Thus, if the terms of trade is low relative to its potential level (so that the home currency is overvalued), the terms of trade tends to depreciate.

Equation (16a) underscores that the terms of trade simply evolves as an autonomous difference equation. Thus, the evolution of the terms of trade does not depend on CU monetary policy, or whether the currency union is in a liquidity trap. Because relative output levels, relative inflation rates, and relative consumption levels also only depend on the terms of trade, monetary policy has no effect on these variables: it can only operate through effects that are felt uniformly across the currency union members.<sup>12</sup>

## 2.2. Calibration

We calibrate our model at quarterly frequency, and assume a symmetric calibration for each country block aside from differences in trade intensities (due to different population size). While many aspects of our calibration are standard, two classes of parameters – including those which govern the responsiveness of inflation, and those which influence trade flows – deserve particular emphasis.

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<sup>11</sup> The parameter  $\phi_{mc}$ , which is derived from eqs. (21) and (16a) using that  $mc_t - mc_t^* = 0$  in the flexible price equilibrium, reflects the sensitivity of relative marginal costs to the terms of trade gap ( $\tau_t - \tau_t^{pot}$ ). With habit persistence, the terms of trade can also be represented as a function only of the terms of trade gap (as a third order difference equation).

<sup>12</sup> Moreover, given that we have solved for both aggregate CU variables and corresponding cross-country differences, country-specific variables may be solved for by the relevant identities. For example, given that aggregate CU output is defined as  $y_t^{CU} = \zeta y_{Dt} + \zeta^* y_{Dt}^*$ , output of the home country may be solved for as  $y_{Dt} = y_t^{CU} + (1 - \zeta)y_t^d$ , where  $y_t^d = y_{Dt} - y_{Dt}^*$ ; and foreign output is given by  $y_{Dt}^* = y_t^{CU} - \zeta y_t^d$ .

The degree to which inflation responds to output slack is the key determinant of both the terms of trade response and of the aggregate response of CU output and inflation. We have calibrated the parameters of the Phillips curve equation and monetary policy rule to imply a low degree of inflation responsiveness on two main grounds. First, if inflation was quite responsive, the much larger negative output gap in the periphery than the core since 2009 would have pushed periphery inflation well below core inflation. However, the evidence indicates that inflation has run only a bit lower in the periphery than in the core since 2009, and hence the periphery’s terms of trade – the solid lines in the upper panel of Figure 2 – has depreciated only a couple of percent.<sup>13</sup> Second, an extensive literature that has estimated the sensitivity of inflation to marginal cost – the parameter  $\kappa_{mc}$  in equation 7 – suggests a low value in the range of  $\kappa_{mc} = 0.009 - 0.014$ .<sup>14</sup> Our own analysis using the terms of trade in Figure 2 and relative labor shares to proxy for the marginal costs  $mc_t - mc_t^*$  seems to corroborate these empirical estimates. In particular, the lower panel plots  $(\tau_t - \tau_{t-1}) - \beta(\tau_{t+1|t} - \tau_t)$  (vertical axis) against  $mc_t - mc_t^*$  (horizontal axis) as implied by equation (22), and is suggestive of a very low sensitivity over the 1996:1-2013:4 sample period. Our specific calibration of  $\kappa_{mc} = 0.005$  is a bit lower than these empirical estimates and also than the value implied by fitting a simple OLS regression as in the bottom panel of Figure 2, but seems appropriate given that our model omits wage rigidities.<sup>15</sup> The implied contract duration parameter is  $\xi_p = 0.93$ .

The second key group of parameters are those determining the responsiveness of trade flows as a share of domestic output, including import share of private (consumption) spending  $\omega_C$ , of public spending  $\omega_G$ , and the trade price elasticity of each of these components ( $\epsilon_c$  and  $\epsilon_g$ ,

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<sup>13</sup> Figure 2 measures the terms of trade based on GDP deflators in the core and periphery, while marginal cost is measured as nominal unit labor cost deflated by the GDP deflator. In the figure and related regression analysis, the core is assumed to be comprised of Germany and France (weighted by GDP shares); and the periphery of Italy and Spain.

<sup>14</sup> The median estimates of the Phillips Curve slope in recent empirical studies by e.g. Adolfson et al (2005), Altig et al. (2011), Galí and Gertler (1999), Galí, Gertler, and López-Salido (2001), Lindé (2005), and Smets and Wouters (2003, 2007) are in the range of 0.009 – .014.

<sup>15</sup> While damping  $\kappa_{mc}$  seems a reasonable expedient to derive a plausible sensitivity of inflation to the output gap in the benchmark model, our larger-scale model in Section 5 explicitly includes wage rigidities.

respectively). *Ceteris paribus*, a higher trade share or higher trade price elasticity amplifies the “leakage” associated with a core fiscal expansion to the periphery, and thus should push in the direction of more balanced effects across regions. Trade data from Eurostat for Spain and Italy indicate an average import/GDP ratio of those economies of about 22 percent in 2007.<sup>16</sup> In calibrating the trade share in our two country framework, a notable complication involves how to treat periphery trade with non-EU members: periphery imports are closer to 14-15 percent of GDP if all non-EU trade is excluded from our computation. We assume an import share of 15 percent of GDP for the periphery in our baseline and hence effectively exclude non-EU trade, but recognize that the trade effects in reality would depend on how the periphery’s real exchange rate varied relative to non-EU trading partners.<sup>17</sup> Given that periphery GDP is about half of that of the core euro area countries, we set the country size parameters  $\zeta = 1/3$  and  $\zeta^* = 2/3$ ; accordingly, balanced trade implies a trade share of 7.5 percent of GDP for the core.

Our model requires parsing this import share of GDP into private and public spending components. We set  $\omega_G^* = \omega_G = 0$  under our benchmark, and then consider  $\omega_G^* = 0.2$  (implying  $\omega_G = 0.4$ ) as a high side alternative. Under the benchmark with  $\omega_G = \omega_G^* = 0$ , the import share of private consumption is about 20 percent in the periphery and 10 percent in the core (i.e.,  $\omega_C = 0.2$  and  $\omega_C^* = 0.1$ ).<sup>18</sup> The trade price elasticity for both private consumption and government spending is assumed to be slightly above unity (1.1), consistent with estimates from the macro literature on trade price elasticities.

The calibration of remaining parameters is fairly standard. The discount factor of  $\beta = 0.99875$  implies a steady state real interest rate of 0.5 percent (at an annualized rate). With a steady state

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<sup>16</sup> This computation excludes their trade with each other (so as to effectively treat them as a single country as in the model).

<sup>17</sup> If the ECB was unconstrained by the ZLB, a tightening of policy would be expected to cause the euro to appreciate, and probably imply some appreciation of the periphery’s exchange rate relative to its non-EU trading partners; in contrast, the periphery real exchange rate might well depreciate in a deep enough liquidity trap.

<sup>18</sup> The sizeable disparity between the import share of consumption and that of GDP reflects that nearly a quarter of output is devoted to government spending.

inflation rate of 2 percent (i.e.,  $\pi = .005$ ), the steady state nominal interest rate is 2.5 percent (i.e.,  $i = .00625$  at a quarterly rate). We set the intertemporal substitution elasticity  $\sigma = 1$ , which is consistent with log utility over consumption.<sup>19</sup> The habit parameter  $\varkappa$  is set to 0.8. This value is on the higher side of the range of estimates in the empirical literature, but helps our model generate a fairly plausible path for the aggregate spending multiplier without additional features such as hand-to-mouth agents (i.e., reasonably consistent with evidence on the government spending multiplier from Blanchard and Perotti (2002), even if modestly lower). The Frisch elasticity of labor supply of  $\frac{1}{\chi} = 0.4$  and capital share of  $\alpha = 0.3$  are in the typical range specified in the literature. The government share of steady state output is set to 23 percent ( $g_y = 0.23$ ), which is in line with the average government spending share of GDP in the euro area in recent years.

Our benchmark model assumes that the currency union central bank follows a Taylor-rule in equation (A.27) that is somewhat more aggressive on inflation than a standard Taylor rule, and thus sets  $\psi_\pi = 2.5$ , and  $\psi_x = 0.125$ .

### 3. Impulse Response to Higher Core Government Spending

Figure 3 examines the effects of a positive shock to core government spending that is scaled to equal one percent of CU baseline GDP (i.e., 1.5 percent of core GDP). The government spending hike is assumed to last 10 quarters, after which spending returns to its baseline level; this spending path is captured by an MA(10) in our scenarios.

We begin by considering impulse responses in normal times in which monetary policy is unconstrained by the zero lower bound. These responses are shown in the left column of Figure 3. From an aggregate perspective, the higher core spending boosts CU output (the solid line in panel A), CU inflation (panel C), and induces the central bank to raise the policy rate (panel E). Output rises

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<sup>19</sup> The scale parameter on the consumption taste shock  $\nu$  is set to 0.01 (this parameter is set to have a negligible impact on model dynamics).

well above potential (not shown) because the Taylor rule implies that real interest rates increase by somewhat less than the potential real rate (recalling equation 3); the positive output gap in turn boosts inflation. The CU output multiplier is less than unity due to some crowding out of private consumption, though habit persistence damps these crowding-out effects, and hence raises the spending multiplier relative to a specification abstracting from habit. As discussed above, these effects on the CU are identical to those that would obtain in a closed economy model.

Turning to the compositional effects across core and periphery, it is evident that the stimulus to real GDP is confined exclusively to the core. While core output (dash-dotted line in panel A) rises more than 1 percent above baseline for the duration of the spending hike – consistent with a average spending multiplier of about 0.8 – periphery output (the dashed line) contracts modestly in the short-run. The relatively large increase in core GDP causes core inflation to run above periphery inflation for some time, and the implied depreciation of the periphery’s terms of trade (the dashed line in panel E) boosts periphery real net exports. However, because the rise in core government spending triggers a sharp rise in real interest rates, the stimulus to periphery GDP from higher real net exports is swamped by a fall in periphery consumption.

To shed more light on why the output effects of core spending hikes are strongly tilted towards the core, it is useful to recall how relative aggregate demand  $y_{Dt} - y_{Dt}^*$  is affected by core government spending (from equation 16a):

$$y_{Dt} - y_{Dt}^* = g_y(1 - \omega_g - \omega_g^*)(g_t - g_t^*) + \epsilon\tau_t + c_y(1 - \omega_c - \omega_c^*)(c_t - c_t^*). \quad (24)$$

With the import share of government spending set to zero ( $\omega_G = \omega_G^* = 0$ ), a 1.5 percent of GDP rise in core government spending (i.e.,  $g_y g_t^* = .015$ ) would cause periphery relative demand  $y_{Dt} - y_{Dt}^*$  to fall by a commensurate amount if the terms of trade  $\tau_t$  remained unchanged, reflecting that in this case neither relative consumption  $c_t - c_t^*$  nor relative trade flows (captured by the term  $\epsilon\tau_t$ ) would adjust. Given sluggish price adjustment, the terms of trade in fact changes very

little in the near-term, which accounts for why core output in fact rises nearly 1.5 percent above periphery output (panel A) immediately following the shock. Subsequently, the gap between core and periphery output narrows as terms of trade depreciation (panel E) boosts periphery real net exports while causing core real net exports to contract, and also induces periphery consumption to rise relative to core consumption. Even so, the figure shows that this narrowing isn't very pronounced quantitatively over the period in which the fiscal expansion remains in force. The adjustment coming from relative trade flows  $\epsilon\tau_t$  is quite modest because sluggish price adjustment damps the movements in the terms of trade (panel F shows that the depreciation peaks at only 0.7 percent), and because the trade responsiveness parameter  $\epsilon$  is fairly small (around 0.3) given observed trade shares and our calibration of trade price elasticities of around unity. Similarly, periphery consumption rises only slightly above core consumption.<sup>20</sup> All told, the rebalancing of the stimulus towards the periphery that occurs through relative price channels is quite small.<sup>21</sup>

We next consider the effects of core fiscal expansion in a liquidity trap. The right column of Figure 3 shows the effects of the same 1.5 percent of GDP rise in core government spending in a liquidity trap lasting 12 quarters; the liquidity trap is generated from an adverse consumption taste shock that persistently depresses the potential real rate  $r_t^{CU,pot}$ . At an aggregate CU level, the highly accommodative monetary policy stance in a liquidity trap makes fiscal expansion more potent in stimulating output and inflation than under the Taylor rule which is in force in normal times. CU output expands around 1.2 percent after four quarters in a 12 quarter liquidity trap (the solid line in panel B) rather than 0.7 percent in the case of no liquidity trap (the solid line in panel A), with the larger expansion reflecting that private consumption is “crowded in” rather than out by a fall in real interest rates. These aggregate implications are consistent with an extensive literature showing

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<sup>20</sup> Recalling the discussion in section 2, periphery consumption rises more than core consumption because periphery expected inflation exceeds core inflation (given that core prices initially rise by more, and that relative prices must converge in the long-run).

<sup>21</sup> Only about 1/4 of the 1.5 percent “autonomous” shift in demand towards the core is offset by relative price changes after 10 quarters (the final quarter of the government spending hike).

that fiscal policy has amplified effects in a liquidity trap, cf. Christiano, Eichenbaum, and Rebelo (2011) and Woodford (2011). Consistent with this literature, the aggregate demand stimulus associated with fiscal expansion quickly dissipates once government spending reverts to its initial level, suggesting that fiscal spending – at least abstracting from practical impediments – could be targeted to periods of high resource slack without risking potentially undesirable after-effects.

The more accommodative monetary policy stance in a liquidity trap relative to normal times imparts a commensurate degree of stimulus to each CU member, recalling from Section 2 that the gap between the output responses in the core and periphery is invariant to monetary policy. Thus, as can be seen by comparing panel B with panel A, the output responses in both the periphery and core in panel B are shifted up by the same exactly the same amount in percent terms relative to the case of no liquidity trap (e.g., about 0.5 percent after four quarters). Output still expands by considerably more in the core, but the spillovers to the periphery are now positive and sizeable. A liquidity trap, in effect, “lifts all boats” in tandem relative to normal times. Intuitively, both periphery and core GDP are boosted by the same degree because ECB policy rates do not rise in a liquidity trap – which provides equivalent stimulus to each member state – and due to the expansionary effect this more accommodative policy stance has on inflation in each member.

The larger GDP effects on both the periphery and core in a liquidity trap are due to a larger response of consumption relative to normal times. By contrast, given that real net exports depend only on the consumption gap  $c_t - c_t^*$  and terms of trade – both of which are invariant to the stance of monetary policy – the response of real net exports turns out to be the same in a liquidity trap as in normal times. Our results showing amplified spillovers are consistent with the qualitative analysis of Fahri and Werning (2012), who also underscore how a crowding in of private consumption plays a key role in generating output positive spillovers in a liquidity trap.

Overall, changes in core government spending seem likely to exert substantial effects on pe-

riphery output in a deep liquidity trap. Under such conditions, a core government spending hike boosts periphery GDP through qualitatively similar channels as would an easing of monetary policy (if the periphery had an independent monetary policy): lower real interest rates boost periphery consumption, and terms of trade depreciation stimulates net exports. However, while monetary easing could generate a large and upfront decline in both nominal and real interest rates, fiscal expansion relies heavily on higher inflation to boost periphery domestic demand. With sluggish price adjustment, the scope to boost periphery inflation quickly and hence stimulate periphery output in the near-term is somewhat limited (relative to the hypothetical case in which the periphery had latitude to reduce policy rates directly).

A second important consequence of sluggish price adjustment is that the core fiscal expansion imparts stimulus to the periphery well after government spending – and aggregate CU output – has returned to its initial level: as seen in Figure 3, periphery output (panel B) remains elevated even after several years. These expansionary effects reflect that periphery inflation must run persistently above core inflation in the medium-run – as seen in panel D – to allow relative prices to converge back to their pre-shock level. Of course, such longer-term stimulus may be undesirable if the economy has largely recovered – a consideration we explore in the welfare analysis of Section 4. But from a purely positive perspective, our simulation results highlight how fiscal stimulus can have longer-lived distributional effects on member states even if the aggregate CU effects dissipate quickly when the fiscal stimulus is withdrawn.

### **3.1. The Longer the Liquidity Trap, the Stronger the Spillover Effects**

A key question is how the effects of a core spending expansion vary with the expected duration of the liquidity trap. The upper panels of Figure 4 show the effect of the same core government spending expansion on both periphery output (left panel) and core output (right panel) for liquidity

traps ranging in duration from zero quarters (normal times) to 12 quarters. The effects are derived as the average response over the first four quarters following the stimulus, and hence can essentially be read off the IRFs in Figure 3 for both the normal times case and for the 12 quarter trap. The figure indicates that the spillovers to the periphery are slightly negative in a liquidity trap lasting four quarters or less. Accordingly, the stimulus associated with fiscal expansion accrues almost wholly to the core in a relatively short-lived liquidity trap.

Our result that the spillovers to the periphery are negative in a shorter-lived liquidity trap – and that the aggregate multipliers are fairly modest – may seem surprising in light of the literature suggesting a sharp disparity between the effects of fiscal expansion between a liquidity trap and normal times. There are three important reasons for why a short-lived liquidity trap doesn’t look too different from normal times in our baseline model. One reason is that we allow for substantial habit persistence in consumption. This allays the strong “crowding out” effects on consumption that would occur in normal times when interest rates rise in response to higher government spending, while limiting the crowding in effects due to lower real interest rates in a liquidity trap.

The second reason – explored more fully below – is that inflation is much less responsive under our calibration than often assumed in the literature.

The third reason is that government spending shock is assumed to follow an MA(10), and hence persists well beyond the duration of the shorter-lived liquidity traps considered in the figure. As emphasized by Woodford (2011) and Christiano, Eichenbaum, and Rebelo (2012), this fiscal overhang attenuates the aggregate CU multiplier relative to a “ideally-structured” fiscal intervention that dissipates before the economy exits the liquidity trap. In particular, to the extent that fiscal spending was expected to remain high even after the economy exited the liquidity trap, long-term interest rates would be pushed up, generating negative spillovers to the periphery in short-lived traps. It turns out that spillovers to the periphery would always be positive – even in a transient

liquidity trap – provided that the core spending only rose during the period in which monetary policy was constrained by the ZLB. Even so, the spillovers are very small quantitatively in a short-lived trap, reflecting that inflation rises very little if the fiscal stimulus is transient, and hence there is little crowding in of private consumption. Moreover, practical impediments make it unlikely to achieve a rapid phase-in and phase-out within a few quarters. As Cogan et al (2011) have pointed out, only around a third of the increased U.S. federal spending on goods and services authorized by the American Reconstruction and Recovery Act was earmarked to be spent within the first two years of the ARRA’s passage in February 2009.

