

Fiscal Consolidation in an Open Economy*

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Abstract

This paper uses a New Keynesian small open economy model to examine how the effects of fiscal consolidation vary depending on whether monetary policy is constrained by currency union membership vs. the zero bound on interest rates.

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1. Introduction

Given heightened concerns about debt sustainability, many countries are implementing ambitious fiscal consolidation plans in which government spending reductions often play a major role. The usual presumption is that the effects of government spending cuts on output are smaller when a country conducts an independent monetary policy (IMP) than when constrained by membership in a currency union, reflecting that interest rate cuts and currency depreciation appear to significantly dampen the adverse impact on aggregate demand. While econometric work (e.g. Ilzetzki, Mendoza and Vegh, 2010, and Serrato and Wingender, 2010) and historical evidence from large-scale fiscal consolidations episodes supports this view (Alesina and Perotti, 1997), it is unclear whether an IMP retains its comparative advantage in an open economy framework if constrained by the zero lower bound, especially in light of “closed economy” analysis showing how a liquidity trap can amplify the fiscal multiplier.¹

This paper uses a New Keynesian DSGE model of a small open economy to examine conditions under which a persistent cut in government spending reduces output more under an IMP constrained by the zero lower bound than in a currency union (CU). Given that adjustment of the policy rate is precluded in both monetary regimes for at least some time, the output effects of fiscal contraction are larger than under an unconstrained IMP. But across the two constrained regimes, the relative magnitude of the output contraction turns out to be highly sensitive to structural features which determine how the real exchange rate and long-term real interest rate respond to fiscal consolidation. If inflation is fairly sensitive to the output gap (i.e., the Phillips Curve has substantial upward slope), output contracts more deeply under an IMP than a CU if policy rates are constrained from adjusting for a sustained period of roughly two years or more. Importantly, the anchoring of the nominal exchange rate in a CU turns out to be a blessing insofar as it avoids the large *appreciation* of the real exchange rate that would occur in a persistent liquidity trap, and implies a smaller rise (if any) in long-term real interest rates. By contrast, if the Phillips Curve is very flat, the real exchange rate depreciates even in a prolonged liquidity trap and long-term real interest rates fall, so that the output contraction under an IMP is smaller than under a CU; thus, the economy benefits from front-loaded depreciation, even if smaller than in the unconstrained case. We conclude by arguing that recent episodes of large-scale fiscal consolidations – including in countries facing each form of monetary constraint – should be highly informative in discriminating

¹ See papers by Coenen et al. (2011), Davig and Leeper (2010), Eggertson (2010), Erceg and Lindé (2010a), Woodford (2011), and Christiano, Eichenbaum, and Rebelo (2011).

between these contrasting predictions of the theory.

2. A New Keynesian Open Economy Model

Our benchmark model is very similar to the small open economy models of Clarida, Galí, and Gertler (2001), and Galí and Monacelli (2005), and features money, imperfect competition, and nominal price rigidities. Only consumption goods are produced and traded. Households consume a domestic and a foreign good that are imperfect substitutes. The domestic good is a composite of a continuum of differentiated goods, each produced by an associated monopolistically competitive firm at home. The home economy is small in the sense that it does not influence foreign output, the foreign price level, or the foreign interest rate; however, the equilibrium terms of trade will depend on both home and foreign disturbances. We abstract from wealth effects due to current account imbalances by allowing households to share consumption risk internationally. The government consumes part of the final domestic good and uses lump-sum taxes to stabilize government debt.² To conserve space, we present only the log linearized version of the model where all variables are expressed as percentage deviations from their long-run equilibrium levels.

Under independent monetary policy, the key equations are given by:

$$x_t = x_{t+1|t} - \hat{\sigma}^{open}(i_t - \pi_{t+1|t} - r_t^{pot}), \quad (1)$$

$$\pi_t = \beta\pi_{t+1|t} + \kappa_x x_t, \quad (2)$$

$$i_t = \max(-i, \gamma_\pi \pi_t + \gamma_x x_t), \quad (3)$$

$$y_t = \hat{\sigma}^{open} \tau_t + g_y g_t + (1 - g_y)(1 - \omega)\nu_c \nu_t \quad (4)$$

$$y_t^{pot} = \frac{1}{\phi_{mc} \hat{\sigma}} [g_y g_t + (1 - g_y)(1 - \omega)\nu_c \nu_t] \quad (5)$$

$$\tau_t^{pot} = -\frac{1}{\hat{\sigma}^{open}} \left(1 - \frac{1}{\phi_{mc} \hat{\sigma}^{open}}\right) [g_y g_t + (1 - g_y)(1 - \omega)\nu_c \nu_t] \quad (6)$$

² Because government consumption is additive in the utility function, this implies that Ricardian equivalence holds.

$$r_t^{pot} = \tau_{t+1|t}^{pot} - \tau_t^{pot}, \quad (7)$$

$$p_t = p_{t-1} + \pi_t, \quad (8)$$

$$e_t = p_t + \tau_t, \quad (9)$$

where $\hat{\sigma}^{open}$, κ_x , and ϕ_{mc} are composite parameters defined as:

$$\hat{\sigma}^{open} = (1 - g_y)[(1 - \nu_c)(1 - \omega)^2\sigma + \omega(2 - \omega)\varepsilon_P] \quad (10)$$

$$\kappa_x = \kappa_{mc}\phi_{mc} \quad (11)$$

$$\phi_{mc} = \frac{\chi}{1 - \alpha} + \frac{1}{\hat{\sigma}^{open}} + \frac{\alpha}{1 - \alpha} \quad (12)$$

All variables are measured as percent or percentage point deviations from their steady state level, and for simplicity, all foreign variables are set equal to their steady state values.³

As in Clarida et al, the first three equations represent the New Keynesian open economy IS curve, Phillips Curve, and monetary rule, respectively, that jointly determine the output gap ($x_t = y_t - y_t^{pot}$), price inflation (π_t), and the nominal policy rate (i_t), with the key difference that equation (3) requires the policy rate to remain above its lower bound ($-i$). Thus, the output gap x_t depends inversely on the deviation of the real interest rate ($i_t - \pi_{t+1|t}$) from its potential rate r_t^{pot} , with the sensitivity parameter $\hat{\sigma}^{open}$ varying positively with the household's intertemporal elasticity of substitution in consumption σ and trade price elasticity ε_P (the relative weight on the latter rises with trade openness ω). Given the Calvo-Yun contract structure, equation (2) indicates that the Phillips Curve slope κ_p varies directly with the product of parameters determining the sensitivity of inflation to marginal cost κ_{mc} and of marginal cost to the output gap ϕ_{mc} (the latter depends inversely on the Frisch elasticity of labor supply $\frac{1}{\chi}$, the parameter $\hat{\sigma}^{open}$, and the labor share in production $(1 - \alpha)$). From equation (5), a contraction in government spending g_t (where g_y is the government spending share of steady state output) or negative taste shock ν_t (where ν_c is a scaling parameter) reduces potential output y_t^{pot} . Even so, both of these exogenous shocks, if

