Asymmetric Shocks in a Currency Union with Monetary and Fiscal Handcuffs*

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Abstract

This paper investigates the impact of the assymmetric shocks within a currency union in a framework that takes account of the zero bound constraint on policy rates, and also allows for constraints on fiscal policy.

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1. Introduction

Following the intensification of the financial crisis in the fall of 2008, many countries implemented large fiscal stimulus packages aimed at mitigating the effects of the recession. A number of influential papers were supportive of these policy actions on the premise that fiscal multipliers were likely to be especially large in an environment in which monetary policy was unlikely to respond by raising interest rates.[1]

The rise in sovereign spreads in a number of European countries since late 2009, especially those with high government debt or deficit levels, has spurred plans for substantial and accelerated fiscal consolidation in those countries. Such fiscal consolidation is perceived as a prerequisite for restoring the confidence of bond markets, as well as for drawing on the European financial assistance package announced in May.

This paper uses an open economy DSGE model to analyze how asymmetric shocks that are concentrated in a subset of member countries of a currency union affect the union both at an aggregate level, and differentially across member states. While this question has a long history in the optimal currency area literature, our framework takes explicit account of possible constraints on both monetary and fiscal policy. In particular, we assume that monetary policy is constrained by the zero lower bound (ZLB) on policy rates, and also consider the possibility that fiscal policy in at least some members may be constrained to react aggressively to debt or deficits.

Our model consists of two country blocks that are integrated into a currency union, and hence share a single currency. The model structure inherits many of the features of a

[1] Eggertson (2008), Eggertson (2009), and Christiano, Eichenbaum, and Rebelo (2009) argue that the fiscal multiplier is likely to be very large in a liquidity trap; Cogan et al (2009) offer a contrasting view.

broad class of new open economy macro models. These include the various nominal and real frictions that have been identified as empirically important in the closed economy models of Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2003), as well as analogous frictions relevant in an open economy framework, such as costs of adjusting trade flows. As in Erceg, Guerrieri, and Gust (2006), the model also allows for the possibility of "rule of thumb" households which consume all of their after-tax income. Fiscal policy is determined separately by each country block, and includes rules for adjusting an endogenous component of government spending or taxes in response to government debt.

We calibrate the model to the euro area, identifying one country block as the "periphery", and the other the "core." Our analysis focuses on a "large periphery" calibration in which the GDP of the periphery is half as large as of the core, which is similar to the combined size of Greece, Ireland, Portugal, Italy, and Spain relative to the remaining countries of the euro area. We also examine an alternative "small periphery" calibration in which the GDP of the periphery is a tiny fraction of the core's GDP. The latter closely approximates the case of a small open economy.

We begin by examining the effects of a contraction in government spending in the periphery. Under "normal conditions" in which monetary policy is unconstrained, the effects of fiscal contraction in a single small economy are considerably more severe than if a sizeable group of its neighbors also reduced spending (based on comparing our small and large periphery calibrations). This reflects that the monetary authority essentially leaves interest rates unchanged in response to a contraction in a small economy, while reducing interest rates considerably in the case of a concerted fiscal contraction. Thus, as familiar from a standard optimal currency area rationale, a small country such as Portugal would be better off if it cut spending at the same time as Italy and Spain; and the smaller GDP decline would translate into a more rapid fall in the stock of debt. The fiscal contraction under the large periphery calibration actually causes output to rise slightly in the core.

The implications contrast starkly with the case in which monetary policy is unable to reduce interest rates due to the ZLB constraint. In this environment, the impact of the fiscal shock in the periphery depends on agents' perceptions about how long the liquidity trap would last in the absence of additional shocks, and the severity of the associated recession. As a benchmark, we choose initial conditions to imply that the liquidity trap would last two years in the absence of an additional shock. Against this backdrop, fiscal contraction in the large periphery case has a considerably more negative impact than when a single small country reduces spending. Moreover, the spillover effects to core countries are negative and very sizeable, cause a substantial deterioration in the budget position of those countries.

Following Bodenstein, Erceg, and Guerrieri (2009) and Erceg and Linde (2010), we allow the duration of the liquidity trap to be determined endogenously. In this framework, the marginal impact on currency union GDP of spending cuts in the periphery grows with the size of the spending cut. For example, while a spending cut of 1 percent of periphery GDP has a multiplier of only a little greater of unity, a spending reduction of 3 percent has a multiplier of 2.8 – reflecting that the larger spending cut actually deepens the duration of the liquidity trap by two quarters. Importantly, a progressively larger share of the contraction in the aggregate GDP of the currency union is borne by the core countries; for example, in reaction to a 3 percent spending cut in the periphery, almost half of the aggregate GDP contraction is borne by the core countries.

The implication that the GDP contraction is grows nonlinearly with the size of the periphery's spending shock makes it difficult to achieve progress in reducing government debt. Periphery government debt actually increases in the size of the spending contraction over a three year horizon. The impact on the currency union is exacerbated considerably if fiscal policy in the core aims to keep core government debt stock from expanding through fiscal consolidation. Such a policy turns out to be counterproductive by dragging out the period in which government debt rises, and further reducing currency union output.

Our results on the impact of monetary and fiscal constraints also carries over to other shocks, such as financial shocks. In particular, we illustrate how a rise in borrowing costs in the periphery has small spillover effects to the core under normal conditions, but can have vastly amplified effects when both monetary and fiscal policy are constrained.

Overall, our results indicate that the usual optimal currency argument suggesting that the effects of shocks are mitigated to the extent that they are common across members of a currency union is not valid in an environment with monetary and fiscal constraints. From a policy perspective, it is desirable to delay the implementation of fiscal consolidation until a point where monetary policy is not constrained by the zero bound.

The reminder of the paper is organized as follows. In the next Section, we present the two country open economy model. In Section 3, we discuss how we calibrate and compute the solution of the model under the zero lower bound for nominal interest rates. The results for the benchmark parameterization of the model are reported in Section 4. In Section 5, we assess the sensitivity of the results for alternative parameterizations of the model. Finally, we provide some conclusions in Section 6.

2. The Model

Our model consists of two country blocks that differ in size, but are otherwise isomorphic. The first country block is called the "periphery", and the second country block the "core." The country blocks 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 periphery block. 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 periphery is calibrated to be an arbitrarily small fraction of the population of the currency union.

2.1. Firms and Price Setting

Production of Domestic Intermediate Goods. There is a continuum of differentiated intermediate goods (indexed by $i \in [0,1]$) in the periphery 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}:

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

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

$$X_t(i) = \left[\frac{P^*_{Mt}(i)}{P^*_{Mt}}\right]^{\frac{-(1+\theta_p)}{\theta_p}} M^*_t, \tag{2}$$

where $X_t(i)$ denotes the quantity demanded of domestic good i in the core block, $P^*_{Mt}(i)$ denotes the price that firm i sets in the core market, P^*_{Mt} is the import price index in the core, and M^*_t is an aggregate of the core's imports (we use an asterisk to denote the core 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:

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

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 by 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

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

The operator 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.[2] The first-order condition for setting the contract price of good i in the home market is

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

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}:

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

The aggregator chooses the bundle of goods that minimizes the cost of producing Y_{Dt}, taking the price $P_{Dt}\left(i\right)$ of each intermediate good $Y_{Dt}(i)$ as given. The aggregator sells units of

[2] 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.

each sectoral output index at its unit cost P_{Dt}:

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

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:

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

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

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

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:

