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# EXIT EXPECTATIONS AND DEBT CRISES IN CURRENCY UNIONS<sup>†</sup>

## Abstract

Membership in a currency union is not irreversible. Expectations of exit may emerge during a sovereign debt crisis, because by exiting countries can redenominate and reduce their liabilities. This possibility alters the dynamics of sovereign debt crises. We establish this formally within a small open economy model of changing policy regimes. The model permits explosive dynamics of debt and sovereign yields inside the currency union and allows us to distinguish between exit expectations and those of an outright default. By estimating the model on Greek data, we quantify the contribution of exit expectations to the crisis dynamics during 2009-2012.

JEL Classification: E41, E52 and E62

Keywords: currency union, euro crisis, exit, fiscal policy, redenomination premium, regime-switching model and sovereign debt crisis

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# 1 Introduction

Countries may join, but also exit currency unions. Market developments foreshadow such events. The euro area is a case in point. Figure 1 displays monthly yields on public debt in Italy, Spain, Ireland, and Greece relative to Germany. They fell strongly in the run up to the creation of the euro in 1999—in sync with expected inflation and depreciation—and stayed close to zero for about a decade. This episode illustrates not only that currency unions provide a nominal anchor to inflation-prone countries (Alesina and Barro, 2002); it also shows that credibility gains materialize prior to the adoption of the common currency. Yet the reverse holds as well: the mere expectation of an exit from a currency union may push up yields, as securities are expected to be redenominated into a new, weaker currency. In fact, “fears of a reversibility of the euro” are arguably an important driver of rising yield spreads after 2009 (ECB, 2013).<sup>1</sup>

Yet these spreads, observed during a sovereign debt crisis, are understood to also provide compensation for the possibility of outright sovereign default (e.g., Lane, 2012). It is perhaps no coincidence that default premia and redenomination premia emerge jointly. After all, public debt, even if issued in nominal terms, is effectively real for an individual member country of a currency union, as it lacks control of inflation. Without support from the union, a member state will have to repudiate its debt if it runs out of funds or faces a rollover crisis (Aguiar et al., 2013, 2014). By exiting the currency union and introducing a new currency, on the other hand, a country regains control of inflation: debt becomes nominal—provided it is issued under domestic law and can be redenominated by fiat. The real value of debt may then be reduced through inflation and depreciation.

How does this possibility impact the dynamics of a sovereign debt crisis while the country still operates within the currency union? In this paper, we explore this question by contrasting how expectations of exit and outright default play out in the context of a vicious circle of ever rising debt levels and sovereign yields. For this purpose we rely on a model of a small open economy which is a member of a currency union. Policy regimes may change, however, and market participants are fully aware of this possibility. Regime change includes, in a first scenario, exit from the currency union. In a second scenario, the regime change entails an outright default on public debt. While policy regimes change according to an exogenous probability, investors suffer losses in the event which are proportional to outstanding government debt, such that redenomination and default premia fluctuate endogenously over time.

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<sup>1</sup>Shambaugh (2012) reports evidence on exit expectations from online betting markets. In February 2012 Buiter and Rahbari (2012) coined the term “Grexit”, while the the German Ifo-think tank published a report on “Greece’s exit from European Monetary Union” in May 2012 (Born et al., 2012).

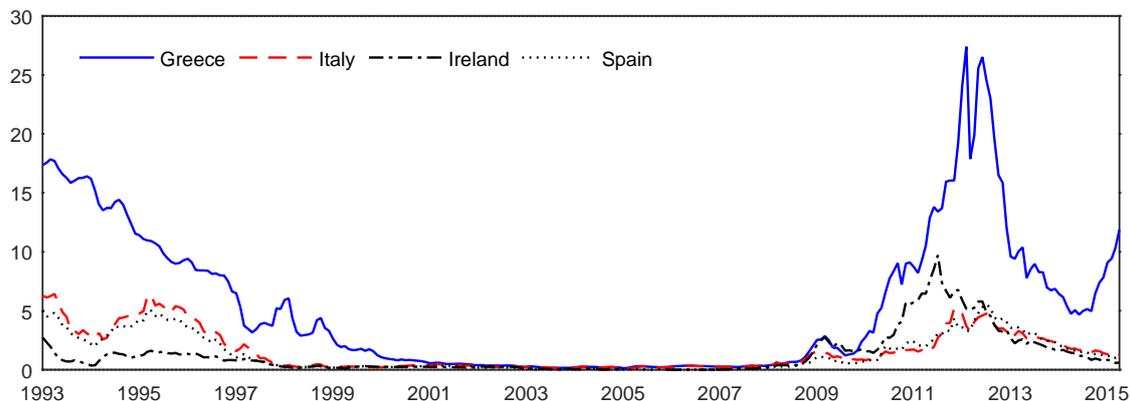


Figure 1: Interest rate spread vis-à-vis Germany for selected euro-area countries (percentage points). Data: monthly observations (1993M1–2015M4) for long-term interest rates for convergence purposes; source: ECB.

Redenomination premia arise if the country is expected to adopt an inflationary policy mix after exit. In order to capture this formally, we follow Leeper (1991) and rely on simple rules to specify policies: upon exit monetary policy is expected to be “passive”, thereby accommodating an “active” fiscal policy. As a result, the initial price level as well as the value of the new currency are expected to be determined upon exit by the need to align the real value of outstanding liabilities and future primary surpluses—an instance of the fiscal theory of the price level (Cochrane, 2001; Sims, 2013; Woodford, 1995).<sup>2</sup> Hence, all else equal, redenomination premia rise in the level of public debt.

Default premia, in turn, arise because the government defaults in some states of the world by repudiating a constant fraction of its liabilities. Of course, debt repudiation and devaluation often occur jointly (Reinhart, 2002). Na et al. (2014) rationalize this observation in a model where default and exchange rates are determined optimally. Central to their analysis is the assumption that governments are indebted in foreign currency, the “original sin” of many emerging market economies. As a result, inflation and devaluation are ineffective in reducing the real value of debt. In our analysis, instead, we assume that public debt is governed by domestic law, in line with actual practise in the euro area (Chamon et al., 2015).<sup>3</sup>

In the first part of our analysis we show that both redenomination and default premia reinforce the dynamics of a sovereign debt crisis while the country operates within the currency union. Such a crisis arises if public debt is high and fiscal policy—for given beliefs of a regime

<sup>2</sup>For the fiscal theory in an open-economy context, see Woodford (1996), Sims (1997) or Bergin (2000). Uribe (2006) studies sovereign default in a fiscal-theory environment.

<sup>3</sup>During the period 2003–2014 most (many) European countries issued more than 60-70 (90) percent of its debt under domestic law. Exceptions are the Baltic countries and Cyprus as well as Greece after the restructuring of its debt in 2012.

change—fails to generate sufficiently high budget surpluses. Beliefs about regime change and future policies matter, because they determine—for given levels of debt—the size of default and redenomination premia which, in turn, impact public finances adversely. As a result, a debt crisis may be triggered by an adverse shift in beliefs about exit as well as default, even though our model does not feature full-fledged self-fulfilling crises.<sup>4</sup>

Moreover we show that, while being reflected similarly in the dynamics of government debt and bond yields, expectations about exit and outright default have distinct implications for how the debt crisis impacts the economy at large. Precisely, if public debt is high, expectations about exit drive up interest rates, not only for the sovereign, but also for private borrowers. This has adverse effects on economic activity, if nominal rigidities persist beyond exit. Moreover, in this case, inflation takes off already before the actual exit takes place due to forward-looking price-setting decisions such that competitiveness declines. Overall, exit expectations may thus induce public debt to have stagflationary effects. By contrast, if exit can be ruled out, public debt is neutral in the baseline version of the model. Debt becomes recessionary, however, once we assume that sovereign default premia spill over into the private sector and impact borrowing conditions adversely (Bocola, 2015; Corsetti et al., 2013a). Yet, even in this case, default and exit expectations impact macroeconomic dynamics differently. This allows us to identify exit and default premia in actual time-series data.

We do so in the second part of our analysis, as we estimate the model on Greek data for the crisis period 2009–2012. The sizeable upward revision of the 2009-fiscal deficit in October 2009 seems to have triggered the Greek debt crisis. In due course, with rising bond yields and a spiralling public debt-to-GDP ratio, the macroeconomic outlook deteriorated further. Eventually, debt was restructured in early 2012. When we interpret the time series through the lens of the model, we find that redenomination premia account for a significant fraction of sovereign yields and for the bulk of the rise in yields in the private sector. By amplifying the crisis dynamics, exit expectations had a sizeable adverse impact on the Greek economy during our sample period.

Our paper also relates to other work which is inspired by the recent euro-area crisis, but with a focus on outright sovereign default (Bi, 2012; Daniel and Shiamptanis, 2012; Lorenzoni and Werning, 2013). Related empirical studies, instead, also focus on exit and redenomination premia. De Santis (2015) seeks to identify redenomination risk on the basis of CDS spreads,

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<sup>4</sup>This is because we assume that default and exit are determined by exogenous probabilities. Calvo (1988) and Cole and Kehoe (2000) are classic references for self-fulfilling debt crises. Aguiar et al. (2013, 2014) model self-fulfilling debt crises while highlighting the role of the monetary/exchange rate regime. Obstfeld (1996) analyzes self-fulfilling currency crises. Yet our analysis reiterates a theme which features prominently in classic studies of the stability of exchange rate regimes, namely that expected regime change tends to destabilize an existing regime (Flood and Garber, 1984; Krugman, 1979).

thereby de facto conditioning his findings on default taking place simultaneously with exit. Krishnamurthy et al. (2014), in turn, decompose yield spreads into redenomination and default premia while accounting for market segmentation as well. According to their measure redenomination premia account for a very small fraction of yield spreads in those countries where sufficient data are available, namely, Italy, Spain, and Portugal. Moreover, they find that ECB policies affected yields mostly through reduced default premia and/or market segmentation effects. Finally, we also draw on earlier work by Davig and Leeper (2007b, 2011) and Bianchi and Ilut (2012), who put forward models where monetary and fiscal policy rules change over time. Andolfatto and Gomme (2003) analyze a model with changes in money-growth rules and imperfect information. All these studies analyze closed-economy models. The remainder of the paper is organized as follows. Section 2 presents the baseline model. Section 3 develops our main findings regarding the role of exit expectations when a member of a currency union faces a sovereign debt crisis. We discuss details regarding the estimation of the model as well as our estimation results in Section 4. Section 5 concludes.

## 2 The model

We model an open economy which is sufficiently small so as to have a negligible impact on the rest of the world. There are a representative household and monopolistically competitive firms, possibly restricted in their ability to adjust prices.<sup>5</sup> Households supply labor to firms, purchase goods produced domestically and in the rest of the world, and trade assets with the rest of the world. The government sells long-term nominal debt to international investors and levies taxes on domestic households and firms. Government debt carries a default premium, as the government reneges on its debt obligations in some states of the world. The economy either forms a currency union with the rest of the world or operates an independent monetary policy.

We capture the behavior of monetary and fiscal policy through simple feedback rules. As a key feature of our analysis, we allow policy rules to change over time, in a way consistent with agents' expectations. Indeed, as stressed by Davig and Leeper (2007a), once it is recognized that policy regimes may differ across time, it seems desirable to endow agents with this very insight. In order to keep the analysis tractable, we assume exogenously given beliefs of regime change within a Markov-Switching Rational Expectations Model.<sup>6</sup>

In what follows we outline the structure of the baseline model which features complete in-

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<sup>5</sup>We consider a New Keynesian environment which has been studied extensively in a small-open economy context, for instance, in Kollmann (2001), Galí and Monacelli (2005) or Corsetti et al. (2013b).

<sup>6</sup>In a stylized two-period model of exchange-rate policies, Drazen and Masson (1994) make beliefs about regime change a function of both the credibility of policy makers and the state of the economy.

ternational financial markets, lump-sum taxation, and abstracts from spillovers of sovereign risk into the private sector. This allows us to illustrate how exit expectations impact macroeconomic dynamics in a transparent way and to contrast their effects to those of default expectations. We will relax these assumptions in our empirical analysis below.

## 2.1 Setup

A representative household has preferences over consumption,  $C_t$  and aggregate hours worked,  $H_t$ :

$$E_0 \sum_{t=0}^{\infty} \beta^t \left( \log C_t - \frac{H_t^{1+\varphi}}{1+\varphi} \right),$$

where  $\varphi^{-1}$  parameterizes the Frisch elasticity of labor supply and  $E_0$  is the mathematical expectation with respect to time-0 information. Consumption is a composite of goods produced at Home,  $C_{H,t}$ , and imports,  $C_{F,t}$ , defined as follows

$$C_t = \left[ (1-\omega)C_{H,t}^{1-\sigma} + \omega C_{F,t}^{1-\sigma} \right]^{\frac{1}{1-\sigma}}.$$

Here,  $\sigma$  denotes the elasticity of intratemporal substitution and  $\omega$  measures the degree of home bias in consumption. Domestically produced goods and imports, in turn, are both CES aggregates defined over different varieties, each produced by a firm  $j \in [0, 1]$

$$C_{H,t} = \left[ \int_0^1 C_{H,t}(j)^{\frac{\gamma-1}{\gamma}} dj \right]^{\frac{\gamma}{\gamma-1}}, \quad C_{F,t} = \left[ \int_0^1 C_{F,t}(j)^{\frac{\gamma-1}{\gamma}} dj \right]^{\frac{\gamma}{\gamma-1}}.$$

The parameter  $\gamma > 1$  measures the degree of substitutability between different varieties. Expenditure minimization implies the following price indices for goods produced at home and imported from abroad

$$P_{H,t} = \left[ \int_0^1 P_{H,t}(j)^{1-\gamma} dj \right]^{\frac{1}{1-\gamma}}, \quad P_{F,t} = \left[ \int_0^1 P_{F,t}(j)^{1-\gamma} dj \right]^{\frac{1}{1-\gamma}},$$

and the consumer price index is

$$P_t = \left[ (1-\omega)P_{H,t}^{1-\sigma} + \omega P_{F,t}^{1-\sigma} \right]^{\frac{1}{1-\sigma}}.$$

Household maximization is subject to a sequence of budget constraints of the type

$$E_t \{ \rho_{t,t+1} \Xi_{t+1} \} + P_t C_t = W_t H_t + \mathcal{Y}_t - T_t + \Xi_t.$$

In this expression,  $W_t$  denotes the nominal wage and  $\mathcal{Y}_t$  are aggregate firm profits.  $T_t$  are taxes collected by the government in a lump-sum manner, while  $\Xi_{t+1}$  is a portfolio of state-contingent assets traded on international financial markets. In turn,  $\rho_{t,t+1}$  is the one-period nominal stochastic discount factor, which—given log-utility in consumption—is given by

$$\rho_{t,t+1} = \beta \frac{C_t}{C_{t+1}} \frac{P_t}{P_{t+1}}.$$

For future reference we define the nominally riskless interest rate as the yield on an asset which pays one unit of *domestic currency* in all states of the world:  $R_t \equiv 1/\{E_t \rho_{t,t+1}\}$ . Note that what domestic currency is may change, as a country exits the currency union.

Households in the rest of the world face a symmetric problem such that in equilibrium, complete risk sharing ties relative consumption tightly to the real exchange rate (see, for instance, Chari et al., 2002). Formally, using an asterisk to denote variables in the rest of the world and  $Q_t$  to denote the real exchange rate, we have

$$\frac{C_t}{C^*} = Q_t.$$

Here we assume symmetric initial conditions across the two regions and define

$$Q_t \equiv \frac{\mathcal{E}_t P^*}{P_t},$$

that is, the real exchange rate corresponds to the price of the foreign consumption basket in terms of the domestic consumption basket.  $\mathcal{E}_t$  is the nominal exchange rate, the price of one unit of foreign currency in terms of domestic currency.