³ We use the notation $y_{t+j|t}$ to denote the conditional expectation of a variable y at period $t + j$ based on information available at t , i.e., $y_{t+j|t} = E_t y_{t+j}$. The superscript 'pot' denotes the level of a variable that would prevail under completely flexible prices, e.g., y_t^{pot} is potential output.

negative, cause the the potential terms of trade τ_t^{pot} to depreciate (a rise in τ_t^{pot} in equation 6) because they depress the marginal utility of consumption (e.g., lower government spending boosts private consumption). If both shocks follow AR(1) processes, and hence have front-loaded effects, a reduction in government spending or negative taste shock reduces the potential real interest rate r_t^{pot} . Finally, equations (8) and (9) are identities for the price level (p_t) and the nominal exchange rate (e_t).

Given that the form of the equations determining output, inflation, and interest rates is identical to that in a closed economy – as emphasized by Clarida et al – results from extensive closed economy analysis are directly applicable for assessing the impact of government spending shocks in a liquidity trap.

We next consider how the model is modified for the CU case. A CU member takes the nominal exchange rate as fixed, so that the terms of trade τ_t is simply the gap between home and foreign price levels, i.e., $\tau_t = -(p_t - p_t^*) = -p_t$.⁴ Moreover, the home economy is assumed to be small enough that the policy rate is effectively exogenous. Given that equation (4) implies that the output gap is proportional to the terms of trade gap, i.e., $x_t = \hat{\sigma}^{open}(\tau_t - \tau_t^{pot})$, the price setting equation (2) may be expressed as a second order difference equation in the terms of trade:

$$\tau_t - \tau_{t-1} = \beta(\tau_{t+1|t} - \tau_t) + \kappa_x \hat{\sigma}^{open}(\tau_t - \tau_t^{pot}), \quad (13)$$

which has the solution:

$$\tau_t = \lambda \tau_{t-1} + \kappa_x \hat{\sigma}^{open} \frac{\lambda}{1 - \beta \rho \lambda} \tau_t^{pot}, \quad (14)$$

The persistence parameter $\lambda = 0.5(a - \sqrt{a^2 - 4/\beta})$, where $a = (\frac{1}{\beta})(1 + \beta + \kappa_x \hat{\sigma}^{open})$, lies between 0 and unity, and ρ is the persistence of the shock processes (assumed to be the same for the taste shock and government spending). Equation (14) has two important implications. First, because $\lambda > 0$, a contraction in government spending – which raises τ_t^{pot} by equation (6) – moves τ_t in the same direction, implying a depreciation. Together with equation (4), this implies that the government spending multiplier m_t is strictly less than unity, i.e., $m_t = \frac{1}{g_y} \frac{dy_t}{dg_t} = 1 + \frac{1}{g_y} \frac{d\tau_t}{d\tau_t^{pot}} \frac{d\tau_t^{pot}}{dg_t} < 1$ (recalling that $\frac{d\tau_t^{pot}}{dg_t} < 0$). Second, as $\kappa_x \hat{\sigma}^{open}$ becomes very small, λ rises toward unity and the coefficient on τ_t^{pot} shrinks, implying very gradual adjustment of the terms of trade to τ_t^{pot} (and hence to a change in government spending); conversely, the terms of trade adjustment is much more rapid if $\kappa_x \hat{\sigma}^{open}$

⁴ In this model, the terms of trade is equivalent to the real exchange rate using domestic price deflators; hence, we use the terms interchangeably.

is larger. In economic terms, the terms of trade adjusts more quickly if the Phillips Curve has a relatively high slope (high κ_x), or if aggregate demand is relatively sensitivity to the terms of trade (high $\hat{\sigma}^{open}$).

To obtain some numerical results, we must assign some reasonable values to the parameters in the model. Our benchmark calibration is fairly standard at a quarterly frequency. We set the discount factor $\beta = 0.995$, and the steady state net inflation $\pi = .005$; this implies a steady state interest rate of $i = .01$ (i.e. four percent at an annualized rate). We set the intertemporal substitution elasticity $\sigma = 1$ (log utility), the capital share parameter $\alpha = 0.3$, the Frisch elasticity of labor supply $\frac{1}{\chi} = 0.4$, the government share of steady state output $g_y = 0.2$, and the scale parameter on the consumption taste shock $\nu_c = 0.01$. Following Eggertsson (2010), we assume that monetary policy completely stabilizes output and inflation in the absense of the zero lower bound, which is achieved by setting γ_π and γ_x in the interest rate reaction function arbitrarily large (1000). Finally, the share of imported goods in the final consumption bundle $\omega = 0.3$, and the substitution elasticity between foreign and domestic good ε_p equals 1.5.

2.1. Simulation Results

The left panel of Figure 1 shows the effects of a 1 percent of baseline GDP cut in government spending under a calibration in which the Phillips Curve slope *relating inflation to marginal cost* $\kappa_{mc} = .025$. This calibration is towards the higher side of empirical estimates, while the right panel shows a calibration which sets $\kappa_{mc} = .007$, towards the very low end of empirical estimates. If factors were completely mobile, these calibrations would imply mean price contract durations of about 7 and 12 quarters, respectively, but – as emphasized by an extensive literature (e.g., Altig et al., 2011) – the reduced form slopes could be regarded as consistent with much shorter contract durations under reasonable assumptions about strategic complementarities. As seen in the upper panels, the potential terms of trade τ_t^{pot} depreciates (rises) initially, and then dies out slowly at the rate $\rho = 0.95$. This fall in the relative price of domestically-produced goods reflects that the government spending cut boosts home consumption relative to foreign consumption. Moreover, the positive wealth effect reduces potential output y_t^{pot} (lower panels). A country with an IMP – *if unconstrained by the zero lower bound* – could achieve this flexible price allocation simply through a monetary rule (3) that responded very aggressively to inflation and/or the output gap. Under such a rule, the terms of trade τ_t would track τ_t^{pot} exactly, and given that inflation remained unchanged from baseline, both the real and nominal interest rate would decline in line with r_t^{pot} (reflecting

that consumption would be expected to fall after its initial rise). Thus, output would track y_t^{pot} irrespective of the degree of price stickiness. With the price level constant, the jump in the real exchange rate would be achieved through nominal exchange rate depreciation.