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

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:

$$\varphi_{Ct} = \left[1 - \frac{\varphi_{M_C}}{2}\left(\frac{\frac{M_{Ct}}{C_{Dt}}}{\frac{M_{Ct-1}}{C_{Dt-1}}} - 1\right)^2\right]. \tag{11}$$

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:

$$\min_{C_{Dt+k}, M_{Ct+k}} \mathbb{E}_t \sum_{k=0}^{\infty} \psi_{t,t+k} \Bigg\{ (P_{Dt+k} C_{Dt+k} + P_{Mt+k} M_{Ct+k}) \tag{12}$$

$$+ P_{Ct+k}\left[C_{A,t+k} - \left(\omega_C^{\frac{\rho_C}{1+\rho_C}} C_{Dt+k}^{\frac{1}{1+\rho_C}} + (1-\omega_C)^{\frac{\rho_C}{1+\rho_C}} (\varphi_{Ct+k} M_{Ct+k})^{\frac{1}{1+\rho_C}}\right)^{1+\rho_C}\right]\Bigg\}.$$

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.[3]

2.2. 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-

[3] Notice that the final investment good is not used by the government.

producing sector (the only producers demanding labor services in our framework). 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:

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

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 periphery. The aggregator minimizes the cost of producing a given amount of the aggregate labor index, taking each household's wage rate $W_t \left(h \right)$ as given, and then sells units of the labor index to the production sector at their unit cost W_t:

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

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

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

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

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left\{ \frac{1}{1-\sigma} \left(C^O_{t+j}(h) - C^O_{t+j-1} - \nu_{ct} \right)^{1-\sigma} + \frac{\chi_0 Z^{1-\sigma}_{t+j}}{1-\chi} (1 - N_{t+j}(h))^{1-\chi} + \frac{\mu_0}{1-\mu} \left(\frac{MB_{t+j+1}(h)}{P_{Ct+j}} \right)^{1-\mu} \right\}, \tag{16}$$

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^O_{t-1}. 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, ν_{ct}. The inclusion of money in the model - which is a zero nominal interest asset - provides a rationale for the zero lower bound on nominal interest rates in the model.

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:

$$\begin{gathered} P_{Ct} C^O_t(h) + P_{It} I_t(h) + MB_{t+1}(h) - MB_t(h) + \int_s \xi_{t,t+1} B_{Dt+1}(h) \\ -B_{Dt}(h) + P_{Bt} B_{Gt+1} - B_{Gt} + \frac{e_t P^*_{Bt} B_{Ft+1}(h)}{\phi_{bt}} - e_t B_{Ft}(h) \\ = (1-\tau_{Nt}) W_t(h) N_t(h) + \Gamma_t(h) + TR_t(h) - T_t(h) + (1-\tau_{Kt}) R_{Kt} K_t(h) + \\ P_{It} \tau_{Kt} \delta K_t(h) - P_{Dt} \phi_{It}(h). \end{gathered} \tag{17}$$

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

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

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,[4] cross-border asset trade is restricted to a single non-state contingent bond issued by the government of the core economy.

The terms B_{Gt+1} and B_{Ft+1} represents each household member's net purchases of the government bonds issued by the periphery and core 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:

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

If the periphery economy is an overall net lender position internationally, then a household will earn a lower return on any holdings of foreign (i.e., core) bonds. By contrast, if the periphery economy has a net debtor position, a household will pay a higher return on its foreign liabilities.

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 to firms 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 write-off of $P_{It}\tau_{Kt}\delta$ per unit of capital. Each member

[4] These contingent claims are in zero net supply from the standpoint of the periphery as a whole; hence, we omit them from the budget constraint for expositional simplicity.

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:

$$\phi_{It}(h) = \frac{1}{2}\phi_I \frac{\left(I_t(h) - I_{t-1}(h)\right)^2}{I_{t-1}(h)}. \tag{20}$$

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

$$W_t(h) = \omega_{t-1}^{\iota_w} \omega^{1-\iota_w} W_{t-1}(h), \tag{21}$$

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 which is here 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

(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:

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

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.

2.3. 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:

$$i_t = \max\left\{-i, (1-\gamma_i)\left(\tilde{\pi}_t + \gamma_\pi(\tilde{\pi}_t - \pi) + \gamma_x \tilde{x}_t\right) + \gamma_i i_{t-1}\right\} \tag{23}$$

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 $-i$. $\tilde{\pi}_t$ 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 member states.

2.4. Fiscal Policy

Government purchases have no direct effect on the utility of households, nor do they affect the production function of the private sector. To capture the possibility of implementation lags in spending, we assume that government spending follows an AR(2) as in Uhlig (2009):

$$g_t - g_{t-1} = \rho_{g_1}(g_{t-1} - g_{t-2}) - \rho_{g_2} g_{t-1} + \varepsilon_{g,t}, \tag{24}$$

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

$$\begin{aligned} P_{Bt}B_{Gt+1} - B_{Gt} = P_{Ct}G_t + TR_t - T_t - \tau_{Nt}W_tL_t - (\tau_{Kt}R_{Kt} - \delta P_{It})K_t \\ -(MB_{t+1} - MB_t). \end{aligned} \tag{25}$$

Equation (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, $tr_t = \frac{TR_t}{P_tY}$, 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, $b_{Gt+1} - b_{Gt}$:

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

where $b_{Gt+1} = \frac{B_{Gt+1}}{P_tY}$ and b_G is the government's target value for the ratio of government debt to nominal (trend) output.

2.5. Resource Constraint and Net Foreign Assets

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

$$Y_{Dt} = C_{Dt} + I_{Dt} + \phi_{It}, \tag{27}$$

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

$$C_{At} = C_t + G_t, \tag{28}$$

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

$$C_t = C_t^O + C_t^{HM} \tag{29}$$

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

$$M_t^* = M_{Ct}^* + M_{It}^*. \tag{30}$$

Finally, at the level of the individual firm:

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

The evolution of net foreign assets can be expressed as:

$$\frac{P_{B,t}^* B_{F,t+1}}{\phi_{bt}} = B_{F,t} + P_{Mt}^* M_t^* - P_{Mt} M_t. \tag{32}$$

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 core block is isomorphic to that of the home country.

3. 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 (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 the 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 (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 $\overline{r}$ 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 2, 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 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 $\varsigma = 0.5$ so that 50 percent of households are Ricardian FL agents.

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 -1. This implies an elasticity of substitution between capital and labor 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).

We maintain the assumption of a relatively flat Phillips curve by setting the price contract duration parameter $\xi_p = 0.9$. We allow for some intrinsic persistence by setting the price indexation parameter $\iota_p = 0.65$. It bears emphasizing that our choice of ξ_p does not necessarily imply an average price contract duration of 10 quarters. Altig et al. (2010) show that even a model with a low slope of the Phillips curve can be consistent with frequent price reoptimization. Our choice of ξ_p implies a Phillips curve slope of about 0.007. This is somewhat lower than the median estimates of literature, which cluster in the range of about 0.009-.014, but well within 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, Lindé (2005), and Smets and Wouters (2003, 2007). As argued in Erceg and Lindé (2010), a low slope of the Phillips curve is consistent with the development during the recent crisis where inflation and inflation expectations have fallen been moderately despite large contractions in output.

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 about as responsive to the wage markup as price inflation is to the price markup.

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 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. The government's intertemporal budget constraint implies that labor income tax rate τ_N equals 0.27 in steady state. The capital tax τ_K is set to 0.