While our results show that a fairly long-lived liquidity trap – of around 3 years – seems a prerequisite for substantial positive spillovers to the periphery, some caution is required in interpreting these estimates. In particular, the benchmark model omits a number of features – including non-Ricardian consumption behavior – that can account for a higher multiplier even if price adjustment is very sluggish. The more policy oriented model we examine in Section 5 yields spillovers to the periphery that are considerably larger than in our benchmark, especially for a fairly long-lived liquidity trap.

### **3.2. The Steeper the Phillips Curve, the Stronger the Spillover Effects**

While slow price adjustment seems consistent with Europe’s experience since the Great Recession, it is possible that the Phillips Curve slope is higher than we have assumed in our benchmark calibration. A higher Phillips Curve slope might be consistent with observed inflation behavior if potential output has fallen by more than typically estimated, especially in the periphery. Alternatively, adverse shocks to credit conditions and weak productivity growth may help explain the apparent resilience of euro area inflation, similar to the forces that Christiano, Eichenbaum, and Trabandt (2013) have argued help account for U.S. inflation behavior.

Accordingly, Figure 5 shows IRFs to the core spending shock under a calibration with a steeper Phillips Curve slope: specifically, we set  $\xi_p = 0.88$ , implying a Phillips Curve slope parameter of  $\kappa_{mc} = .017$ , which is slightly above the median point estimates in the literature discussed earlier. The output spillovers in normal times (panel A) are not much different under this calibration than under our benchmark (panel A of Figure 3). The faster terms of trade adjustment (panel E) than in the benchmark does imply somewhat more balanced stimulus across the periphery and core (recalling equation (24)). However, this effect in the direction of more balance – which is quite modest quantitatively – is essentially offset as the bigger rise in CU inflation prompts a larger rise in CU policy rates, which reduces the aggregate CU multiplier relative to benchmark.

The fiscal expansion under the higher Phillips Curve slope does have dramatically different implications than in the benchmark in a persistent liquidity trap. With the higher Phillips Curve slope, the higher inflation implies much lower real interest rates, and consequently a much larger expansion of CU GDP (comparing panel B of Figure 5 with panel B of Figure 3). Given that this aggregate stimulus is evenly distributed, periphery GDP increases about 1/2 as much as core GDP in a 12 quarter trap. The dashed lines in the upper panels of Figure 4 show how the effects on core and periphery GDP vary with the duration of the liquidity trap under this calibration.

This calibration is useful for highlighting conditions that might give rise to very large positive fiscal spillovers, and is of particular interest given that calibrations of the Phillips Curve slope in this range are often used in the literature. Although the implied responsiveness of inflation seems somewhat of a stretch in light of the Great Recession experience, the scenario does underscore some upside risk to fiscal spillovers if inflation proves more responsive than assumed under the benchmark.

### 3.3. The Larger the Import Content of Spending, the Stronger the Spillover Effects

Policymakers often draw attention to terms of trade adjustment as a key channel through which the periphery might benefit from a core fiscal expansion. Nevertheless, even if price adjustment turned out to be much faster than appears plausible – as in our last scenario – it is striking how little of the GDP stimulus to the core is redirected to the periphery through terms of trade adjustment. Accordingly, we next consider how allowing for a sizeable component of core spending to fall on periphery imports could facilitate rebalancing the aggregate demand stimulus more evenly across the core and periphery. In the extreme case in which the core government spending was disbursed equally across currency union members according to population size – a “no home bias” case in which  $\omega_G^* = 1/3$  and  $\omega_G = 2/3$  – the periphery and core would share equally in the stimulus. Figure 6 shows the effects in a less extreme case when the import share of core government spending  $\omega_G^*$  is set to 0.20 (20 percent of government spending in the steady state). As this reallocation of spending has no consequences for CU aggregates, the effects of the core spending hike on CU output are identical to Figure 3 (in which  $\omega_G^* = 0$ ). However, the changes in the pattern of GDP response across core and periphery are striking: the rise in periphery GDP is more than half as large as the rise in core GDP even in normal times. Thus, core spending may provide considerable stimulus to the periphery even in a short-lived liquidity trap if it falls substantially on periphery imports. The boost to both periphery (and core) GDP is even larger in a long-lived liquidity trap.

Overall, these results underscore how direct purchases may allow core fiscal spending to have much more balanced effects on core and periphery output even if terms of trade adjustment is quite sluggish. It is important to note, however, that the greater spillovers to periphery GDP reflect a larger boost to periphery real net exports than in the baseline without direct purchases; periphery consumption actually rises a bit less than under our baseline calibration that was shown

in Figure 3a.<sup>22</sup> As we will discuss in the next section, these compositional effects turn out to be consequential in evaluating the extent to which increasing the import share of government purchases affects welfare.

#### 4. Welfare Effects of Higher Core Government Spending

The literature analyzing the effects of fiscal expansion in a liquidity trap has largely focused on environments which abstract from differences in economic conditions across countries or states. The implicit assumption is that each member of a common currency area – whether a country or state – faces an equally severe downturn, and would get a similar boost in government spending if a stimulus package were enacted. The situation facing policymakers in Europe is different in two important respects. First, resource slack in the periphery economies is much larger than in the core, and inflation is correspondingly more subdued. Second, assuming that fiscal stimulus would have to come mainly from the core economies, the expansionary effects on CU GDP would be likely to be concentrated in the core economies.

These asymmetries across member states – both in initial business cycle positions, and in the effects of fiscal policy – have important implications for gauging the welfare effects of fiscal expansion. In this section, we illustrate some of the considerations that would seem relevant in designing a fiscal stimulus program in this environment.

To conduct our analysis, we use two alternative measures of welfare. First, we assume a standard ad hoc loss function in which the policymaker only cares about minimizing squared output gaps and inflation gaps in both the core and periphery economies:

$$L_t^{CP} = \frac{1}{4} \sum_{s=0} \beta^s \left\{ \zeta \left[ (\pi_{t+s}^{Per} - \pi^*)^2 + \lambda_y (x_{t+s}^{Per})^2 \right] + (1 - \zeta) \left[ (\pi_{t+s}^{Core} - \pi^*)^2 + \lambda_y (x_{t+s}^{Core})^2 \right] \right\}, \quad (25)$$

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<sup>22</sup> Because the output expansion is more balanced across regions, there is less upward pressure on the terms of trade; and hence periphery inflation doesn't have to rise as much to bring relative prices back to their long-run equilibrium level. This smaller rise in periphery inflation translates into a smaller rise in periphery consumption.

Thus, the welfare loss  $L_t^{CP}$  is population-weighted average of the loss function for each CU member (core or periphery). Each region’s loss function is simply a sum of the squared inflation gap ( $\pi^*$  is set to 2 percent) and squared output gap, with the parameter  $\lambda_y$  determining the relative weight on the output gap set to 1/3 for each region. The inflation target  $\pi^*$  is set to 2 percent. While this loss function is admittedly simple, it helps address the interesting question of the extent to which fiscal policy can substitute for monetary policy when the latter is constrained by the ZLB by “filling in” output and inflation gaps.<sup>23</sup> Our second welfare measure – considered in Section 4.2 – is based on the discounted utility of households in our model.

#### **4.1. Welfare Results under Ad Hoc Loss Function**

##### **4.1.1. Fiscal Expansion in Core and Periphery (Fiscal Union)**

As a useful reference point for assessing the effects of a fiscal expansion in the core, we first consider the optimal fiscal expansion if the euro area countries were part of a fiscal union. From the perspective of the euro area as a whole, there would seem a strong rationale for fiscal expansion under current conditions: output gaps are large, inflation is below target, and monetary policy is likely to be constrained by the ZLB for several years. A fiscal union would presumably give more scope to the periphery economies to expand domestic fiscal spending than in the current environment in which concerns about debt sustainability and adverse market reactions appear to impose tight constraints. Exactly how much latitude is unclear, as it would depend on the specific features of the fiscal compact. However, it seems plausible that such a union might allow an expansion in euro area government spending that was distributed roughly equally across member states on a per capita basis.<sup>24</sup> Accordingly, we assume that each member state boosts fiscal

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<sup>23</sup> This assumption would seem most reasonable to the extent that the additional stimulus is on goods for which there was considerable scope to substitute purchases intertemporally (e.g., construction or transport equipment).

<sup>24</sup> Analysis of U.S. fiscal stimulus programs such as the ARRA suggest reasonably balanced expenditure across U.S. states in per capita terms (e.g., Orr and Sporn, 2012), notwithstanding that spending on some components of these programs (such as unemployment compensation) depend on regional economic conditions.

spending by a commensurate amount under fiscal union.

The welfare benefits of a fiscal stimulus program clearly depend on how output and inflation gaps in the core and periphery would evolve absent any fiscal stimulus. Our baseline assumes adverse consumption demand shocks cause a prolonged recession in the euro area that is especially concentrated in the periphery.<sup>25</sup> The solid lines in Figure 7 depict this baseline. Specifically, the output gap in the core (the solid line in panel C) is about  $-2$  percent in 2015 and nearly closes within three years; whereas the output gap in the periphery (panel D) is about  $-5$  percent initially, and slack remains sizeable even after a few years. Inflation stays well below 2 percent in both the core (panel E) and periphery (panel F), but runs particularly low in the periphery (with some deflation in 2015).<sup>26</sup> Our calibration of the Taylor rule implies that the CU interest rate remains pinned at zero for 12 quarters. Table 1 reports the losses under the welfare measure (25) that are derived from cumulating the discounted squared output and inflation gaps from 2015:Q1 to 2020:Q4; given that the effects of the fiscal actions we consider on output and inflation gaps are small after six years, the welfare gains reported below would change very little if the horizon were extended beyond that period. Clearly, losses are heavily concentrated in the periphery.

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<sup>25</sup> The effects of fiscal stimulus on output and inflation gaps analyzed below do not hinge on the particular type of shock(s) driving the output gap in the baseline. Other shocks, such as the productivity shocks  $z_t$  and  $z_t^*$ , would yield similar results if calibrated to imply the same evolution of the core and periphery output gaps as shown in Figure 7 (i.e., both the positive effects would be similar, as well as the normative implications under the quadratic criterion). This invariance reflects the tight link between output gaps and inflation in our benchmark model, and would not obtain if there were features such as wage rigidities that implied tradeoffs. It is important to note that the welfare results under the utility-based criterion considered in Section 4.2 do depend somewhat on the nature of the shocks driving the output and inflation gaps, reflecting that welfare depends on the evolution of consumption and other variables; however, we found that experimenting with different underlying shocks had relatively little effect on our results (provided that the alternative shocks implied similar output gap and inflation responses).

<sup>26</sup> The output gaps in the baseline are broadly similar – albeit somewhat smaller – to those forecast by the OECD in its interim economic outlook that was released in March 2015 (for example, the OECD projects that the output gap in the euro area will be about 3 percent in 2015, compared with 2-1/2 percent in our baseline, and almost 6 percent in the periphery, compared with 4 percent in our baseline). The large and persistent output gaps in the baseline in turn imply considerable downward pressure on inflation, notwithstanding that Phillips Curve slope is very flat under our baseline calibration; under more typical calibrations of Phillips Curve slope used in the literature, the decline in inflation would be even sharper.

**Table 1: Losses under Baseline: Ad Hoc Welfare Function**

	Overall Loss $L_t^{CP}$	Core	Periphery
Discounted Loss	21.5	12.5	39.5

Note: The overall loss  $L_t^{CP}$  is based on eq. (25) for 2015:Q1 to 2020:Q4. The core and periphery losses are based on their respective discounted squared inflation and output gaps with  $\lambda_y = 1/3$ .

Against this backdrop, we assume that a CU-wide fiscal stimulus is initiated that boosts government spending by 1 percent of baseline GDP in both the core and periphery. The stimulus begins in the same quarter as the adverse shocks and lasts 12 quarters, and thus is “well-timed” to coincide with the period in which monetary policy is constrained. We compute the model solution – both under the baseline and for the scenario with higher fiscal spending – using a nonlinear solution algorithm for solving perfect foresight models in DYNARE.<sup>27</sup>

The blue dashed lines in Figure 7 labelled “Fiscal Union: CU-Wide Stimulus” show the effects of this fiscal expansion. The joint fiscal expansion narrows the periphery output gap (panel D) substantially – as well as the gap between periphery inflation (panel F) and the 2 percent target – while nearly closing the core output gap (panel C). Panel A in Table 2 reports the welfare gains from fiscal stimulus, which is measured as the difference between the welfare loss assuming no stimulus (from Table 1) and the welfare loss under the stimulus program. Aggregate welfare improves substantially, with welfare losses cut by half relative to the baseline. While both the core and periphery experience welfare improvements, the periphery experiences much larger absolute gains given the large initial output and inflation gaps in that region (which are penalized heavily under the quadratic objective).

Fiscal policy in this setting is similar to monetary policy insofar as both forms of stimulus operate with equal force on each member state, and hence can’t close output (and inflation) gaps in each. Larger welfare improvements could be achieved by channeling relatively more of the

<sup>27</sup> We assume in our simulations below that the CU central bank does not counteract the core fiscal stimulus by raising rates any earlier than in the absence of stimulus. This limited form of commitment modestly amplifies the stimulus from the fiscal expansion. Upon exit, policy rates follow the Taylor rule, and thus eventually react to the higher demand caused by the fiscal expansion.

fiscal stimulus to the periphery where the marginal value of additional stimulus is higher – and thus essentially using core and periphery spending as separate instruments to “fill gaps” in each member state.<sup>28</sup> Of course, political economy considerations could well preclude such targeted spending.

**Table 2: Gains From Fiscal Expansion: Ad Hoc Welfare Function**

<b>Panel A: Welfare Gains under Fiscal Union</b>			
	Currency Union	Core	Periphery
	11.2	7.8	18.1
<b>Panel B: Welfare Gains under “Core Only” Fiscal Expansion</b>			
	Currency Union	Core	Periphery
Benchmark ( $\omega_G^* = 0$ )	10.4	8.3	14.5
High Import Share ( $\omega_G^* = 0.2$ )	10.9	7.9	16.8

Note: The table reports absolute gains, computed as  $\text{Loss}^{\text{Baseline}} - \text{Loss}^{\text{Scenario}}$ .

#### 4.1.2. Fiscal Expansion only in Core

We next assess how a fiscal expansion that was concentrated exclusively in the core would affect welfare in both the core and periphery; for comparability with the previous analysis, we continue to assume that the core spending hike equals 1 percent of CU GDP. As seen by the red dotted lines in Figure 7 labeled “Core Only Stimulus,” the core spending hike provides a much larger boost to core GDP and inflation than to the periphery: the core output gap turns noticeably positive, while the periphery output gap only narrows modestly.

The first row of Panel B in Table 2 reports the welfare gains under the core-only fiscal expansion

<sup>28</sup> As is clear from previous work by Gali and Monacelli (2008), it would not be optimal to close output or inflation gaps in each member state if there were some costs of expanding government spending (at least beyond a certain level). First, it would be essential to balance any direct fiscal costs against the benefits of reducing output (and inflation) gaps. Second, the optimal policy would also take account of how current increases in government spending affected the terms of trade and hence future output (and inflation) gaps. In particular, higher periphery government spending would boost periphery relative prices and thus tend to hurt periphery net exports in the future. Because the optimal policy would take account of both the direct fiscal costs and the loss in future competitiveness, it would not be optimal to close the periphery output gap completely (and similarly for the core).

under our benchmark calibration in which the import content of government spending is zero ( $\omega_G^* = 0$ ). The core fiscal expansion improves welfare by less than under the fiscal union case (reported in the upper panel), especially for the periphery. This is because the core expansion boosts aggregate demand relatively more in exactly the region in which it is “least needed” according to the ad hoc welfare criterion. The disparity in the welfare results between the core-only and fiscal union cases would be noticeably larger if the size of the fiscal expansion under each case were chosen optimally to maximize the quadratic welfare criterion (25): this reflects that the optimal expansion turns out to be considerably larger under fiscal union because fiscal union allows more of the fiscal stimulus to be channeled to the region where its marginal value is comparatively high.<sup>29</sup>

Even so, it is remarkable that the core-only fiscal expansion does achieve a good portion of the welfare gains that would accrue under fiscal union. Because output and inflation gaps are very large in the periphery – and output spillovers to the periphery sizeable in a long-lived liquidity trap – the periphery derives substantial benefits from core fiscal expansion. Moreover, even the core benefits from a modest-sized expansion that can help pare its own output and inflation gap.

An expansion of government spending in the core would raise welfare even more if some of the increase in core government spending was on imported periphery goods. As we have shown in Section 3.3, such an approach balances the stimulus to output and inflation more evenly across the core and periphery, and thus appears more akin to fiscal union than the case in which core spending falls exclusively on domestically-produced goods. For a calibration with a high core import share of 20 percent ( $\omega_G^* = 0.2$ ), the effects of a core-only fiscal expansion on output and inflation gaps in each region are very similar to that achieved under fiscal union (and hence not shown in Figure 7 for expositional reasons). By implication, Panel B in Table 2 shows that the welfare gains to the currency union approach those achieved under fiscal union, with both the core and periphery

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<sup>29</sup> The optimal spending hike under fiscal union is 2.5 percent of CU GDP, while the optimal hike for the core-only case is 3.1 percent of Core GDP, which is equal to 2.1 percent of CU GDP. Under an optimally-sized fiscal expansion, the welfare gain to the CU is 18.0 under fiscal union, compared with 14.9 under the core-only expansion.

experiencing nearly commensurate welfare gains.

Stepping beyond the particular baseline in Figure 7, it is interesting to consider the question of whether core fiscal expansion could improve CU welfare if the periphery experienced a deep recession, but conditions were more favorable in the core (than say in Figure 7), so that the central bank was not expected to hold interest rates at the zero bound for very long. Quite intuitively, it turns out that a core fiscal expansion could improve periphery welfare considerably even in this situation provided that the core government spent a substantial fraction on imports from the periphery; in this case, the stimulus to periphery net exports would dominate any drag due to higher long-term interest rates, and narrow the periphery output gap (recalling Panel B in Figure 4). By contrast, an expansion of core government spending that fell wholly on domestically-produced goods would do little to help the periphery under these same underlying conditions (recalling that output spillovers are small in a short-lived liquidity trap).