Because the nominal exchange rate is fixed in a CU, the government spending cut initially boosts τ_t^{pot} much more than the actual terms of trade τ_t (upper panels). The negative terms of trade gap $\tau_t - \tau_t^{pot}$ – which may be regarded as an “overvalued” terms of trade – causes output to fall persistently below potential. The negative output gap causes inflation to fall persistently – implying a progressive depreciation of the terms of trade – and the progressive narrowing of the terms of trade gap eventually moves output towards potential. As noted previously, the adjustment process proceeds more quickly with shorter-lived price contracts, which explains why the output contraction in the left panel is smaller and less persistent than in the right panel. In addition, factors that raise the sensitivity $\hat{\sigma}^{open}$ of demand to the terms of trade – such as a higher elasticity of demand for traded goods – would also speed-up the adjustment. Importantly, although the terms of trade adjust sluggishly in line with the price level, it does at least move in the “right direction” for narrowing the output gap. Moreover, as highlighted by Corsetti et al. (2011), the ex ante long-term real interest rate actually falls in response to a temporary fall in government spending: although inflation declines in the near-term, the terms of trade (and hence price level) must eventually revert to steady state, implying some rise in long-run expected inflation.⁵

While greater price flexibility cushions the impact of a government spending cut in a CU, more price flexibility – or more generally, a more upward sloping Phillips Curve slope – can greatly deepen the contraction that occurs under an IMP subject to the zero bound constraint, and imply an output multiplier much larger than in a CU. In this vein, Figure 1 shows the effects of the government spending contraction under an IMP against the backdrop of initial conditions which imply an ten quarter liquidity trap (i.e., a negative taste shock that is scaled to induce a liquidity trap lasting ten quarters in the absence of the fiscal shock). As the government spending shock reduces r_t^{pot} while the policy rate remains fixed, the output gap would contract even if expected inflation remained constant. However, the output contraction is reinforced by a persistent decline in inflation that is particularly large when price adjustment is relatively rapid (the left panel). Thus, the peak output decline is 1.5 under the IMP, compared with 0.8 in a CU. Importantly, the large output decline under the IMP reflects two factors. First, long-term ex ante real interest rates rise substantially, in contrast to the decline that occurs in a CU. Second, the rise in the real interest

⁵ With a permanent fall in spending, the rise in long-term real interest rates would be very small.

rate under an IMP implies a “perverse” initial appreciation of the terms of trade (as seen in the upper left panel). Thus, although the CU precludes the nominal exchange rate from adjusting, the lack of adjustment serves to better cushion output than the appreciation that occurs under an IMP.

Under more sluggish price adjustment, the multiplier is only about 0.6 under an IMP, smaller than the multiplier of 0.9 in a CU. With inflation much less responsive, long-term real interest rates fall under an IMP, and this allows a front-loaded depreciation of the terms of trade to cushion the impact on output. Overall, our results underscore that the same conditions which tend to mitigate the effects of fiscal consolidation in a CU – namely, an upward-sloping Phillips Curve – tend to exacerbate the effects under an IMP constrained by the zero lower bound; and conversely, a flatter Phillips Curve tends to make an IMP look relatively more attractive, since the real exchange rate can immediately adjust to lessen the bite on aggregate demand.

While the results in Figure 1 consider the specific case of a ten quarter liquidity trap, it is natural to ask how long a liquidity trap is required for fiscal consolidation to produce a more contractionary effect under an IMP than a CU. To address this question, Figure 2 plots the output response to 1 percent of GDP contraction under different assumptions about the duration of the liquidity trap faced under an IMP (with the longer-lived traps generated by progressively largely adverse taste shocks). As in Figure 1, the left panel adopts the calibration in which price adjustment is relatively faster, while the right panel assumes that price adjustment is slower. In the former case, the output contraction becomes much more pronounced as the liquidity trap lengthens – increasing in a convex fashion – with the multiplier in the case of a eight quarter liquidity trap exceeding the multiplier under a CU of 0.8 (the dashed line). With a three year liquidity trap, the spending multiplier is nearly 3, as a sharp rise in long-term real interest rates (caused by lower expected inflation) causes a large improvement in the terms of trade (lower panel). In this environment, the anchoring of the long-run price level provided by a CU is clearly very beneficial in insulating the economy from the potential pressures that can arise in a liquidity trap. By contrast, with long-lived 12 quarter price contracts, the liquidity trap must last 12 quarters for the multiplier under an IMP to exceed that under a CU; for liquidity traps of less than two years, the front-loaded depreciation of the terms of trade (lower right panel) significantly mitigates the effects of the spending cut on output. As the slope of the Phillips Curve becomes flatter, the liquidity trap duration required to produces a larger output downturn than in a CU becomes progressively longer.

Our analysis has focused on a simple model that abstracts from an array of empirically-relevant

nominal and real frictions. Even so, our key points continue to hold in more realistic open economy settings. Figure 3 shows responses to a 1 percent of GDP fiscal contraction in a larger-scale open economy model used in Erceg and Lindé (2010b) that embeds nominal wage and price rigidities, endogenous capital accumulation, rule-of-thumb consumers, and incomplete exchange rate passthrough in the short-run. The left panel with “faster price adjustment” adopts a calibration of the price and wage contract duration parameters that is broadly representative of the estimates of the slopes of price and wage Phillips Curves based on data prior to the financial crisis, and specifically, adopts the estimate of Altig et al. (2011) of $\kappa_{mc} = 0.014$. The right panel shows estimates under an alternative calibration that imposes an extremely flat price (and wage) Phillips Curve of $\kappa_{mc} = 0.002$.⁶ The unconstrained IMP follows a Taylor rule, while the constrained policy is derived under the assumption that the liquidity trap lasts ten quarters.

Under the calibration with relatively faster price adjustment, output declines over 2 percent after 4 quarters under the constrained IMP, compared with only about 0.7 percent in a CU. The larger output decline in the former case reflects a larger fall in inflation (middle left panel) – which pushes up long-term real interest rates – and a sizeable real appreciation of the exchange rate. Thus, the fiscal shock is amplified by a sharp contraction in private domestic demand and real net exports. In a CU, the real exchange rate depreciates slightly even in the near-term, and the long-term real interest rate is about constant. By contrast, under very slow price adjustment – the right panel – the effects of fiscal consolidation on output are modestly smaller under a constrained IMP than CU. The smaller output decline under an IMP reflects both a front-loaded exchange rate depreciation and fall in long-term real interest rates (since inflation barely moves, and policy rates fall after two years). For a short-lived liquidity trap, the advantages of an IMP are even larger.