Using Eurostat data for 2008, the average share of imports of the periphery countries (of Greece, Ireland, Portugal, Italy, and Spain) 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 our large periphery calibration under the additional assumption that the import intensity of consumption is equal to 3/4 that of investment. These periphery countries comprise about 1/3 of euro area GDP, or are half as large as the core countries, so that $\zeta = 0.5$. Given that trade is balanced in steady state, this parameterization implies an export and import share of the core countries of 7 percent of GDP.

Our small periphery calibration is based on data for the Greek economy. The import share of the Greek economy from the rest of the euro area is also around 14 percent, so that the trade parameters ω_C and ω_I remain unchanged across these calibrations; however, since Greece only comprises about 2 percent of euro area GDP, its trade share of the core block is only 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 $\gamma_i = 0.$. Relative to the standard Taylor rule, this rule is more aggressive in responding to inflation, and incorporates considerable interest rate inertia; features which we believe are relevant for ECB monetary policy. For the tax rate reaction function, we choose $\nu_0 = 0.9$, $\nu_1 = 0.02$, $\nu_2 = 0.05$, and $b_G = 0.75$. The benchmark tax rule is not very aggressive, and has similar implications to adjustment via lump-sum taxes.

4. Results

Given the nonlinear zero bound constraint, the effects of shocks depend on the perceived depth and duration of the underlying liquidity trap. Accordingly, we begin by using our model to generate initial macroeconomic conditions that roughly capture some features of the recent recession in the euro area, including a large decline in output relative to trend, and extended period of near-zero policy rates.

The solid lines in Figure 1 depict a "Euro area recession scenario " under the benchmark calibration of our model when the zero lower bound is imposed on the policy rule. The underlying shocks are identical negative consumption taste shocks (ν_{Ct}. and ν^*_{Ct}.) to each country block. The taste shocks are assumed to follow an AR(1) with persistence of 0.9. For comparison purposes, we also include results in Figure 1 when policy is not constrained by the zero lower bound.

The shocks induce a sharp contraction in aggregate GDP of about 6 percent below steady state at its peak, and the presence of the zero lower bound constraint contributes with almost 2 percent to this contraction. Policy rates fall quickly to their lower bound of zero, and remain at zero for eight quarters (in this figure, nominal variables are shown in levels to highlight the zero bound constraint on interest rates). Thus, given perfect foresight, agents expect the liquidity trap would last eight quarters in the absence of additional shocks. Inflation falls from its steady state level of 2 percent to a trough of -1 percent, and remains below zero for a sustained period .

4.1. Fiscal Consolidation in the Periphery

We begin by assessing the impact of a front-loaded contraction in government spending in the periphery under the small periphery calibration, which approximates the effects on a small open economy. The government spending shock follows an AR(1) with a persistence of 0.99 and is scaled to equal one percent of steady state GDP. The impulse response functions shown in Figure 2 are computed as the difference between this scenario which includes both the consumption taste shocks and government spending shock, and the previous scenario with only the taste shocks to each country (shown in Figure 1).

Under normal conditions in which monetary policy can react (labeled "currency union: normal"), the nearly permanent contraction in government spending has a substantial and highly persistent effect on periphery GDP. Periphery output falls about 1 percent initially, consistent with an impact multiplier of about unity, and remains below baseline for a very prolonged period. The protracted output decline reflects that the monetary policy essentially leaves nominal interest rates unchanged in response to the periphery's output decline given its tiny weight in aggregate GDP (the policy rate falls only 1 basis point). With inflation falling, real interest rates rise in the short-run in the periphery. Output gradually recovers as private consumption is boosted through a positive wealth effect, the real exchange rate gradually depreciates as prices fall, and the real interest rate declines (reflecting that prices overshoot, and eventually start rising again).

It is useful to contrast the protracted output decline under a currency union with the alternative in which the periphery economy had an independent monetary policy and flexible exchange rate, again assuming that monetary policy can react (labeled "flexible exchange rate: normal"). In this case, interest rates would drop immediately, and the real exchange rate would depreciate, substantially reducing the persistence of the contraction in periphery output. For example, periphery GDP is only 0.3 percent below baseline after 2 years, compared with 0.8 percent in the currency union case. The faster output rebound also allows the spending reduction to translate into a much more rapid decline in the government debt/GDP ratio.

The contraction in the small periphery economy under a currency union is invariant to whether monetary policy is constrained or unconstrained by the ZLB (as seen by comparing the two cases shown in Figure 2). As discussed below, this reflects that shocks to a small country have a tiny effect on the potential real interest rate in the currency union as a whole, and do not affect the duration of the liquidity trap in the union.

Figure 3 presents a parallel analysis for the case of the large periphery. Under "normal conditions" in which monetary policy is unconstrained, the output response under a currency union is much less persistent than for the small periphery calibration analyzed in Figure 2. This reflects that the monetary authority reduces interest rates considerably in the case of a concerted fiscal contraction. The speed of the recovery in GDP still isn't as rapid as would occur if the large periphery's exchange rate was flexible, reflecting that interest rates fall by somewhat less, and the real exchange rate depreciates gradually rather than immediately (comparing the "flexible exchange rate: normal" with the "currency union: normal" calibrations); nevertheless, the disparity is relatively modest. Thus, as familiar from a standard optimal currency area rationale, a small country such as Portugal would be better off if it cut spending at the same time as Italy and Spain. Moreover, GDP in the core block actually rises, as the stimulative effect of lower interest rates outweighs the contractionary impact of the fall in exports to the periphery; and the government debt/GDP ratio falls a bit.

We now turn to the case in which the currency union is constrained from reducing interest rates due to the zero lower bound on nominal interest rates ("currency union: ZLB" in Figure 3). In this case, periphery GDP shows a much more protracted contraction than under normal times, with output remaining more than 1 percent below baseline for six quarters. The prolonged output decline reflects that the sluggish reaction of policy rates causes real interest rate to rise for a period of over two years.

Core GDP contracts by 0.4 percent at trough, in striking contrast to the case in which monetary policy adjusts. The GDP decline in the core reflects that the fall in core real net exports to the periphery is reinforced by a rise in core real interest rates. The highly persistent decline in core GDP induces the core government debt/GDP ratio to rise by almost 1 percent of GDP after two years.

Figure 4 considers the effects of a government spending contraction of progressively larger magnitude in the large periphery, ranging from 1 percent of periphery GDP (as in Figure 3) to 3 percent. The response of both periphery and core GDP increases in a nonlinear fashion with the size of the spending cuts, implying an increasing marginal impact. Thus, cutting reducing periphery spending by 2 percent of GDP reduces periphery output by a little more than 2 percent, and core output by about 1 percent; by an additional spending cut of 1 percent of GDP has almost as large a depressing impact on both periphery and core output.

The increasing marginal impact parallels the analysis of a fiscal expansion in the closed economy analysis of Erceg and Linde (2010), except with the reverse sign. In the Erceg and Linde analysis, a fiscal expansion has a diminished marginal impact on output as the size of the expansion grows larger. Because fiscal stimulus shrinks the duration of the liquidity trap, monetary policy responds relatively more quickly to any incremental stimulus. In the simulations shown in Figure 4, the fiscal contraction in the periphery extends the duration of the currency union's liquidity trap by two quarters, compared with the eight quarter trap for a 1 percent of GDP consolidation. This greatly increases the multiplier, in part because the expected inflation response is quite sensitive to the duration of the trap (falling more as the trap lengthens).

Given that the 3 percent of GDP output decline in the periphery translates into a 1 percent decline in government spending as a fraction of currency union output, the implied multiplier for the union as a whole is about 2-3/4 percent (as seen from the aggregate currency union output response in Figure 4). Because the core comprises 2/3 of currency union output, the contraction in the core actually accounts for almost half of the aggregate output decline in the currency union.