#### 4.2. Welfare Results under Utility-Based Criterion

Our previous welfare results indicate that an expansion of core spending may improve periphery welfare considerably by shrinking the periphery’s sizeable output and inflation gaps; and that comparatively large welfare improvements – for both core and periphery – may be achieved to the extent that a larger share of core spending falls on periphery imports.

We next consider the robustness of these normative results to an alternative welfare measure based on the discounted conditional expected utility of the representative household in each member state in our model:

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \zeta_{t+j} \left\{ \ln (C_{t+j} - \varkappa C_{t+j-1} - C\nu_{t+j}) - \chi_0 \frac{(N_{t+j})^{1+\chi}}{1+\chi} + \frac{\vartheta_G}{1 - \frac{1}{\sigma_G}} (G_{t+j} - \varkappa_G G_{t+j-1})^{1 - \frac{1}{\sigma_G}} \right\}. \quad (26)$$

Household utility depends positively on public and private consumption, and inversely on hours

worked. Welfare in the currency union on the “utility-based” metric is simply a population-weighted average of the utility functionals of periphery and core households.<sup>30</sup>

#### 4.2.1. Fiscal Expansion in Core and Periphery (Fiscal Union)

Panel A of Table 3 reports welfare gains under fiscal union using the utility-based objective (26). Because we continue to assume that government spending in each CU member would expand by 1 percent of GDP under fiscal union, the impulse responses are the same as in Figure 7 (the dashed lines labelled “Fiscal Union”). The utility gains in the table are summarized in terms of a “consumption equivalent compensation” (CEV henceforth), which is the permanent percent increase in household private consumption – relative to the baseline with no fiscal expansion – that is required to make households equally well off as under the government spending expansion. Following the usual approach in the literature, household welfare depends on how the fiscal expansion affects the entire infinite discounted sum of period utility. The aggregate CU CEV is a population-weighted average over the core and periphery.

As under the ad hoc loss criterion above, the equal-sized fiscal expansion in each CU member is strongly welfare-improving. Fiscal expansion is beneficial because it boosts utility directly through increasing government services, and indirectly through inducing an expansion of private consumption, with the latter reflecting that the higher inflation induced by the fiscal expansion reduces real interest rates. Crucially, this increase in utility from public and private goods comes at a low cost in terms of foregone leisure because labor is underutilized and inflation suboptimally low. The low level of inflation is undesirable because it implies substantial inefficiency in goods production in our modeling framework with staggered price setting (Rotemberg and Woodford,

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<sup>30</sup> To perform this welfare analysis, we assume that households regard government spending on goods and services as somewhat more substitutable through time than private consumption, and that habit persistence is somewhat lower (specifically, we set  $\sigma_G = 2$ , so that the elasticity of substitution is 2, and the habit persistence parameter  $\kappa_G = 0.4$ ). Finally, we set  $\vartheta_G$  to account for a steady state share of government consumption to output of .23, and  $\chi_0$  so that  $N$  (hours worked per capita) equals unity in the steady state.

1997), and hence acts like a tax on production; accordingly, a key benefit of fiscal expansion is that it boosts productivity by pushing inflation closer to target (assumed to be 2 percent). Aside from the implication – clear from Panel A in Table 3 – that the periphery benefits more from fiscal expansion due to its relatively large degree of slack, the logic favoring fiscal expansion under fiscal union closely parallels that provided by Woodford (2011) for a closed economy. In particular, because the fiscal expansion is the same in each CU member, it has no effect on the terms of trade or net exports; accordingly, all of induced expansion in employment goes to increasing either public or private consumption.

**Table 3: Welfare Gains From Fiscal Expansion: Utility-Based**

<b>Panel A: Welfare Gains under Fiscal Union</b>			
	Aggregate CU	Core	Periphery
	.015	.008	.028
<b>Panel B: Welfare Gains under “Core Only” Fiscal Expansion</b>			
	Aggregate CU	Core	Periphery
Benchmark ( $\omega_G^* = 0$ )	.010	.013	.002
High Import Share ( $\omega_G^* = 0.2$ )	.012	.027	-.018

Note: The table reports consumption equivalent compensation (*CEV* henceforth), i.e. the percentage point increase in households’ consumption that makes them—in expectation—equally well-off under no-stimulus as when core government spending expands. Aggregate CEV is calculated as the weighted sum of CEV in the core and periphery.

#### 4.2.2. Fiscal Expansion only in Core

The utility-based metric in effect poses a much more stringent test than the simple ad hoc loss function (25) for assessing whether increases in core government spending improves periphery welfare: assuming as we do that the periphery gets no direct utility benefits from the higher core government spending (e.g., from better roads in France), periphery welfare only improves if the core spending hike boosts periphery consumption enough to offset the cost of working additional hours. Thus,

the composition of the rise in periphery GDP matters a great deal for welfare, as well as the timing of the rise in consumption. Even if the periphery output gap is large and the output spillovers to the periphery fairly big – conditions that lead to substantial periphery welfare improvements under the simple quadratic loss function – periphery welfare may fall under the utility-based criterion if the rise in periphery GDP is driven by net exports, or if the stimulus persists too long.

As seen in Panel B in Table 3 (above), the expansion of core spending in the case in which the import content is zero ( $\omega_G^* = 0$ ) yields an improvement in core welfare. Core welfare improves because the core’s sizeable resource slack makes it less costly – and hence more desirable – to produce more government services. The effects on periphery welfare are more complicated. Periphery discounted welfare improves, though by considerably less than core welfare. The core fiscal expansion turns out to boost the period utility of periphery households in the near-term, but has slightly negative effects on their period utility at horizons much beyond a year.

Figure 8 is helpful for understanding these welfare results. Focusing first on our benchmark case with  $\omega_G^* = 0$  – shown by the red dotted lines – it is evident that periphery consumption (panel B), real net exports (panel F), and employment (panel D) each respond positively to the core spending shock. As might be expected in a deep recession, the benefits of the rise in periphery (private) consumption outweigh the cost in terms of labor effort at least in the near-term, which accounts for why the *period* utility of the representative periphery household (panel H) improves for over a year. Some of the improvement in periphery household utility reflects that the core spending hike boosts periphery inflation from a suboptimally low level, and this reduced inflation tax distortion means that less labor is required to produce any given quantity of output.

It may seem surprising that the core fiscal expansion doesn’t provide an even more sustained boost to periphery welfare: after all, the periphery responses look very similar qualitatively to the usual effects of a favorable monetary shock under an independent monetary policy, insofar as

lower periphery real interest rates crowd in consumption, and a depreciation of the periphery's terms of trade boosts real net exports. Monetary stimulus of this type might be expected to be very beneficial given the periphery's poor initial conditions. However, to achieve welfare benefits under the metric (26), it is critical that the policy action boost consumption in the near-term when the gap between the marginal utility of consumption and disutility of work is especially large. From the prism of the utility-based welfare metric, there are two key problems with how the core fiscal expansion affects the periphery. First, a sizeable share of the expansion in periphery output – about 1/4 under our benchmark calibration – is due to higher real net exports rather than increased periphery consumption; in effect, this diversion of employment towards net exports operates like a tax, because it means that the rise in periphery employment is associated with a smaller near-term consumption boost. Second, the stimulus to periphery consumption is very spread out over time, as evident in panel B (and discussed previously in Section 3.3). The protracted consumption response reflects that the fall in periphery real interest rates is driven exclusively by higher periphery inflation, which rises only gradually; this contrasts with a nominal interest rate cut which could deliver more front-loaded stimulus. Given the recovery in the economy and that the marginal utility of consumption is depressed by past consumption weakness (due to habit persistence), the medium and longer-run boost to consumption seen in Figure 8 isn't worth the labor cost.

These considerations also help explain why an expansion of core spending causes periphery welfare to deteriorate considerably – as reported in Panel B in Table 3 – in the case in which core imports are sizeable ( $\omega_G^* = 0.2$ ). These results differ dramatically from the implications of the ad hoc loss function in which the higher import content was a major plus for welfare in both CU members. As we have seen – and is also shown by the blue dashed lines in Figure 8 – the periphery GDP expansion under the higher import share calibration is more heavily driven by net exports, which the utility-based welfare measure views as undesirable.

As might be expected, periphery household welfare can improve more if initial conditions are noticeably worse than in Figure 7, and cause discounted welfare to improve. To illustrate this, Table 4 reports the effects of the same core spending expansion against an alternative baseline in which output gaps in each member are much larger (slightly below minus 8 percent in the periphery, and close to minus 3 percent in the core), and inflation falls well below zero in the currency union as a whole. Periphery period utility – as well as CU welfare – improves very persistently under these conditions, leading to an improvement in the discounted welfare measure. The output spillovers to the periphery are not only larger than in Figure 7, but fueled by a bigger consumption rise; moreover, the benefits of boosting both consumption and inflation are larger given the poorer initial conditions.

**Table 4: Welfare Gains of Core Fiscal Expansion**

<b>under More Adverse Baseline: Utility-Based</b>			
	Aggregate CU	Core	Periphery
Benchmark ( $\omega_G^* = 0$ )	0.021	.027	.010
High Import Share ( $\omega_G^* = 0.2$ )	0.024	.040	-0.007

Note: The table reports consumption equivalent compensation (*CEV* henceforth), i.e. the percentage point increase in households' consumption that makes them—in expectation—equally well-off under no-stimulus as when core government spending expands. Aggregate CEV is calculated as the weighted sum of CEV in the core and periphery.

Taking stock of our results, each of the alternative welfare measures we have considered suggest that a suitably-designed fiscal stimulus program in the core can improve *near-term* welfare in both the periphery and core. The welfare improvements under each measure are clearly larger and more persistent the worse the baseline and longer monetary policy is likely to be constrained from raising interest rates. Welfare improvements would also be larger if spillovers to periphery consumption were bigger than in our baseline (as would occur if e.g., prices were more flexible than in our benchmark). However, there is clearly some tension between how the welfare measures score policy actions which reduce the output gap significantly, but don't provide much short-run

stimulus to consumption. This tension can have important implications for the design of a core stimulus program, and in particular, for assessing the desirability of a higher import content of core government purchases.

Our sense is that the utility-based analysis is useful for highlighting how the welfare effects of fiscal expansion depend on how the stimulus affects the composition of demand – between consumption and net exports – and that fiscal policy may have long-lived effects arising through relative price channels that may possibly reduce welfare. Even so, the utility-based welfare metric probably understates some of the benefits of reducing the output gap and unemployment in economies plagued by high resource slack. Indeed, our model embeds two key assumptions – of perfect consumption risk-sharing, and that all variation in labor effort occurs at the intensive margin – that tend to minimize the costs of a large output gap, and correspondingly, to understate the benefits of fiscal expansion. While these assumptions are useful for analytical tractability, employment opportunities in reality exhibit much more dispersion across households, and each household’s consumption depends on how it fares in the labor market. These considerations suggest that policies that could markedly reduce the periphery’s output gap – and as a result, reduce consumption dispersion and improve labor market functioning – would be likely to enhance periphery welfare. All in all, we think that the welfare benefits of fiscal expansion probably lie between the two measures, but tilt more in the direction suggested by the simple ad hoc loss function.

## **5. The Effects of a Core Spending Expansion in a Larger Scale Model**

The benchmark model is useful for highlighting many of the key factors likely to shape how a core fiscal expansion would affect the periphery. However, the benchmark model likely understates both the aggregate effects of core fiscal expansion and spillovers to the periphery due to the exclusion of Keynesian accelerator effects on household and business spending. A consequence is that the

aggregate multiplier is relatively modest even in a liquidity trap unless inflation rises significantly.

Accordingly, we next reconsider the effects of a core spending expansion in a larger-scale two country model with endogenous investment that closely follows Erceg and Linde (2013). Abstracting from open economy features, the specification of each country block builds heavily on the estimated models of Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2003, 2007). Thus, the model includes both sticky nominal wages and prices, allowing for some intrinsic persistence in both components; habit persistence in consumption; and embeds a  $Q$ -theory investment specification modified so that changing the level of investment (rather than the capital stock) is costly. However, our model departs from this earlier literature by assuming that some fraction of households are “Keynesian”, and simply consume their current after-tax income in a hand-to-mouth fashion; this evidently contrasts with our benchmark model which assumes that all households make consumption decisions based on their permanent income. Galí, López-Salido and Vallés (2007) show that the inclusion of non-Ricardian households helps account for structural VAR evidence indicating that private consumption rises in response to higher government spending. Although the inclusion of hand-to-mouth agents amplifies the spending multiplier even in normal times, its effect on the aggregate multiplier is considerably larger in a liquidity trap, and in particular, can help generate sizeable spillovers to the periphery even if the Phillips Curve is very flat.

On the open economy dimension, the model assumes producer currency pricing as in the benchmark. Financial markets are assumed to be incomplete, meaning that there is a single “internationally traded” bond available to core and periphery households. However, given that the trade price elasticity is calibrated to be close to unity, the implications of incomplete markets are similar to those of complete markets; as we have discussed above, even complete markets may allow for sizeable country-specific fluctuations in consumption given that households have different preferences

over goods (see Cole and Obstfeld, 1991, for a more detailed discussion).

A detailed description of the model and its calibration is provided in Appendix B. However, several features of the calibration are worth pointing out. First, our calibration assumes a central bank reaction function which responds quite aggressively to inflation (when unconstrained by the ZLB), and also imposes that both wages and prices respond very sluggishly to shocks. Specifically, the monetary rule has a long-run coefficient of 2.5 on inflation, of 0.5 on the output gap, and 0.7 on the lagged interest rate. Our choice of a Calvo price contract duration parameter of  $\xi_P = .93$  implies a very low Phillips Curve slope of about .005, and wages exhibit a commensurate degree of stickiness. As in the benchmark model, these parameter choices are aimed at capturing the resilience of core inflation in the euro area, including in periphery countries which have experienced large and persistent resource gaps. Second, we set the share of Keynesian households to optimizing households to a little below half, implying that the former comprise about 1/4 of aggregate consumption in the steady state. Finally, government spending in each country is assumed to be comprised of domestic and imported goods in exactly the same proportion as private spending – 10 percent for the core, and hence 20 percent for the periphery. This is in between the low and high values for  $\omega_G$  we used in the benchmark model.

### 5.1. Higher Core Spending

Figure 9 shows the effects of a front-loaded increase in core government expenditures equal to 1 percent of CU steady state output (i.e., 1.5 percent of core output). As in Section 4, core government spending rises for 12 quarters before reverting to baseline (i.e., it follows an MA(12)). The spending hike occurs against the backdrop of initial conditions consistent with a deep recession and liquidity trap that is also expected to last 12 quarters.<sup>31</sup>

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<sup>31</sup> The initial conditions are generated by a sequence of adverse demand (consumption taste) and supply (productivity) shocks. The baseline paths of output, inflation, and the CU policy rate are broadly similar to those shown in Figure 7, though the output gaps are a bit larger, and inflation falls somewhat less (reflecting the productivity

The responses to a core spending hike both in normal times and in a liquidity trap are very similar qualitatively to those of the benchmark model. The red dashed lines show the normal situation in which policy is unconstrained. CU output (the red dashed line in panel A) rises considerably on impact – the multiplier is about unity – and then dies out more quickly than the path of government spending as CU policy rates (panel B) increase. The stimulus to GDP is heavily concentrated in the core (panel C). Periphery real net exports benefit from terms of trade depreciation (panel G) – reflecting that higher core government spending puts upward pressure on the relative price of core goods – and due to some direct purchases of goods/services from the core government. However, periphery GDP (panel D) is essentially flat as the stimulus to net exports is offset by a fall in domestic demand (panel H shows consumption) that is induced by the higher policy rates.

Aggregate CU output (solid line in panel A) rises much more in a protracted liquidity trap, and periphery GDP (panel D) also rises substantially. Although core inflation (panel E) rises relatively more than periphery inflation (panel F) in the near-term, the rise in periphery inflation is both sizeable and persistent, as is required to eventually bring the terms of trade back to its pre-shock level. Given the ZLB, the implied fall in real interest rates provides a strong impetus to domestic demand in both the periphery (panel H) and core that is in turn amplified by the Keynesian hand-to-mouth consumption behavior. Periphery GDP also benefits from some expansion of real net exports due to a modest depreciation of the periphery’s terms of trade.

All told, periphery GDP rises about 1 percent after a year, which is more than half as large as the expansion in core GDP. Thus, as in the benchmark model of Section 2, the output stimulus due to core fiscal expansion becomes much more balanced in a prolonged liquidity trap. The implied CU multiplier of slightly below two is very close to the empirical estimates of Auerbach (2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2065, 2066, 2067, 2068, 2069, 2070, 2071, 2072, 2073, 2074, 2075, 2076, 2077, 2078, 2079, 2080, 2081, 2082, 2083, 2084, 2085, 2086, 2087, 2088, 2089, 2090, 2091, 2092, 2093, 2094, 2095, 2096, 2097, 2098, 2099, 2100, 2101, 2102, 2103, 2104, 2105, 2106, 2107, 2108, 2109, 2110, 2111, 2112, 2113, 2114, 2115, 2116, 2117, 2118, 2119, 2120, 2121, 2122, 2123, 2124, 2125, 2126, 2127, 2128, 2129, 2130, 2131, 2132, 2133, 2134, 2135, 2136, 2137, 2138, 2139, 2140, 2141, 2142, 2143, 2144, 2145, 2146, 2147, 2148, 2149, 2150, 2151, 2152, 2153, 2154, 2155, 2156, 2157, 2158, 2159, 2160, 2161, 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and Gorodnichenko (2012) of the government spending multiplier in a deep recession. Of course, the magnitude of the periphery output response in Figure 9 is considerably larger than in the benchmark model (comparing to Figure 7, which also assumes a 12 quarter liquidity trap), suggesting that the estimates of spillovers from the latter are probably on the conservative side.<sup>32</sup>

## 6. Conclusions

Our paper has considered the implications for the euro area of a fiscal expansion in the core economies, with particular focus on how the periphery would be affected. We have shown that not only does the fiscal multiplier for the euro area as a whole become much larger in a prolonged liquidity trap, but also that the stimulative effects become relatively more balanced between the core and periphery (though still tilted in favor of the core). Periphery GDP expands as domestic demand is “crowded in” by lower real interest rates, and as net exports are boosted by terms of trade depreciation and an expansion of domestic demand in the core economies. Accordingly, fiscal policy seems a potent tool to improve welfare throughout the euro area, at least to the extent that welfare can be proxied by inflation and output gaps.