3. Implications and Open Questions

Conditional on some key structural parameters, including those highlighted above, our modeling framework has clear implications to help gauge whether the output effects of fiscal consolidation in an economy such as the United Kingdom – where policy rates are constrained by their ZLB – are likely to be larger than in a CU member such as Portugal or Belgium. But given that even the qualitative answer hinges on factors that determine the responsiveness of inflation, which view

⁶ Under “faster price adjustment,” the contract duration parameters for prices and wages are $\xi_p = 0.86$ and $\xi_w = 0.82$, respectively, while $\xi_p = 0.95$ and $\xi_w = 0.90$ under “slower price adjustment.” The model and calibration of other parameters are described in Erceg and Lindé (2010b), and for your convenience also in the Appendix (see Appendix Appendix A).

does the evidence favor?

There is a substantial amount of econometric evidence estimating the sensitivity of price inflation to marginal cost, and of wage inflation to the wage markup; as noted, the calibration in the left panel of Figure 3 seems squarely in line with such evidence. On this basis, fiscal consolidation would have a significantly deeper contractionary impact on an open economy provided that monetary policy were constrained for a period exceeding two years; and the seeming strictures of a CU would in fact ameliorate the output contraction. Moreover, the relative impact under an IMP would appear even more dire in the case of a longer-lived trap, or if price and wage-sensitivity were somewhat higher.

However, the resilience of inflation during the recent global recession suggests the possibility that the responsiveness of inflation may be considerably lower than implied by most existing econometric evidence. As seen in the left panel of Figure 3, the 1 percent of GDP fiscal contraction reduces inflation sharply by around 2 percentage points. Moreover, under the same calibration of price adjustment, a fall in output of say 6-8 percent or more below its pre-crisis trend path – as was experienced by the United States and Europe during the recent recession – would imply a fall in both inflation and one-year ahead expected inflation of more than 4 percentage points below the central bank’s perceived inflation target if mainly driven by aggregate demand shocks. This implied decline is much larger than actually occurred in either the United States, where core inflation and market expectations of core inflation have remained well above 1 percent, or in major economies in Europe.

It is quite conceivable that inflation behavior during the past few years can be rationalized as consistent with econometric evidence based on pre-crisis observations. For example, financial shocks and other shocks may have adversely impacted the supply side of the economy enough to accomodate observed inflation behavior within the range of existing econometric evidence. However, future analysis may well point to a somewhat lower degree of inflation responsiveness. If so, outside of a very prolonged liquidity trap, our analysis would indicate that an economy with an IMP may be somewhat better poised to absorb the effects of fiscal consolidation than a CU, with real exchange rate and interest movements tending to cushion rather than amplify the impact.

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Appendix A. The Erceg and Lindé (2010) Model

Our large model consists of a currency union with two country blocks that differ in size, but are otherwise isomorphic. The first country block is called the “South”, and the second country block the “North.” Given the isomorphic structure, our exposition below largely focuses on the structure of the South. It is important to recall, however, that differences in country size translate into difference in steady state trade shares. Thus, the standard small open economy paradigm emerges as a special case in which the population size of the South is calibrated to be an arbitrarily small fraction of the currency union.

Our specification of the financial accelerator channel closely parallels earlier work by Bernanke, Gertler, and Gilchrist (1999) and Christiano, Motto, and Rostagno (2008). Given that the mechanics underlying the financial accelerator are well-understood, we simplify our exposition by focusing on a special case of our model which abstracts from a financial accelerator. We conclude our model description with a brief description of how the model is modified to include the financial accelerator (Section A.6).

A.1. Firms and Price Setting

A.1.1. Production of Domestic Intermediate Goods

There is a continuum of differentiated intermediate goods (indexed by $i \in [0, 1]$) in the South block, 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} :

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

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

$$X_t(i) = \left[\frac{P_{Mt}^*(i)}{P_{Mt}^*} \right]^{\frac{-(1+\theta_p)}{\theta_p}} M_t^*, \quad (\text{A.2})$$

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 block’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:

$$Y_t(i) = \left(\omega_K^{\frac{\rho}{1+\rho}} K_t(i)^{\frac{1}{1+\rho}} + \omega_L^{\frac{\rho}{1+\rho}} (Z_t L_t(i))^{\frac{1}{1+\rho}} \right)^{1+\rho}. \quad (\text{A.3})$$

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 .

We assume 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 reoptimize 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. When ι_p is set close to unity, this formulation introduces structural inertia into the price-setting equation.

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

$$\mathbb{E}_t \sum_{j=0}^{\infty} \xi_p^j \psi_{t,t+j} \left[\prod_{h=1}^j \pi_{t+h-1} P_{Dt}(i) Y_{Dt+j}(i) - MC_{t+j} Y_{Dt+j}(i) \right]. \quad (\text{A.4})$$

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.^{A.1} The first-order condition for setting the contract price of good i in the home market is

$$\mathbb{E}_t \sum_{j=0}^{\infty} \psi_{t,t+j} \xi_p^j \left(\frac{\prod_{h=1}^j \pi_{t+h-1}(i)}{(1 + \theta_p)} - MC_{t+j} \right) Y_{Dt+j}(i) = 0. \quad (\text{A.5})$$

The problem for firm i of reoptimizing its price for the export market in period t is identical to that in (A.4), with the exception that $X_{t+j}(i)$ enters instead of Y_{Dt+j} .

^{A.1} 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.

A.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} :

$$Y_{Dt} = \left[\int_0^1 Y_{Dt}(i)^{\frac{1}{1+\theta_p}} di \right]^{1+\theta_p}. \quad (\text{A.6})$$

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} :

$$P_{Dt} = \left[\int_0^1 P_{Dt}(i)^{\frac{-1}{\theta_p}} di \right]^{-\theta_p}. \quad (\text{A.7})$$

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

$$M_t^* = \left[\int_0^1 X_t(i)^{\frac{1}{1+\theta_p}} di \right]^{1+\theta_p}, \quad (\text{A.8})$$

and sells M_t^* at price P_{Mt}^* :

$$P_{Mt}^* = \left[\int_0^1 P_{Mt}^*(i)^{\frac{-1}{\theta_p}} di \right]^{-\theta_p}. \quad (\text{A.9})$$

A.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:

$$C_{At} = \left(\omega_C^{\frac{\rho_C}{1+\rho_C}} C_{Dt}^{\frac{1}{1+\rho_C}} + (1 - \omega_C)^{\frac{\rho_C}{1+\rho_C}} (\varphi_{Ct} M_{Ct})^{\frac{1}{1+\rho_C}} \right)^{1+\rho_C}, \quad (\text{A.10})$$

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 φ_{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 ω_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 φ_{Ct} is assumed to take the quadratic form:

$$\varphi_{Ct} = \left[1 - \frac{\varphi_{MC}}{2} \left(\frac{\frac{M_{Ct}}{C_{Dt}}}{\frac{M_{Ct-1}}{C_{Dt-1}}} - 1 \right)^2 \right]. \quad (\text{A.11})$$