The more adverse impact on output means that it is difficult for a fiscal consolidation to achieve progress in reducing the government debt. Figure 4 shows that periphery government debt actually rises by more at horizons of up to 3 years as spending is cut by larger amounts. Government debt in the core countries rises by almost 5 percent of GDP. Progress in reducing government debt only becomes apparent once monetary policy has latitude to reduce interest rates.

There is clearly a high value in a discretionary fiscal expansion in the core to help offset fiscal contraction in the periphery. Even so, it is possible that fiscal policy in the core may be aimed at keeping the core government debt stock from expanding through balanced budget rules that adjust spending or taxes very aggressively to keep debt near its target. In Figure 5, we proxy for such a rule by examining the impact of a spending cut in the core block that is similar in magnitude to that in the periphery. This policy turns out to be counterproductive by further reducing currency union output, and by extending the period over which government debt rises (due to the fiscal consolidation in periphery and core) to five years.

4.2. Financial Shock in the Periphery

We next consider the effects of a financial shock in the periphery. To do so, we incorporate a financial accelerator into both country blocks of our benchmark model following the basic approach of Bernanke, Gertler and Gilchrist (1999). Thus, entrepreneurs acquire capital to supply to homogeneous factor markets, but must pay an external finance premium on the funds they borrow from households due to an agency problem. We follow Christiano, Motto and Rostagno (2007) by assuming that the debt contract between the entrepreneurs and lenders (households) is written in nominal terms (rather than real terms as in Bernanke, Gertler and Gilchrist, 1999).

In our log-linearized framework, the corporate finance premium in each country depends on the degree of leverage of the non-financial corporate sector, plus an exogenous disturbance. Thus, for the periphery:

$$i_t^{corp} = i_t + \vartheta l_t + \varepsilon_t. \tag{33}$$

where $i_t^{corp} - i_t$ is the spread of the nominal corporate bond rate over the policy rate, l_t is the leverage ratio (the ratio of the value of the capital stock to the net worth of entrepreneurs), and ε_t is an exogenous financial spread shock. A similar relation holds for the core. The calibration of the parameters determining the financial accelerator follows Bernanke, Gertler and Gilchrist (1999), and is identical across country blocks.[5]

To examine the implications of the zero bound constraint, we construct initial conditions that produce macroeconomic effects similar to that depicted in Figure 1 for both the "small periphery" and "large periphery" calibration. In particular, the same adverse taste shock in

[5] The monitoring cost, μ, expressed as a proportion of entrepreneurs' total gross revenue, is 0.12. The default rate of entrepeneurs is 3 percent per year, and the variance of the idiosyncratic productivity to entrepreneurs is 0.28.

each country causes output to decline substantially, and generates a liquidity trap lasting 8 quarters.

Figure 6 shows the effects of a financial shock in the periphery that causes periphery financial spreads to rise by very persistently (i.e., with a root of 0.99) with 50 basis points under our "small periphery" calibration. The spread shock reduces periphery output by boosting the cost of capital. Under normal conditions in which monetary policy is unconstrained, output falls more sharply under a currency union (dash-dotted red lines) than it would if the periphery had an independent monetary policy (solid black lines). In the context of a currency union, it makes little difference whether the ZLB binds monetary policy given the small size of the periphery.

Figure 7 shows the effects of the same-sized financial shock in the periphery under our "large periphery" calibration. In a currency union unconstrained by the ZLB, the financial shock depresses periphery output less sharply than in the small open economy case: for example, periphery GDP only falls about 0.2 percent below baseline after four quarters, compared with almost 0.4 percent (comparing the red dash-dotted lines in Figures 7 and 6). Moreover, core output expands slightly.

Paralleling our previous analysis of the fiscal shock, the effects on the large periphery are dramatically different when monetary policy is constrained by the ZLB (dashed green lines). Periphery output contracts more persistently and by a greater degree, and the spillover effect to the core are sizeable. In particular, given that the core is twice the size of the periphery, half of the decline in currency union output is attributable to the fall in core output. The output declines result in a rise in government debt in core and periphery that is substantially larger than in normal times.

Figure 8 analyzes financial shocks to the large periphery of varying size, ranging from the 50 basis point increase (from Figure 7) to 150 basis points. The effects on output in both the periphery and core increase in a sharply nonlinear manner, again reflecting that large shocks extend the duration over which monetary policy is constrained to respond to the ZLB. The 150 basis point shock to the periphery points government debt in the periphery by 7 percentage points after two years, and by about half as much in the core.

Finally, figure 9 examines the case in which a 50 basis point rise in spreads in the large periphery is amplified by fiscal consolidation in the periphery. The fiscal consolidation in the periphery – equal to 1 percent of GDP – results in a much more sizeable output decline in both core and the periphery. Moreover, the fiscal consolidation boosts government debt in the periphery for roughly two years relative to the case without a fiscal response.

5. Sensitivity Analysis

In this section, we examine the robustness of the results for alternative parameterizations of the model. In particular, we examine the robustness w.r.t. the share of hand-to-mouth households, and the policy rule. We also examine robustness w.r.t. the profile of government spending cut and alternative fiscal instruments as the labor income tax rate.

[**Remains to be written.**]

6. Conclusions

[**Remains to be written.**]

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Figure 1: Baseline Scenario When Monetary Policy is Unconstrained and Subject to the Zero Lower Bound