Firms operate in a monopolistically competitive environment and face price adjustment frictions à la Calvo. Prices are sticky in producer currency and the law of one price holds at the level of varieties. A generic firm  $j \in [0, 1]$  operates a linear technology of the form

$$Y_t(j) = H_t(j).$$

Whenever possible, it sets prices so as to maximize the present value of discounted profits

$$\max_{P_{H,t}(j)} E_t \sum_{k=0}^{\infty} \xi^k \rho_{t,t+k} Y_{t,t+k}(j) [P_{H,t}(j) - W_{t+k}]$$

subject to the demand function

$$Y_{t,t+k}(j) = \left( \frac{P_{H,t}(j)}{P_{H,t+k}} \right)^{-\gamma} Y_{t+k}.$$

Here,  $P_{H,t}(j)$  denotes the reset price of firm  $j$  at time  $t$  and  $\xi$  is the period-probability of not being able to reset a posted price.

$Y_t$  measures total output, which implies the aggregate relationship<sup>7</sup>

$$Y_t = \left( \frac{P_{H,t}}{P_t} \right)^{-\sigma} [(1 - \omega)C_t + \omega Q_t^\sigma C^*].$$

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<sup>7</sup>Here we use that the domestic country is small, which implies that  $P_F^* = P^*$ , that is, the consumption basket in the rest of the world is made up entirely of foreign-produced goods (see, e.g., De Paoli, 2009).

Aggregate output and labour are related via

$$H_t = \int_0^1 H_t(j) dj = \int_0^1 Y_t(j) dj = \int_0^1 \left( \frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\gamma} Y_t dj = \Delta_t Y_t,$$

where  $\Delta_t$  measures price dispersion. For future reference, we define net exports-to-GDP as

$$NX_t \equiv \frac{1}{Y_t} \left( Y_t - \frac{P_t}{P_{H,t}} C_t \right).$$

The government sells nominal long-term debt to international investors. Specifically, the long-term government bond portfolio is defined as perpetuities with coupons that decay exponentially, as in Woodford (2001). The government's flow budget constraint is given by

$$\Psi_t D_t = (1 + \iota \Psi_t) D_{t-1} (1 - \theta_t) - T_t.$$

Here parameter  $\iota \geq 0$  determines the maturity of debt, which is given by  $1/(1 - \iota)$  periods.  $\Psi_t$  denotes the price of government debt, which is given by

$$\Psi_t / \mathcal{E}_t = \frac{E_t(1 + \iota \Psi_{t+1})(1 - \theta_{t+1}) / \mathcal{E}_{t+1}}{R^*},$$

where  $R^*$  is the opportunity cost of funds for international investors, namely, the nominal yield on an asset which pays one unit of *foreign currency* in all states of the world. The nominal exchange rate appears because we assume that government debt is issued under domestic law. Whenever the domestic economy is (starting to operate or already) operating an independent monetary policy, assets issued under domestic law are denominated in domestic currency. When the domestic economy is part of a currency union, all assets are denominated in common currency. Also in this case, however, the law under which they are issued cannot be ignored, as payoffs are contingent on whether the domestic economy remains part of the currency union in the future.<sup>8</sup> Moreover, note that we assume that the government reneges on its debt obligations in some states of the world. In the event, it applies a haircut to its outstanding liabilities of size  $\theta_t \in [0, 1]$ .

The model is closed by regime-dependent rules for monetary and fiscal policy, which, given the other variables, pin down  $R_t$ ,  $\theta_t$  and  $T_t$  as specified below.

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<sup>8</sup>In the recent euro area crisis, market participants expected securities issued under Greek law to be converted into new currency upon exit (see, for example, Buiters and Rahbari 2012). As for Greek government debt, we note that more than 90% of Greek debt were issued under Greek law prior to the restructuring in 2012, which is the time span considered in the empirical part of the paper below (see, e.g., Buchheit et al. 2013; Chamon et al. 2015). Similarly, historical examples of “forcible conversions” of debt issued in foreign currency, but under home law highlights the role of jurisdiction for currency conversions (Reinhart and Rogoff 2011).

## 2.2 Equilibrium with changing policy regimes

We analyze how equilibrium outcomes depend on (expected) policy regimes within a Markov-Switching Linear Rational Expectations (MS-LRE) model. In a first step, we linearize the equilibrium conditions around a deterministic steady state, which we assume to be independent of policy regimes. There is no default and zero inflation in steady state and purchasing power parity holds. In a second step, we posit the different policy regimes, discuss the transitions among those and define the equilibrium.

In what follows, we refer to variables in terms of log-deviations from steady state using small-case letters. Furthermore, a small-case letter with a hat indicates deviations from steady state measured in percentage points of steady-state output. All derivations can be found in Appendix A.

A first set of equilibrium conditions is *invariant across policy regimes*. The dynamic IS equation and the open-economy New Keynesian Phillips curve are, in turn, given by

$$y_t = E_t y_{t+1} - \varpi(r_t - E_t \pi_{H,t+1}), \quad (2.1)$$

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \kappa(\varphi + \varpi^{-1})y_t. \quad (2.2)$$

Here, we define  $\varpi := 1 + \omega(2 - \omega)(\sigma - 1)$  and  $\kappa := (1 - \beta\xi)(1 - \xi)/\xi$ . Importantly, in deriving the Phillips curve (2.2) we assume that  $\xi$  is constant across regimes and across regime change, an assumption which we relax in Section 3.4 below.

Under complete international financial markets output is tied to the real exchange rate  $q_t$ , the price of foreign consumption in terms of domestic consumption:<sup>9</sup>

$$(1 - \omega)y_t = \varpi q_t, \quad (2.3)$$

$$q_t = (1 - \omega)(e_t - p_{H,t}). \quad (2.4)$$

The ratio of public debt to GDP evolves as

$$\beta \hat{d}_t = \hat{d}_{t-1} + \zeta \left( \beta \frac{1 - \iota}{1 - \beta\iota} i_t - \pi_{H,t} - \Delta y_t - \theta_t \right) - \hat{t}_t, \quad (2.5)$$

where  $i_t$  denotes the sovereign bond yield,  $\hat{t}_t$  denote taxes in units of GDP and  $\zeta$  parameterizes the public debt-to-GDP ratio in steady state.<sup>10</sup> The yield, in turn, is related to the nominal

<sup>9</sup>For future reference, notably Section 4 below, note that the CPI and the PPI are linked via  $p_t = p_{H,t} + \omega/(1 - \omega)q_t$ .

<sup>10</sup>The public debt-to-GDP ratio is given by  $\frac{\Psi}{\beta} \frac{D_t}{P_{H,t} Y_t}$ , whereas the taxes-to-GDP ratio is given by  $\frac{T_t}{P_{H,t} Y_t}$ . Up to first order, the sovereign bond yield is related to the price of public debt via  $i_t = -(1 - \iota\beta) \log(\Psi_t/\Psi)$ , where  $\Psi = \beta/(1 - \iota\beta)$  is the price of debt in steady state. More details are provided in Appendix A.

interest rate and expected default as follows

$$i_t = (1 - \iota\beta)(r_t + E_t\theta_{t+1}) + \iota\beta E_t i_{t+1}. \quad (2.6)$$

Policy rules form a second set of equilibrium relationships and *vary parametrically across policy regimes*. The evolution of regimes over time is captured by a Markov chain  $\{\varsigma_t\}$  specified below, and regime-dependent parameters are indexed by appropriate subscripts.

As in Lorenzoni and Werning (2013), we assume the government raises lump-sum taxes in order to service debt as follows

$$\hat{t}_t = \psi_{\varsigma_t} \hat{d}_{t-1} - \mu_t. \quad (2.7)$$

Here,  $\psi_{\varsigma_t} \geq 0$  measures the responsiveness of taxes to debt which varies across regimes and  $\mu_t$  denotes a “deficit shock”, a one time transfer of resources from the government to the representative household. The parameter  $\psi_{\varsigma_t}$  represents the fiscal capacity of the country and/or its willingness to raise taxes in response to a build up of public debt. Similarly, we posit a rule for default

$$\theta_t = \zeta^{-1} \theta_{\varsigma_t} \hat{d}_{t-1}, \quad (2.8)$$

such that default only applies in regimes where  $\theta_{\varsigma_t} > 0$ , which captures the haircut applied to government debt in excess of its steady-state level.

Monetary policy, in turn, is characterized by the following rule

$$\mathbb{1}_{\varsigma_t} e_t + (\mathbb{1}_{\varsigma_t} - 1)(r_t - \phi_\pi \pi_{H,t}) = 0. \quad (2.9)$$

Here  $\mathbb{1}_{\varsigma_t}$  is an indicator function which takes on the value of one in regimes where the country is part of a currency union, and of zero if monetary policy is independent. In the first case, there is no independent monetary policy, and the exchange rate is fixed exogenously at its steady-state value, assumed to be unity. In the second case, the central bank follows a Taylor-type rule which targets producer price inflation, with a feedback coefficient  $\phi_\pi \geq 0$ .

We consider four policy regimes, defined by specific combinations of the policy-rule parameters  $\mathbb{1}_{\varsigma_t}, \theta_{\varsigma_t}, \psi_{\varsigma_t}$ . Moreover, regimes may differ in terms of their expected duration. Specifically, we consider a regime “Union” which is characterized by membership in the currency union. However, membership is not perfectly credible, in contrast to “Union Permanent”, where further regime change is ruled out. In addition, we consider regime “Exit”, characterized by independent monetary policy. This regime is also an absorbing state, that is, we do not allow for further regime change. Finally, there is regime “Union Default”, a regime where the country operates in the monetary union and applies a haircut to government debt. Formally,

we have

$$\varsigma_t \in \{\text{Union, Union Default, Union Permanent, Exit}\}. \quad (2.10)$$

Transitions across policy regimes are determined by matrix  $P = [p_{ij}] = [\text{Prob}(\varsigma_t = j; \varsigma_{t-1} = i)]$ , on which we impose a specific structure:

$$P = \begin{pmatrix} 1 - \epsilon - \delta & \delta & 0 & \epsilon \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}.$$

We assume that the economy initially operates in *Union*, such that the Markov chain specifies the following sequence of regime transitions:

$$\begin{array}{l} \nearrow_{\delta} \quad \text{U Def } (\psi > 1 - \beta, \theta > 0, \mathbb{1} = 1) \rightarrow_1 \text{U Per } (\psi > 1 - \beta, \theta = 0, \mathbb{1} = 1)_{\odot 1} \\ \text{Union } (\theta = 0, \mathbb{1} = 1)_{\odot 1 - \epsilon - \delta} \\ \searrow_{\epsilon} \quad \text{Exit } (\theta = 0, \mathbb{1} = 0)_{\odot 1} \end{array} \quad (2.11)$$

We rule out default in all regimes except in *Union Default*, where  $\theta > 0$ . In *Union Default* and *Union Permanent*, fiscal policy adjusts taxes sufficiently in response to debt to ensure intertemporal solvency at given prices ( $\psi > 1 - \beta$ ), it is “passive” in the terminology of Leeper (1991). Given the transition matrix above this assumption ensures the existence of an equilibrium (see below the definition of stability).<sup>11</sup> In contrast,  $\psi$  is left unrestricted in *Union* and *Exit*.

Given this sequence of regime transitions, expectations about regime change will generally impact the allocation in the initial regime. The economy starts out in *Union* and stays there with probability  $1 - \epsilon - \delta$ . In turn,  $\delta$  is the probability of a one-time haircut occurring in the next period. Accordingly in the period after the haircut, the economy moves to *Union Permanent* with probability one. By contrast,  $\epsilon$  is the probability of exit from the currency union. Here we assume that, in the period of exit, domestic law securities are converted at par into new currency. At the same time, the nominal exchange rate adjusts to clear the foreign exchange market. Furthermore, once the economy has settled in either *Union Permanent* or

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<sup>11</sup>Strictly speaking,  $\psi > 1 - \beta$  is required only in *Union Permanent* for an equilibrium to exist, given that this regime is an absorbing state of the Markov chain. By contrast, *Union Default* is purely transitory such that the size of  $\psi$  in this regime does not impact equilibrium dynamics and stability. For simplicity, then, we restrict it to be the same as in *Union Permanent*.

*Exit*, these regimes will remain in place indefinitely.<sup>12</sup>

We are now in the position to define an equilibrium, following Farmer et al. (2011). First, we restate equations (2.1) - (2.9) more compactly

$$\Gamma_{\varsigma_t} x_t = E_t x_{t+1} + \Lambda_{\varsigma_t} \mu_t \quad (2.12)$$

where  $x_t = (y_t, r_t, i_t, \theta_t, \pi_{H,t}, p_{H,t}, e_t, q_t, \hat{d}_t, \hat{t}_t)'$  and  $\pi_{H,t} = p_{H,t} - p_{H,t-1}$ . The matrices  $\Gamma_{\varsigma_t}$  and  $\Lambda_{\varsigma_t}$  contain the model's deep parameters and  $\varsigma_t$  indicates that they are regime dependent. Regimes and transition probabilities are defined in (2.10) and (2.11).

**Definition 1.** A rational expectations equilibrium is a mean square stable (MSS) stochastic process that, given the Markov chain  $\{\varsigma_t\}$ , satisfies equation (2.12).

**Definition 2.** An  $n$ -dimensional process  $\{x_t\}$  is MSS if there exists an  $n$ -vector  $x_\infty$  and an  $n \times n$  matrix  $\Sigma_\infty$  such that in all regimes

- $\lim_{n \rightarrow \infty} E_t[x_{t+n}] = x_\infty$
- $\lim_{n \rightarrow \infty} E_t[x_{t+n} x_{t+n}'] = \Sigma_\infty$ .

Note that the concept of stability as defined above differs from stability as it is commonly applied in fixed-regime models. Intuitively, explosive trajectories in some regimes are not an issue, if the economy does not stay in these regimes for too long. What matters is that trajectories are not globally explosive, which is ruled out by MSS. The expected duration of regimes is thus key for stability.<sup>13</sup>

### 3 Results

We now investigate how exit expectations impact equilibrium dynamics in the initial regime. In this regime, the economy is part of a currency union but membership is imperfectly credible. Throughout we contrast the effect of exit expectations to those of default expectations. We show first that the redenomination premium drives up yields of all securities issued under domestic law. Second, the emergence and size of a redenomination premium depends on

<sup>12</sup>Assuming absorbing states allows us to keep the analysis tractable. At the same time we acknowledge that reentering a monetary union or another haircut in the future cannot be ruled out in practice. Yet we abstract from these possibilities as their effect on the equilibrium outcome in the initial regime is bound to be small.

<sup>13</sup>Note that MSS collapses to the conventional criterion of stability applied in fixed-regime models (see for instance Blanchard and Kahn 1980) in absorbing states of the Markov chain. Thus, we require bounded dynamics in *Union Permanent* and *Exit*, while locally explosive dynamics are (in principle) possible in all other regimes.

expectations regarding the conduct of monetary-fiscal policy after exit. Third, the economy may experience explosive dynamics in the initial regime, that is, a sovereign debt crisis, depending on the country's fiscal stance. Finally, we establish that expectations about exit may have stagflationary effects in the presence of public debt, whereas expectations of default are neutral for the allocation in the baseline model.

### 3.1 Default versus redenomination premia

We start from the basic observation that interest rates reflect expectations of future policies via a version of the uncovered interest parity (UIP) condition. Combine equations (2.1), (2.3) and (2.4) to obtain

$$r_t = E_t \Delta e_{t+1}. \quad (3.1)$$

This condition holds under all policy regimes, but the case of a currency union is of particular interest. In this case  $e_t = 0$ , while  $e_{t+1} \neq 0$  is possible only if the country exits the currency union. Recall that the nominal interest rate  $r_t$  corresponds to the yield of a one-period discount bond issued under domestic jurisdiction, which pays one unit of common currency if no exit occurs, and one unit of new currency if exit does occur. More precisely, we may think of  $r_t$  as the spread in the yield of such a bond relative to one issued under foreign jurisdiction. The latter pays one unit of common currency in all states of the world. It represents the *spread*, because variables are expressed in terms of deviation from steady state and we only consider shocks originating in the domestic economy, such that yields on foreign securities are constant.

Condition (3.1) holds in equilibrium and reflects the absence of arbitrage possibilities, as market participants are able to trade securities both under domestic and under foreign jurisdiction. Imagine that exit from the currency union cannot be ruled out and that, upon exit, the newly created domestic currency is expected to depreciate ( $E_t \Delta e_{t+1} > 0$ ). In this case, a domestic discount bond must promise high returns ex ante, as a foreign discount bond pays off strictly better (in terms of new domestic currency) in those states of the world where exit and depreciation occur.  $r_t$  therefore represents a “redenomination premium”.