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:

$$\begin{aligned} \min_{C_{Dt+k}, M_{Ct+k}} \mathbb{E}_t \sum_{k=0}^{\infty} \psi_{t,t+k} & \left\{ (P_{Dt+k} C_{Dt+k} + P_{Mt+k} M_{Ct+k}) \right. \\ & \left. + P_{Ct+k} \left[C_{A,t+k} - \left(\omega_C^{\frac{\rho_C}{1+\rho_C}} C_{Dt+k}^{\frac{1}{1+\rho_C}} + (1 - \omega_C)^{\frac{\rho_C}{1+\rho_C}} (\varphi_{Ct+k} M_{Ct+k})^{\frac{1}{1+\rho_C}} \right)^{1+\rho_C} \right] \right\}. \end{aligned} \quad (\text{A.12})$$

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 ω_I in the investment index to differ from that of the weight ω_C in the consumption goods index.^{A.2}

A.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 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:

$$L_t = \left[\int_0^1 (\zeta N_t(h))^{\frac{1}{1+\theta_w}} dh \right]^{1+\theta_w}, \quad (\text{A.13})$$

^{A.2} Notice that the final investment good is not used by the government.

where $\theta_w > 0$ and $N_t(h)$ is hours worked by a typical member of household h . The parameter ζ 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 :

$$W_t = \left[\int_0^1 W_t(h)^{\frac{1}{\theta_w}} dh \right]^{-\theta_w}. \quad (\text{A.14})$$

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

$$N_t(h) = \left[\frac{W_t(h)}{W_t} \right]^{-\frac{1+\theta_w}{\theta_w}} L_t / \zeta. \quad (\text{A.15})$$

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 ς and the share of HM households by $1 - \varsigma$.

We consider first the problem faced by FL households. The utility functional for an optimizing representative member of household h is

$$\begin{aligned} \mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left\{ \frac{1}{1-\sigma} (C_{t+j}^O(h) - \kappa C_{t+j-1}^O - \nu_{ct})^{1-\sigma} + \right. \\ \left. \frac{\chi_0 Z_{t+j}^{1-\sigma}}{1-\chi} (1 - N_{t+j}(h))^{1-\chi} + \mu_0 F\left(\frac{MB_{t+j+1}(h)}{PC_{t+j}}\right) \right\}, \end{aligned} \quad (\text{A.16})$$

where the discount factor β 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 optimizing 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, $\frac{MB_{t+1}(h)}{PC_t}$, and a preference shock, ν_{ct} . The subutility function $F()$ over real balances is assumed to have a satiation point, in order to rationalize the possibility of a zero nominal interest rate; see Eggertsson and Woodford (2003) for further discussion.

Household h faces a flow budget constraint in period t which states that its combined expendi-

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

$$\begin{aligned}
& P_{Ct}C_t^O(h) + P_{It}I_t(h) + MB_{t+1}(h) - MB_t(h) + \int_s \xi_{t,t+1}B_{Dt+1}(h) \\
& \quad - B_{Dt}(h) + P_{Bt}B_{Gt+1} - B_{Gt} + \frac{P_{Bt}^*B_{Ft+1}(h)}{\phi_{bt}} - B_{Ft}(h) \\
& = (1 - \tau_{Nt})W_t(h)N_t(h) + \Gamma_t(h) + TR_t(h) - T_t(h) + (1 - \tau_{Kt})R_{Kt}K_t(h) + \\
& \quad P_{It}\tau_{Kt}\delta K_t(h) - P_{Dt}\phi_{It}(h).
\end{aligned} \tag{A.17}$$

Investment in physical capital augments the per capita capital stock $K_{t+1}(h)$ according to a linear transition law of the form:

$$K_{t+1}(h) = (1 - \delta)K_t(h) + I_t(h), \tag{A.18}$$

where δ 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,^{A.3} cross-border asset trade is restricted to a single non-state contingent bond issued by the government of the North economy.

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:

$$\phi_{bt} = \exp\left(-\phi_b \left(\frac{B_{Ft+1}}{P_t Y_t}\right)\right). \tag{A.19}$$

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 τ_{Nt} is a stochastic tax on labor income. The household leases capital at the after-tax rental rate $(1 - \tau_{Kt})R_{Kt}$, where τ_{Kt} is a stochastic tax on capital income. The household receives a depreciation

^{A.3} These contingent claims are in zero net supply from the standpoint of the South as a whole; hence, we omit them from the budget constraint for expositional simplicity.

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, $TR_t(h)$ and pays a lump-sum tax $T_t(h)$. 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:

$$\phi_{It}(h) = \frac{1}{2}\phi_I \frac{(I_t(h) - I_{t-1})^2}{I_{t-1}}. \quad (\text{A.20})$$

In every period t , each member of FL household h maximizes the utility functional (A.16) 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 (A.15), budget constraint (A.17), and transition equation for capital (A.18). 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:

$$W_t(h) = \omega_{t-1}^{\iota_w} \omega^{1-\iota_w} W_{t-1}(h), \quad (\text{A.21})$$

where ω_{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 (A.16) 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, $P_{Ct}C_t^{HM}(h)$, to his current after-tax disposable income, which consists of labor income plus net lump-sum transfers from the government:

$$P_{Ct}C_t^{HM}(h) = (1 - \tau_{Nt})W_t(h)N_t(h) + TR_t(h) - T_t(h). \quad (\text{A.22})$$

The HM households set their wage to be the average wage of the forward-looking households. Since HM households face the same labor demand schedule as the forward-looking households, each HM household works the same number of hours as the average for forward-looking households.

A.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:

$$i_t = \max \{-i, (1 - \gamma_i) (\tilde{\pi}_t + \gamma_\pi (\tilde{\pi}_t - \pi) + \gamma_x \tilde{x}_t) + \gamma_i i_{t-1}\} \quad (\text{A.23})$$

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 then implies that i_t cannot fall below $-i$ and that the systematic part of the policy rule is below $-i$ when $i_t = -i$. $\tilde{\pi}_t$ is price inflation rate of the currency union, π 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 here 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.