While an extensive literature has focused on the potential benefits of fiscal policy in a liquidity trap, most of this analysis has abstracted from differences in business cycle positions across member states. Our analysis suggests that fiscal spending is likely to be much more effective in boosting welfare to the extent that it can be targeted to countries or states facing relatively adverse business cycle conditions. Thus, a euro area fiscal compact that would allow more distressed countries greater latitude to engage in deficit-financed spending could yield substantial benefits. Of course, there are many challenges of designing a fiscal union, including of how to limit the moral hazard risks that such insurance might pose to other members of the compact.

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<sup>32</sup> We also considered the effects of adding a financial accelerator channel along the lines of Bernanke, Gertler, and Gilchrist (1999), and found that the output response in both the periphery and core was modestly larger than shown in Figure 9.

From a methodological perspective, our modeling framework has abstracted from a number of features that would seem useful extensions for future research. First, our analysis is conducted under the assumption of perfect foresight, implying that the public is convinced that the economy will eventually recover absent fiscal action. The benefit of fiscal expansion would likely be greater in a stochastic environment in which fiscal expansion could help mitigate downside tail risks that likely are substantial in a prolonged liquidity trap. Second, our model assumes a representative agent structure with perfect risk sharing. The benefits of fiscal expansion – especially using a utility-based welfare criterion – would presumably be greater in a heterogeneous agent framework in which risk-sharing was much less pervasive, and each household’s consumption more dependent on its particular employment opportunities. Finally, our modeling framework does not allow for sovereign and private borrowing spreads to respond to fiscal expansion, which could potentially amplify its effects both at home and abroad.<sup>33</sup>

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<sup>33</sup> On the other hand, McKay, Nakamura, and Steinsson (2015) argue that taking account of borrowing constraints and uninsurable income risk may imply a somewhat lower interest elasticity of demand than implied by models which assume that financial markets are complete at the national level. A lower interest elasticity would damp the fiscal multiplier in a liquidity trap.

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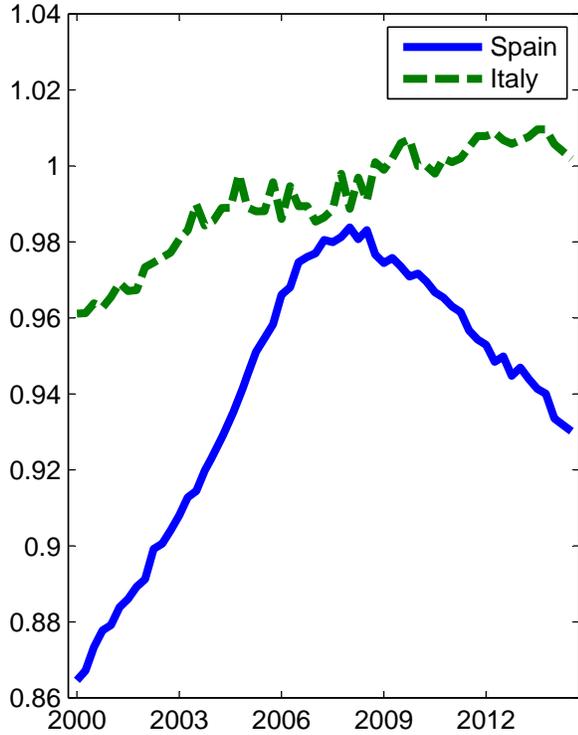
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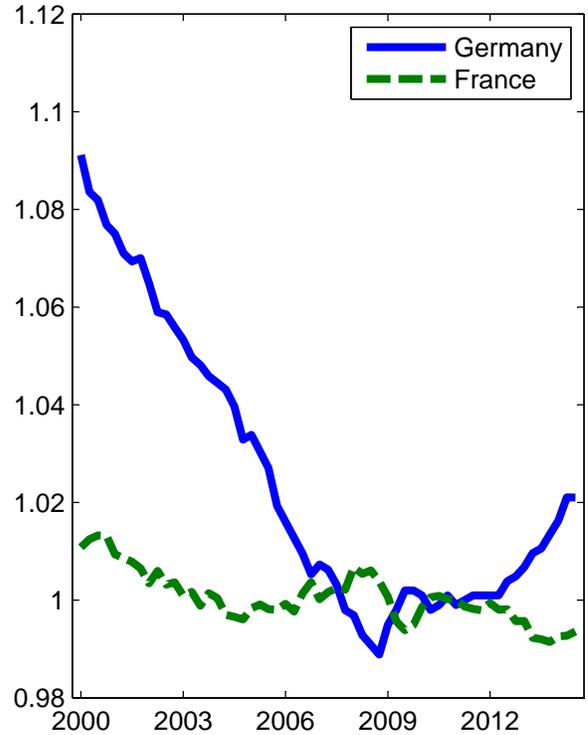
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**Figure 1: Relative Prices and Unemployment in Euro Area**

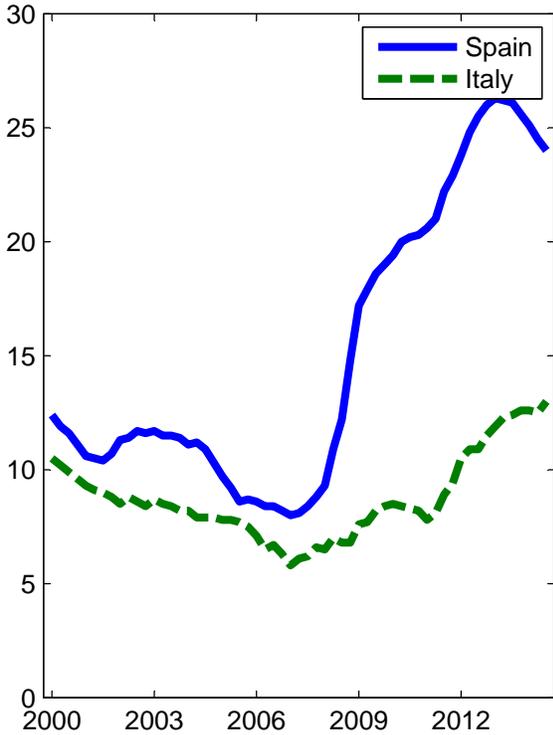
**Relative GDP Deflator: Periphery vs. EA**



**Relative GDP Deflator: Core vs. EA**



**Unemployment Rates: Periphery**



**Unemployment Rates: Core**

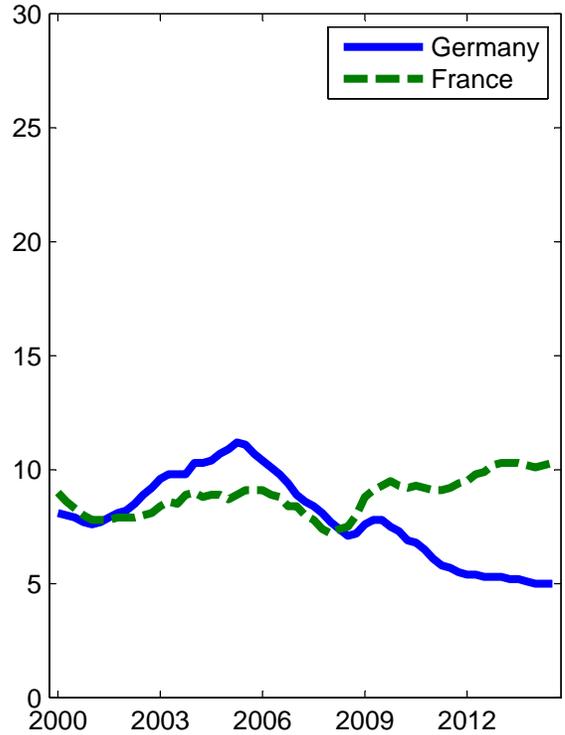
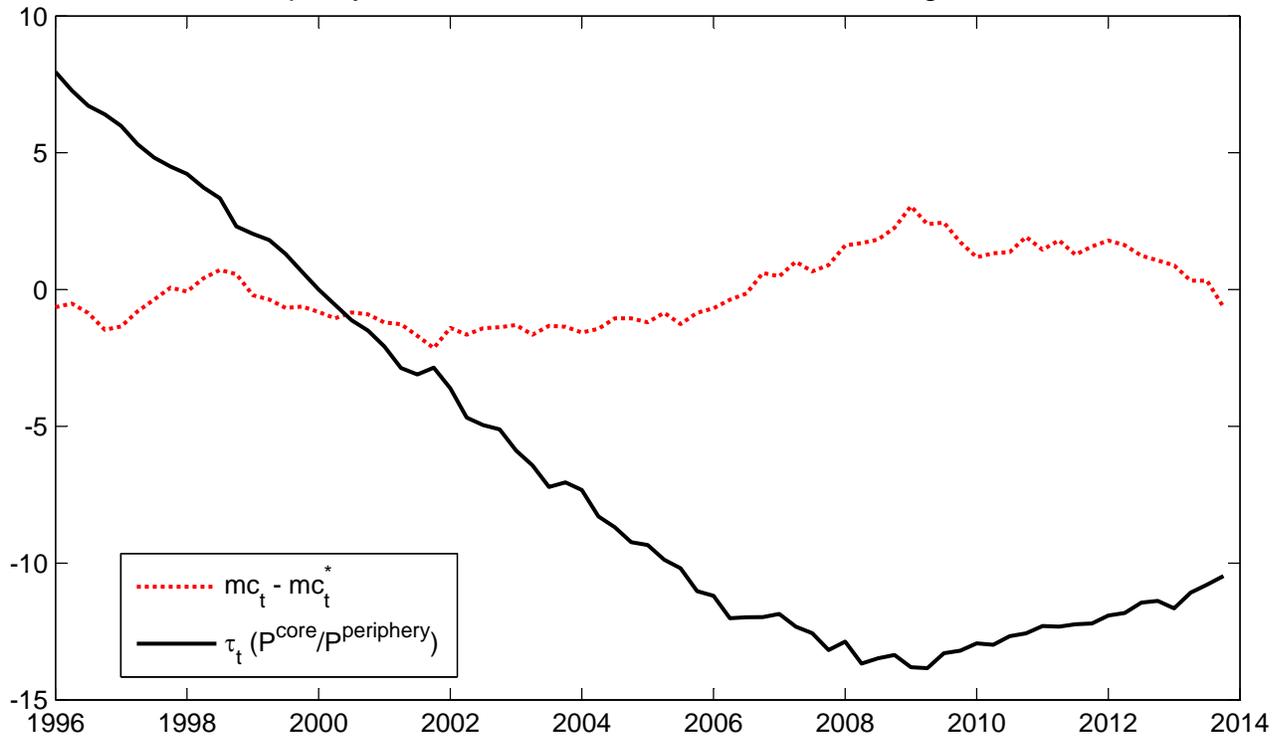
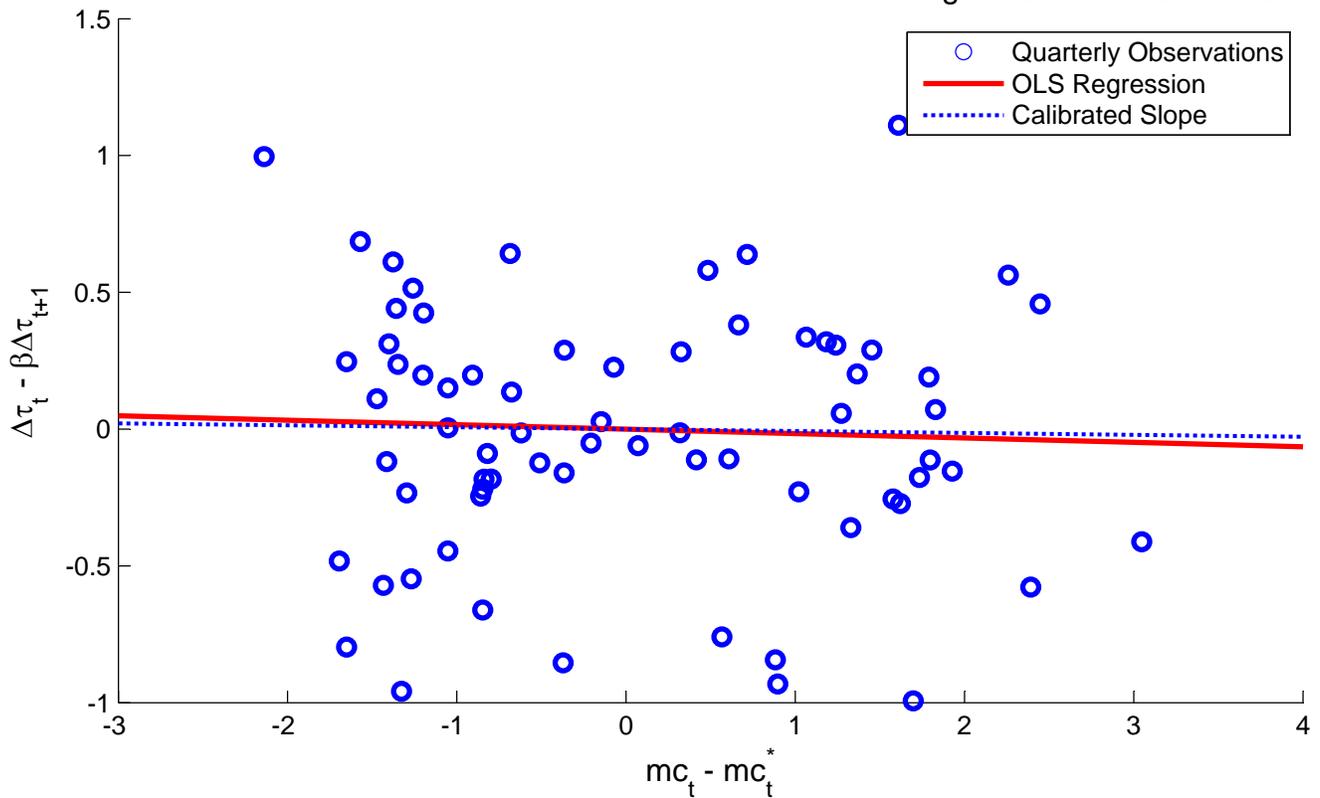


Figure 2: Calibrating the Speed of Price Adjustment

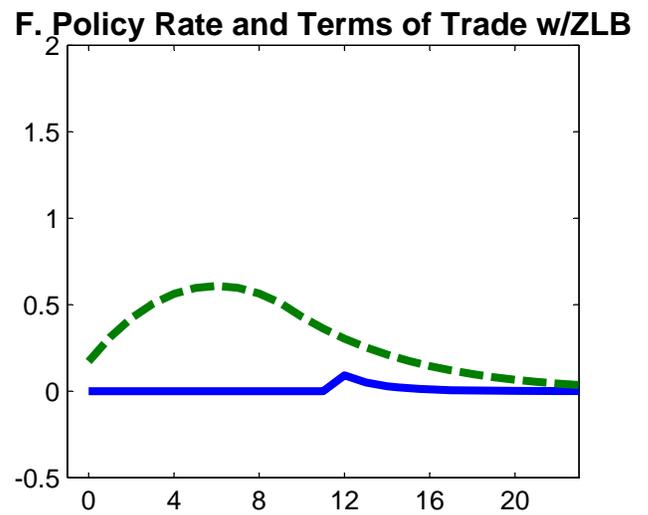
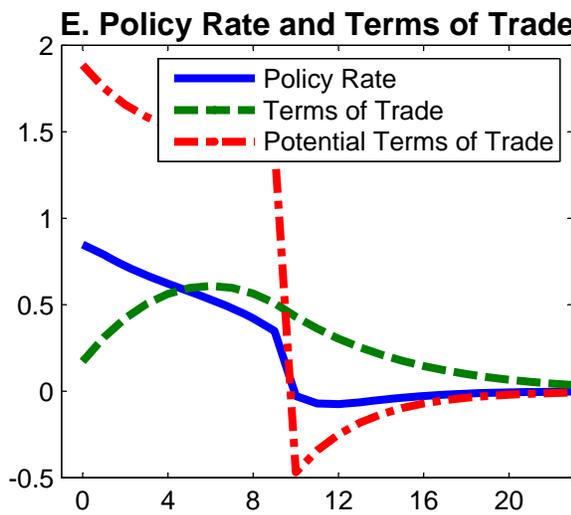
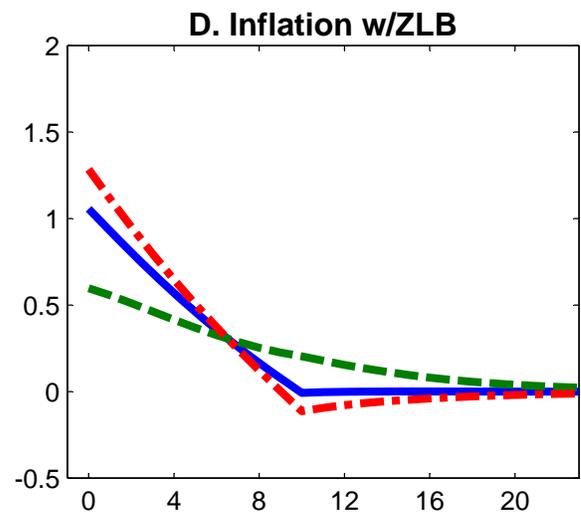
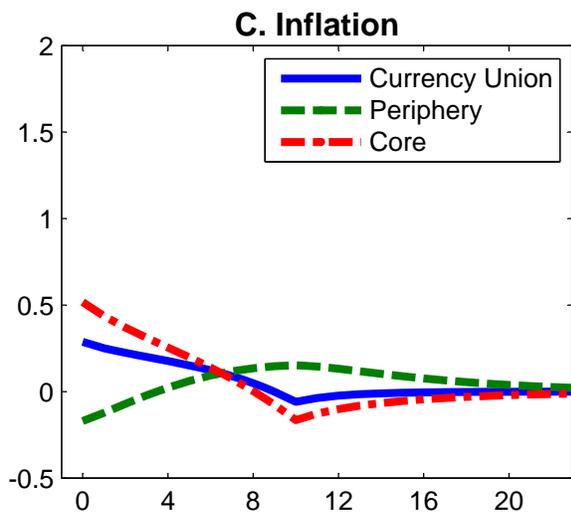
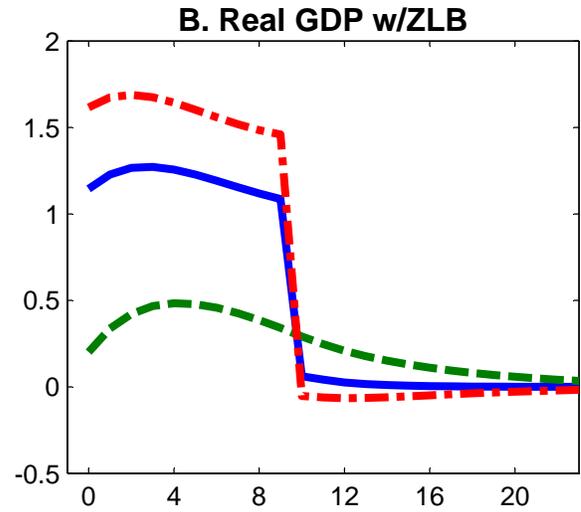
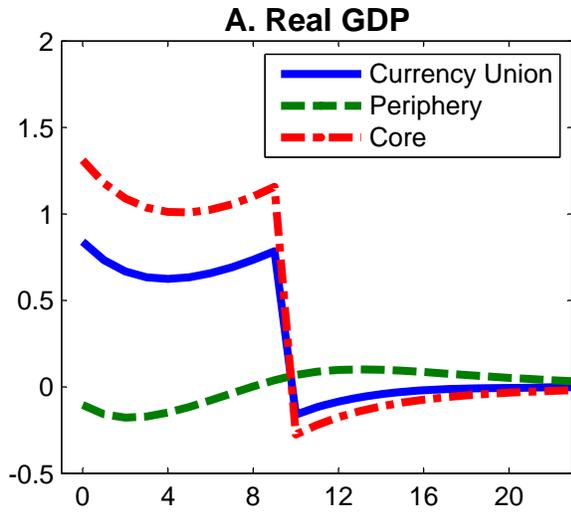
Periphery/Core Terms of Trade and Relative Marginal Cost