Government debt is issued under domestic law and sovereign yields may thus carry a redenomination premium. In addition, government debt is subject to the risk of an outright sovereign default. By applying the law of iterated expectations, we may solve (2.6) forward to obtain

$$i_t = (1 - \iota\beta) E_t \sum_{j=0}^{\infty} (\iota\beta)^j (r_{t+j} + \theta_{t+1+j}). \quad (3.2)$$

Note that, over and above the redenomination premium, sovereign debt must pay a “default

premium” to the extent that a haircut is expected in some states of the world. The average maturity of debt matters for how strongly sovereign yields respond to expected haircuts and exit. Moreover, to the extent that debt is long term, expectations regarding exit or default in the far future are reflected in today’s yield spread. Importantly, both redenomination and default premia raise the refinancing cost of the government. As we now show, this may result in explosive debt dynamics while the country still operates within the currency union.

### 3.2 Explosive debt dynamics within a currency union

In this subsection, we consider a special case of the model which can be solved in closed form. We assume that prices are flexible ( $\xi \rightarrow 0$ ) and that there is short-term debt only ( $\iota \rightarrow 0$ ). Note, moreover, that we rely on our assumptions on the transition probabilities in order to obtain a closed-form solution: since the two target regimes are absorbing, we solve the model backwards using the method of undetermined coefficients.<sup>14</sup>

In all regimes, flexible prices imply constant output  $y_t = 0$  by equation (2.2). Given equation (2.1), this implies a constant real interest rate,  $r_t - E_t \pi_{H,t+1}$ , and a constant real exchange rate,  $q_t = 0$  (see equation (2.3)). The latter, in turn, requires  $p_{H,t} = e_t$  by (2.4), such that prices move one-for-one with the nominal exchange rate. Hence, in the flexible-price case under consideration, public debt and deficits do not affect private consumption and output in real terms, even if yields may carry redenomination and default premia.

To understand how expectations of an exit impact the equilibrium dynamics in *Union*, we first solve for the change in the exchange rate in *Exit* (and thus in particular, in the period where exit actually occurs). As it turns out, the degree of nominal depreciation upon exit crucially depends on how strongly the newly independent monetary policy raises nominal interest rates in response to inflation, as captured by parameter  $\phi_\pi$ . Note that, as we assume conversion at par, inflation *in the period of exit* is given by the initial price level in new currency, determined in general equilibrium, relative to the price level which prevailed in terms of old currency, the

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<sup>14</sup>All derivations can be found in Appendix B. The analytical solution presented in Section 3.2 is the unique mean square stable minimum state variable solution to the model, provided  $(1 - \epsilon - \delta) ((1 - \psi)\Theta^d)^2 < 1$ , where  $\Theta^d$  is defined below. If the latter condition is violated, no solution exists. The condition holds unless either  $\epsilon$  or  $\delta\theta$  are close to unity, and unless  $\delta$  and  $\epsilon$  are both close to zero while  $\psi < 1 - \beta$ . See Farmer et al. (2009) for further details on mean square stability. In general, a minimum state variable solution is mean square stable whenever the eigenvalues of  $(P' \otimes I_{n^2}) \text{diag}(F_{\varsigma_1} \otimes F_{\varsigma_1}, \dots, F_{\varsigma_h} \otimes F_{\varsigma_h})$  are all inside the unit circle, where  $h$  denotes the number of regimes,  $\otimes$  is the Kronecker product and the  $F$  are solution matrices in the respective regimes, i.e.  $x_t = F_{\varsigma_h} x_{t-1} + G_{\varsigma_h} \mu_t$ .

period before exit. Specifically, we obtain for nominal depreciation

$$\Delta e_t = \Theta^e \left[ (1 - \psi_{\text{Exit}}) \hat{d}_{t-1} + \mu_t \right], \quad (3.3)$$

$$\text{where } \Theta^e = \begin{cases} 0 & \text{if } \phi_\pi > 1 \\ \frac{1 - \psi_{\text{Exit}} - \beta\phi_\pi}{\zeta(1 - \beta\phi_\pi)(1 - \psi_{\text{Exit}})} > 0 & \text{if } 0 \leq \phi_\pi \leq 1. \end{cases}$$

In case monetary policy satisfies the Taylor principle ( $\phi_\pi > 1$ ), the exchange rate will remain unchanged upon exit.<sup>15</sup> By contrast, if monetary policy adjusts nominal rates only weakly in response to inflation ( $0 \leq \phi_\pi \leq 1$ ), the exchange rate depreciates, and more so the lower the central bank's feedback coefficient (note that  $\Theta^e$  attains a maximum at  $\phi_\pi = 0$ ). Intuitively, as  $\phi_\pi \leq 1$  monetary policy permits inflation to adjust in order to stabilize public debt in real terms, such that nominal depreciation is larger, the larger is the amount of outstanding debt and the larger is the current budget deficit. The fiscal theory of the price level applies, such that the initial price level as well as exchange rate adjust after exit in order to align the real value of debt with the expected sequence of real primary surpluses.<sup>16</sup> Note that the effect becomes more pronounced as fiscal policy adjusts its surplus less to the level of outstanding debt (as  $\psi_{\text{Exit}}$  declines). Furthermore, the solution for public debt in *Exit* is given by the following expression

$$\hat{d}_t = \frac{\phi_\pi}{1 - \psi_{\text{Exit}}} \left[ (1 - \psi_{\text{Exit}}) \hat{d}_{t-1} + \mu_t \right] \quad \text{if } 0 \leq \phi_\pi \leq 1, \quad (3.4)$$

such that (the real value of) public debt is wiped out completely within one period after exit if monetary policy does not respond to the resulting inflation and nominal depreciation ( $\phi_\pi = 0$ ). It follows that in this case, as debt returns to steady state within one period, the nominal exchange rate jumps immediately to its new permanent level, as can be seen from equation (3.3).<sup>17</sup>

Given equation (3.1), expectations of an exit coupled with nominal depreciation upon exit lead to a redenomination premium prior to exit. Hence, equation (3.3) makes clear that a premium arises only to the extent that market participants expect the central bank to be accommodative after exit. For the remainder of this section we therefore assume that agents entertain such a belief, such that premia arise in the initial regime.

<sup>15</sup>We note that this no longer holds for the sticky-price version of the model. In this case, because of real exchange rate dynamics, the exchange rate may depreciate upon exit in the absence of debt and deficits and independently of whether the Taylor principle is satisfied or not (see Section 4 below).

<sup>16</sup>For uniqueness and stability of equilibrium, it is required that fiscal policy insures intertemporal solvency ( $\psi_{\text{Exit}} > 1 - \beta$ ) in case  $\phi_\pi > 1$ , an instance of "active monetary, passive fiscal" policy. Instead it is required that  $\psi_{\text{Exit}} < 1 - \beta$  in case of  $\phi_\pi \leq 1$ , an instance of "active fiscal, passive monetary" policy (Leeper 1991). As we vary  $\phi_\pi$ , we assume  $\psi_{\text{Exit}}$  satisfies these assumptions throughout.

<sup>17</sup>This continues to be true in the sticky-price version of the model, see Figure 3 below.

The redenomination premium is reflected in sovereign bond yields, see equation (3.2). Higher debt service, all else equal, contributes to rising debt levels, see equation (2.5). As a result, there may be a vicious cycle: rising debt levels raise expectations of a depreciation upon exit and vice versa. To see this formally, we establish the solution for public debt in *Union*

$$\hat{d}_t = \Theta^d \left[ (1 - \psi_{\text{Union}}) \hat{d}_{t-1} + \mu_t \right], \quad (3.5)$$

where  $\Theta^d = \frac{1}{\beta} \left( 1 - \epsilon \left( \frac{1 - \psi_{\text{Exit}} - \beta \phi_\pi}{1 - \beta \phi_\pi} \right) - \delta \theta \right)^{-1} \geq \frac{1}{\beta}$ .

We note that  $\Theta^d(1 - \psi_{\text{Union}})$ , the autoregressive root on debt in equation (3.5), may be either above or below unity. In case regime change is ruled out ( $\epsilon = \delta = 0$ ), or if exit is ruled out and no haircut is expected ( $\epsilon = \theta = 0$ ),  $\Theta^d = \beta^{-1}$  and debt is mean reverting provided  $\psi_{\text{Union}} > 1 - \beta$ . In the reverse case of  $\psi_{\text{Union}} < 1 - \beta$ , debt is on an explosive trajectory even in the absence of expectations about regime change. As expectations about exit or default rise,  $\Theta^d$  increases up to the point where—for a given fiscal policy parameter  $\psi$ —public debt is on an explosive trajectory. To see this, note that  $\Theta^d$  increases in  $\epsilon$ , that is, as exit becomes more likely, and it increases in  $\delta \theta$ , that is, as the expected losses due to a haircut become larger. Moreover, for any given probability of exit, debt becomes more explosive as monetary and fiscal policy are expected to be more accommodative upon exit (as  $\phi_\pi$  or  $\psi_{\text{Exit}}$  decline). Conversely we may say that, for given expectations about exit or default, a sufficiently aggressive fiscal stance in *Union* may shield the economy from explosive dynamics. In related work, Lorenzoni and Werning (2013) consider default and slow moving debt crises and find that sufficiently responsive fiscal policy may shield the economy from explosive dynamics. Our result shows that this insight carries over to the case of exit expectations.

As public debt settles on a (locally) explosive path, its price collapses and yields take off

$$i_t = \left( \Theta^\theta + \Theta^r \right) \left[ (1 - \psi_{\text{Union}}) \hat{d}_{t-1} + \mu_t \right], \quad (3.6)$$

where  $\Theta^\theta = \delta \theta \frac{\Theta^d}{\zeta} > 0$  and  $\Theta^r = \epsilon \left( \frac{1 - \psi_{\text{Exit}} - \beta \phi_\pi}{1 - \beta \phi_\pi} \right) \frac{\Theta^d}{\zeta} > 0$ .

The above expression decomposes sovereign yields into a redenomination premium and a default premium, captured by the two parameters  $\Theta^r$  and  $\Theta^\theta$ .<sup>18</sup> As discussed above, the redenomination premium is sensitive to expected monetary (and fiscal) policy upon exit. In sum, as debt builds up, expected losses to be realized in some states of the world increase. Investors are compensated by lower bond prices, but this raises debt levels further. It follows that the size of the necessary adjustment—be it through outright default or through exit and nominal depreciation—increases in the duration of the initial regime.

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<sup>18</sup>One can further show that  $r_t = \Theta^r \left[ (1 - \psi_{\text{Union}}) \hat{d}_{t-1} + \mu_t \right]$  and  $E_t \theta_{t+1} = \Theta^\theta \left[ (1 - \psi_{\text{Union}}) \hat{d}_{t-1} + \mu_t \right]$ , thus the superscripts ‘*r*’ and ‘*θ*’.

### 3.3 Exit expectations matter

Exit expectations matter for how the debt dynamics feed back into the economy. To illustrate this and to contrast the effect of exit expectations to that of default expectations, we rely on model simulations using the algorithm developed in Farmer et al. (2009) and Farmer et al. (2011). We use the same parameter values as in our application of the model to Greece. Section 4 provides details. An exception are the parameters  $\epsilon$ ,  $\delta$ ,  $\theta$  and  $\iota$ , which we vary in what follows. Figure 2 displays impulse responses of selected variables to a purely transitory deficit shock. We show results for the two polar cases: a scenario with exit expectations but without outright default ( $\epsilon = 0.1, \delta = 0.1, \theta = 0$ ), represented by solid lines, and a scenario with default expectations but without exit ( $\epsilon = 0, \delta = 0.2, \theta = 0.5$ ), represented by dashed lines. In each case, thick lines show results for an average debt maturity of 7.1 years—corresponding to the actual value in Greece as of 2009Q3—while thin lines show results for a shorter average maturity (5 years).

The upper left panel displays the deficit shock. The shock is assumed to be purely transitory and equal to one percent of annual steady-state output. In response to the shock, public debt (upper right panel) and sovereign yield spreads (2<sup>nd</sup> row left panel) rise steadily, irrespectively of whether there are only exit expectations or expectations about default. Thus, exit and default premia induce explosive dynamics in this example. This is because—in the initial regime—neither taxes nor the price level adjust (sufficiently) to stabilize the real value of public debt. As such, we note that a transitory deficit shock induces long-lasting effects—the model generates substantial internal propagation.

The dynamic adjustment of the economy differs fundamentally, however, depending on whether there are exit expectations or default expectations. In case of default expectations (dashed lines) the deficit shock has no bearing on the economy other than on public finances. In particular, in the absence of exit expectations, private yield spreads  $r_t$  are zero (2<sup>nd</sup> row right panel). Thus, while the government’s refinancing costs rise with expected default, private-sector interest rates remain unaffected. Intuitively, while yields on government debt increase notionally in expected losses due to a sovereign default, the *effective* ex ante interest rate remains unchanged. This holds irrespectively of whether government debt is held domestically or by international investors. In fact, Ricardian equivalence obtains either way.<sup>19</sup> The maturity of debt matters insofar as it determines how strongly sovereign yield spreads react to the expected haircut. For shorter maturities (thin dashed lines), sovereign yield spreads increase more strongly, resulting in a faster accumulation of public debt.

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<sup>19</sup>Intuitively, if bonds are priced actuarially fair, the possibility of sovereign default does not alter the present value of expected future taxation, see, for instance, Uribe (2006). This result also holds for the non-linear model and independently of the size of the haircut parameter.

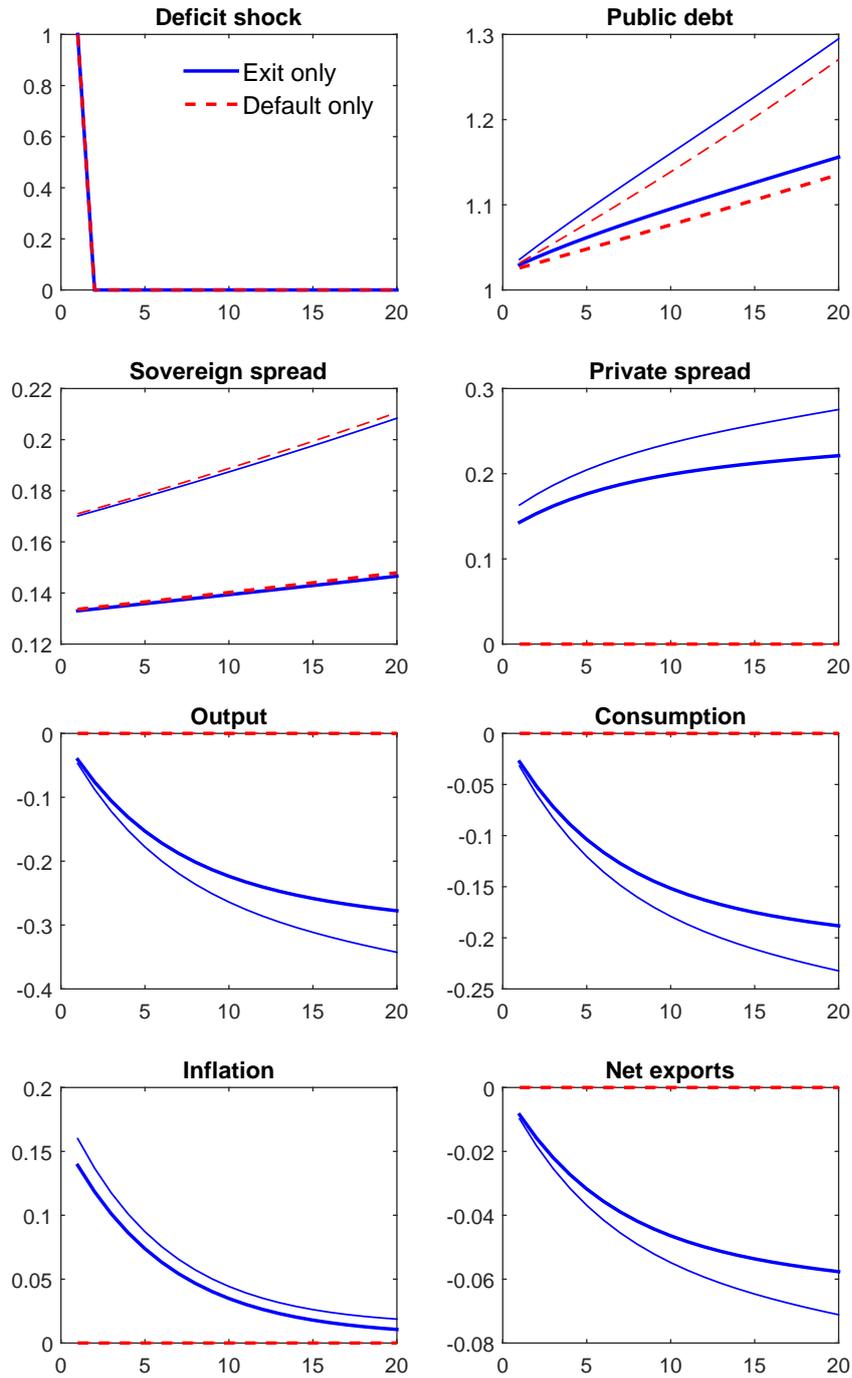


Figure 2: Impulse responses to a deficit shock in *Union*, conditional on staying in *Union*. Notes: Solid (dashed) lines represent exit-only (default-only) scenario, thick (thin) lines correspond to average debt maturity of 7.1 (5) years; horizontal axes measure time in quarters; vertical axes measure deviations from steady state in percent, and percentage points in case of debt to GDP, net exports to GDP and the deficit shock (annual steady-state GDP in all cases); (producer-price) inflation and interest rates are annualized.