A.4. Fiscal Policy

Government purchases have no direct effect on the utility of households, nor do they affect the production function of the private sector. We assume that government spending follows an AR(1) process:

$$g_t = \rho_{g1} g_{t-1} + \varepsilon_{g,t}. \quad (\text{A.24})$$

The government does not need to balance its budget each period, and issues nominal debt to finance its deficits according to:

$$P_{Bt} B_{Gt+1} - B_{Gt} = P_{Ct} G_t + T R_t - T_t - \tau_{Nt} W_t L_t - (\tau_{Kt} R_{Kt} - \delta P_{It}) K_t - (M B_{t+1} - M B_t). \quad (\text{A.25})$$

Equation (A.25) aggregates the capital stock, money and bond holdings, and transfers and taxes over all households so that, for example, $T_t = \zeta_t \int_0^1 T_t(h) dh$. The capital tax τ_{Kt} is assumed to be fixed, and the ratio of real transfers to (trend) GDP, $tr_t = \frac{T R_t}{P_t Y}$, is also fixed. Given that the central bank uses the nominal interest rate as its policy instrument, the level of seigniorage revenues are determined by nominal money demand.

The distortionary tax on labor income τ_{Nt} adjusts in response to both the debt/GDP ratio,

b_{Gt+1} , and to the total government deficit, $b_{Gt+1} - b_{Gt}$:

$$\tau_{Nt} = \nu_0 \tau_{N,t-1} + \nu_1 (b_{Gt+1} - b_G) + \nu_2 (b_{Gt+1} - b_{Gt}), \quad (\text{A.26})$$

where $b_{Gt+1} = \frac{B_{Gt+1}}{P_t Y}$ and b_G is the government's target value for the ratio of government debt to nominal (trend) output. Hence, τ_{Nt} works as an automatic stabilizer and ensures that the level of debt to trend output is stationary.

A.5. Resource Constraint and Net Foreign Assets

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

$$Y_{Dt} = C_{Dt} + I_{Dt} + \phi_{It}, \quad (\text{A.27})$$

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

$$C_{At} = C_t + G_t, \quad (\text{A.28})$$

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

$$C_t = C_t^O + C_t^{HM}. \quad (\text{A.29})$$

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

$$M_t^* = M_{Ct}^* + M_{It}^*. \quad (\text{A.30})$$

Finally, at the level of the individual firm:

$$Y_t(i) = Y_{Dt}(i) + X_t(i) \quad \forall i. \quad (\text{A.31})$$

The evolution of net foreign assets can be expressed as:

$$\frac{P_{B,t}^* B_{F,t+1}}{\phi_{bt}} = B_{F,t} + P_{Mt}^* M_t^* - P_{Mt} M_t. \quad (\text{A.32})$$

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 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).

A.6. Production of capital services

We incorporate 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 A.18) and A.20). 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. 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). Banks obtain funds to lend to the entrepreneurs by issuing deposits to households at the interest rate set by the central bank. By assuming perfect competition and free entry among banks and that all bank portfolios are well diversified (i.e., that each bank lends out to a continuum of entrepreneurs, whose default risk is independently distributed), it follows that banks make zero profits in each state of the economy and that there is no credit risk to households associated with bank deposits.^{A.4}

Appendix B. 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 (A.23), 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 endogenous, and is affected by shocks hitting the model economy.

The model is calibrated at a quarterly frequency. Structural parameters are set at identical values for each of the two country blocks, except for the parameter ζ determining population size

^{A.4} We refer to Bernanke, Gertler and Gilchrist (1999) and Christiano, Motto and Rostagno (2008) for further details. An excellent exposition is also provided in Christiano, Trabandt and Walentin (2007).

(as discussed below), 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 σ 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 χ_0 is set so that employment comprises one-third of the household's time endowment, while the parameter μ_0 on the subutility function for real balances is set at an arbitrarily low value (given the separable specification, variation in real balances has no impact on other variables). We choose $\varsigma = 0.47$ so that about 50 percent of households are Ricardian FL agents. This share implies that consumption of HM households equals about 21 percent of total consumption in steady state. The lower share of total consumption reflects that HM households consume less on average than FL households as they are assumed not to save and accumulate any capital.

The depreciation rate of capital δ is set at 0.025. (consistent with an annual depreciation rate of 10 percent). The parameter ρ in the CES production function of the intermediate goods producers is set to -2 . This implies an elasticity of substitution between capital and labor, $(1 + \rho)/\rho$, of $1/2$, somewhat below the unity elasticity implied by the Cobb-Douglas specification. The quasi-capital share parameter ω_K – together with the price markup parameter of $\theta_P = 0.10$ is chosen to imply a steady state investment to output ratio of 20 percent. We set the cost of adjusting investment parameter $\phi_I = 3$, slightly below the value estimated by Christiano, Eichenbaum and Evans (2005).

The calibration of the parameters determining the financial accelerator follows Bernanke, Gertler and Gilchrist (1999), and is identical across country blocks. In particular, the monitoring cost, μ , 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.

Given strategic complementarities in wage-setting across households, the wage markup influences the slope of the wage Phillips curve. Our choices of a wage markup of $\theta_W = 1/3$ and a wage contract duration parameter of $\xi_w = 0.85$ – along with a wage indexation parameter of $\iota_w = 0.65$ – imply that wage inflation is somewhat more responsive to the wage markup (0.007) than price

inflation is to the price markup in the slow adjustment case (0.002), but less responsive compared to the faster price adjustment case (0.014).

The parameters pertaining to fiscal policy are set as follows. The share of government spending of total expenditure is set equal to 20 percent. The government debt to GDP ratio, b_G , is set to 0.75, about equal to the average level of debt in euro area countries at end-2008. The lump-sum tax revenue to GDP ratio is set to a small value of 0.02. Given that the capital tax τ_K is set to zero, the government's intertemporal budget constraint implies that the labor income tax rate τ_N equals 0.35 in steady state.

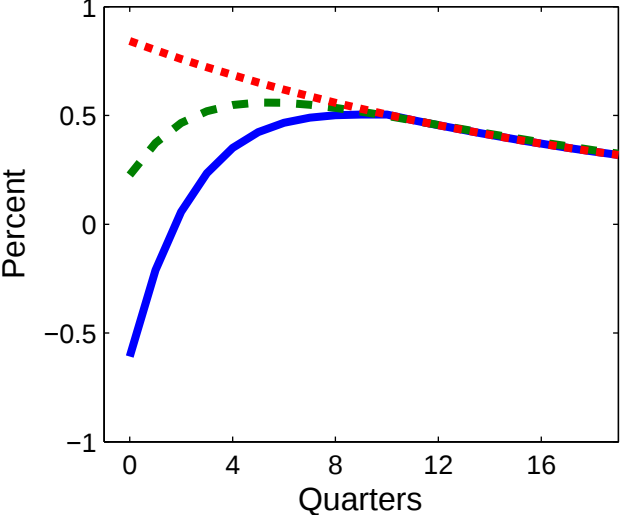
Using Eurostat data for 2008, the average share of imports of small open economy countries (like Greece, Ireland and Portugal) from the remaining countries of the euro area comprised about 14 percent of GDP in 2008. This pins down the trade share parameters ω_C and ω_I for the South under the additional assumption that the import intensity of consumption is equal to $3/4$ that of investment. The size of the South relative to the North is based on data for the Greek, Portugal and the Ireland economies. Each of these economies accounts for about 2 percent of euro area GDP, so that $\zeta = 0.02$. This case approximates a small open economy. Given that trade is balanced in steady state, this parameterization implies an export and import share of the North countries of about 0.3 percent.