Quasi First Difference of Terms of Trade Vs. Difference of Marginal Cost: 1996Q1 - 2013Q4



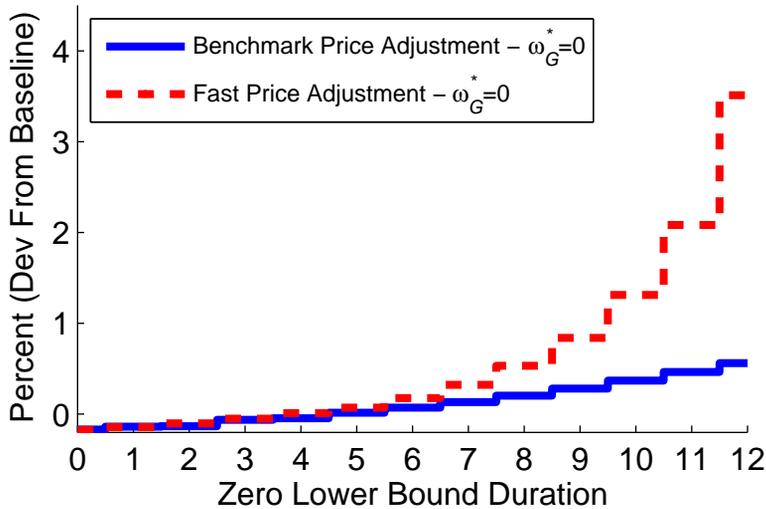
**Figure 3: Rise in Core Government Spending**  
**No Liquidity Trap**                      **12 Quarter Liquidity Trap**



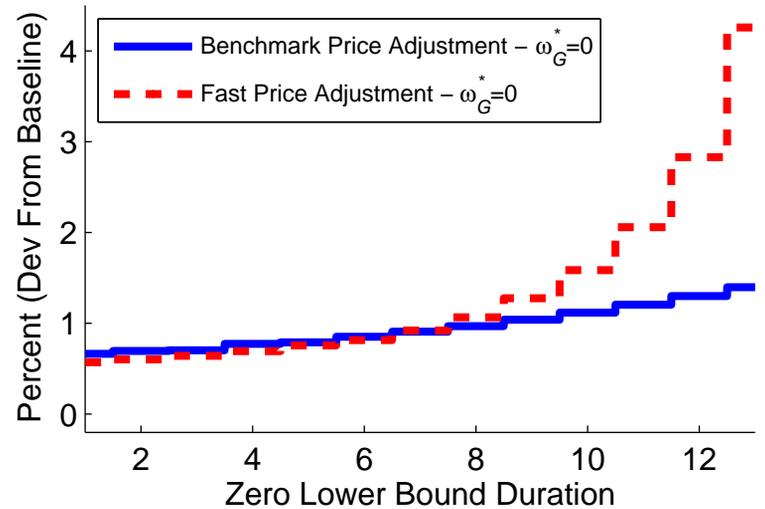
**Figure 4: Core Government Spending Hike: Output Responses in Core and Periphery as Function of Liquidity Trap Duration.**

**Panel A: Benchmark (Slow) vs. Faster Price Adjustment, No Import Content in Core Govt Spending**

**Periphery Output (Average First Year)**

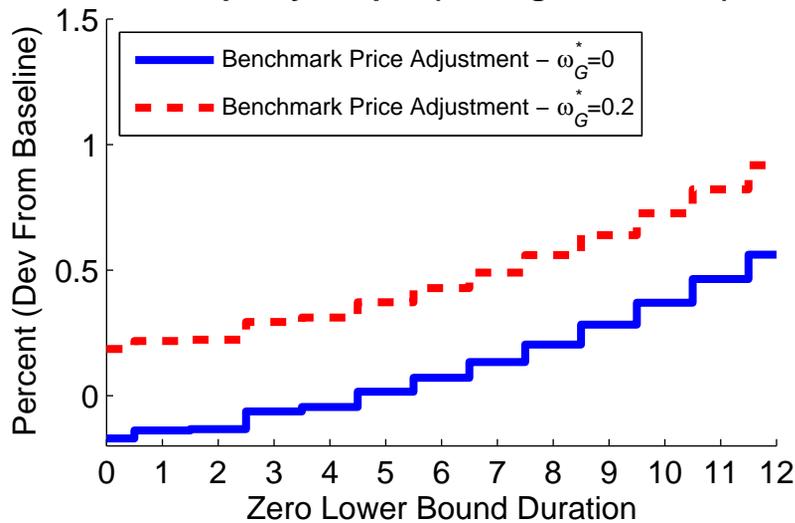


**Core Output (Average First Year)**



**Panel B: Benchmark (Slow) Price Adjustment, Varying the Degree of Import Content in Core Govt Spending**

**Periphery Output (Average First Year)**



**Core Output (Average First Year)**

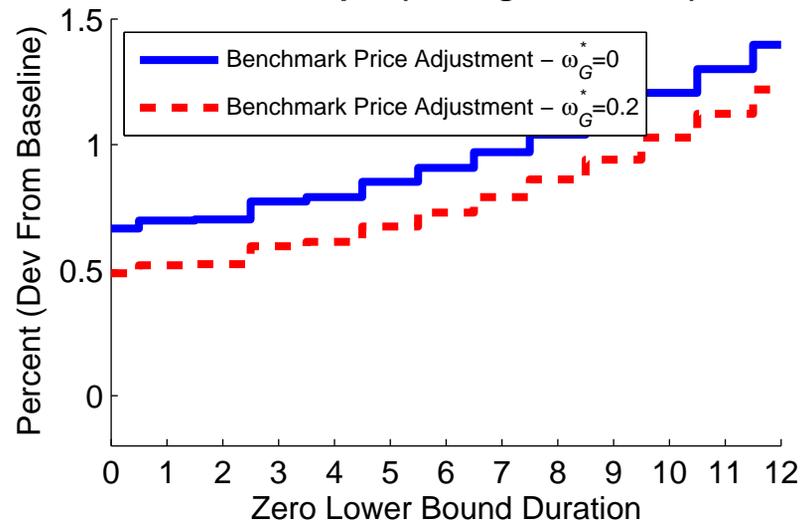






Figure 7: Impact of Fiscal Stimulus When ECB Keeps Exitdate Unchanged.

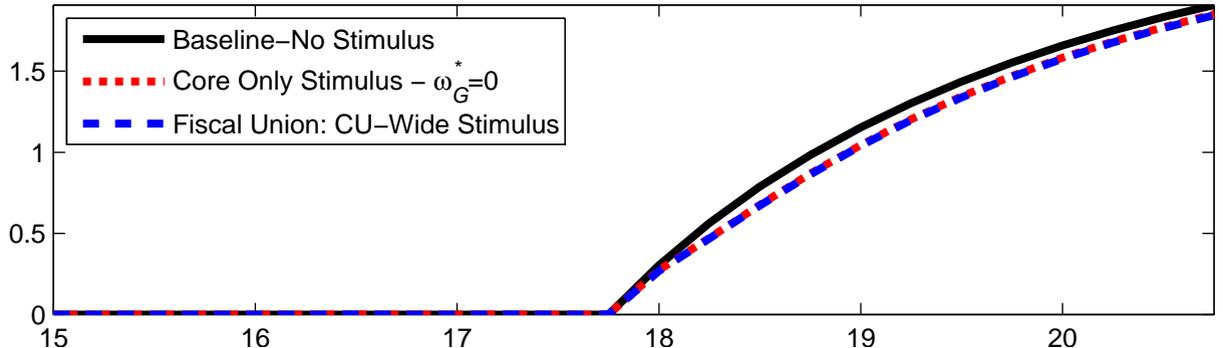
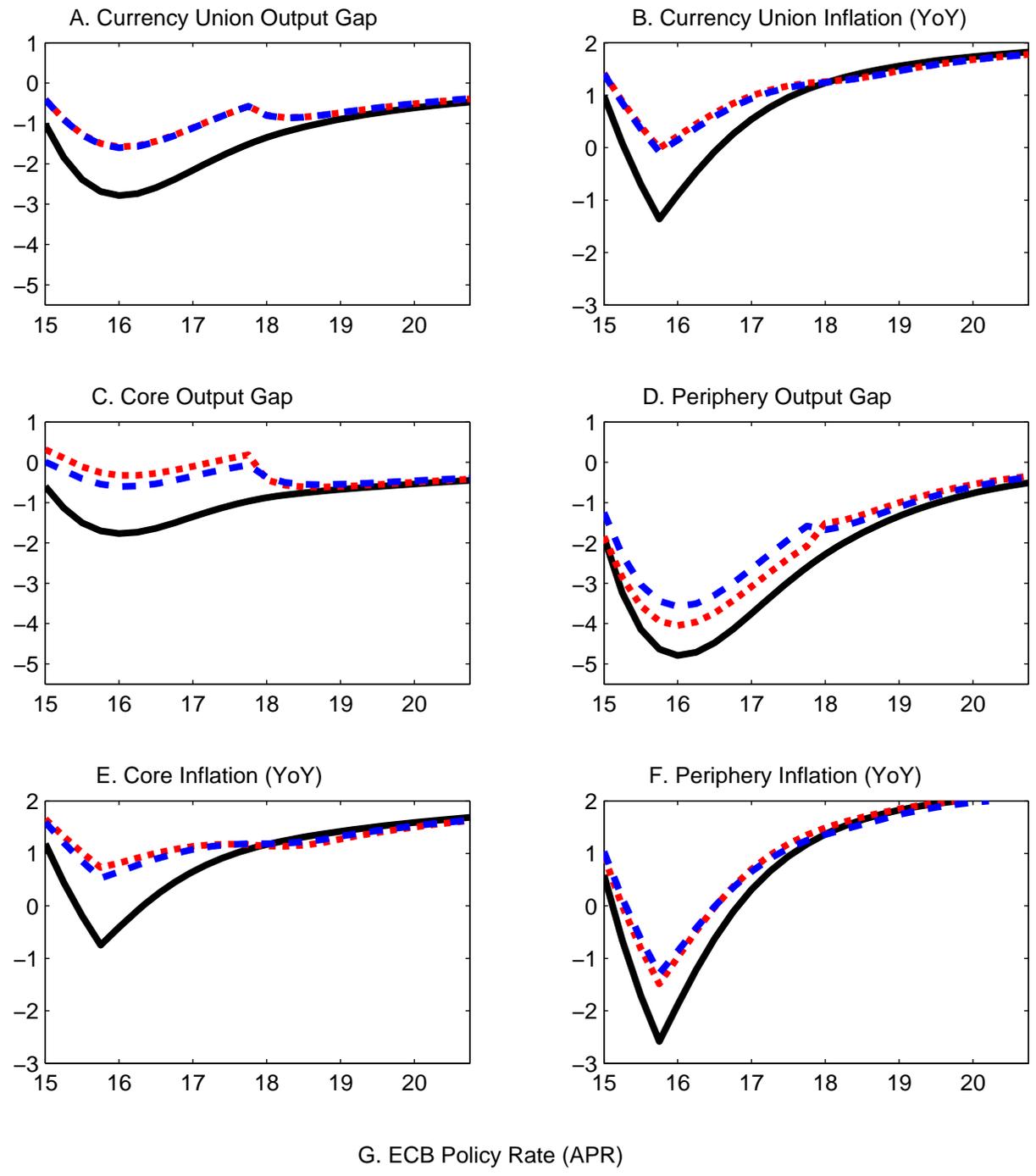
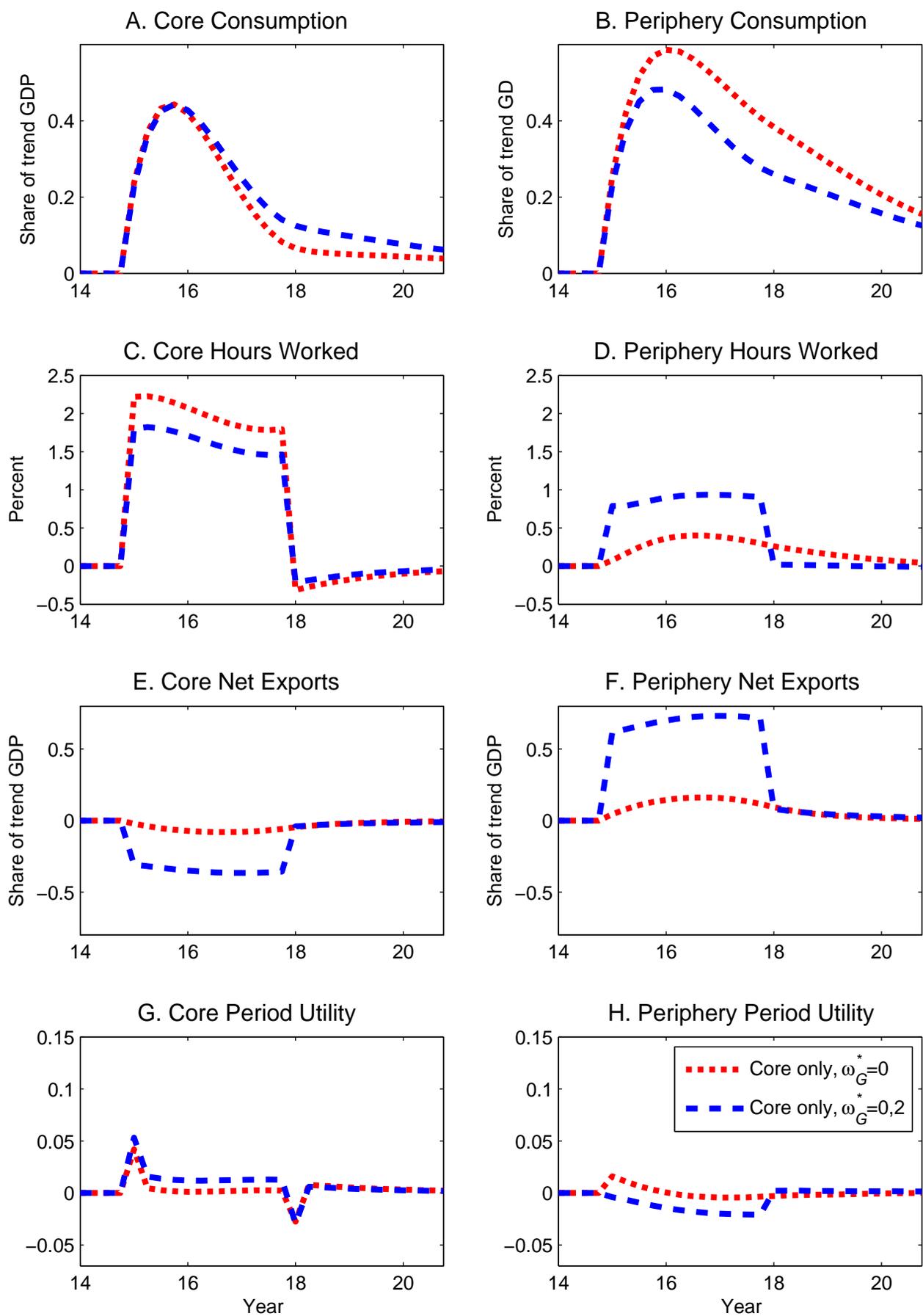
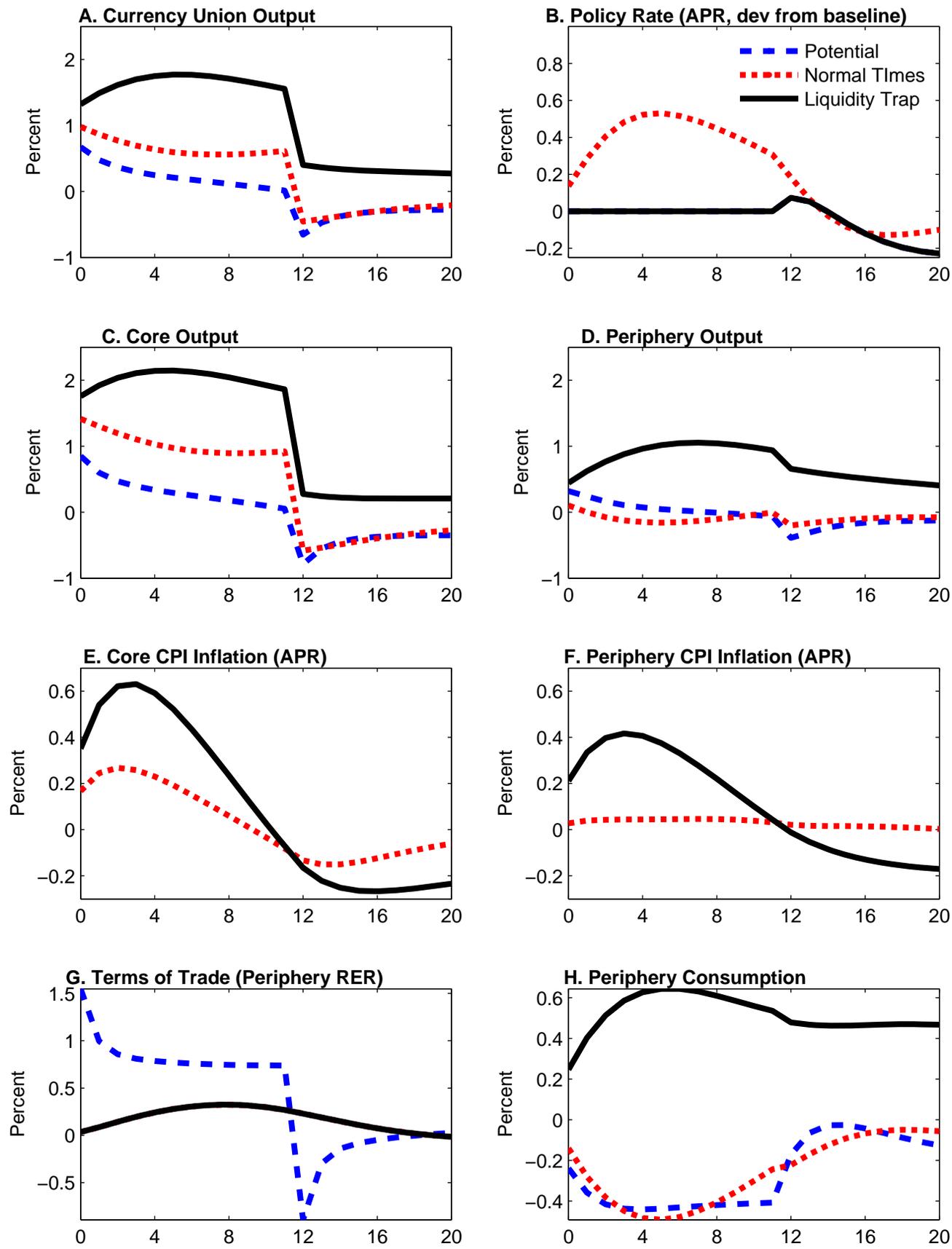


Figure 8: Rise in Core Government Spending in Recession (Deviation From Baseline).