By contrast, in the case of exit expectations (solid lines), deficits have allocative consequences. Private yield spreads rise along with sovereign spreads. Again, the maturity of public debt matters for how quickly public debt and yield spreads increase. Thus, as highlighted in Sims (2013) and Leeper and Zhou (2013), long-term government debt provides a buffer against risk premia arising in sovereign yields—in this case driven by expectations about exit and default. As private yield spreads rise, output (3<sup>rd</sup> row left panel) declines along with consumption (3<sup>rd</sup> row right panel).<sup>20</sup> At the same time, (producer-price) inflation rises (bottom left panel), appreciating the real exchange rate thereby crowding out net exports (bottom row right panel), leading to a further drop in output.<sup>21</sup> Hence, deficit shocks turn out to be stagflationary in the presence of exit expectations.

### 3.4 Dynamics after (and before) exit

Exit expectations impact macroeconomic dynamics to the extent that they entail expectations of a weaker currency after exit. For a given probability of exit and a given level of debt, expected inflation and depreciation upon exit determine the redenomination premium. The dynamics of inflation, in turn, depend on the price-setting behavior of firms and the conduct of monetary policy after exit. In order to illustrate how exit expectations impact the economy prior to exit it is instructive to consider the actual adjustment when exit takes place—under varying assumptions regarding both price setting and the conduct of monetary policy after exit. Specifically, we report results from an additional experiment where exit from the currency union materializes in period 10 after the deficit shock. To simplify the discussion, we assume that default is not possible ( $\epsilon = 0.1, \delta = 0.1, \theta = 0$ ). Also, we only look at the case where the maturity of debt is 7.1 years.

We consider the role of price setting first. So far we have assumed that price-setting behavior is unaffected by exit. In what follows we introduce a more general specification, which allows for the possibility that the frequency of price-setting changes after exit. In particular, this nests the possibility of a full price reset after exit.<sup>22</sup> Technically, to allow for the possibility of a change in rigidity, we modify the Phillips curve (2.2) in the initial regime such that firms anticipate that the frequency of price adjustment changes with an exit from the currency

<sup>20</sup>Consumption is given by  $c_t = q_t$ , the linearized version of the risk sharing condition presented in the non-linear model in Section 2. See the Appendix A for further details.

<sup>21</sup>The nominal exchange rate (relative to steady state) is zero in the initial regime,  $e_t = 0$ , such that the real exchange rate appreciates one for one with a rise in producer prices,  $q_t = -(1 - \omega)p_{H,t}$ , from equation (2.4). Net exports to GDP are given by  $\widehat{nx}_t = y_t - c_t - \omega/(1 - \omega)q_t$ , see the Appendix A.

<sup>22</sup>More precisely, we allow for the possibility that prices become fully flexible after exit. In our setup this is equivalent to a scenario where prices become flexible in the period of exit, but are again sticky in all periods thereafter—which corresponds to “a full reset”. Intuitively, in *Union*, firms know that upon exit they will be able to reset prices optimally, thus their current pricing decision is unaffected by what will happen after the period of exit.

union (see Appendix C for details). The generalized Phillips curve is given by

$$\begin{aligned}\pi_{H,t} = & \beta [\lambda E_t(\pi_{H,t+1}|\text{Union}) + \delta \Lambda_1 E_t(\pi_{H,t+1}|\text{U Def}) + \epsilon \Lambda_2 E_t(\pi_{H,t+1}|\text{Exit})] \\ & + \kappa (\varphi + \varpi^{-1}) \Lambda_1 y_t,\end{aligned}\tag{3.7}$$

where  $\lambda \equiv 1 - \epsilon - \delta$  is the probability of staying in *Union* and the two correction factors  $\Lambda_1$  and  $\Lambda_2$  are given by

$$\begin{aligned}\Lambda_1 &= \frac{(1 - \beta\lambda\xi)(1 - \beta\xi_{\text{Exit}})}{(1 - \beta\xi)(1 - \beta\xi_{\text{Exit}}) + (1 - \beta\xi)\beta\epsilon\xi_{\text{Exit}} + (1 - \beta\xi_{\text{Exit}})\beta\delta\xi} \\ \Lambda_2 &= \frac{\xi_{\text{Exit}}}{\xi} \frac{1 - \xi}{1 - \xi_{\text{Exit}}} \frac{1 - \beta\xi}{1 - \beta\xi_{\text{Exit}}} \Lambda_1.\end{aligned}$$

Note that in case  $\xi = \xi_{\text{Exit}}$ ,  $\Lambda_1 = \Lambda_2 = 1$ , and we obtain the Phillips curve of the baseline model.<sup>23</sup> Moreover, note that in case  $\xi_{\text{Exit}} = 0$ , that is, prices become flexible after exit,  $\Lambda_1 = \frac{1 - \beta\lambda\xi}{1 - \beta(\lambda + \epsilon)\xi}$  and  $\Lambda_2 = 0$  such that i) the Phillips curve becomes steeper ( $\Lambda_1$  increases), the larger the probability of an exit—as this effectively reduces price stickiness—and ii) firms in *Union* “do not look beyond exit” when setting prices.

Inflation dynamics after exit are governed by parameter  $\xi_{\text{Exit}}$ . Still, we note from (3.7) that this parameter matters also for the dynamics prior to exit. To illustrate this, we simulate a version of the model which features the generalized Phillips curve (3.7) rather than the baseline version (2.2). Figure 3 shows the response of selected variables to the deficit shock. We contrast results for the case where price adjustment is unchanged upon exit (solid lines) to an alternative where prices are flexible after exit such that there is a full reset of prices upon exit (dashed-dotted lines) and a case where nominal rigidities decline to an intermediate level (dashed lines). In the last case, price rigidity declines from  $\xi = 0.85$  to  $\xi_{\text{Exit}} = 0.74$ , in line with our estimates for Greece below. Note that in this case the fraction of firms which adjust prices upon exit is still moderate, but larger than in case of an unchanged pricing scheme.

The upper-left panel shows the response of the nominal exchange rate. In the baseline case, there is a discrete upward shift upon exit and further, more gradual depreciation thereafter. Overall, the response of the exchange rate is quite similar in the alternative scenarios, yet in the long run it depreciates by more as prices become more flexible. By contrast, the response of inflation (upper-right panel) is highly dependent on the degree of rigidity: it increases sharply in case prices are flexible after exit. While inflation also takes up in the baseline case, its response is muted relative to a scenario of more flexible prices. As a result, if prices are fully flexible after exit, the real exchange rate does not adjust after exit (bottom-left panel). Instead, in the baseline case, the sluggish response of inflation after exit induces the

<sup>23</sup>Here we use that  $\lambda + \delta + \epsilon = 1$ , and apply the law of iterated expectations.

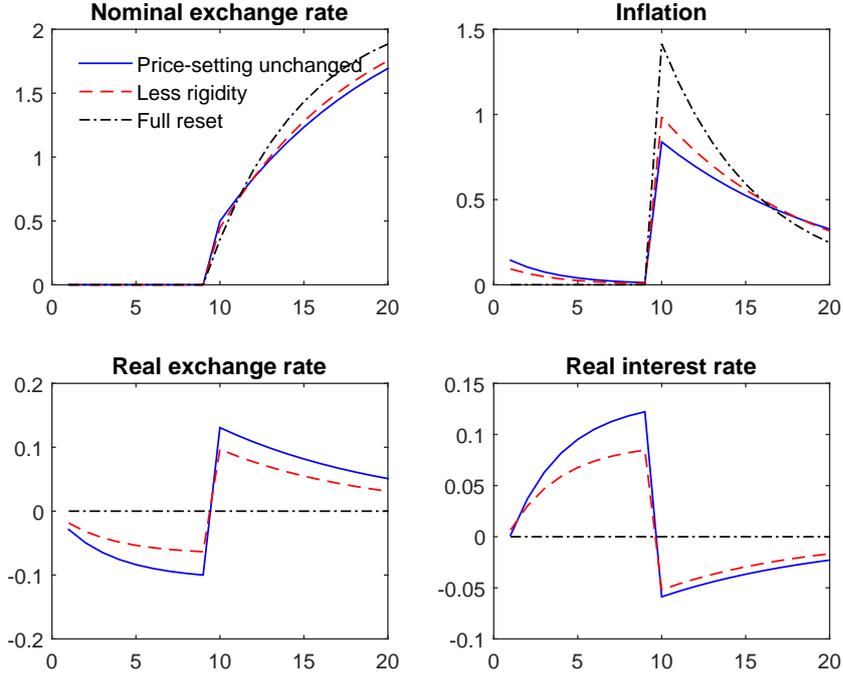


Figure 3: Impulse responses to a deficit shock in *Union* and actual exit in period 10 for different levels of rigidity in *Exit*. Solid line corresponds to unchanged rigidity ( $\xi = \xi_{\text{Exit}} = 0.85$ ), dashed line correspond to  $\xi_{\text{Exit}} = 0.778$ , dashed-dotted lines assume flexible prices after exit; horizontal axes measure time in quarters; vertical axes measure deviations from steady state in percent, (producer-price) inflation and interest rates are annualized.

real exchange rate to depreciate upon exit, along with the nominal exchange rate. The same holds, albeit to a lesser extent, in the intermediate case of reduced rigidity after exit.

The lower-right panel shows the ex ante real interest rate, which governs the intertemporal allocation of private domestic expenditure. Thus the response of this variable drives the recession observed in Figure 2. It is given by

$$r_t - E_t \pi_{H,t+1} = E_t (\Delta e_{t+1} - \pi_{H,t+1}) = (1 - \omega)^{-1} E_t \Delta q_{t+1}, \quad (3.8)$$

where the above relation follows from combining the UIP condition (3.1) and the definition of the real exchange rate (2.4). Thus, equilibrium requires that an expected real depreciation is met by increased real interest rates. If prices are flexible throughout (see Section 3.2), the above expression is zero because—upon exit—inflation is expected to adjust one-for-one with the depreciation of the nominal exchange rate. In other words, while market participants expect *nominal* depreciation upon exit, which raises *nominal* interest rates in the initial regime, they do not expect *real* depreciation, such that *real* interest rates in the initial regime are unchanged. As Figure 3 shows, it is enough for price rigidity to disappear *upon exit* for

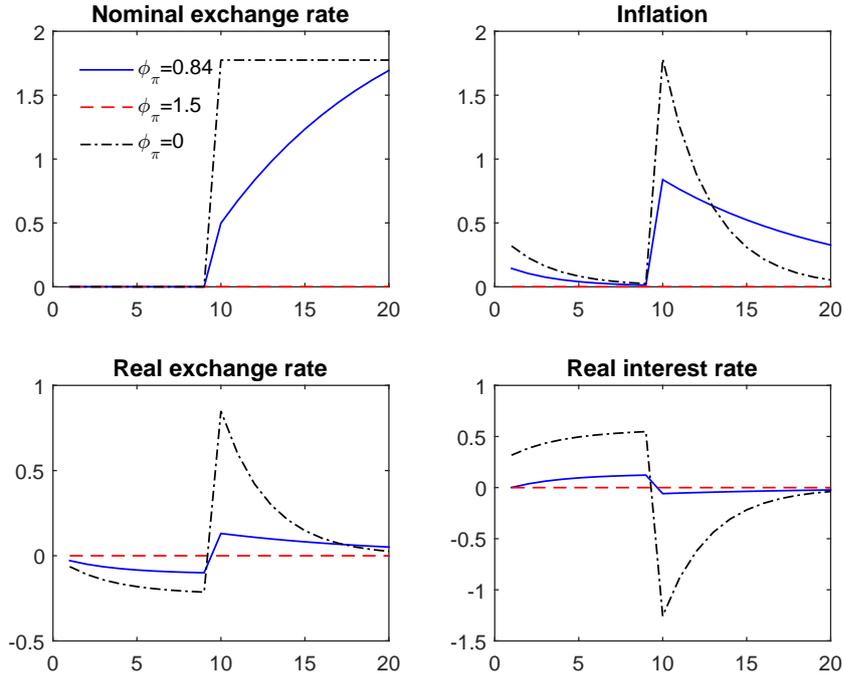


Figure 4: Impulse responses to a deficit shock in *Union* and actual exit in period 10 for different assumptions regarding monetary policy in *Exit*. Solid lines (dashed) corresponds to passive (active) monetary policy after exit, dashed-dotted lines correspond to inactive policy ( $\phi_\pi = 0$ ); horizontal axes measure time in quarters; vertical axes measure deviations from steady state in percent, (producer-price) inflation and interest rates are annualized.

the same result to obtain in the sticky-price model.

Empirically, large devaluations tend to be associated with a strong improvement in competitiveness, that is, a real depreciation, because prices tend to adjust more sluggishly than the nominal exchange rate (Burstein et al., 2005). We also point out that, unless there is full flexibility after exit, inflation rises (somewhat) already prior to exit, implying an appreciation of the real exchange rate in the initial regime (see Figure 3). This is because forward looking firms tend to raise prices, given that they expect inflation and depreciation upon exit which, in turn, will raise marginal costs. As stressed above, an appreciation of the real exchange rate in the initial regime further contributes to the recession.

We now turn to the role of monetary policy in shaping adjustment dynamics after exit and, hence, also prior to exit. Figure 4 contrasts results obtained for different assumptions regarding the conduct of monetary policy after exit. In the baseline case, we assume that monetary policy is passive upon exit (solid lines), with a Taylor coefficient smaller but close to one, as in the scenario for Greece developed in detail below. We consider two alternative scenarios. Under the first monetary policy is expected to be highly accommodative upon exit,

that is, “inactive” (dashed-dotted lines), while under the second, monetary policy is assumed to actively fighting inflation upon exit (satisfying the Taylor principle—dashed lines). This experiment thus echoes our earlier discussion from Section 3.2 above.

We observe that a more accommodative monetary stance upon exit leads to a stronger response of both the nominal exchange rate and of inflation after exit. In particular, the nominal exchange rate jumps to its new permanent level straight away if the Taylor-rule coefficient is equal to zero. Larger swings in nominal variables for given price rigidities translate into larger swings in both real exchange rate and real interest rate, both prior to exit and after exit. Thus, the stagflation observed in the initial regime becomes more pronounced as the newly autonomous monetary authority is expected to be more accommodative after exit. By contrast, a “hawkish” central bank satisfying the Taylor principle after exit eliminates the effects of exit expectations altogether, as explained in the previous section. Recall however that this requires the fiscal authority to be able to raise enough (real) surpluses after exit to satisfy its intertemporal budget constraint.