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. While this is higher than most empirical estimates using macro data, the presence of adjustment costs reduces the near-term relative price sensitivity. In particular, we set the adjustment cost parameters $\varphi_{M_C} = \varphi_{M_I} = 3$, implying a half-life of adjustment of about half a year. We choose a small value (0.00001) for the financial intermediation cost ϕ_b , which is sufficient to ensure the model has a unique steady state.

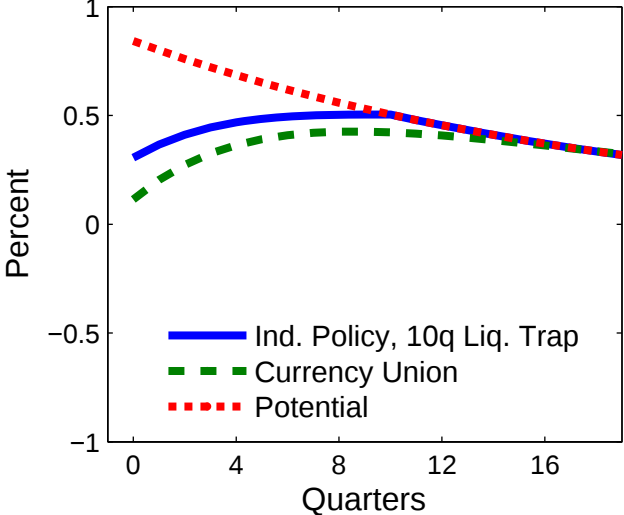
We set the parameters of the monetary rule so that $\gamma_\pi = 1.5$, $\gamma_x = 0.125$, and $\gamma_i = 0.7$. Relative to the standard Taylor rule, this rule is more aggressive in responding to inflation, and incorporates considerable interest rate inertia; these features seem a relevant characterization of ECB monetary policy. For the tax rate reaction function, we choose $\nu_0 = 0.9$, $\nu_1 = 0.02$, $\nu_2 = 0.05$. This benchmark tax rule is not very aggressive, and has similar implications to adjustment via lump-sum taxes in the short run.

Figure 1: Persistent Contraction in Government Spending
Fast Price Adjustment **Slow Price Adjustment**

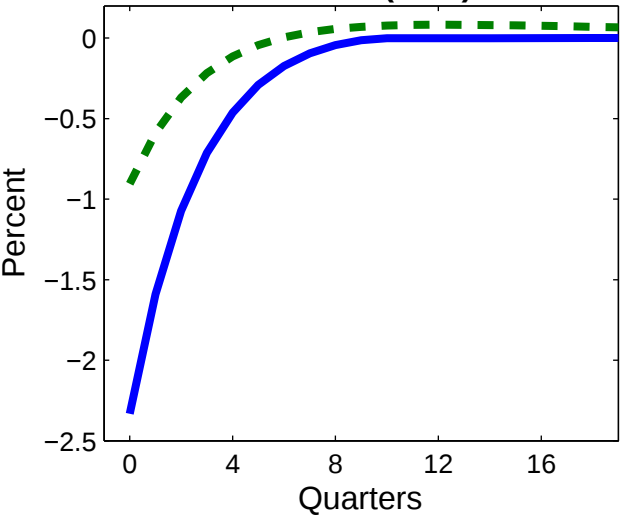
Terms of Trade



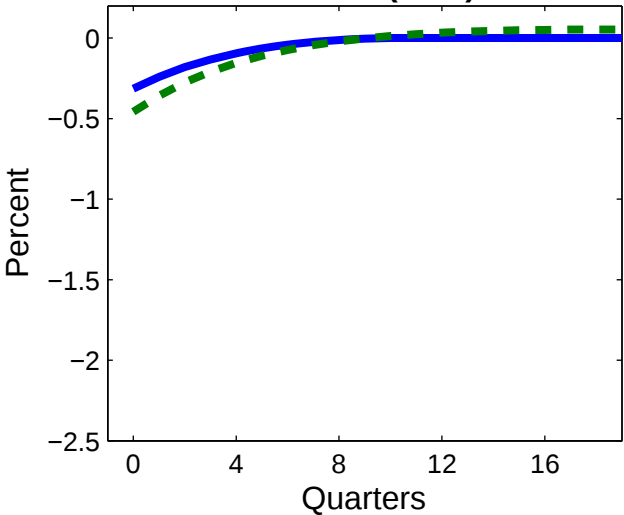
Terms of Trade



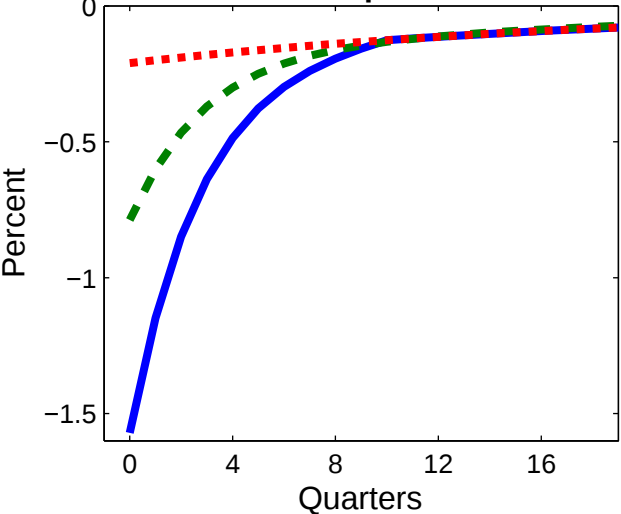
Inflation (APR)



Inflation (APR)