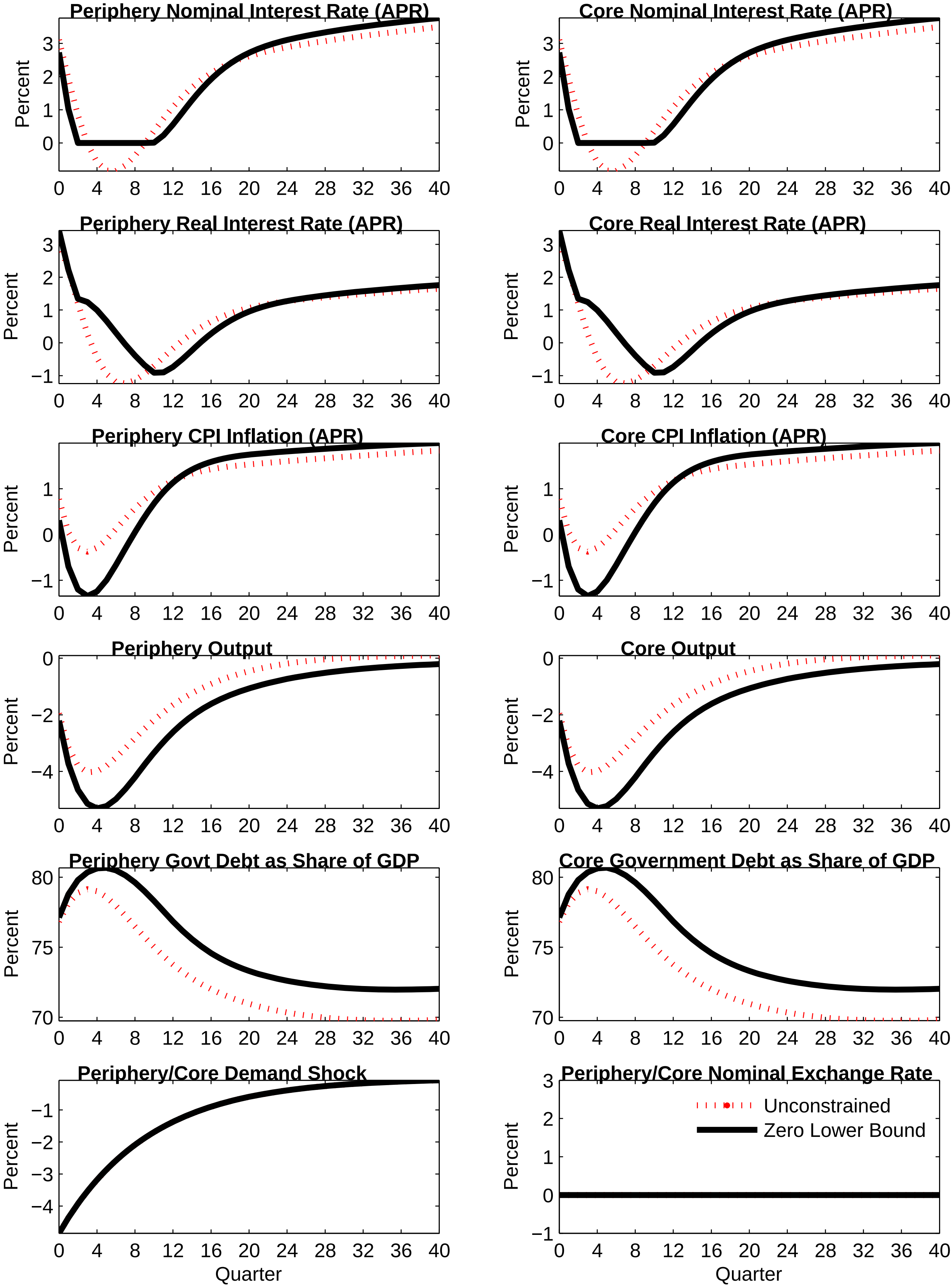

Figure 2: Responses to a Front−Loaded Decrease in Government Spending in Small Periphery under Flexible Exchange Rate and in a Currency Union

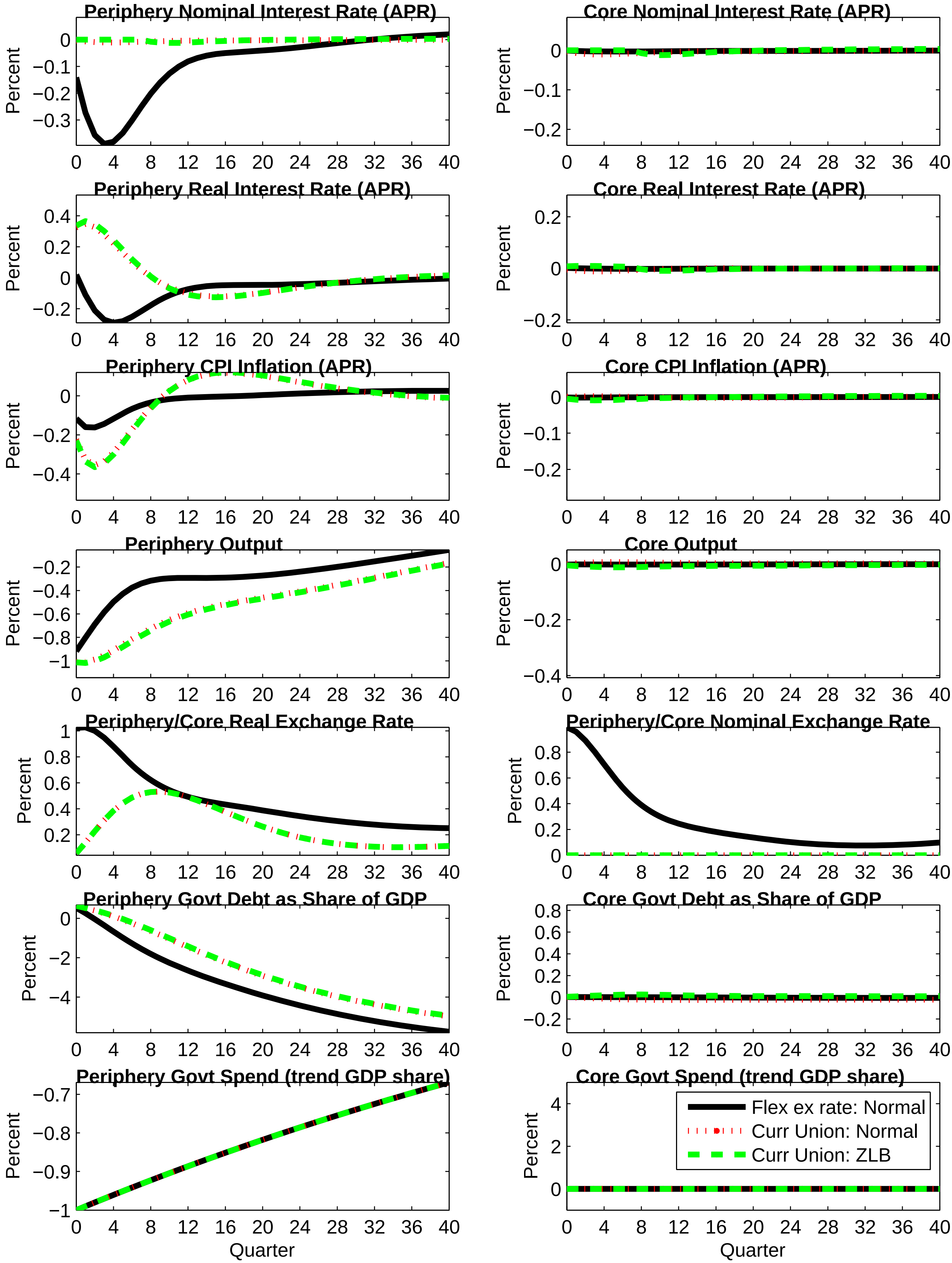

Figure 3: Responses to a Front−Loaded Decrease in Government Spending in Large Periphery under Flexible Exchange Rate and in a Currency Union