## 4 Greece 2009–2012

In this section we quantify the contribution of exit expectations to actual crisis dynamics in Greece. For this purpose, we estimate a variant of the model on time-series data for the period 2009Q3–2012Q1. The sovereign debt crisis in Greece started in earnest in 2009Q4, shortly after the newly elected Papandreou government announced a substantial overshooting of the previous government’s projection for the 2009-budget deficit, from 6 to 12.7 percent of GDP (Gibson et al. 2012). We limit our analysis to the period prior to the restructuring of Greek public debt in March/April 2012, because we are interested in the repercussions of *expected* exit and default, rather than the event itself. Recall that before the restructuring Greek public debt—in line with our modelling assumption—was issued almost exclusively under Greek jurisdiction (Buchheit et al., 2013; Chamon et al., 2015).

Two properties of the model are essential for the estimation. First, the model allows us to tell redenomination and default premia apart, because they impact the transmission of shocks in distinct ways. Second, our Markov-switching linear rational expectation model permits equilibria which feature locally explosive dynamics. This is important, because Greek time series for debt and yields appear to follow explosive trajectories in our sample period. However, our baseline model abstracts from a number of complications which appear essential for a serious quantitative assessment of the macroeconomic developments in Greece. Hence, we introduce a number of model extensions before turning to the data.

## 4.1 Extended model

First, in bringing the model to the data we rely on the generalized Phillips curve, as introduced in the previous section (see equation (3.7)). So, rather than imposing that the price-setting scheme is undisturbed by exit, we let the extent of price flexibility after exit be determined in the estimation. Next, we note that in the baseline model, public debt is non-neutral in the presence of expectations of an exit, but neutral in the presence of expectations of an outright default. The latter property may seem inadequate to the extent that output growth tends to be reduced if default looms (Yeyati and Panizza, 2011). We therefore allow for the possibility that sovereign default premia spill over to the private sector via a “sovereign risk channel” (Bocola, 2015; Corsetti et al., 2014). In order to do so, we relax the assumption that international financial markets are complete. In the extended model, the household budget constraint is given by

$$\Psi_{B,t}B_t + \Psi_{B^*,t}B_t^*\mathcal{E}_t + P_tC_t = W_tH_t + \mathcal{Y}_t + B_{t-1} + B_{t-1}^*\mathcal{E}_t + \mu_t,$$

where  $B_t$  and  $B_t^*$  are nominally non-contingent bonds issued under domestic and foreign law, respectively, both of which are traded with the rest of the world.<sup>24</sup> We also allow for taxes to be distortionary, namely proportional to the output of firms.<sup>25</sup>

In order to allow for the possibility that sovereign default risk spills over to bond prices in the private sector we postulate the following relationships

$$\Psi_{B,t} = (R_t)^{-1}E_t(1 - \chi\theta_{t+1}), \quad \Psi_{B^*,t} = (R^*)^{-1}E_t(1 - \chi\theta_{t+1}).$$

Here  $R_t$ , as before, denotes the nominally risk-free interest rate on a bond issued under domestic law, that is, on a bond that pays one unit of domestic currency in all states of the world.<sup>26</sup> Following Corsetti et al. (2013a) we rationalize a value of  $\chi$  larger than zero by the observation that private-sector contracts may not be fully enforced in the event of a sovereign default. Importantly, however, we assume that even though lenders may not be fully serviced in the event of sovereign default, borrowers do not retain resources in due course.<sup>27</sup>

<sup>24</sup>In the absence of complete international financial markets small open economy models will generally feature non-stationary dynamics. To avoid this property, we assume an endogenous discount factor (Schmitt-Grohe and Uribe, 2003). Also, we assume that  $B_t$  is in zero net supply, that is, all (cross-border) private saving is under foreign law. This roughly corresponds to actual practice in Greece as of 2009-2012 (Buiter and Rahbari, 2012).

<sup>25</sup>Hence the term  $T_t$  does not appear in the household budget constraint any longer. The deficit shock,  $\mu_t$ , however, continues to appear as it represents a lump-sum transfer to the household.

<sup>26</sup>If the sovereign risk channel is operative,  $R_t$  really is a “shadow” interest rate, as securities are not actually traded at this interest rate.

<sup>27</sup>Hence, an actual default has no direct bearing on the household’s budget constraint. Otherwise, borrowers’ interest rate would rise with sovereign risk only *notionally*, not affecting behaviour up to first order, as explained in Curdia and Woodford (2010). Bocola (2015) models the pass-through of sovereign risk while explicitly accounting for financial intermediation.

In order to be able to estimate the model, we further augment it by introducing five additional shocks. We introduce a world-demand shock, because world demand falls rather dramatically in the wake of the global financial crisis, presumably contributing to the recession in Greece during our sample period. We also account for the possibility that Greece loses competitiveness vis-à-vis its euro area partners by introducing a cost-push shock (see, e.g., Born et al. 2012). In principle, a series of positive cost-push shocks could generate an “overvalued” real exchange rate, thereby contributing to the recession.<sup>28</sup> Moreover, we permit variation in private and sovereign yield spreads which is independent of default and redenomination premia and other fundamentals due to private and sovereign “liquidity shocks”. This addresses concerns that “market segmentation” is an important factor driving yield spreads during the recent euro area crisis (Krishnamurthy et al., 2014). Lastly, we allow the rest of the world to subsidize the domestic government through a transfer payment which we model as an exogenous process. Such a subsidy may result from favorable borrowing conditions granted to Greece by official lenders such as the IMF or the EFSM. We measure it as the difference between interest rate payments on sovereign debt implied by market rates and actual interest payments. All disturbances are assumed Gaussian with zero mean, mutually uncorrelated, and iid across time. Figures E.1 and E.2 in Appendix E show impulse responses of selected variables to all shocks.

In the extended model, the government flow budget constraint reads as

$$\Psi_t D_t + \tau_t P_{H,t} Y_t + Z_t = (1 + \iota \Psi_t) D_{t-1} (1 - \theta_t) + \mu_t.$$

Here,  $Z_t$  is the transfer payment and  $\tau_t$  is the tax rate proportional to output, which, as before, may depend on the size of public debt through the feedback parameter  $\psi_{\zeta_t}$ . We provide more details on the extended model in Appendix A.

## 4.2 Data and estimation

We estimate the model using a Bayesian approach (see, e.g., Smets and Wouters, 2007). For this purpose we rely on quarterly time series for six variables: output, CPI inflation, sovereign and private-sector yield spreads, the primary budget surplus as well as transfers from abroad. As discussed above, our sample covers the period 2009Q3–2012Q1. The data is obtained from ECB and Eurostat and described in more detail in Appendix D. Figure E.3 shows the data. Both sovereign and private yield spreads are measured relative to their German counterparts. Private-sector yield spreads are measured using interest rates earned on short-term deposits of non-financial institutions and households with domestic banks; results based on loan rates

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<sup>28</sup>Cost-push shocks are also an important factor when it comes to accounting for inflation dynamics (Smets and Wouters, 2007).

Table 1: Prior and posterior distribution of estimated model parameters

	Prior distribution			Posterior distribution			
	Distribution	Mean	Std	Mean	Std	10 %	90 %
$\epsilon$	Gamma	0.055	0.05	0.038	0.012	0.024	0.053
$\delta$	Gamma	0.055	0.05	0.065	0.057	0.009	0.140
$\chi$	Beta	0.2	0.1	0.131	0.056	0.053	0.220
$\xi_{\text{Exit}}$	Beta	0.66	0.1	0.744	0.102	0.603	0.864
$\sigma_{\text{deficit}}$	Inverse-G.	0.01	$\infty$	0.105	0.025	0.077	0.138
$\sigma_{\text{cost-push}}$	Inverse-G.	0.01	$\infty$	0.007	0.002	0.005	0.010
$\sigma_{\text{world-demand}}$	Inverse-G.	0.01	$\infty$	0.078	0.019	0.057	0.103
$\sigma_{\text{sov-liqu}}$	Inverse-G.	0.01	$\infty$	0.013	0.003	0.009	0.017
$\sigma_{\text{priv-liqu}}$	Inverse-G.	0.01	$\infty$	0.003	0.001	0.002	0.004
$\sigma_{\text{transfers}}$	Inverse-G.	0.01	$\infty$	0.032	0.007	0.025	0.041

Notes: exit probability measured by  $\epsilon$ , probability of outright default measured by  $\delta$ ,  $\chi$  parameterizes pass-through of sovereign risk into private yields,  $\xi_{\text{Exit}}$  captures price rigidities after exit. The remaining six parameters measure the standard deviations of the shocks. The posterior distributions are computed on the basis of the Metropolis-Hastings algorithm. Other parameters are held fixed in the estimation, see main text for details.

are very similar. Sovereign yield spreads are measured using yields on ten-year government debt, because the average maturity of public debt during the sample period is quite high (see below). Both, private and public spreads follow apparently explosive trajectories (see Figure E.3). Our measures for CPI-inflation and output growth are also computed in terms of differences relative to their German counterpart. While output growth is persistently negative throughout, inflation is particularly high during the first half of the sample. The primary budget surplus is also persistently negative throughout the sample period. Finally, transfers are measured in percent of output, using secondary-market interest rates and actual interest payments on public debt. They start to rise sharply from the 2011 onwards, but are negative during the first half of the sample. This reflects high actual financing costs relative to secondary-market rates during the early stage of the crisis, because substantial amounts of short term debt (carrying higher yields) had to be refinanced.

Given that our sample is short, we only estimate a subset of model parameters. Specifically, we estimate the probability of exit and default,  $\epsilon$  and  $\delta$ , as well as parameter  $\chi$  which captures the strength of the sovereign risk channel. Moreover, we estimate the degree of price rigidity after exit, captured by  $\xi_{\text{Exit}}$ . As discussed in Section 3, this parameter also determines the extent of real depreciation in the event of an exit. Lastly, we estimate the standard deviation of all six disturbances.

As prior distributions we choose a Gamma distribution with mean 0.055 and standard de-

viation 0.05 for both  $\epsilon$  and  $\delta$ . The mean implies a probability of either exit or default of 25 percent within the next 18 months, in line with views maintained by market participants during our sample period (e.g., Buiters and Rahbari, 2012 and UBS, 2010). Regarding  $\chi$ , we choose a Beta distribution with mean 0.2 and standard deviation 0.1. We thereby try to account for results from a variety of empirical studies. While Neri (2013) finds that the pass-through of sovereign risk into bank lending rates is quite low in Greece (about 0.07), other studies find that the adverse effect of sovereign risk on borrowing conditions is quite a bit stronger (Harjes, 2011; Zoli, 2013). Regarding  $\xi_{\text{Exit}}$  we maintain as prior a Beta distribution centered around 0.66 with standard deviation 0.1. Given that we assume  $\xi = 0.85$  (see below), this accommodates the notion that prices should become more flexible upon and after exit. However, under our prior they are unlikely to become fully flexible, given that large devaluations are typically associated with strong movements in real exchange rates (Burstein et al. 2005). Finally, we employ an Inverted-Gamma distribution with mean 0.01 and an infinite variance for the standard deviations of all shocks. Table 1 summarizes our priors in the left panel.

The remaining parameters are kept fixed in the estimation procedure. The discount factor  $\beta$  is set to 0.99. We set  $\varphi = 3$ , implying a Frisch elasticity of labor supply of one third (Domeij and Flodén, 2006). The trade-price elasticity  $\sigma$  is set to 1.5, in line with estimates for Greece by Bennett et al. (2008). For  $\omega$  we assume a value of 0.2, corresponding to the 2009 export-to-GDP ratio in Greece. We set  $\gamma = 11$ , such that the steady-state mark up is equal to 10 percent. Moreover, we assume  $\iota = 0.9648$  which implies an average maturity of debt of 7.1 years (Krishnamurthy et al., 2014). To account for a relatively flat Phillips curve during the recent crisis period we set  $\xi = 0.85$  (see, e.g., IMF 2013). Furthermore, we set  $\zeta = 2.4$ , such that public debt in steady state amounts to 60% of annual GDP. Recall that steady-state debt is not subject to the haircut if default takes place. At the time of the restructuring Greek debt held by official institutions (EFSF, ECB/NCB and IMF) amounted to about 60 Percent of GDP and was indeed exempted from the restructuring. Private investors, instead, accepted a haircut of approximately 64 percent (Zettelmeyer et al., 2013). We thus set  $\theta = 0.64$ .

We assume that fiscal policy is passive during union membership, though with a small feedback coefficient:  $\psi_{\text{Union}} = \psi_{\text{U Per}} = 0.02$ . This ensures that explosive dynamics in the initial regime are driven by exit and default expectations. Moreover, we assume an inflationary monetary-fiscal mix after exit by setting  $\phi_{\pi} = 0.84$  and  $\psi_{\text{Exit}} = 0$ . This choice is guided by estimates for the pre-Volker period in the U.S. The seminal study of Clarida et al. (2000), for instance, reports a value of  $\phi_{\pi} = 0.83$ . Similarly, Traum and Yang (2011) estimate of a full-fledged business cycle model and report a value of  $\phi_{\pi} = 0.84$ . They also report values for the

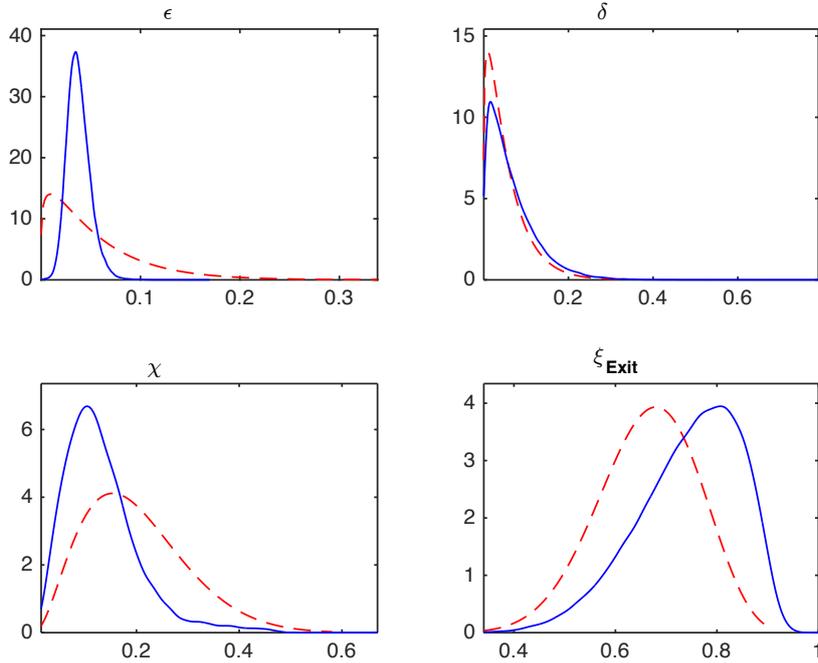


Figure 5: Prior (dashed) and posterior (solid) distribution of model parameters. Notes: exit probability measured by  $\epsilon$ , probability of outright default measured by  $\delta$ ,  $\chi$  parameterizes pass-through of sovereign risk into private yields,  $\xi_{\text{Exit}}$  captures price rigidities after exit.

debt-feedback of taxes and public expenditures very close to zero. Finally, given  $\zeta$ , we set  $B^*\mathcal{E}/PY = -1.056$  in order to match the Greek net foreign asset to GDP position in 2009, equal to  $-86.4\%$  according to estimates by ECB (2013).

We approximate the posterior distribution of the parameters using a standard Metropolis-Hastings algorithm. In order to ensure convergence we run two chains with 1,000,000 draws each. The posterior distribution is approximated by every second draw of the last 100,000 draws of each chain.