**Figure 9: Core Spending Hike in Large-Scale Model in Normal Times and in a Liquidity Trap.**



## Appendix A. The Benchmark Model

This Appendix provides a detailed description of the benchmark model from which the log-linearized equations in Section 2 are derived.

### A.1. Households

The utility functional of household  $h$  in the home economy is given by:

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \varsigma_{t+j} \left\{ \begin{aligned} & \frac{1}{1-\frac{1}{\sigma}} (C_{t+j}(h) - \varkappa C_{t+j-1} - C \nu_{t+j})^{1-\frac{1}{\sigma}} - \chi_0 \frac{(N_{t+j}(h))^{1+\chi}}{1+\chi} + \frac{\vartheta_g}{1-\frac{1}{\sigma_g}} G_{t+j}^{1-\frac{1}{\sigma_g}} \\ & + \mu_0 F \left( \frac{MB_{t+j+1}(h)}{P_{C_{t+j}}} \right) \end{aligned} \right\} \quad (\text{A.1})$$

The preference specification in equation (A.1) implies that household  $h$  derives utility from private consumption  $C_t(h)$ , government spending  $G_t(h)$ , and real balances  $\frac{MB_t(h)}{P_{C_t}}$ , whereas utility declines in hours worked  $N_t(h)$ . The utility function is assumed to be separable in each of these arguments.

The subutility function over consumption incorporates external habit persistence – captured by the presence of lagged aggregate consumption  $C_{t-1}$  – with the degree of habit determined by the parameter  $\varkappa \in (0, 1)$ . There are two types of preference shocks, including a consumption taste (demand) shock  $\nu_t$ , and a discount factor shock  $\varsigma_t$ . The latter type of shock has been widely used in the ZLB literature (see e.g, Eggertsson, 2010, and Christiano, Eichenbaum and Rebelo, 2011) as a driving force of the “Great Recession.” Following Eggertsson and Woodford (2003), the subutility function over real balances,  $F \left( \frac{MB_{t+j+1}(h)}{P_{t+j}} \right)$ , is assumed to have a satiation point for  $\overline{MB}/P$ . Hence, inclusion of money - which is a zero nominal interest asset - provides a rationale for the zero lower bound on nominal interest rates. However, we maintain the assumptions that money is additive and that  $\mu_0$  is arbitrarily small so that changes in real money balances have negligible implications for government debt and output. Finally, we assume that  $0 < \beta < 1$ ,  $\sigma > 0$ ,  $\chi > 0$ ,  $\chi_0 > 0$  and  $\vartheta_g > 0$ .

Household  $h$  faces a flow budget constraint in period  $t$  which states that combined expenditure

on goods and on the net accumulation of financial assets must equal its disposable income:

$$P_{Ct}(1 + \tau_{Ct})C_t(h) + \int_s \xi_{t,t+1} B_{t+1}(h) - B_t(h) + B_{G,t}(h) = (1 - \tau_{N,t})W_t(h)N_t(h) - T_t \quad (\text{A.2})$$

$$+ R_{Kt}K + (1 + i_{t-1}^{CU})B_{G,t-1}(h) + \Gamma_t(h).$$

In (A.2), all variables have been expressed in per capita terms. A household may either spend its income either on consumption goods, which are subject to a sales tax of  $\tau_{Ct}$ , or can save by investing in either government bonds  $B_{G,t}(h)$  or contingent claims. The term  $\xi_{t,t+1}$  denotes the price of an asset that will pay one unit of domestic currency in a particular state of nature at date  $t+1$ , and  $B_{t+1}(h)$  the quantity of claims purchased. Each household earns per capita labor income net of taxes  $(1 - \tau_{N,t})W_t(h)N_t(h)$ , earns rental income of  $R_{Kt}K$  on its fixed stock of capital  $K$ , receives an aliquot share  $\Gamma_t(h)$  of the firm profits, and pays lump sum taxes of  $T_t$  to the government.

Each household  $h$  maximizes the utility functional (A.1) with respect to its consumption, hours worked, government bonds, and holdings of contingent claims subject to its budget constraint (A.2), taking bond prices, the wage, the rental price of capital ( $R_{Kt}$ ), and the price of the consumption bundle ( $P_{Ct}$ ) as given. The first order condition(s) for contingent claims both at home and abroad implies the complete markets condition that the marginal utility of a “euro” is equalized across home and foreign households:

$$\lambda_t = \lambda_t^*,$$

Because the marginal utility of consumption equals  $\Lambda_{Ct} = \lambda_t P_{Ct}$  (and analogously for foreign households), the complete markets condition may be written in the familiar form:

$$\Lambda_{Ct}^* = \Lambda_{Ct} \frac{P_{Ct}^*}{P_{Ct}} = \Lambda_{Ct} Q_{Ct}. \quad (\text{A.3})$$

Thus, a depreciation of the home economy’s consumption-based real exchange rate ( $Q_{Ct}$  rises)

boosts the marginal utility of foreign consumption relative to the marginal utility of home consumption.

The first order conditions with respect to  $C_t$ ,  $N_t$ , and  $B_{G,t}$  are given by:

$$\begin{aligned}\Lambda_{Ct} &= \frac{(C_t - \varkappa C_{t-1} - C\nu_t)^{-\frac{1}{\sigma}}}{(1 + \tau_{C,t})}, \\ mrs_t &= \frac{\chi_0 N_t^\chi}{\Lambda_{Ct}} = (1 - \tau_{N,t}) \frac{W_t}{P_{Ct}}, \\ \Lambda_{Ct} &= \beta \mathbf{E}_t \delta_t \frac{(1 + i_t^{CU}) P_{Ct}}{P_{Ct+1}} \Lambda_{Ct+1}.\end{aligned}\tag{A.4}$$

The first of these conditions indicates that the marginal utility of consumption decreases in current consumption, but decreases in past consumption due to habit. The second equation is the labor supply curve, which relates the household's marginal cost of working – expressed in terms of the consumption good, i.e.,  $mrs_t = \frac{\chi_0 N_t^\chi}{\Lambda_{Ct}}$  – to the after-tax consumption real wage. The final expression is the consumption Euler equation, where  $\delta_t = \frac{\varsigma_{t+1}}{\varsigma_t}$  is simply a rescaling of the time preference shock.

The problem for the foreign households  $h^*$  is isomorphic to the problem outlined above for the domestic households.

## A.2. Firms and Price-Setting

Below, we describe the problem for the home producers of both final and intermediate goods.

### A.2.1. Production of Final Goods

We assume that a single final domestic output good  $Y_{Dt}$  is produced using a continuum of differentiated intermediate goods  $Y_{Dt}(f)$ . The technology for transforming these intermediate goods into

the final output good is constant returns to scale, and is of the Dixit-Stiglitz form:

$$Y_{Dt} = \left[ \int_0^1 Y_{Dt}(f)^{\frac{1}{1+\theta_p}} df \right]^{1+\theta_p}, \quad (\text{A.5})$$

where  $\theta_p > 0$ .

Firms that produce the final output good are perfectly competitive in both product and factor markets. Thus, final goods producers minimize the cost of producing a given quantity of the output index,  $Y_{Dt}$ , taking as given the price  $P_{Dt}(f)$  of each intermediate good  $Y_{Dt}(f)$ . Moreover, final goods producers sell units of the final output good at a price  $P_{Dt}$  that can be interpreted as the aggregate domestic price index:

$$P_{Dt} = \left[ \int_0^1 P_{Dt}(f)^{\frac{-1}{\theta_p}} df \right]^{-\theta_p}. \quad (\text{A.6})$$

### A.2.2. Production of Domestic Intermediate Goods

Intermediate good  $i$  is produced by a monopolistically competitive firm, whose output  $Y_{Dt}(i)$  is produced according to a Cobb-Douglas production function:

$$Y_{Dt}(i) = K(i)^\alpha (Z_t L_t(i))^{1-\alpha}, \quad (\text{A.7})$$

where  $Z_t$  denotes a stationary, country-specific shock to the level of technology. Intermediate goods producers face perfectly competitive factor markets for hiring capital and labor. Thus, each firm chooses  $K(i)$  and  $L_t(i)$ , taking as given both the rental price of capital  $R_{Kt}$  and the aggregate wage rate  $W_t$ . Within a country, labor and the capital stock (albeit fixed in the aggregate) are completely mobile; thus, the standard static first-order conditions for cost minimization imply that all intermediate firms have identical marginal cost per unit of output:

$$MC_t = \left( \frac{W_t}{1-\alpha} \right)^{1-\alpha} \left( \frac{R_{Kt}}{\alpha} \right)^\alpha \frac{1}{Z_t^{1-\alpha}}, \quad (\text{A.8})$$

where the standard static cost minimization problem of the firm implies that

$$R_{Kt} = \frac{\alpha}{1 - \alpha} W_t \frac{L_t}{K}. \quad (\text{A.9})$$

Intermediate goods-producing firms set prices according to Calvo-style staggered contracts, and set the same price in both the home and foreign market (i.e., the home market price  $P_{Dt}(i)$  equals the price in the foreign market of  $P_{Mt}^*(i)$ ). In particular, firm  $i$  faces a constant probability,  $1 - \xi_p$ , of being able to re-optimize its price,  $P_{Dt}(i)$ . Firms which are not allowed to reoptimize their prices in period  $t$  (which is the case with probability  $\xi_p$ ), update their prices according to the following formula

$$\tilde{P}_{Dt}(i) = (1 + \pi_D) P_{Dt-1}(i), \quad (\text{A.10})$$

where  $\pi_D$  is the steady-state (net) inflation rate and  $\tilde{P}_{Dt}$  is the updated price.

Given Calvo-style pricing frictions, firm  $i$  that is allowed to reoptimize its price ( $P_{Dt}^{opt}(i)$ ) solves the following problem

$$\max_{P_{Dt}^{opt}(i)} \text{E}_t \sum_{j=0}^{\infty} \xi_p^j \psi_{t,t+j} \left[ (1 + \pi_D)^j P_{Dt}^{opt}(i) - MC_{t+j} \right] Y_{Dt+j}(i),$$

where  $\psi_{t,t+j}$  is the stochastic discount factor (the conditional value of future profits in utility units, i.e.  $\beta^j \text{E}_{t \leq t+j} \frac{\lambda_{t+j}}{\lambda_t}$ , recalling that the household is the owner of the firms),  $\theta_p$  the net markup and the demand function for firm  $i$  has the following general form  $Y_{Dt+j}(i) = \left[ \frac{P_{Dt}^{opt}(i)}{P_{Dt}} \right]^{\frac{-(1+\theta_p)}{\theta_p}} Y_{Dt}$ . The first-order condition is given by:

$$\text{E}_t \sum_{j=0}^{\infty} \xi_p^j \psi_{t,t+j} \left[ \frac{(1 + \pi_D)^j P_{Dt}^{opt}(i)}{1 + \theta_p} - MC_{t+j} \right] Y_{Dt+j}(i) = 0. \quad (\text{A.11})$$

Given that all firms which can re-optimize set the same price, the price index for domestically-produced goods evolves according to:

$$P_{Dt} = \left[ (1 - \xi_p) \left( P_{Dt}^{opt} \right)^{\frac{-1}{\theta_p}} + \xi_p \left( (1 + \pi) P_{Dt-1} \right)^{\frac{-1}{\theta_p}} \right]^{-\theta_p}. \quad (\text{A.12})$$

The productive structure of the foreign economy is isomorphic. Thus, the final good is comprised of a bundle of intermediate goods according to the production function  $Y_{Dt}^* = \left[ \int_0^1 Y_{Dt}^*(f)^{\frac{1}{1+\theta_p}} df \right]^{1+\theta_p}$ , and the price of this final good is output of the of final goods is denoted by  $P_{Dt}^* = \left[ \int_0^1 P_{Dt}^*(f)^{\frac{-1}{\theta_p}} df \right]^{-\theta_p}$ .

### A.3. Traded Goods

Household consumption  $C_t$  in the home economy depends both on its consumption of the domestically-produced final output good  $C_{Dt}$  and on its consumption of the foreign final output good  $M_{Ct}$  (i.e., consumer goods imports) according to the CES utility function:

$$C_t = \left( (1 - \omega_C)^{\frac{\rho_C}{1+\rho_C}} C_{Dt}^{\frac{1}{1+\rho_C}} + \omega_C^{\frac{\rho_C}{1+\rho_C}} M_{Ct}^{\frac{1}{1+\rho_C}} \right)^{1+\rho_C}. \quad (\text{A.13})$$

The quasi-share parameter  $\omega_C$  in equation (A.13) may be interpreted as determining household preferences for home relative to foreign goods, or equivalently, the degree of home bias in household consumption expenditure. The domestically-produced final good is purchased at a price of  $P_{Dt}$ , while the foreign imported good is purchased at a price of  $P_{Mt}$ ; given the fixed exchange rate and our assumption of producer currency pricing, the law of one price holds, so that  $P_{Mt} = P_{Dt}^*$ . Households choose  $C_{Dt}$  and  $M_{Ct}$  to minimize the cost of producing the consumption good  $C_t$  taking the prices  $P_{Dt}$  and  $P_{Mt}$  as given. This familiar cost-minimization problem implies the following demand schedules for the imported and domestically-produced good:

$$M_{Ct} = \omega_C \left( \frac{P_{Mt}}{P_{Ct}} \right)^{\frac{-(1+\rho_C)}{\rho_C}} C_t \quad \text{and} \quad C_{Dt} = (1 - \omega_C) \left( \frac{P_{Dt}}{P_{Ct}} \right)^{\frac{-(1+\rho_C)}{\rho_C}} C_t, \quad (\text{A.14})$$

while the consumer price index  $P_{Ct}$ , is given by:

$$P_{Ct} = \left( (1 - \omega_C) P_{Dt}^{\frac{1}{1+\rho_C}} + \omega_C P_{Mt}^{\frac{1}{1+\rho_C}} \right)^{1+\rho_C}. \quad (\text{A.15})$$

Similarly to households, the home government also produces final government goods (and services)  $G_t$  using both the domestically-produced final good  $G_{Dt}$  and imports of the foreign final good  $M_{Gt}$  according to the CES production function:

$$G_t = \left( (1 - \omega_G)^{\frac{\rho_G}{1+\rho_G}} G_{Dt}^{\frac{1}{1+\rho_G}} + \omega_G^{\frac{\rho_G}{1+\rho_G}} M_{Gt}^{\frac{1}{1+\rho_G}} \right)^{1+\rho_G}. \quad (\text{A.16})$$

The parameter  $\omega_G$  measures the import share of government consumption; thus, total home imports depend both on the demand of households, and of the government. The government's demand schedules for both the domestically-produced final good and for imported goods are isomorphic to that of households:

$$M_{Gt} = \omega_G \left( \frac{P_{Mt}}{P_{Gt}} \right)^{\frac{-(1+\rho_G)}{\rho_G}} G_t \quad \text{and} \quad G_{Dt} = (1 - \omega_G) \left( \frac{P_{Dt}}{P_{Gt}} \right)^{\frac{-(1+\rho_G)}{\rho_G}} G_t, \quad (\text{A.17})$$

although it is important to note that the degree of home bias in government spending  $\omega_G$  may differ from that in private spending  $\omega_C$ , and that the government's willingness to substitute between home and traded goods ( $\frac{-(1+\rho_G)}{\rho_G}$ ) may also differ from that of households ( $\frac{-(1+\rho_C)}{\rho_C}$ ). The price index for government purchases is given by:

$$P_{Gt} = \left( (1 - \omega_G) P_{Dt}^{\frac{1}{1+\rho_G}} + \omega_G P_{Mt}^{\frac{1}{1+\rho_G}} \right)^{1+\rho_G}. \quad (\text{A.18})$$

We define the terms-of-trade as

$$\tau_t = \frac{P_{Mt}}{P_{Dt}} = \frac{P_{Dt}^*}{P_{Dt}}, \quad (\text{A.19})$$

so that an increase in  $\tau_t$  implies that the home economy can buy less imports for any given level of exports.