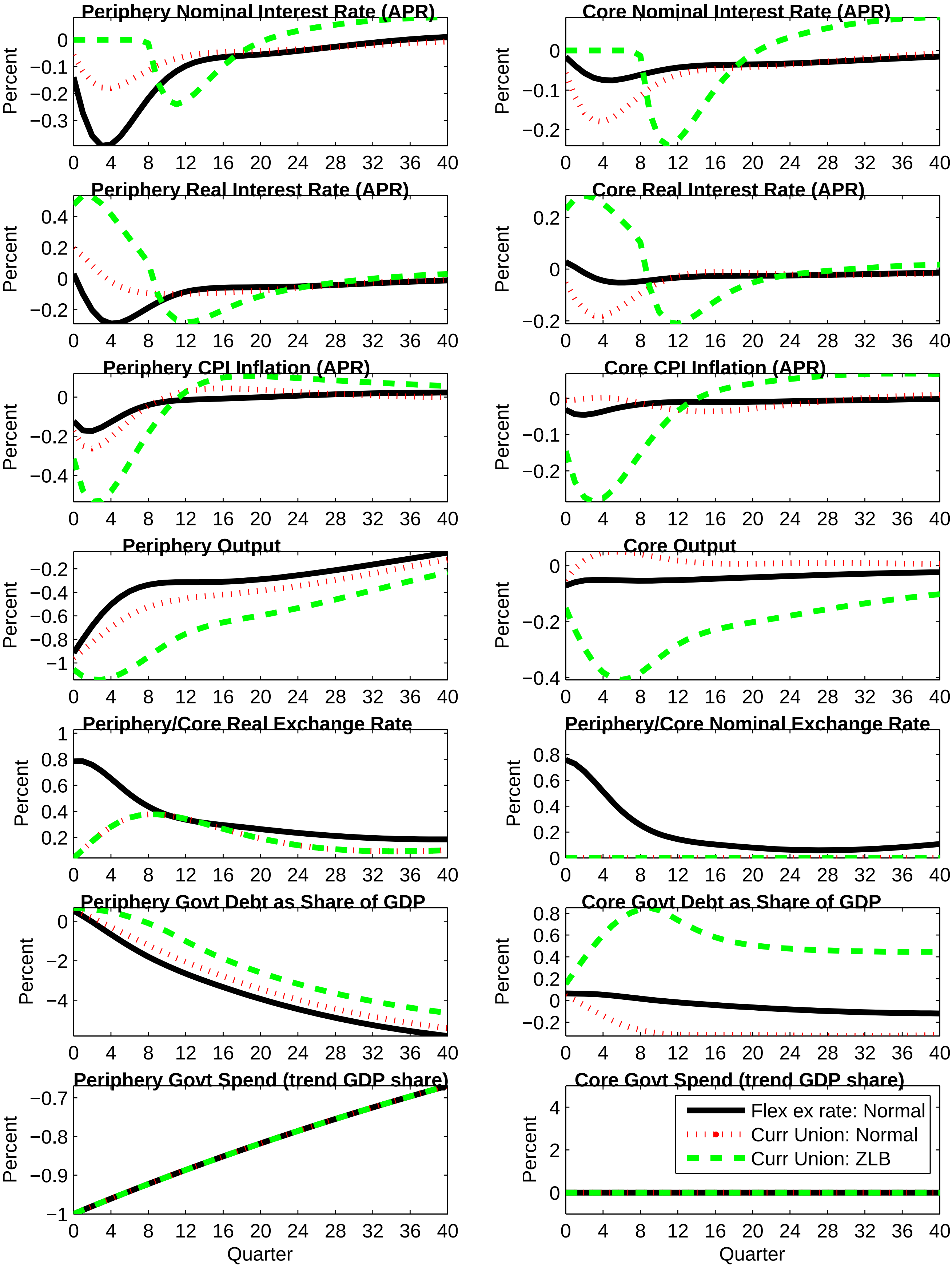

Figure 4: Responses to Government Spending Cuts of Different Magnitudes for Large Periphery Currency Union Member in a Liquidity Trap

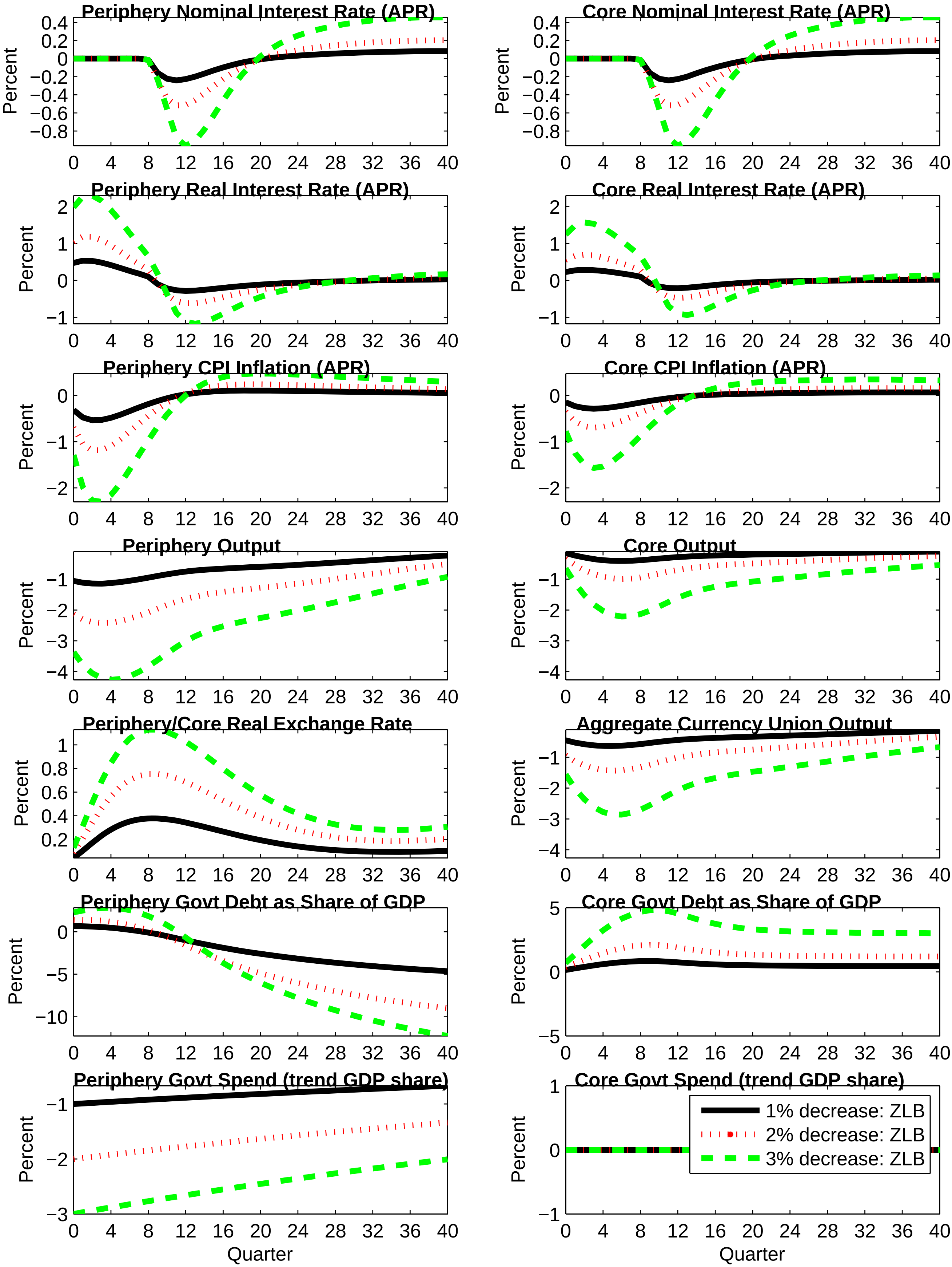

Figure 5: Responses to Government Spending Cut in Large Periphery Currency Union Member With and Without Core Spending Adjustment