### 4.3 Estimation results

Turning to the estimation results, we report key statistics in the right panel of Table 1. We note that the posterior mean has shifted above the prior mean in the case of  $\delta$ , which now stands at 6.5%, and below the prior mean in the case of  $\epsilon$ , which stands at 3.7%. At the same time, probability bands are quite large for  $\delta$ . The posterior mean for  $\chi$  implies that only 13% of sovereign risk spills over into the private sector. This finding, in line with Neri (2013), suggests that the role of the sovereign risk channel is limited in the Greek debt crisis. Lastly, the estimate of  $\xi_{\text{Exit}}$  suggests that nominal rigidities are expected to decline only moderately

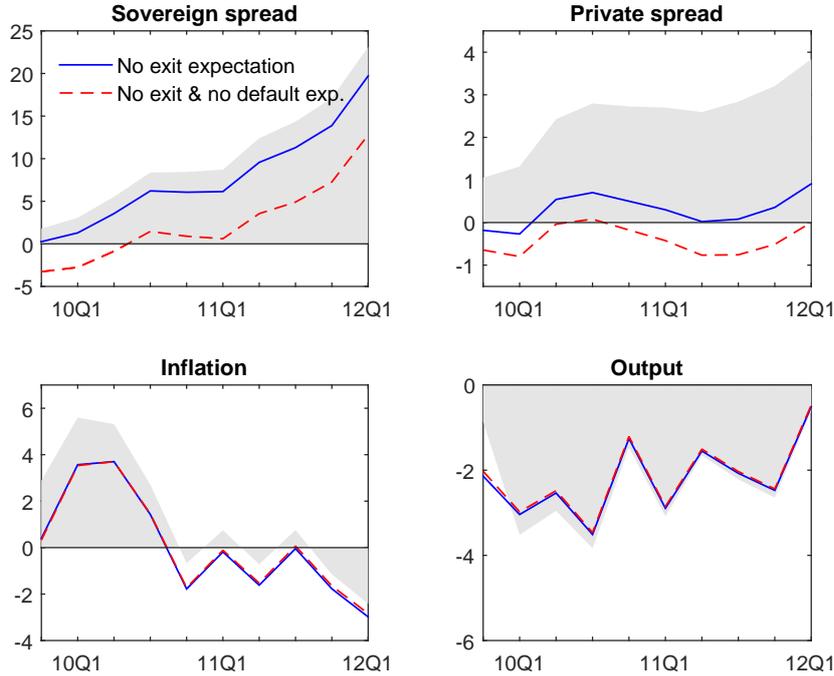


Figure 6: Counterfactual (vs actual) outcome of observed variables. Notes: grey area indicates actual time series/predicted by estimated model; counterfactuals: solid line corresponds scenario where exit is ruled out ( $\epsilon = 0$ ), dashed line represent dynamics in the absence of exit and default expectations ( $\epsilon = \theta = 0$ ).

upon exit. Figure 5 displays prior and posterior distributions for these parameters, illustrating the extent of identification (see Figure E.4 in Appendix E for the distributions of the standard errors of the shocks). We apply a Kalman smoother to reconstruct the sequences of unobserved shocks at the posterior mean and show the results in Figure E.5 in Appendix E.

We now turn to the central issue, namely, the quantitative contribution of exit (and default) expectations to the crisis dynamics in Greece. For this purpose, we simulate the model using the estimated shock sequences and the posterior mean of the estimated parameters (baseline) and contrast the outcome to two counterfactuals. First, we isolate the effect of exit expectations by running a simulation as in the baseline, except that expectations of exit are ruled out ( $\epsilon = 0$ ). Second, we also rule out outright default by setting the haircut parameter to zero ( $\theta = 0$ ). Figure 6 shows the result. In the figure, the grey area corresponds to the actual outcome, that is, the baseline predicted by the estimated model. The solid blue and dashed red line, in turn, correspond to the counterfactual scenario where either exit or both exit and default expectations are absent. Given initial conditions in 2009Q3, we compute the counterfactual outcome for periods 2009Q4–2012Q1.

We find that exit expectations substantially impact the crisis dynamics during this period. Consider, first, the sovereign yield spread (upper left panel). Absent exit expectations, spreads would have been lower by some 1.5 to 3.5 percentage points at the beginning and the end of the period, respectively. At the height of the crisis, the redenomination premium thus accounts for about 15 percent of the yield spread. At the same time, sovereign yields carry a substantial premium which compensates for the possibility of an outright default. Without expectations of exit *and* default yields would have been lower by some 5 to 10 percentage points. The remainder, that is, roughly one-half of the spread is explained by liquidity shocks. This finding is in line with Krishnamurthy et al. (2014), who find “market segmentation” important when accounting for sovereign yield spreads in several crisis countries (although Greece is not included in their sample).

Our finding of a significant redenomination premium lends support to the view expressed by ECB president Mario Draghi in his “Whatever-it-takes”-speech on July 26, 2012. Regarding sovereign yield spreads he remarks: “These premia have to do, as I said, with default, with liquidity, but they also have to do more and more with convertibility, with the risk of convertibility.” In fact, this consideration provides the rationale for what later becomes known as the “Outright Monetary Transactions” Program of the ECB. In this regard it is crucial that these premia also show up in private-sector yields. Draghi emphasizes: “To the extent that the size of these sovereign premia hampers the functioning of the monetary policy transmission channel, they come within our mandate” (ECB, 2012).

The upper right panel of Figure 6 shows the decomposition of private-sector yields according to our counterfactuals. Results are clear cut: redenomination premia basically account for almost all of the private-sector spread observed during our sample period. If, in addition to exit, default is ruled out as well, there is a further reduction in private yield spreads, but the effect is small. This reflects the low estimate of  $\chi$ . Note that spreads may be negative because of liquidity shocks.

Exit expectations also matter for macroeconomic outcomes. We contrast counterfactual and actual outcomes of CPI inflation and output growth in the bottom panels of Figure 6. We find that in the absence of exit expectations inflation is reduced and particularly so in the early stage of the crisis period, that is, exit expectations are inflationary—in line with the discussion in Sections 3.3 and 3.4 above. The overall effect on output turns out to be moderate. In fact, during the first quarter of our sample, output growth would have even been lower in the absence of exit expectations. This is surprising in light of our discussion from Section 3.3, where we found exit expectations to be contractionary. However, as we assume international financial markets to be incomplete in the estimated model, this is not necessarily true. In

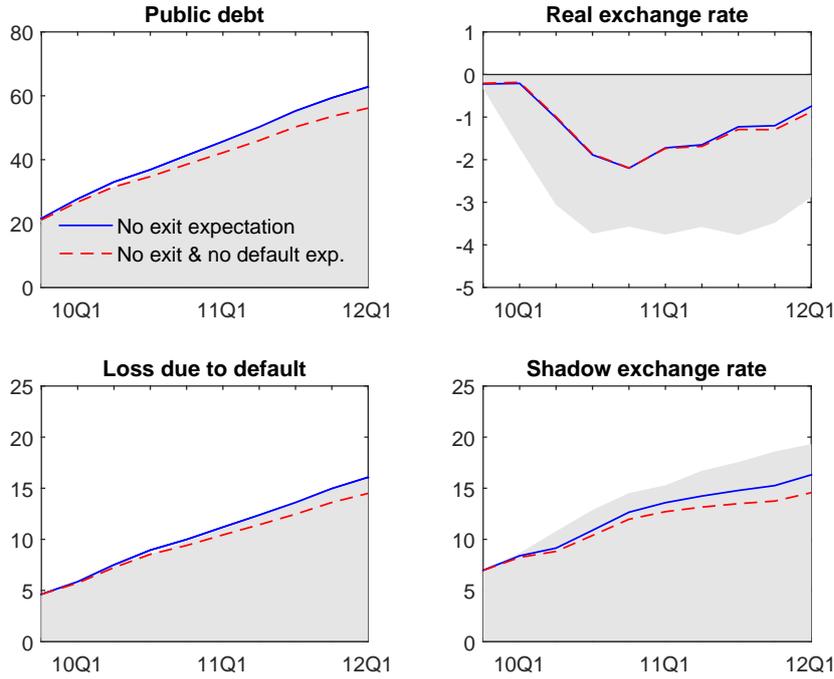


Figure 7: Counterfactual (vs actual) outcomes of additional variables. Notes: gray areas indicate time series predicted by estimated model; counterfactuals: solid (dashed) line captures scenario w/o exit (w/o exit and default). Upper panel shows public debt (percentage points of GDP) and real exchange rate. Loss due to default: percentage points reduction in debt to GDP. Shadow exchange rate: nominal exchange rate if exit were to take place.

this case, exit reduces the real value of public debt in the hands of international investors and entails a wealth transfer to domestic tax payers. This implication of an exit, all else equal, stimulates domestic demand prior to exit and may (partly) offset the adverse effect of exit expectations on private demand via increased yields. The first effect dominates in the first quarter. Starting in 2010Q1, however, the latter effect dominates: growth would have been higher in the absence of exit expectations.<sup>29</sup>

The estimated model also makes predictions regarding variables which are not used in the estimation. Four of these are of particular interest, and we compute their evolution under the baseline as well as under the two counterfactual scenarios. Results are shown in Figure 7. The upper left panel shows the evolution of public debt, measured in percentage points of output and in excess of the steady-state level of 60 percent. The model prediction under the baseline scenario is indicated by the gray area. It captures the actual increase by some

<sup>29</sup>At the same time, exit induces a negative wealth effect to the extent that the domestic household is indebted in terms of foreign-law securities, the latter rising in value as the newly created domestic currency depreciates in real terms. The response of domestic output is a convolution of those different factors.

40 percentage points during the sample period very well.<sup>30</sup> Our counterfactual simulations show that default expectations contributed to the build-up of debt, but the bulk is due to the persistently negative primary surpluses and the strong drop in output at the time.<sup>31</sup> The upper right panel of Figure 7 shows the real exchange rate, predicted to appreciate in the early stage of the crisis. Competitiveness does not start to improve before 2011 according to our estimates, in line with actual developments. This is partly due to exit expectations: they account for more than half of the real appreciation in our sample period, as the counterfactual simulations illustrate.

Default and redenomination premia fluctuate endogenously in line with the expected losses in the event of outright default and exit. We quantify this effect in the bottom panels of Figure 7. In the left panel, we show the percentage point reduction in the debt-to-GDP ratio had outright default occurred in a given period. We note that, absent expectations about exit or default, the haircut would have been smaller, due to public debt building up at a lower pace (recall the upper left panel).<sup>32</sup> A similar logic applies to the shadow exchange rate (lower right panel). It is computed as the nominal exchange rate which would clear the foreign exchange market, were the country to exit the union in the respective period (see also Flood and Garber, 1984). According to our estimates, the nominal exchange rate would have depreciated by more than 20 percent had exit taken place at the end of our sample period. In principle, depreciation in the event of exit can be due to an appreciated real exchange rate or due to a particular monetary-fiscal policy mix after exit whenever public debt is high. The present paper has highlighted the mechanisms which underly the second channel and, indeed, according to our estimates, debt-induced depreciation accounts for the bulk of the depreciation of the shadow exchange rate, because the appreciation of the real exchange rate is fairly moderate.

## 5 Conclusion

Countries may join, as well as exit currency unions. Expectations of an exit, in particular, may arise in the context of a sovereign debt crisis, because countries can redenominate their liabilities by exiting. The real value of debt will then decline with the value of the new

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<sup>30</sup>Public debt in Greece amounted to some 130 percent of GDP in 2009Q4 and to 170 Percent in 2012Q1. Hence the model underestimates the level of debt at the beginning of the sample period.

<sup>31</sup>Note that under the baseline public debt is on an explosive trajectory: the largest relevant eigenvalue is 1.0122. It drops to 1.005 in the absence of exit expectations and to 0.997 if outright default is ruled out as well.

<sup>32</sup>Note that under the counterfactual of no exit and default, expectations have not been rational in the sense that a default occurs, even though it has not been anticipated. A similar logic applies for the shadow exchange rate.

currency. Against this background, we ask how exit expectations impact the dynamics of a sovereign debt crisis within a currency union. We put forward a small open economy model with changing policy regimes. In particular, we focus on a country which operates inside a currency union, but may exit or, alternatively, apply a haircut to its outstanding liabilities while continuing to be a member of the union.

Market participants are aware of these possibilities and expectations of exit and default matter for the equilibrium outcome. We show that exit expectations drive up yields of securities issued under domestic law, both public and private, provided that the new currency is expected to depreciate upon exit. This, in turn, depends on expectations regarding the monetary/fiscal policy mix after exit and on the state of public finances. Exit expectations, in particular, make public debt stagflationary whenever nominal rigidities are expected to persist beyond exit. Moreover, a member of the currency union may experience a vicious circle of ever rising debt levels and sovereign yields, if either expectations of exit and default are high or fiscal policy is insufficiently responsive to public debt.

The model is able to distinguish between expectations of exit and expectations of outright default. Furthermore, it is able to generate explosive dynamics in debt and yield spreads, and thus captures important aspects of the actual euro area crisis. We estimate an extended version of the model on Greek times series data for the period 2009–2012. We find that the estimated model performs rather well: we obtain plausible estimates for exit and default probabilities as well as for the dynamics of public debt and the real exchange rate, both not included in the vector of observables. Importantly, we find that redenomination premia account for a significant fraction of sovereign yield spreads, and almost all the spread observed in private-sector yields. This finding lends support to the view that “fears of a reversibility of the euro” were indeed pervasive, at least as far as Greece is concerned. Moreover, exit expectations contributed to crisis dynamics by raising prices, thereby reducing competitiveness. Their effect on output growth was, instead, moderate.

Our analysis is silent on the benefits and costs of an actual exit, which we leave for future research. At this point we simply stress that—irrespective of whether actual exit would benefit the country or not—the expectation of it happening intensifies the adverse dynamics of a sovereign debt crisis in a member country of a currency union. Our findings are thus in line with a more general insight: policy frameworks which lack credibility tend to generate inferior outcomes.

## References

- Aguiar, M., Amador, M., Farhi, E., and Gopinath, G. (2013). Crisis and Commitment: Inflation Credibility and the Vulnerability to Sovereign Debt Crises. NBER Working Paper 19516.
- Aguiar, M., Amador, M., Farhi, E., and Gopinath, G. (2014). Coordination and Crisis in Monetary Unions. NBER Working Paper 20277.
- Alesina, A. and Barro, R. J. (2002). Currency unions. *Quarterly Journal of Economics*, 117(2):409–436.
- Andolfatto, D. and Gomme, P. (2003). Monetary policy regimes and beliefs. *International Economic Review*, 44(1):1–30.
- Bennett, H., Escolano, J., Fabrizio, S., Gutiérrez, E., Ivaschenko, I., Lissovolik, B., Moreno-Badia, M., Schule, W., Tokarick, S., Xiao, Y., and Zarnic, Z. (2008). Competitiveness in the southern euro area: France, Greece, Italy, Portugal, and Spain. IMF Working paper WP/08/112.
- Bergin, P. R. (2000). Fiscal solvency and price level determination in a monetary union. *Journal of Monetary Economics*, 45(1):37–53.
- Bi, H. (2012). Sovereign Default Risk Premia, Fiscal Limits, and Fiscal Policy. *European Economic Review*, 56:389–410.
- Bianchi, F. and Ilut, C. (2012). Monetary/fiscal policy mix and agents’ beliefs. Mimeo, Duke University.
- Blanchard, O. J. and Kahn, C. M. (1980). The solution of linear difference models under rational expectations. *Econometrica*, 48(5):1305–1311.
- Bocola, L. (2015). The Pass-Through of Sovereign Risk. Federal Reserve Bank of Minneapolis, Working Papers 722.
- Born, B., Buchen, T., Carstensen, K., Grimme, C., Kleemann, M., Wohlrabe, K., and Wollmershäuser, T. (2012). Greece’s exit from european monetary union: historical experience, macroeconomic implications and organisational implementation. *ifo Schnelldienst*, 65.
- Buchheit, L. C., Gulati, G. M., and Tirado, I. (2013). The Problem of Holdout Creditors in Eurozone Sovereign Debt Restructurings.