#### A.4. Fiscal Policy

The government finances its nominal spending on goods and services  $P_{Gt}G_t$  through a consumption sales tax, labor tax, and lump-sum tax (we assume that seignorage revenue is de minimis). Thus, evolution of nominal government debt,  $B_{G,t}$ , is determined by:

$$B_{G,t} = (1 + i_{t-1}) B_{G,t-1} + P_{Gt}G_t - \tau_{C,t}P_{Ct}C_t - \tau_{N,t}W_tL_t - T_t. \quad (\text{A.20})$$

We assume that the consumption sales tax  $\tau_{C,t}$  and labor tax  $\tau_{N,t}$  are determined exogenously, so that lump-sum taxes adjust to satisfy the government's intertemporal budget constraint. Thus, the fiscal rule has no effect on macro variables (other than the stock of debt and the lump-sum tax level itself).

### A.5. Aggregate Resource Constraints

The aggregate resource constraint for the domestic economy is given by

$$Y_{Dt} = C_{Dt} + G_{Dt} + \frac{\zeta^*}{\zeta} [M_{Ct}^* + M_{Gt}^*], \quad (\text{A.21})$$

where exports are weighted by the relative population size of the foreign to home country  $\frac{\zeta^*}{\zeta}$  as the variables are expressed in per capita terms. Similarly, the resource constraint for the foreign economy is given by

$$Y_{Dt}^* = C_{Dt}^* + G_{Dt}^* + \frac{\zeta}{\zeta^*} [M_{Ct} + M_{Gt}]. \quad (\text{A.22})$$

where exports are weighted by the relative population size of the home to foreign country  $\frac{\zeta}{\zeta^*}$ . The total population is normalized to unity, i.e.,

$$\zeta + \zeta^* = 1. \quad (\text{A.23})$$

We also make the assumption that trade is balanced for both private consumption and government services, which implies that:

$$\zeta \omega_C = \zeta^* \omega_C^*, \quad (\text{A.24})$$

and

$$\zeta \omega_G = \zeta^* \omega_G^*. \quad (\text{A.25})$$

Given complete financial markets, the current account and net foreign assets are always equal

to zero. The nominal trade balance (in absolute levels) is given by

$$TB_t \equiv \frac{\zeta^*}{\zeta} P_{Dt} [M_{Ct}^* + M_{Gt}^*] - P_{Mt} [M_{Ct} + M_{Gt}]. \quad (\text{A.26})$$

## A.6. Monetary Policy

The currency union central bank is assumed to adhere to a Taylor-type policy rule subject to the ZLB. Given that we start out with a log-linearized version of the model, it is convenient to simply specify the reaction function as a linear relation (aside from the zero lower bound), expressing variables in deviation from baseline form:

$$i_t^{CU} = \max(-i, \psi_\pi \pi_t^{CU} + \psi_x x_t^{CU}), \quad (\text{A.27})$$

Here  $i$  denotes the steady-state (net) nominal interest rate (equal to  $r + \pi$  where  $r \equiv 1/\beta - 1$ ),  $\pi_t^{CU}$  is currency union inflation, and  $x_t^{CU}$  is the currency union output gap. Currency union inflation  $\pi_t^{CU}$  is itself a population-weighted average of the inflation rate  $\pi_{Ct}$  in both the home and foreign country:

$$\pi_t^{CU} = \zeta \pi_{Ct} + \zeta^* \pi_{Ct}^*. \quad (\text{A.28})$$

where each country inflation rate is simply the log percentage change in the respective consumption price index (i.e.,  $\pi_{Ct} = \ln(P_{Ct}/P_{Ct-1})$ ). The CU output gap  $x_t^{CU}$  is the difference between currency union output  $y_t^{CU}$  and its potential level  $y_t^{CU,pot}$ , with both variables again simply population-weighted averages of the respective country variables:

$$y_t^{CU} = \zeta y_{Dt} + \zeta^* y_{Dt}^*, \quad (\text{A.29})$$

and:

$$y_t^{CU,pot} = \zeta y_{Dt}^{pot} + \zeta^* y_{Dt}^{*,pot}. \quad (\text{A.30})$$

## Appendix B. The Large-Scale Open Economy Model

This model is adapted from Erceg and Lindé (2013) aside from some features of the fiscal policy specification. Our model consists of two countries (or country blocks) that differ in size, but are otherwise isomorphic. The first country is the home economy, or “South”, while the second country is referred to as the “North.” The countries share a common currency, and monetary policy is conducted by a single central bank. During “normal” times when the zero bound constraint on policy rates is not binding, the central bank adjusts policy rates in response to the aggregate inflation rate and output gap of the currency union. By contrast, fiscal policy may differ across the two blocks. Given the isomorphic structure, our exposition below largely focuses on the structure of the South.

Although the large scale model that we consider in Section 5 abstracts from a financial accelerator, we found that the output responses to a core spending shock are amplified modestly relative to Figure 9 when the model is augmented to include a financial accelerator following the approach of Bernanke, Gertler, and Gilchrist (1999) and Christiano, Motto, and Rostagno (2008). Our model description concludes with a brief description of how the model is modified to include a financial accelerator (Section B.6).

### B.1. Firms and Price Setting

#### B.1.1. Production of Domestic Intermediate Goods

There is a continuum of differentiated intermediate goods (indexed by  $i \in [0, 1]$ ) in the South, each of which is produced by a single monopolistically competitive firm. In the domestic market, firm  $i$  faces a demand function that varies inversely with its output price  $P_{Dt}(i)$  and directly with

aggregate demand at home  $Y_{Dt}$ :

$$Y_{Dt}(i) = \left[ \frac{P_{Dt}(i)}{P_{Dt}} \right]^{\frac{-(1+\theta_p)}{\theta_p}} Y_{Dt}, \quad (\text{B.31})$$

where  $\theta_p > 0$ , and  $P_{Dt}$  is an aggregate price index defined below. Similarly, firm  $i$  faces the following export demand function:

$$X_t(i) = \left[ \frac{P_{Mt}^*(i)}{P_{Mt}^*} \right]^{\frac{-(1+\theta_p)}{\theta_p}} M_t^*, \quad (\text{B.32})$$

where  $X_t(i)$  denotes the quantity demanded of domestic good  $i$  in the North block,  $P_{Mt}^*(i)$  denotes the price that firm  $i$  sets in the North market,  $P_{Mt}^*$  is the import price index in the North, and  $M_t^*$  is an aggregate of the North's imports (we use an asterisk to denote the North's variables).

Each producer utilizes capital services  $K_t(i)$  and a labor index  $L_t(i)$  (defined below) to produce its respective output good. The production function is assumed to have a constant-elasticity of substitution (CES) form:

$$Y_t(i) = \left( \omega_K^{\frac{\rho}{1+\rho}} K_t(i)^{\frac{1}{1+\rho}} + \omega_L^{\frac{\rho}{1+\rho}} (Z_t L_t(i))^{\frac{1}{1+\rho}} \right)^{1+\rho}. \quad (\text{B.33})$$

The production function exhibits constant-returns-to-scale in both inputs, and  $Z_t$  is a country-specific shock to the level of technology. Firms face perfectly competitive factor markets for hiring capital and labor. Thus, each firm chooses  $K_t(i)$  and  $L_t(i)$ , taking as given both the rental price of capital  $R_{Kt}$  and the aggregate wage index  $W_t$  (defined below). Firms can costlessly adjust either factor of production, which implies that each firm has an identical marginal cost per unit of output,  $MC_t$ . The (log-linearized) technology shock is assumed to follow an AR(1) process:

$$z_t = \rho_z z_{t-1} + \varepsilon_{z,t}. \quad (\text{B.34})$$

We assume that purchasing power parity holds, so that each intermediate goods producer sets the same price  $P_{Dt}(i)$  in both blocks of the currency union, implying that  $P_{Mt}^*(i) = P_{Dt}(i)$  and that  $P_{Mt}^* = P_{Dt}$ . The prices of the intermediate goods are determined by Calvo-style staggered contracts

(see Calvo, 1983). In each period, a firm faces a constant probability,  $1 - \xi_p$ , of being able to re-optimize its price ( $P_{Dt}(i)$ ). This probability of receiving a signal to reoptimize is independent across firms and time. If a firm is not allowed to optimize its prices, we follow Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2003), and assume that the firm must reset its home price as a weighted combination of the lagged and steady state rate of inflation  $P_{Dt}(i) = \pi_{t-1}^{\iota_p} \pi^{1-\iota_p} P_{Dt-1}(i)$  for the non-optimizing firms. This formulation allows for structural persistence in price-setting if  $\iota_p$  exceeds zero.

When a firm  $i$  is allowed to reoptimize its price in period  $t$ , the firm maximizes:

$$\max_{P_{Dt}(i)} \mathbb{E}_t \sum_{j=0}^{\infty} \psi_{t,t+j} \xi_p^j \left[ \prod_{h=1}^j \pi_{t+h-1} (P_{Dt}(i) - MC_{t+j}) (Y_{Dt+j}(i) + X_t(i)) \right]. \quad (\text{B.35})$$

The operator  $\mathbb{E}_t$  represents the conditional expectation based on the information available to agents at period  $t$ . The firm discounts profits received at date  $t+j$  by the state-contingent discount factor  $\psi_{t,t+j}$ ; for notational simplicity, we have suppressed all of the state indices.<sup>B.1</sup> The first-order condition for setting the contract price of good  $i$  is:

$$\mathbb{E}_t \sum_{j=0}^{\infty} \psi_{t,t+j} \xi_p^j \left( \frac{\prod_{h=1}^j \pi_{t+h-1}(i) P_{Dt}(i)}{(1 + \theta_p)} - MC_{t+j} \right) (Y_{Dt+j}(i) + X_t(i)) = 0. \quad (\text{B.36})$$

### B.1.2. Production of the Domestic Output Index

Because households have identical Dixit-Stiglitz preferences, it is convenient to assume that a representative aggregator combines the differentiated intermediate products into a composite home-produced good  $Y_{Dt}$ :

$$Y_{Dt} = \left[ \int_0^1 Y_{Dt}(i)^{\frac{1}{1+\theta_p}} di \right]^{1+\theta_p}. \quad (\text{B.37})$$

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<sup>B.1</sup>We define  $\xi_{t,t+j}$  to be the price in period  $t$  of a claim that pays one dollar if the specified state occurs in period  $t+j$  (see the household problem below); then the corresponding element of  $\psi_{t,t+j}$  equals  $\xi_{t,t+j}$  divided by the probability that the specified state will occur.

The aggregator chooses the bundle of goods that minimizes the cost of producing  $Y_{Dt}$ , taking the price  $P_{Dt}(i)$  of each intermediate good  $Y_{Dt}(i)$  as given. The aggregator sells units of each sectoral output index at its unit cost  $P_{Dt}$ :

$$P_{Dt} = \left[ \int_0^1 P_{Dt}(i)^{\frac{-1}{\theta_p}} di \right]^{-\theta_p}. \quad (\text{B.38})$$

We also assume a representative aggregator in the North who combines the differentiated South products  $X_t(i)$  into a single index for foreign imports:

$$M_t^* = \left[ \int_0^1 X_t(i)^{\frac{1}{1+\theta_p}} di \right]^{1+\theta_p}, \quad (\text{B.39})$$

and sells  $M_t^*$  at price  $P_{Dt}$ .

### B.1.3. Production of Consumption and Investment Goods

Final consumption goods are produced by a representative consumption goods distributor. This firm combines purchases of domestically-produced goods with imported goods to produce a final consumption good ( $C_{At}$ ) according to a constant-returns-to-scale CES production function:

$$C_{At} = \left( \omega_C^{\frac{\rho_C}{1+\rho_C}} C_{Dt}^{\frac{1}{1+\rho_C}} + (1 - \omega_C)^{\frac{\rho_C}{1+\rho_C}} (\varphi_{Ct} M_{Ct})^{\frac{1}{1+\rho_C}} \right)^{1+\rho_C}, \quad (\text{B.40})$$

where  $C_{Dt}$  denotes the consumption good distributor's demand for the index of domestically-produced goods,  $M_{Ct}$  denotes the distributor's demand for the index of foreign-produced goods, and  $\varphi_{Ct}$  reflects costs of adjusting consumption imports. The final consumption good is used by both households and by the government. The form of the production function mirrors the preferences of households and the government sector over consumption of domestically-produced goods and imports. Accordingly, the quasi-share parameter  $\omega_C$  may be interpreted as determining the preferences of both the private and public sector for domestic relative to foreign consumption goods, or equivalently, the degree of home bias in consumption expenditure. Finally, the adjustment

cost term  $\varphi_{Ct}$  is assumed to take the quadratic form:

$$\varphi_{Ct} = \left[ 1 - \frac{\varphi_{MC}}{2} \left( \frac{\frac{M_{Ct}}{C_{Dt}}}{\frac{M_{Ct-1}}{C_{Dt-1}}} - 1 \right)^2 \right]. \quad (\text{B.41})$$

This specification implies that it is costly to change the proportion of domestic and foreign goods in the aggregate consumption bundle, even though the level of imports may jump costlessly in response to changes in overall consumption demand.

Given the presence of adjustment costs, the representative consumption goods distributor chooses (a contingency plan for)  $C_{Dt}$  and  $M_{Ct}$  to minimize its discounted expected costs of producing the aggregate consumption good:

$$\begin{aligned} \min_{C_{Dt+k}, M_{Ct+k}} \mathbb{E}_t \sum_{k=0}^{\infty} \psi_{t,t+k} & \left\{ (P_{Dt+k} C_{Dt+k} + P_{Mt+k} M_{Ct+k}) \right. \\ & \left. + P_{Ct+k} \left[ C_{A,t+k} - \left( \omega_C^{\frac{\rho_C}{1+\rho_C}} C_{Dt+k}^{\frac{1}{1+\rho_C}} + (1 - \omega_C)^{\frac{\rho_C}{1+\rho_C}} (\varphi_{Ct+k} M_{Ct+k})^{\frac{1}{1+\rho_C}} \right)^{1+\rho_C} \right] \right\}. \end{aligned} \quad (\text{B.42})$$

The distributor sells the final consumption good to households and the government at a price  $P_{Ct}$ , which may be interpreted as the consumption price index (or equivalently, as the shadow cost of producing an additional unit of the consumption good).

We model the production of final investment goods in an analogous manner, although we allow the weight  $\omega_I$  in the investment index to differ from that of the weight  $\omega_C$  in the consumption goods index.<sup>B.2</sup>

## B.2. Households and Wage Setting

We assume a continuum of monopolistically competitive households (indexed on the unit interval), each of which supplies a differentiated labor service to the intermediate goods-producing sector (the only producers demanding labor services in our framework) following Erceg, Henderson and

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<sup>B.2</sup>Notice that the final investment good is not used by the government.

Levin (2000). A representative labor aggregator (or “employment agency”) combines households’ labor hours in the same proportions as firms would choose. Thus, the aggregator’s demand for each household’s labor is equal to the sum of firms’ demands. The aggregate labor index  $L_t$  has the Dixit-Stiglitz form:

$$L_t = \left[ \int_0^1 (\zeta N_t(h))^{\frac{1}{1+\theta_w}} dh \right]^{1+\theta_w}, \quad (\text{B.43})$$

where  $\theta_w > 0$  and  $N_t(h)$  is hours worked by a typical member of household  $h$ . The parameter  $\zeta$  is the size of a household of type  $h$ , and effectively determines the size of the population in the South. The aggregator minimizes the cost of producing a given amount of the aggregate labor index, taking each household’s wage rate  $W_t(h)$  as given, and then sells units of the labor index to the production sector at their unit cost  $W_t$ :

$$W_t = \left[ \int_0^1 W_t(h)^{\frac{1}{\theta_w}} dh \right]^{-\theta_w}. \quad (\text{B.44})$$

The aggregator’s demand for the labor services of a typical member of household  $h$  is given by

$$N_t(h) = \left[ \frac{W_t(h)}{W_t} \right]^{-\frac{1+\theta_w}{\theta_w}} L_t / \zeta. \quad (\text{B.45})$$

We assume that there are two types of households: households that make intertemporal consumption, labor supply, and capital accumulation decisions in a forward-looking manner by maximizing utility subject to an intertemporal budget constraint (FL households, for “forward-looking”); and the remainder that simply consume their after-tax disposable income (HM households, for “hand-to-mouth” households). The latter type receive no capital rental income or profits, and choose to set their wage to be the average wage of optimizing households. We denote the share of FL households by  $1-\varsigma$  and the share of HM households by  $\varsigma$ .

We consider first the problem faced by FL households. The utility functional for an optimizing

representative member of household  $h$  is

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left\{ \frac{1}{1-\sigma} (C_{t+j}^O(h) - \varkappa C_{t+j-1}^O - \nu_{ct})^{1-\sigma} + \frac{\chi_0 Z_{t+j}^{1-\sigma}}{1-\chi} (1 - N_{t+j}(h))^{1-\chi} + \mu_0 F\left(\frac{MB_{t+j+1}(h)}{P_{C_{t+j}}}\right) \right\}, \quad (\text{B.46})$$

where the discount factor  $\beta$  satisfies  $0 < \beta < 1$ . As in Smets and Wouters (2003, 2007), we allow for the possibility of external habit formation in preferences, so that each household member cares about its consumption relative to lagged aggregate consumption per capita of forward-looking agents  $C_{t-1}^O$ . The period utility function depends on an each member's current leisure  $1 - N_t(h)$ , his end-of-period real money balances,  $\frac{MB_{t+1}(h)}{P_{Ct}}$ , and a preference shock,  $\nu_{ct}$ . The subutility function  $F(\cdot)$  over real balances is assumed to have a satiation point to account for the possibility of a zero nominal interest rate; see Eggertsson and Woodford (2003) for further discussion.<sup>B.3</sup> The (log-linearized) consumption demand shock  $\nu_{ct}$  is assumed to follow an AR(1) process:

$$\nu_{ct} = \rho_\nu \nu_{ct-1} + \varepsilon_{\nu_{c,t}}. \quad (\text{B.47})$$

Forward-looking household  $h$  faces a flow budget constraint in period  $t$  which states that its combined expenditure on goods and on the net accumulation of financial assets must equal its disposable income:

$$\begin{aligned} & P_{Ct}(1 + \tau_{Ct})C_t^O(h) + P_{It}I_t(h) + MB_{t+1}(h) - MB_t(h) + \int_s \xi_{t,t+1} B_{Dt+1}(h) \\ & \quad - B_{Dt}(h) + P_{Bt}B_{Gt+1} - B_{Gt} + \frac{P_{Bt}^* B_{Ft+1}(h)}{\phi_{bt}} - B_{Ft}(h) \\ & = (1 - \tau_{Nt})W_t(h)N_t(h) + \Gamma_t(h) + TR_t(h) + (1 - \tau_{Kt})R_{Kt}K_t(h) + \\ & \quad P_{It}\tau_{Kt}\delta K_t(h) - P_{Dt}\phi_{It}(h). \end{aligned} \quad (\text{B.48})$$

Consumption purchases are subject to a sales tax of  $\tau_{Ct}$ . Investment in physical capital augments the per capita capital stock  $K_{t+1}(h)$  according to a linear transition law of the form:

$$K_{t+1}(h) = (1 - \delta)K_t(h) + I_t(h), \quad (\text{B.49})$$

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<sup>B.3</sup>For simplicity, we assume that  $\mu_0$  is sufficiently small that changes in the monetary base have a negligible impact on equilibrium allocations, at least to the first-order approximation we consider.

where  $\delta$  is the depreciation rate of capital.