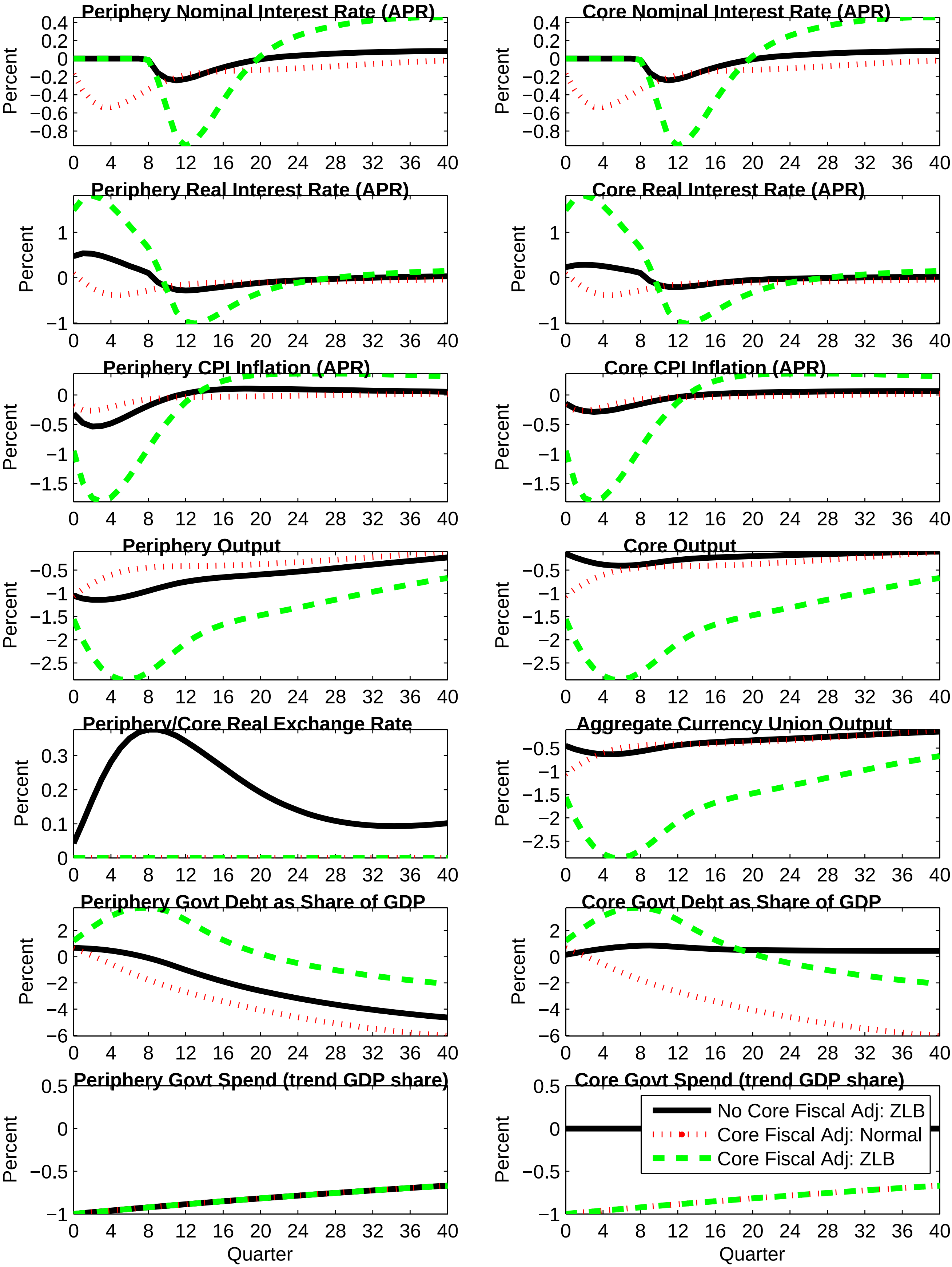

Figure 6: Responses to a Financial Spread Increase in Small Periphery under Flexible Exchange Rate and in a Currency Union

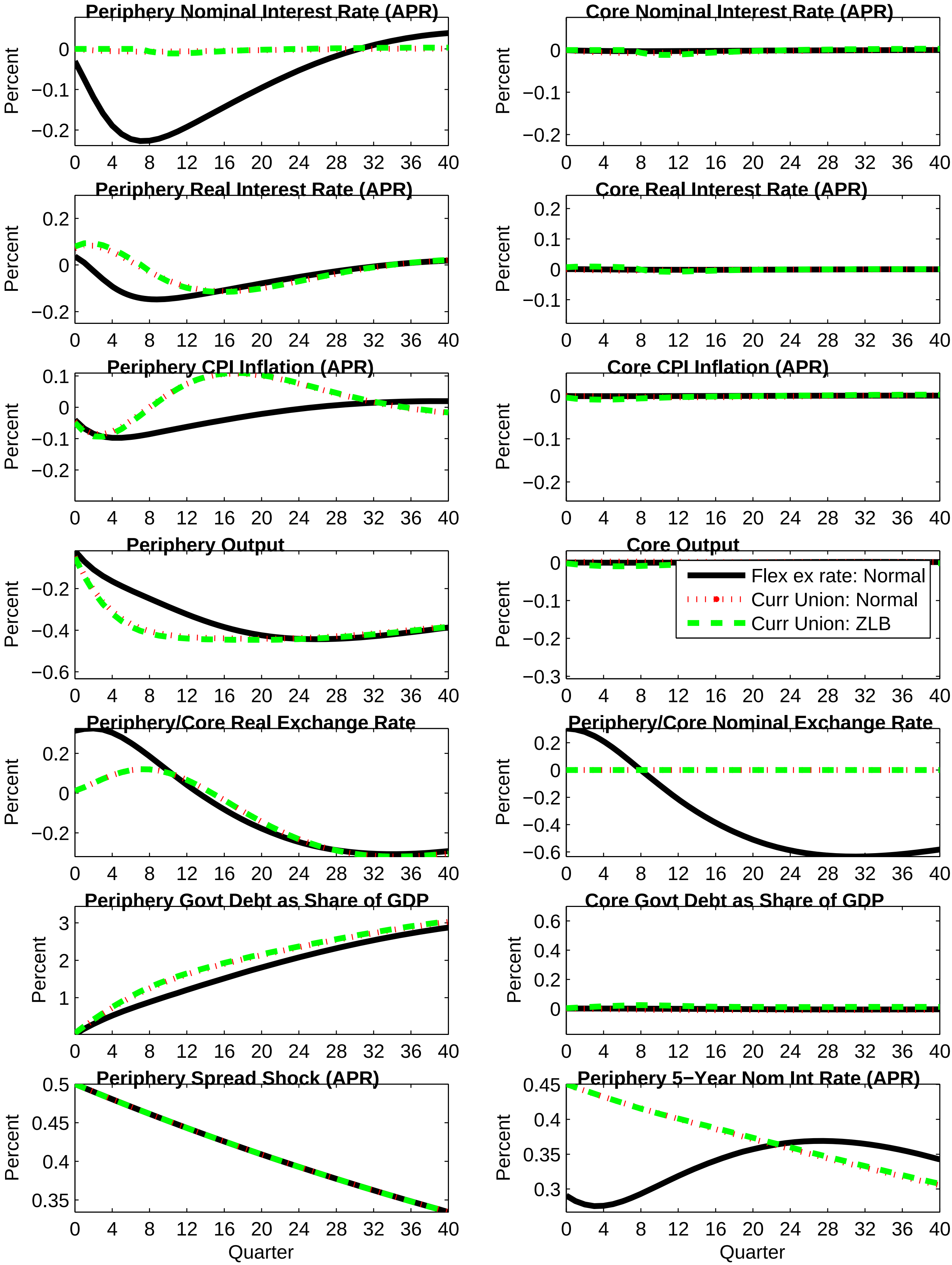

Figure 7: Responses to a Financial Spread Increase in Large Periphery under Flexible Exchange Rate and in a Currency Union