Output



Output

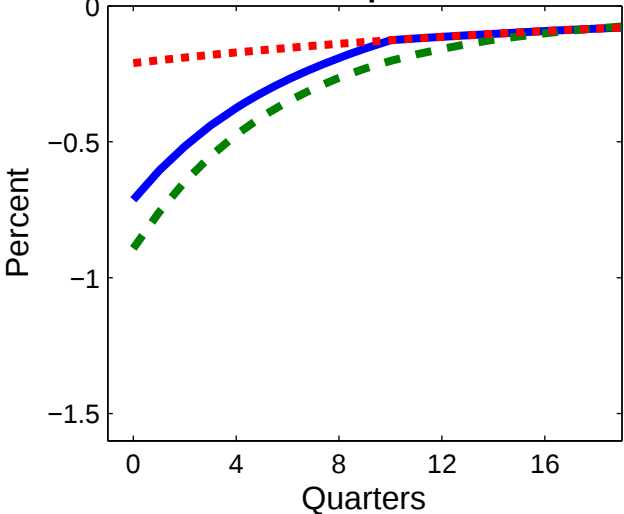
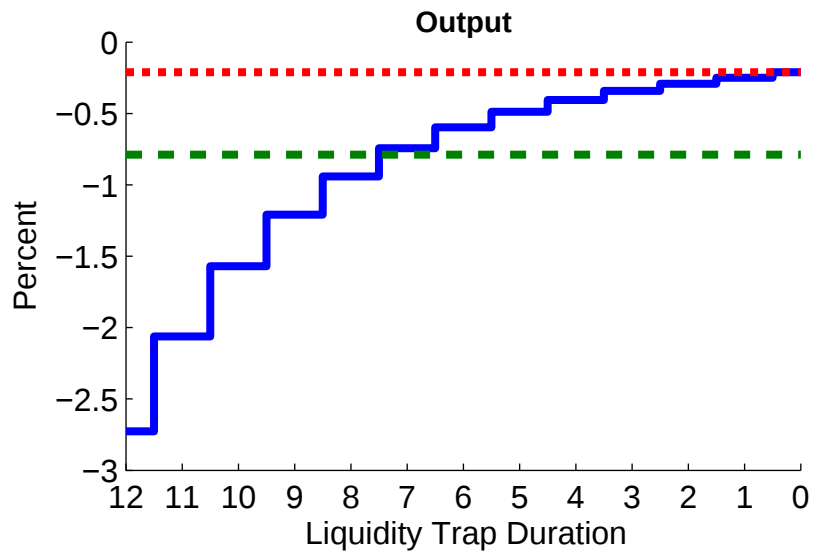


Figure 2: Impact Output Response to Immediate Government Spending Cut With Independent Monetary Policy and in a Currency Union

Fast Price Adjustment



Slow Price Adjustment

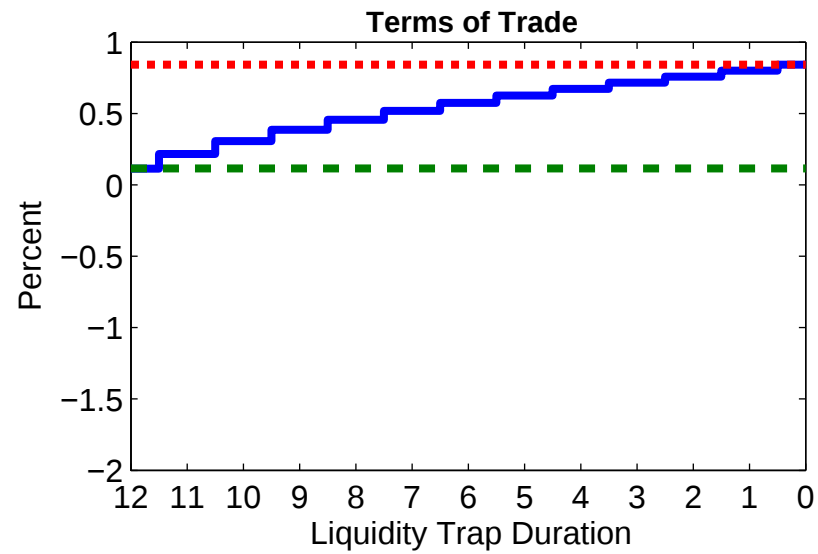
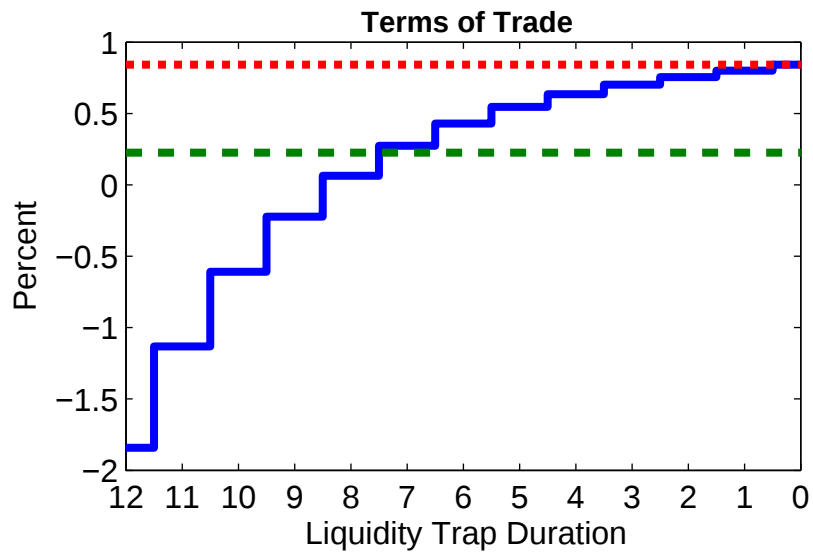
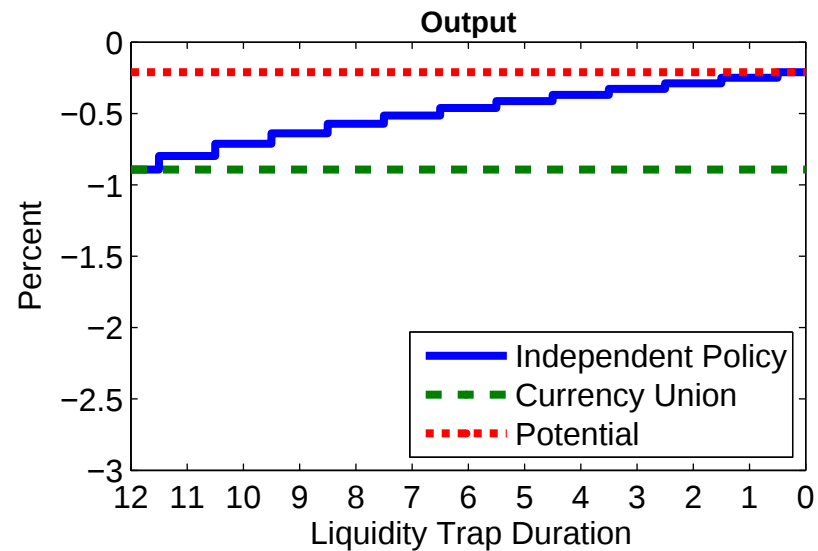


Figure 3: Persistent Government Spending Cut in Large Model
Faster Price Adjustment **Slower Price Adjustment**