- Buiter, W. and Rahbari, E. (2012). Global Economics View, February 6.
- Burstein, A., Eichenbaum, M., and Rebelo, S. (2005). Large devaluations and the real exchange rate. *Journal of Political Economy*, 113(4):742–784.
- Calvo, G. A. (1988). Servicing the Public Debt: The Role of Expectations. *American Economic Review*, 78(4):647–61.
- Chamon, M., Schumacher, J., and Trebesch, C. (2015). Foreign Law Bonds: Can They Reduce Sovereign Borrowing Costs? mimeo.
- Chari, V. V., Kehoe, P. J., and McGrattan, E. R. (2002). Can Sticky Price Models Generate Volatile and Persistent Real Exchange Rates? *Review of Economic Studies*, 69(3):533–63.
- Clarida, R., Gal, J., and Gertler, M. (2000). Monetary Policy Rules And Macroeconomic Stability: Evidence And Some Theory. *The Quarterly Journal of Economics*, 115(1):147–180.
- Cochrane, J. H. (2001). Long-term debt and optimal policy in the fiscal theory of the price level. *Econometrica*, 69(1):69–116.
- Cole, H. L. and Kehoe, T. J. (2000). Self-Fulfilling Debt Crises. *Review of Economic Studies*, 67(1):91–116.
- Corsetti, G., Kuester, K., Meier, A., and Müller, G. (2013a). Sovereign Risk, Fiscal Policy, and Macroeconomic Stability. *Economic Journal*, 123:F99–F132.
- Corsetti, G., Kuester, K., Meier, A., and Müller, G. J. (2014). Sovereign risk and belief-driven fluctuations in the euro area. *Journal of Monetary Economics*, 61(0):53 – 73. Carnegie-Rochester-NYU Conference Series on Fiscal Policy in the Presence of Debt Crises held at the Stern School of Business, New York University on April 19-20, 2013.
- Corsetti, G., Kuester, K., and Müller, G. J. (2013b). Floats, pegs and the transmission of fiscal policy. In Céspedes, L. F. and Galí, J., editors, *Fiscal Policy and Macroeconomic Performance*, volume 17 of *Central Banking, Analysis, and Economic Policies*, chapter 7, pages 235–281. Central Bank of Chile.
- Curdia, V. and Woodford, M. (2010). Credit Spreads and Monetary Policy. *Journal of Money, Credit and Banking*, 42(s1):3–35.
- Daniel, B. C. and Shiamptanis, C. (2012). Fiscal risk in a monetary union. *European Economic Review*, 56:12891309.

- Davig, T. and Leeper, E. (2007a). Generalizing the Taylor principle. *American Economic Review*, 97(3):607–635.
- Davig, T. and Leeper, E. (2007b). Fluctuating macro policies and the fiscal theory of the price level. *NBER Macroeconomics Annual 2006*, 21:247–298.
- Davig, T. and Leeper, E. M. (2011). Monetary-fiscal policy interactions and fiscal stimulus. *European Economic Review*, 55(2):211–227.
- De Paoli, B. (2009). Monetary policy and welfare in a small open economy. *Journal of International Economics*, 77(1):11–22.
- De Santis, R. (2015). A measure of redenomination risk. ECB Working paper 1785.
- Domeij, D. and Flodén, M. (2006). The labor-supply elasticity and borrowing constraints: Why estimates are biased. *Review of Economic Dynamics*, 9(2):242–262.
- Drazen, A. and Masson, P. R. (1994). Credibility of policies versus credibility of policymakers. *Quarterly Journal of Economics*, 109(3):735–754.
- ECB (2012). Speech by Mario Draghi at the Global Investment Conference in London. <https://www.ecb.europa.eu/press/key/date/2012/html/sp120726.en.html>.
- ECB (2013). Annual report 2012.
- Farmer, R. E., Waggoner, D. F., and Zha, T. (2009). Understanding markov-switching rational expectations models. *Journal of Economic Theory*, 144(5):1849–1867.
- Farmer, R. E., Waggoner, D. F., and Zha, T. (2011). Minimal state variable solutions to markov-switching rational expectations models. *Journal of Economic Dynamics and Control*, 35(12):2150–2166.
- Flood, R. P. and Garber, P. M. (1984). Collapsing exchange-rate regimes : Some linear examples. *Journal of International Economics*, 17(1-2):1–13.
- Galí, J. and Monacelli, T. (2005). Monetary policy and exchange rate volatility in a small open economy. *Review of Economic Studies*, 72:707–734.
- Gibson, H. D., Hall, S. G., and Tavlás, G. S. (2012). The Greek financial crisis: Growing imbalances and sovereign spreads. *Journal of International Money and Finance*, 31:498–516.

- Harjes, T. (2011). Financial Integration and Corporate Funding Costs in Europe After the Financial and Sovereign Debt Crisis. In *IMF Country Report No. 11/186*. International Monetary Fund.
- IMF (2013). World Economic Outlook, April 2013.
- Kollmann, R. (2001). The Exchange Rate in a Dynamic-Optimizing Business Cycle Model with Nominal Rigidities: A Quantitative Investigation. *Journal of International Economics*, 55:243–262.
- Krishnamurthy, A., Nagel, S., and Vissing-Jorgensen, A. (2014). ECB Policies involving Government Bond Purchases: Impact and Channels.
- Krugman, P. (1979). A Model of Balance-of-Payments Crises. *Journal of Money, Credit and Banking*, 11(3):311–325.
- Lane, P. R. (2012). The European Sovereign Debt Crisis. *Journal of Economic Perspectives*, 26(3):49–68.
- Leeper, E. M. (1991). Equilibria under 'active' and 'passive' monetary and fiscal policies. *Journal of Monetary Economics*, 27(1):129–147.
- Leeper, E. M. and Zhou, X. (2013). Inflation's Role in Optimal Monetary-Fiscal Policy. NBER Working Papers 19686, National Bureau of Economic Research, Inc.
- Lorenzoni, G. and Werning, I. (2013). Slow Moving Debt Crises. NBER Working Papers 19228, National Bureau of Economic Research, Inc.
- Na, S., Schmitt-Grohé, S., Uribe, M., and Yue, V. (2014). A Model of the Twin Ds: Optimal Default and Devaluation.
- Neri, S. (2013). The impact of the sovereign debt crisis on bank lending rates in the euro area. *Questioni di Economia e Finanza (Occasional Papers) 170*, Bank of Italy, Economic Research and International Relations Area.
- Obstfeld, M. (1996). Models of currency crises with self-fulfilling features. *European Economic Review*, 40(3-5):1037–1047.
- Reinhart, C. M. (2002). Default, currency crises, and sovereign credit ratings. *World Bank Economic Review*, 16(2):151–169.
- Reinhart, C. M. and Rogoff, K. S. (2011). The forgotten history of domestic debt. *Economic Journal*, 121(552):319–350.

- Schmitt-Grohe, S. and Uribe, M. (2003). Closing small open economy models. *Journal of International Economics*, 61(1):163–185.
- Shambaugh, J. C. (2012). The euro’s three crises. *Brookings Papers on Economic Activity*, (Spring):157 – 231.
- Sims, C. A. (1997). Fiscal foundations of price stability in open economies. mimeo, Yale University.
- Sims, C. A. (2013). Paper money. *American Economic Review*, 103(2):563–584.
- Smets, F. and Wouters, R. (2007). Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach. *American Economic Review*, 97(3):586–606.
- Traum, N. and Yang, S.-C. S. (2011). Monetary and fiscal policy interactions in the post-war U.S. *European Economic Review*, 55(1):140–164.
- UBS (2010). UBS investment research: Eleven for oh-eleven.
- Uribe, M. (2006). A fiscal theory of sovereign risk. *Journal of Monetary Economics*, (53):1857–1875.
- Woodford, M. (1995). Price-level determinacy without control of a monetary aggregate. *Carnegie-Rochester Conference Series on Public Policy*, 43(1):1–46.
- Woodford, M. (1996). Control of the public debt: A requirement for price stability? NBER Working Papers 5684, National Bureau of Economic Research, Inc.
- Woodford, M. (2001). Fiscal Requirements for Price Stability. *Journal of Money, Credit and Banking*, 33(3):669–728.
- Yeyati, E. L. and Panizza, U. (2011). The elusive costs of sovereign defaults. *Journal of Development Economics*, 94(1):95–105.
- Zettelmeyer, J., Trebesch, C., and Gulati, M. (2013). The greek debt exchange: An autopsy. *Economic Policy*, 28:513–569.
- Zoli, E. (2013). Italian Sovereign Spreads; Their Determinants and Pass-through to Bank Funding Costs and Lending Conditions. IMF Working Papers 13/84, International Monetary Fund.

## A Model appendix

### A.1 Baseline model

Here we present details on the baseline model outlined in Section 2. In the following, lower-case letters denote the percentage deviation of a variable from its steady-state value, “hats” denote (percentage point) deviations from steady state scaled by nominal output. Variables in the rest of the world are assumed to be constant. The steady state is the same across regimes and characterized by zero net inflation, purchasing power parity, and zero default. We allow for non-zero public debt to GDP in steady state.

**Households’** first order conditions are given by an Euler equation

$$(C_t)^{-1} = \beta R_t E_t (C_{t+1})^{-1} \frac{P_t}{P_{t+1}}$$

and by a consumption-leisure condition

$$\frac{W_t}{P_t} = C_t H_t^\varphi.$$

Log-linearization of these two conditions, as well as of the risk sharing condition stated in the main text, yields

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

$$w_t^r := w_t - p_t = c_t + \varphi h_t, \tag{A.2}$$

$$c_t = q_t, \tag{A.3}$$

where  $\pi_t = p_t - p_{t-1}$  is CPI inflation.

**Intermediate good firms** face the demand function

$$Y_t(j) = \left( \frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\gamma} Y_t,$$

so that

$$\int_0^1 Y_t(j) dj = \Delta_t Y_t,$$

where  $\Delta_t = \int_0^1 \left( \frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\gamma} dj$  measures price dispersion. Aggregation gives

$$\Delta_t Y_t = \int_0^1 H_t(j) dj = H_t.$$

A first order approximation is given by  $y_t = h_t$ . The first order condition to the price setting problem is given by

$$E_t \sum_{k=0}^{\infty} \xi^k \rho_{t,t+k} Y_{t,t+k}(j) \left[ P_{H,t}(j) - \frac{\gamma}{\gamma-1} W_{t+k} \right] = 0.$$

Linearizing the firm's first order condition and using the definition of price indices, one obtains a variant of the New Keynesian Phillips curve (see, e.g., Galí and Monacelli, 2005):

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \kappa m c_t^r, \quad (\text{A.4})$$

where  $\kappa := (1 - \xi)(1 - \beta\xi)/\xi$  and marginal costs are defined in real terms, deflated with the domestic price index

$$m c_t^r = w_t - p_{H,t} = w_t^r - (p_{H,t} - p_t). \quad (\text{A.5})$$

**The real exchange rate** and the relation between the producer and consumer price indexes can be written as

$$q_t = e_t - p_t \quad (\text{A.6})$$

$$p_t = (1 - \omega)p_{H,t} + \omega p_{F,t} = (1 - \omega)p_{H,t} + \omega e_t, \quad (\text{A.7})$$

where in the last line we have used the law of one price, that is,  $P_{F,t} = \mathcal{E}_t P_F^*$  such that  $p_{F,t} = e_t$ .

**Goods market** clearing in linear terms can be written as

$$y_t = -\sigma(p_{H,t} - p_t) + (1 - \omega)c_t + \omega\sigma q_t,$$

which, combined with (A.6) and (A.7), can be written as

$$y_t = (1 - \omega)c_t + \omega\sigma(2 - \omega)/(1 - \omega)q_t. \quad (\text{A.8})$$

Net exports to GDP are given by

$$\widehat{nx}_t = y_t - c_t + \omega/(1 - \omega)q_t,$$

where we have used (A.7) and (A.6).

**The key equations** in the main text are obtained as follows. Combining equations (A.6) and (A.7) yields equation (2.4). Insert risk sharing (A.3) into goods market clearing (A.8) to obtain equation (2.3) in the main text. Rewrite the Euler equation (A.1)

$$\begin{aligned} c_t &= E_t c_{t+1} - (r_t - E_t[(1 - \omega)\pi_{H,t+1} + \omega\Delta e_{t+1}]) \\ &= E_t c_{t+1} - (r_t - E_t \pi_{H,t+1} - \frac{\omega}{\varpi} E_t \Delta y_{t+1}), \end{aligned}$$

where we use (A.7) in the first line and (2.3) and (2.4) from the main text in the second line. Combine (A.3) and (2.3) from the main text to obtain

$$c_t = \frac{1 - \omega}{\varpi} y_t.$$

Use this expression to substitute for consumption in the Euler equation above to obtain

$$y_t = E_t y_{t+1} - \varpi(r_t - E_t \pi_{H,t+1}),$$

which is (2.1) in the main text. Use (A.2), (A.3), (A.6), (A.7) and production technology  $y_t = h_t$  to rewrite marginal cost

$$mc_t^r = w_t^r - (p_{H,t} - p_t) = c_t + \varphi h_t - (p_{H,t} - p_t) = (\varpi^{-1} + \varphi) y_t.$$

Insert this into Phillips curve (A.4) to obtain (2.2) in the main text.

**Sovereign yields and debt.** Define the *gross yield* of government debt as

$$I_t = \frac{1 + \iota \Psi_t}{\Psi_t}$$

and linearize to obtain

$$i_t = -(1 - \iota \beta) \log(\Psi_t / \Psi), \quad (\text{A.9})$$

where  $\Psi = \frac{\beta}{1 - \iota \beta}$  is the price of debt in steady state (this follows from the bond price schedule in the main text). Linearize the bond price schedule to obtain

$$-\log(\Psi_t / \Psi) = E_t(\Delta e_{t+1} + \theta_{t+1}) - \iota \beta E_t \log(\Psi_{t+1} / \Psi).$$

Insert (A.9) and (3.1) from the main text to obtain (2.6). Given the public debt-to-GDP ratio,  $\frac{\Psi}{\beta} \frac{D_t}{P_{H,t} Y_t}$ , the government's flow budget constraint can be written as

$$\beta \left( \frac{\Psi_t}{\Psi} \right) \left( \frac{\Psi}{\beta} \frac{D_t}{P_{H,t} Y_t} \right) = \beta \left( \frac{1}{\Psi} + \iota \frac{\Psi_t}{\Psi} \right) \left( \frac{\Psi}{\beta} \frac{D_{t-1}}{P_{H,t-1} Y_{t-1}} \right) \frac{Y_{t-1}}{Y_t} \frac{P_{H,t-1}}{P_{H,t}} (1 - \theta_t) - \frac{T_t}{P_{H,t} Y_t}.$$

We linearize the flow constraint and denote  $\hat{d}_t$  the deviation of debt to GDP from steady state,  $\hat{t}_t$  the deviation of taxes to GDP from steady state, and  $\zeta$  the level of debt to GDP in steady state. We insert (A.9) in the linearized budget constraint to obtain (2.5).

## A.2 Extended model

Here we present details on the extended model which we estimate in Section 4. We provide the non-linear model equations, along with first order conditions, and details on the linearization. The steady state is the same across regimes and characterized by zero net inflation, purchasing power parity and zero default. However, we allow for non-zero public debt to GDP, as well as for non-zero net foreign assets to GDP in steady state.

**Household** preferences are now given by

$$E_0 \sum_{t=0}^{\infty} \beta_t \left( \log C_t - \eta_t \frac{H_t^{1+\varphi}}{1+\varphi} \right).$$

where the discount factor is endogenous and assumed to depend on the country's (aggregate) net foreign asset position, scaled by nominal output, in deviation from steady state,  $\zeta_{B^*}$ :

$$\beta_{t+1} = \beta \left( 1 + \alpha \left[ \frac{\mathcal{E}_t \tilde{B}_t^*}{P_{H,t} Y_t} - \zeta_{B^*} \right] \right)^{-1} \beta_t, \quad \beta_0 = 1.$$

Households maximize utility subject to the budget constraint stated in Section 4.1. We note that in equilibrium,  $B_t^* = \tilde{B}_t^*$ , and that  $B_t = 0$  is in zero net supply.  $\eta_t$  is a shock affecting the household's disutility of labour, which acts as a cost-push shock to firms.  $\alpha$  is a (small) positive constant, which induces stationarity to the model.

First order conditions are given by

$$\Psi_{B,t} = \frac{\beta_{t+1}}{\beta_t} E_t \frac{(C_{t+1})^{-1}}{(C_t)^{-1}} \frac{P_t}{P_{t+1}}, \quad \Psi_{B^*,t} = \frac{\beta_{t+1}}{\beta_t} E_t \frac{(C_{t+1})^{-1}}{(C_t)^{-1}} \frac{P_t}{P_{t+1}} \frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}$$

as well as the consumption leisure condition

$$\frac{W_t}{P_t} = \eta_t C_t H_t^\varphi.$$

As stated in the main text, we postulate the bond-prices to be affected by a “sovereign risk channel” as follows

$$\Psi_{B,t} = \nu_t (R_t)^{-1} E_t (1 - \chi \theta_{t+1}), \quad \Psi_{B^*,t} = \nu_t (R^*)^{-1} E_t (1 - \chi \theta_{t+1}).$$

In these expressions,  $\nu_t$  is a shock affecting bond prices directly, which we call a “private liquidity shock”.