Financial asset accumulation of a typical member of FL household  $h$  consists of increases in nominal money holdings ( $MB_{t+1}(h) - MB_t(h)$ ) and the net acquisition of bonds. While the domestic financial market is complete through the existence of state-contingent bonds  $B_{Dt+1}$ , cross-border asset trade is restricted to a single non-state contingent bond issued by the government of the North economy.<sup>B.4</sup>

The terms  $B_{Gt+1}$  and  $B_{Ft+1}$  represents each household member's net purchases of the government bonds issued by the South and North governments, respectively. Each type of bond pays one currency unit (e.g., euro) in the subsequent period, and is sold at price (discount) of  $P_{Bt}$  and  $P_{Bt}^*$ , respectively. To ensure the stationarity of foreign asset positions, we follow Turnovsky (1985) by assuming that domestic households must pay a transaction cost when trading in the foreign bond. The intermediation cost depends on the ratio of economy-wide holdings of net foreign assets to nominal GDP,  $P_t Y_t$ , and are given by:

$$\phi_{bt} = \exp\left(-\phi_b \left(\frac{B_{Ft+1}}{P_t Y_t}\right)\right). \quad (\text{B.50})$$

If the South is an overall net lender position internationally, then a household will earn a lower return on any holdings of foreign (i.e., North) bonds. By contrast, if the South has a net debtor position, a household will pay a higher return on its foreign liabilities. Given that the domestic government bond and foreign bond have the same payoff, the price faced by domestic residents net of the transaction cost is identical, so that  $P_{Bt} = \frac{P_{Bt}^*}{\phi_{bt}}$ . The effective nominal interest rate on domestic bonds (and similarly for foreign bonds) hence equals  $i_t = 1/P_{Bt} - 1$ .

Each member of FL household  $h$  earns after-tax labor income,  $(1 - \tau_{Nt})W_t(h)N_t(h)$ , where  $\tau_{Nt}$  is a stochastic tax on labor income. The household leases capital at the after-tax rental rate  $(1 - \tau_{Kt})R_{Kt}$ , where  $\tau_{Kt}$  is a stochastic tax on capital income. The household receives a depreciation

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<sup>B.4</sup>Notice that the contingent claims  $B_{Dt+1}$  are in zero net supply from the standpoint of the South as a whole.

write-off of  $P_{It}\tau_{Kt}\delta$  per unit of capital. Each member also receives an aliquot share  $\Gamma_t(h)$  of the profits of all firms and a lump-sum government transfer,  $TR_t(h)$  (which is negative in the case of a tax). Following Christiano, Eichenbaum and Evans (2005), we assume that it is costly to change the level of gross investment from the previous period, so that the acceleration in the capital stock is penalized:

$$\phi_{It}(h) = \frac{1}{2}\phi_I \frac{(I_t(h) - I_{t-1})^2}{I_{t-1}}. \quad (\text{B.51})$$

In every period  $t$ , each member of FL household  $h$  maximizes the utility functional (B.46) with respect to its consumption, investment, (end-of-period) capital stock, money balances, holdings of contingent claims, and holdings of domestic and foreign bonds, subject to its labor demand function (B.45), budget constraint (B.48), and transition equation for capital (B.49). In doing so, a household takes as given prices, taxes and transfers, and aggregate quantities such as lagged aggregate consumption and the aggregate net foreign asset position.

Forward-looking (FL) households set nominal wages in staggered contracts that are analogous to the price contracts described above. In particular, with probability  $1 - \xi_w$ , each member of a household is allowed to reoptimize its wage contract. If a household is not allowed to optimize its wage rate, we assume each household member resets its wage according to:

$$W_t(h) = \omega_{t-1}^{\iota_w} \omega^{1-\iota_w} W_{t-1}(h), \quad (\text{B.52})$$

where  $\omega_{t-1}$  is the gross nominal wage inflation in period  $t - 1$ , i.e.  $W_t/W_{t-1}$ , and  $\omega = \pi$  is the steady state rate of change in the nominal wage (equal to gross price inflation since steady state gross productivity growth is assumed to be unity). Dynamic indexation of this form introduces some element of structural persistence into the wage-setting process. Each member of household  $h$  chooses the value of  $W_t(h)$  to maximize its utility functional (B.46) subject to these constraints.

Finally, we consider the determination of consumption and labor supply of the hand-to-mouth (HM) households. A typical member of a HM household simply equates his nominal consumption

spending,  $P_{Ct}(1 + \tau_{Ct})C_t^{HM}(h)$ , to his current after-tax disposable income, which consists of labor income plus lump-sum transfers from the government:

$$P_{Ct}(1 + \tau_{Ct})C_t^{HM}(h) = (1 - \tau_{Nt})W_t(h)N_t(h) + TR_t(h). \quad (\text{B.53})$$

The HM households are assumed to set their wage equal to the average wage of the forward-looking households. Since HM households face the same labor demand schedule as the forward-looking households, this assumption implies that each HM household works the same number of hours as the average for forward-looking households.

### B.3. Monetary Policy

We assume that the central bank follows a Taylor rule for setting the policy rate of the currency union, subject to the zero bound constraint on nominal interest rates. Thus:

$$i_t = \max \{-i, (1 - \gamma_i)(\tilde{\pi}_t + \gamma_\pi(\tilde{\pi}_t - \pi) + \gamma_x\tilde{x}_t) + \gamma_i i_{t-1}\} \quad (\text{B.54})$$

In this equation,  $i_t$  is the quarterly nominal interest rate expressed in deviation from its steady state value of  $i$ . Hence, imposing the zero lower bound implies that  $i_t$  cannot fall below  $-i$ .  $\tilde{\pi}_t$  is price inflation rate of the currency union,  $\pi$  the inflation target, and  $\tilde{x}_t$  is the output gap of the currency union. The aggregate inflation and output gap measures are defined as a GDP-weighted average of the inflation rates and output gaps of the South and North. Finally, the output gap in each member is defined as the deviation of actual output from its potential level, where potential is the level of output that would prevail if wages and prices were completely flexible.

#### B.4. Fiscal Policy

The government does not need to balance its budget each period, and issues nominal debt  $B_{Gt+1}$  at the end of period  $t$  to finance its deficits according to:

$$P_{Bt}B_{Gt+1} - B_{Gt} = P_{Ct}G_t + TR_t - \tau_{Nt}W_tL_t - \tau_{Ct}P_{Ct}C_t - (\tau_{Kt}R_{Kt} - \delta P_{It})K_t - (MB_{t+1} - MB_t), \quad (\text{B.55})$$

where  $C_t$  is total private consumption. Equation (B.55) aggregates the capital stock, money and bond holdings, and transfers and taxes over all households so that, for example,  $TR_t = \int_0^1 TR_t(h)dh$ . The taxes on capital  $\tau_{Kt}$  and consumption  $\tau_{Ct}$  are assumed to be fixed, and the ratio of real transfers to (trend) GDP,  $tr_t = \frac{TR_t}{P_tY}$ , is also fixed.<sup>B.5</sup> Government purchases have no direct effect on the utility of households, nor do they affect the production function of the private sector.

The process for the (log of) government spending is given by an AR(1) process:

$$(g_t - g) = \rho_g (g_{t-1} - g) + \varepsilon_{g,t}. \quad (\text{B.56})$$

We assume that policymakers in the core and periphery adjust labor income taxes to stabilize the debt/GDP ratio and the deficit. Specifically, the labor tax rate evolves according to:

$$\tau_{Nt} - \tau_N = \nu_1 (\tau_{Nt-1} - \tau_N) + (1 - \nu_1) [\nu_2 (b_{Gt} - b_G) + \nu_3 (\Delta b_{Gt+1} - \Delta b_G)]. \quad (\text{B.57})$$

#### B.5. Resource Constraint and Net Foreign Assets

The domestic economy's aggregate resource constraint can be written as:

$$Y_{Dt} = C_{Dt} + I_{Dt} + \phi_{It}, \quad (\text{B.58})$$

where  $\phi_{It}$  is the adjustment cost on investment aggregated across all households. The final consumption good is allocated between households and the government:

$$C_{At} = C_t + G_t, \quad (\text{B.59})$$

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<sup>B.5</sup>Given that the central bank uses the nominal interest rate as its policy instrument, the level of seigniorage is determined by nominal money demand.

where  $C_t$  is total private consumption of FL (optimizing) and HM households:

$$C_t = C_t^O + C_t^{HM}. \quad (\text{B.60})$$

Total exports may be allocated to either the consumption or the investment sector abroad:

$$M_t^* = M_{Ct}^* + M_{It}^*. \quad (\text{B.61})$$

Finally, at the level of the individual firm:

$$Y_t(i) = Y_{Dt}(i) + X_t(i) \quad \forall i. \quad (\text{B.62})$$

The evolution of net foreign assets can be expressed as:

$$\frac{P_{B,t}^* B_{F,t+1}}{\phi_{bt}} = B_{F,t} + P_{Mt}^* M_t^* - P_{Mt} M_t. \quad (\text{B.63})$$

This expression can be derived from the budget constraint of the FL households after imposing the government budget constraint, the consumption rule of the HM households, the definition of firm profits, and the condition that domestic state-contingent non-government bonds ( $B_{Dt+1}$ ) are in zero net supply.

Finally, we assume that the structure of the foreign country (the North) is isomorphic to that of the home country (the South).

## B.6. Production of capital services

In an augmented variant of the model, we incorporated a financial accelerator mechanism into both country blocks of our benchmark model following the basic approach of Bernanke, Gertler and Gilchrist (1999). Thus, the intermediate goods producers rent capital services from entrepreneurs (at the price  $R_{Kt}$ ) rather than directly from households. Entrepreneurs purchase physical capital from competitive capital goods producers (and resell it back at the end of each period), with the latter employing the same technology to transform investment goods into finished capital goods

as described by equations B.49) and B.51). To finance the acquisition of physical capital, each entrepreneur combines his net worth with a loan from a bank, for which the entrepreneur must pay an external finance premium (over the risk-free interest rate set by the central bank) due to an agency problem. Banks obtain funds to lend to the entrepreneurs by issuing deposits to households at the interest rate set by the central bank, with households bearing no credit risk (reflecting assumptions about free competition in banking and the ability of banks to diversify their portfolios). In equilibrium, shocks that affect entrepreneurial net worth – i.e., the leverage of the corporate sector – induce fluctuations in the corporate finance premium.<sup>B.6</sup>

## B.7. Solution Method and Calibration

To analyze the behavior of the model, we log-linearize the model’s equations around the non-stochastic steady state. Nominal variables are rendered stationary by suitable transformations. To solve the unconstrained version of the model, we compute the reduced-form solution of the model for a given set of parameters using the numerical algorithm of Anderson and Moore (1985), which provides an efficient implementation of the solution method proposed by Blanchard and Kahn (1980). When we solve the model subject to the non-linear monetary policy rule (B.54), we use the techniques described in Hebden, Lindé and Svensson (2009). An important feature of the Hebden, Lindé and Svensson algorithm is that the duration of the liquidity trap is endogenously determined.<sup>B.7</sup>

The model is calibrated at a quarterly frequency. Structural parameters are set at identical

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<sup>B.6</sup>We follow Christiano, Motto and Rostagno (2008) by assuming that the debt contract between entrepreneurs and banks is written in nominal terms (rather than real terms as in Bernanke, Gertler and Gilchrist, 1999). For further details about the setup, see Bernanke, Gertler and Gilchrist (1999), and Christiano, Motto and Rostagno (2008). An excellent exposition is also provided in Christiano, Trabandt and Walentin (2007).

<sup>B.7</sup>In future work, it would be of interest to solve the model in a fully non-linear form.

values for each of the two country blocks, except for the parameter  $\zeta$  determining population size (as discussed below), the fiscal rule parameters, and the parameters determining trade shares. We assume that the discount factor  $\beta = 0.995$ , consistent with a steady-state annualized real interest rate  $\bar{r}$  of 2 percent. By assuming that gross inflation  $\pi = 1.005$  (i.e. a net inflation of 2 percent in annualized terms), the implied steady state nominal interest rate  $i$  equals 0.01 at a quarterly rate, and 4 percent at an annualized rate.

The utility functional parameter  $\sigma$  is set equal to 1 to ensure that the model exhibit balanced growth, while the parameter determining the degree of habit persistence in consumption  $\varkappa = 0.8$ . We set  $\chi = 4$ , implying a Frisch elasticity of labor supply of 1/2, which is roughly consistent with the evidence reported by Domeij and Flodén (2006). The utility parameter  $\chi_0$  is set so that employment comprises one-third of the household’s time endowment, while the parameter  $\mu_0$  on the subutility function for real balances is set at an arbitrarily low value (so that variation in real balances do not affect equilibrium allocations). We set the share of HM agents  $\varsigma = 0.47$ , implying that these agents account for about 20 percent of aggregate private consumption spending (the latter is much smaller than the population share of HM agents because the latter own no capital).

The depreciation rate of capital  $\delta$  is set at 0.03 (consistent with an annual depreciation rate of 12 percent). The parameter  $\rho$  in the CES production function of the intermediate goods producers is set to  $-2$ , implying an elasticity of substitution between capital and labor  $(1 + \rho)/\rho$ , of 1/2. The quasi-capital share parameter  $\omega_K$  – together with the price markup parameter of  $\theta_P = 0.20$  – is chosen to imply a steady state investment to output ratio of 15 percent. We set the cost of adjusting investment parameter  $\phi_I = 3$ , slightly below the value estimated by Christiano, Eichenbaum and Evans (2005). In the augmented version of the model with a financial accelerator, our calibration of parameters follows Bernanke, Gertler and Gilchrist (1999). In particular, the monitoring cost,  $\mu$ , expressed as a proportion of entrepreneurs’ total gross revenue, is set to 0.12. The default rate

of entrepreneurs is 3 percent per year, and the variance of the idiosyncratic productivity shocks to entrepreneurs is 0.28.

Our calibration of the parameters of the monetary policy rule and the Calvo price and wage contract duration parameters – while within the range of empirical estimates – tilt in the direction of reducing the sensitivity of inflation to shocks. These choices seem reasonable given the resilience of inflation in most euro area countries in the aftermath of the global financial crisis. In particular, we set the parameters of the monetary rule such that  $\gamma_\pi = 1.5$ ,  $\gamma_x = 0.125$ , and  $\gamma_i = 0.7$ , implying a considerably larger response to inflation than a standard Taylor rule (which would set  $\gamma_\pi = 0.5$ ). The price contract duration parameter  $\xi_p = 0.92$ , and the price indexation parameter  $\iota_p = 0.65$ . Our choice of  $\xi_p$  implies a Phillips curve slope of about 0.005, which is a bit lower than the median estimates in the literature that cluster in the range of 0.009 – 0.014, but well within the standard confidence intervals provided by empirical studies (see e.g. Adolfson et al (2005), Altig et al. (2010), Galí and Gertler (1999), Galí, Gertler, and López-Salido (2001), Lindé (2005), and Smets and Wouters (2003, 2007)). Our choices of a wage markup of  $\theta_W = 1/3$ , a wage contract duration parameter of  $\xi_w = 0.90$ , and a wage indexation parameter of  $\iota_w = 0.65$ , together imply that wage inflation is about as responsive to the wage markup as price inflation is to the price markup.<sup>B.8</sup>

The parameters pertaining to fiscal policy are intended to roughly capture the revenue and spending sides of euro area government budgets. The share of government spending on goods and services is set equal to 23 percent of steady state output. The government debt to GDP ratio,  $b_G$ , is set to 0.75, roughly equal to the average level of debt in euro area countries at end-2008. The ratio of transfers to GDP is set to 20 percent. The steady state sales (i.e., VAT) tax rate  $\tau_C$  is set to 0.2, while the capital tax  $\tau_K$  is set to 0.30. Given the annualized steady state real interest rate

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<sup>B.8</sup>Given strategic complementarities in wage-setting, the wage markup influences the slope of the wage Phillips Curve.

(2 percent), the government's intertemporal budget constraint then implies that the labor income tax rate  $\tau_N$  equals 0.42 in steady state. We assume an unaggressive tax adjustment rule in (B.57) by setting  $\nu_1 = 0.985$  and  $\nu_2 = \nu_3 = .1$ .

The size of the South is calibrated to be 1/3 of euro area GDP, so that  $\zeta = 0.5$ . This corresponds to the collective share of Greece, Ireland, Portugal, Italy, and Spain in euro area GDP, or alternatively, to the combined GDP of France and Spain (clearly, our model framework can be applied to many other country pairings, with similar implications). Identifying the former group of countries as the South to calibrate trade shares, the average share of imports of the South from the remaining countries of the euro area was about 14 percent of GDP in 2008 (based on Eurostat). This pins down the trade share parameters  $\omega_C$  and  $\omega_I$  for the South under the additional assumption that the import intensity of consumption is equal to 3/4 that of investment. Given that trade is balanced in steady state, this calibration implies an export and import share of the North countries of 7 percent of GDP.

We assume that  $\rho_C = \rho_I = 2$ , consistent with a long-run price elasticity of demand for imported consumption and investment goods of 1.5. The adjustment cost parameters are set so that  $\varphi_{M_C} = \varphi_{M_I} = 1$ , which slightly damps the near-term relative price sensitivity. The financial intermediation parameter  $\phi_b$  is set to a very small value (0.00001), which is sufficient to ensure the model has a unique steady state.

Finally, the persistence coefficient  $\rho_{\nu_c}$  for the consumption demand shock  $\nu_{ct}$  (see eq. B.47) is set to 0.9, while the persistence coefficient  $\rho_z$  for the technology shock (see eq. B.34) assumes the value 0.975. Finally, the persistence of the government spending shock,  $g_t$  in eq. (B.56),  $\rho_g$  is set to 0.9.

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