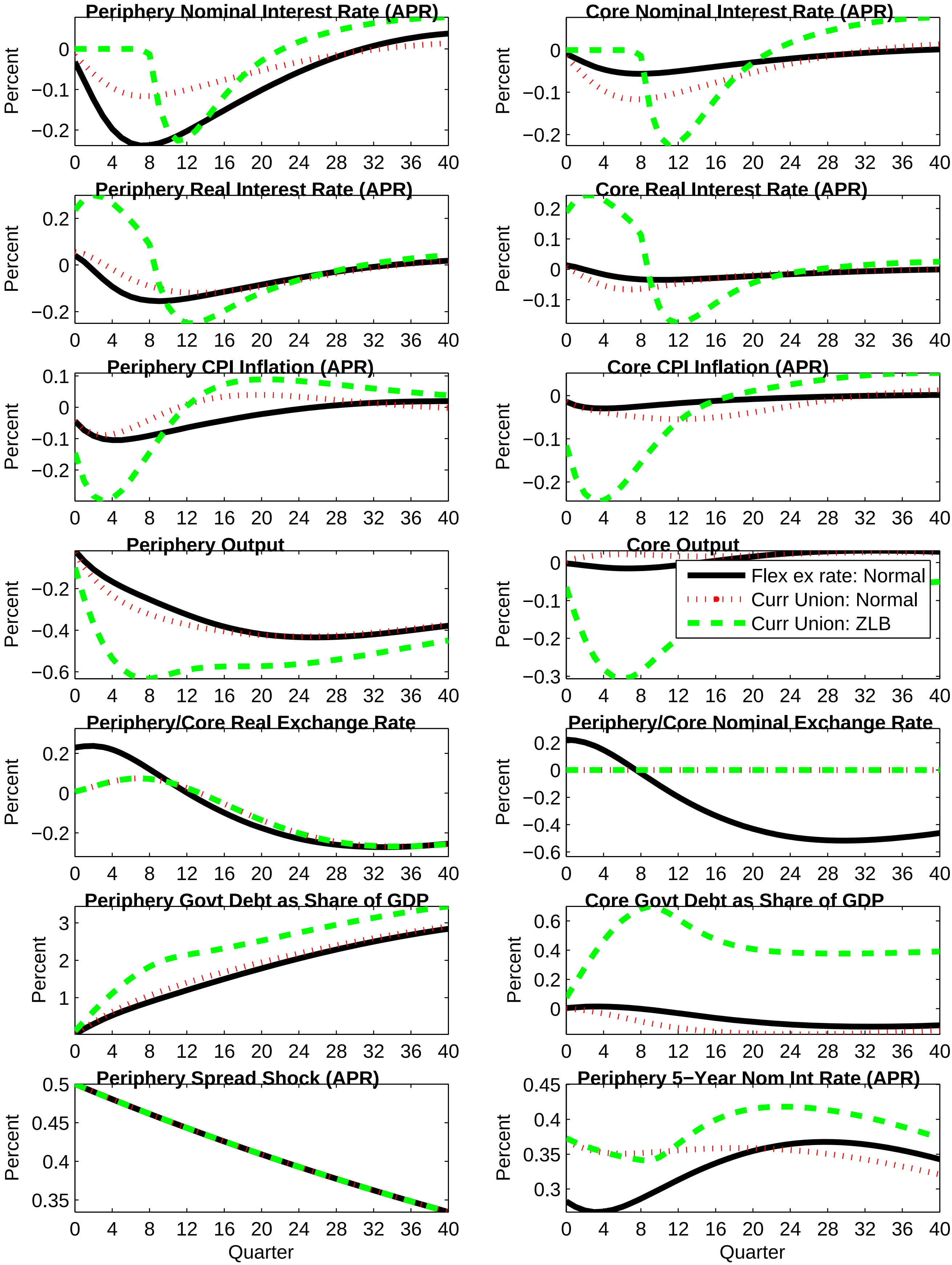

Figure 8: Responses to a Financial Spread Increases of Different Sizes in Large Periphery in a Currency Union in a Liquidity Trap

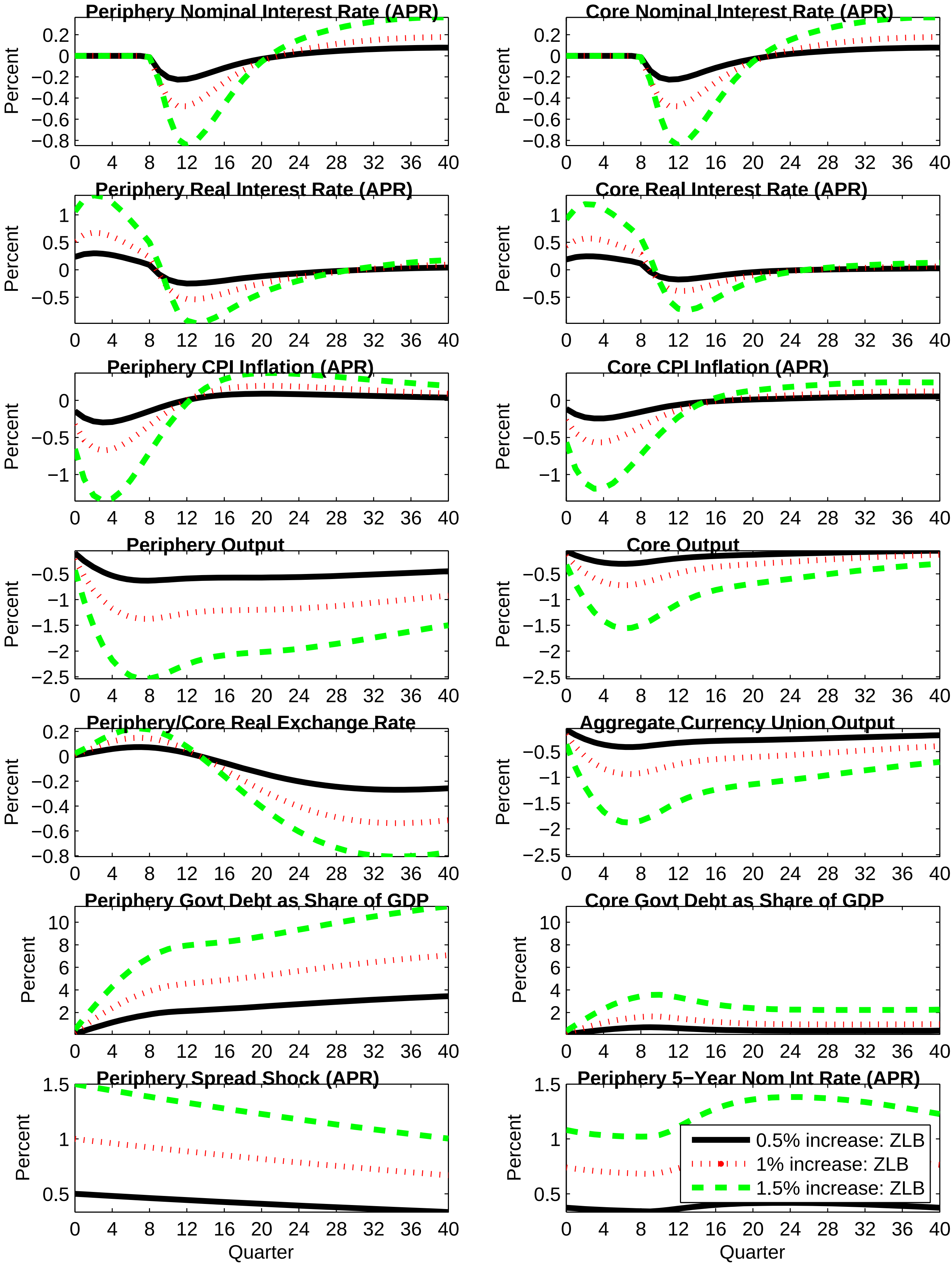

Figure 9: Responses to Increase in Financial Spreads in Large Periphery Currency Union Member With and Without Spending Adjustment