Linearizing and combining the previous equations yields an Euler equation and an uncovered interest parity (UIP) condition<sup>1</sup>

$$c_t = E_t c_{t+1} - (r_t - E_t \pi_{t+1} + \chi E_t \theta_{t+1} + \nu_t - \alpha \hat{b}_t^*) \quad (\text{A.10})$$

$$r_t = E_t e_{t+1} - e_t. \quad (\text{A.11})$$

Note that the effective ex ante real interest rate depends on sovereign risk if  $\chi > 0$ , by the private sector liquidity shock  $\nu_t$ , and by the stock of net foreign assets—a positive stock of net foreign assets reduces the ex ante real interest rate, making the household more impatient. Moreover, the leisure-consumption trade-off becomes

$$w_t - p_t = c_t + \varphi h_t + \eta_t. \quad (\text{A.12})$$

We rewrite the household budget constraint as

$$\beta \frac{\Psi_{B^*,t}}{\beta} \frac{B_t^* \mathcal{E}_t}{P_{H,t} Y_t} + \frac{P_t C_t}{P_{H,t} Y_t} = (1 - \tau_t) + \frac{B_{t-1}^* \mathcal{E}_{t-1}}{P_{H,t-1} Y_{t-1}} \frac{P_{H,t-1}}{P_{H,t}} \frac{Y_{t-1}}{Y_t} \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} + \mu_t,$$

where we use that  $W_t H_t + \mathcal{Y}_t = W_t H_t + (\int_0^1 ((1 - \tau_t) P_{H,t}(j) Y_t(j) - W_t H_t(j)) dj) = P_{H,t} Y_t$  (see the firm's problem below), and that  $B_t = 0$  in equilibrium. Here,  $\tau_t$  denotes the sales-tax rate at time  $t$  applied to firms. As mentioned above, we allow for non-zero net foreign assets in steady state. At the same time, we still assume purchasing power parity in steady state. This implies  $P = P_H$  and thus (from the previous constraint) generally requires that  $C \neq Y$ . In the following, let  $\zeta_c := C/Y$ .<sup>2</sup> Linearization gives

$$\beta \hat{b}_t^* + \zeta_c (c_t - y_t + (p_t - p_{H,t})) = -\tilde{\tau}_t + \hat{b}_{t-1}^* + \zeta_{B^*} (\beta (\chi E_t \theta_{t+1} + \nu_{B,t}) + \Delta e_t - \pi_{H,t} - \Delta y_t) + \mu_t, \quad (\text{A.13})$$

where  $\tilde{\tau}_t$  denotes the (absolute) deviation of the sales tax rate  $\tau_t$  from steady state, and where we have linearized the bond price schedule for  $\Psi_{B^*,t}$  above to replace

$$-\log \left( \frac{\Psi_{B^*,t}}{\Psi_{B^*}} \right) = \chi E_t \theta_{t+1} + \nu_{B,t}.$$

**Intermediate good firms** now face the following problem:

$$\max_{P_{H,t}(j)} E_t \sum_{k=0}^{\infty} \xi^k \rho_{t,t+k} Y_{t,t+k}(j) [(1 - \tau_{t+k}) P_{H,t}(j) - W_{t+k}],$$

where

$$Y_{t,t+k}(j) = \left( \frac{P_{H,t}(j)}{P_{H,t+k}} \right)^{-\gamma} Y_{t+k}$$

<sup>1</sup>Here and below, we slightly abuse notation by giving the shock in the non-linear model the same name as the relative deviation of the shock from steady state.

<sup>2</sup>From the budget constraint, we see that  $\zeta_c = 1 - \tau + (1 - \beta) \zeta_{B^*}$ , where  $\tau$  is made explicit in the government's problem below (it is given by  $\tau = (1 - \beta) \zeta$ , where  $\zeta$  is public debt to GDP in steady state).

as before. The first order condition is given by

$$E_t \sum_{k=0}^{\infty} \xi^k \rho_{t,t+k} Y_{t,t+k}(j) \left[ (1 - \tau_{t+k}) P_{H,t}(j) - \frac{\gamma}{\gamma - 1} W_{t+k} \right].$$

Linearization gives

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \kappa (w_t - p_{H,t} - \tilde{\tau}_t / (1 - \tau)), \quad (\text{A.14})$$

where again  $\kappa := (1 - \xi)(1 - \beta\xi)/\xi$ . The remaining conditions of the firm's problem are as in the baseline model above, such that up to first order, output corresponds to working hours of the households

$$y_t = h_t. \quad (\text{A.15})$$

**Market clearing** requires the same condition to be satisfied as in the baseline model, except that i)  $C_t^*$  is allowed to be time varying and stochastic (the “foreign demand shock”) and ii) the steady state level for  $C^* \neq C$ . Rather, we have  $\zeta_{c^*} := C^*/Y = (1 - (1 - \omega)\zeta_c)/\omega$ .<sup>3</sup> Linearization gives

$$y_t = -\sigma(p_{H,t} - p_t) + (1 - \omega)\zeta_c c_t + \omega\zeta_{c^*}(\sigma q_t + c_t^*). \quad (\text{A.16})$$

Net exports to GDP are defined as in the baseline model above.

**The price of government debt** changes to

$$\Psi_t / \mathcal{E}_t = \varkappa_t \frac{E_t(1 + \iota\Psi_{t+1})(1 - \theta_{t+1}) / \mathcal{E}_{t+1}}{R^*},$$

where  $\varkappa_t$  is a shock affecting the price of government debt directly, which we call a “sovereign liquidity shock”. Linearization gives

$$i_t = (1 - \iota\beta)(r_t + E_t\theta_{t+1} + \varkappa_t) + \iota\beta E_t i_{t+1}, \quad (\text{A.17})$$

where we have used (A.9) and (A.11) as before. The budget constraint, stated in Section 4.1 can be written as

$$\beta \left( \frac{\Psi_t}{\Psi} \right) \left( \frac{\Psi}{\beta} \frac{D_t}{P_{H,t} Y_t} \right) + \tau_t = \beta \left( \frac{1}{\Psi} + \iota \frac{\Psi_t}{\Psi} \right) \left( \frac{\Psi}{\beta} \frac{D_{t-1}}{P_{H,t-1} Y_{t-1}} \right) \frac{Y_{t-1}}{Y_t} \frac{P_{H,t-1}}{P_{H,t}} (1 - \theta_t) + Z_t - \mu_t,$$

where  $Z_t$  is an exogenous (stochastic) transfer from abroad to the domestic government, called a “transfer shock”, and where  $\mu_t$  is the deficit shock as before (a lump-sum transfer to the domestic household). Note that in steady state,  $\tau = (1 - \beta)\zeta$ . Linearization gives

$$\beta \hat{d}_t = \hat{d}_{t-1} + \zeta \left( \beta \frac{1 - \iota}{1 - \iota\beta} i_t - \pi_{H,t} - \Delta y_t - \delta_t \right) - \tilde{\tau}_t - Z_t + \mu_t, \quad (\text{A.18})$$

<sup>3</sup>This follows from  $Y = (1 - \omega)C + \omega C^*$  in steady state, thus  $1 = (1 - \omega)\zeta_c + \omega\zeta_{c^*}$ .

where we have used (A.9) to replace the price of government debt by the yield on public debt to GDP. Lastly, we posit a policy rule for the tax rate equivalent to the one in our baseline model, such that

$$\tilde{\tau}_t = \psi \hat{d}_{t-1}, \quad (\text{A.19})$$

where the feedback parameter  $\psi$  may vary with the policy regime. Similarly, the policy for default is the same as before

$$\theta_t = \zeta^{-1} \theta \hat{d}_{t-1}, \quad (\text{A.20})$$

where  $\theta$  may vary with the policy regime.

**Equilibrium conditions** include rules for monetary policy ( $r_t = \phi_\pi \pi_{H,t}$  or  $e_t = 0$ ). The extended model can be summarized by equations (A.10)-(A.20), along with (A.6) and (A.7). This gives a system of 14 equations in the 14 unknowns

$$\{c_t, y_t, h_t, w_t, p_t, p_{H,t}, e_t, q_t, i_t, r_t, \hat{d}_t, \tilde{\tau}_t, \theta_t, \hat{b}_t^*\}.$$

There are exogenous processes for  $\{\mu_t, Z_t, \varkappa_t, \nu_t, \eta_t, c_t^*\}$ .

## B Closed-form solution of special case (Section 3.2)

Here we provide details on the closed-form solution of the special case which we study in detail in Section 3.2. In this case, we consider the baseline model, but let  $\iota \rightarrow 0$  and  $\xi \rightarrow 0$ . To solve the model we exploit the property that *Exit* and *Union Permanent* are absorbing states of the Markov chain. This allows us to solve the model backwards using the method of undetermined coefficients.

If  $\iota = 0$  and  $\xi = 0$ , the model collapses to

$$r_t = E_t \pi_{H,t+1} \quad (\text{B.1})$$

$$e_t = p_{H,t} \quad (\text{B.2})$$

$$\beta \hat{d}_t = (1 - \psi_{s_t}) \hat{d}_{t-1} + \zeta (\beta i_t - \pi_{H,t} - \theta_t) + \mu_t \quad (\text{B.3})$$

$$i_t = r_t + E_t \theta_{t+1} \quad (\text{B.4})$$

$$\theta_t = \zeta^{-1} \theta_{s_t} \hat{d}_{t-1} \quad (\text{B.5})$$

as well as  $y_t = q_t = 0$  and policy  $r_t = \phi_\pi \pi_{H,t}$  or  $e_t = 0$ .

**Target regimes.** In *Union Permanent*,  $e_t = 0$ , such that from (B.2)  $p_{H,t} = 0$  and therefore  $\pi_{H,t} = 0$ . Since default is not possible in this regime, and further regime change is ruled out,  $r_t = i_t = 0$  from (B.1) and (B.4). Debt to GDP evolves according to

$$\beta \hat{d}_t = (1 - \psi_{\text{UPer}}) \hat{d}_{t-1} + \mu_t,$$

and is mean-reverting provided  $\psi_{\text{UPer}} > 1 - \beta$  (which holds by assumption). Dynamics are identical in *Union Default*, except for the fact that

$$\begin{aligned} \beta \hat{d}_t &= (1 - \psi_{\text{UDef}}) \hat{d}_{t-1} - \zeta \theta_t + \mu_t \\ &= (1 - \psi_{\text{UDef}} - \theta) \hat{d}_{t-1} + \mu_t, \end{aligned}$$

where we have used (B.5). This is true because we assume *Union Default* to be purely transitory, such that expected default is equal to zero, thus  $i_t = 0$  also in this regime.

In *Exit*, both default and expected default are equal to zero, thus  $i_t = r_t$  from equation (B.4). By contrast, generally  $e_t = p_{H,t} \neq 0$  in this regime. The system (B.1)-(B.5) collapses to

$$\begin{aligned} \phi_\pi \pi_{H,t} &= E_t \pi_{H,t+1} \\ \beta \hat{d}_t &= (1 - \psi_{\text{Exit}}) \hat{d}_{t-1} + \zeta (\beta \phi_\pi - 1) \pi_{H,t} + \mu_t. \end{aligned}$$

It features one forward looking ( $\pi_{H,t}$ ), one backward looking variable ( $\hat{d}_t$ ). As can be easily checked, the system exhibits bounded (and determinate) dynamics to the extent that either i)  $\psi_{\text{Exit}} > 1 - \beta$  along with  $\phi_\pi > 1$  or ii)  $\psi_{\text{Exit}} < 1 - \beta$  along with  $\phi_\pi < 1$ , as in Leeper (1991).

A guess and verify approach yields for case i)

$$\begin{aligned} \pi_{H,t} &= 0 \\ \beta \hat{d}_t &= (1 - \psi_{\text{Exit}}) \hat{d}_{t-1} + \mu_t \end{aligned}$$

and for case ii)

$$\begin{aligned} \pi_{H,t} &= \frac{1 - \psi_{\text{Exit}} - \beta \phi_\pi}{\zeta (1 - \beta \phi_\pi) (1 - \psi_{\text{Exit}})} [(1 - \psi_{\text{Exit}}) \hat{d}_{t-1} + \mu_t] \\ \hat{d}_t &= \frac{\phi_\pi}{1 - \psi_{\text{Exit}}} [(1 - \psi_{\text{Exit}}) \hat{d}_{t-1} + \mu_t]. \end{aligned}$$

**Initial regime.** In *Union*, which is the initial regime of the Markov chain,  $p_{H,t} = 0$  and thus  $\pi_{H,t} = 0$  from equation (B.2). However, generally  $r_t \neq 0$  because of expected changes in inflation and nominal depreciation (equations (B.1) and (B.2)), and  $i_t \neq 0$  because of (in addition

to the variation in  $r_t$ ) expected outright default (equation (B.4)). Moreover, movements in  $i_t$  feed back into  $\hat{d}_t$  through equation (B.3).

We assume that  $\psi_{\text{Exit}} < 1 - \beta$  along with  $\phi_\pi < 1$ , such that inflation moves with the level of debt in *Exit*. By applying the law of iterated expectations we can then write equation (B.3) as

$$i_t = \left[ \varepsilon \frac{1 - \psi_{\text{Exit}} - \beta\phi_\pi}{\zeta(1 - \beta\phi_\pi)} + \delta\zeta^{-1}\theta \right] \hat{d}_t, \quad (\text{B.6})$$

where  $\varepsilon$  denotes the probability of moving to *Exit*, and  $\delta$  denotes the probability of moving to *Union Default*, see sequence (2.11) in the main. Insert this into (B.3)

$$\beta\hat{d}_t = (1 - \psi_{\text{Union}})\hat{d}_{t-1} + \zeta\beta i_t + \mu_t$$

and rearrange for  $\hat{d}_t$  to obtain (3.5) from the main text. Substitute back the result for  $\hat{d}_t$  into (B.6) to obtain (3.6) from the main text.

## C The generalized Phillips curve

Here we provide details on the derivation of the generalized Phillips curve, equation (3.7) in the main text. Recall that we consider a Calvo setup and denote with  $\xi_{\text{Exit}}$  the probability that a firm may not adjust its price in *Exit*, while denotes  $\xi$  this probability in all other regimes. Let  $\lambda$  be the probability of staying in *Union*, such that  $\varepsilon + \delta + \lambda = 1$ .

The firm maximization problem in *Union* is given by

$$\begin{aligned} \max_{P_{H,t}(j)} & \sum_{k=0}^{\infty} (\lambda\xi)^k E_t(\rho_{t,t+1} Y_{t,t+k}(j) [P_{H,t}(j) - W_{t+k}] \mid \text{Union}) \\ & + \sum_{i=1}^{\infty} \sum_{k=i}^{\infty} (\lambda\xi)^{i-1} \delta \xi^{k-i+1} E_t(\rho_{t,t+1} Y_{t,t+k}(j) [P_{H,t}(j) - W_{t+k}] \mid \text{U Def in } t+i) \\ & + \sum_{i=1}^{\infty} \sum_{k=i}^{\infty} (\lambda\xi)^{i-1} \varepsilon \xi_{\text{Exit}}^{k-i+1} E_t(\rho_{t,t+1} Y_{t,t+k}(j) [P_{H,t}(j) - W_{t+k}] \mid \text{Exit in } t+i) \end{aligned}$$

subject to the conventional demand constraints given in the main text. Here, expectations are conditional on still being in the first regime, or on having switched regimes at time  $t+i$ . Keeping track of the time of the switch is important, since it determines when the shift in rigidity occurs.

The first order condition can be written as

$$\begin{aligned}
0 &= \sum_{k=0}^{\infty} (\lambda\xi)^k E_t \left( \rho_{t,t+1} Y_{t,t+k}(j) \left[ \frac{P_{H,t}(j) P_{H,t-1}}{P_{H,t-1} P_{H,t+k}} - \frac{\gamma}{\gamma-1} \frac{W_{t+k}}{P_{H,t+k}} \right] \mid \text{Union} \right) \\
&+ \sum_{i=1}^{\infty} (\lambda\xi)^{i-1} \delta \xi^{1-i} \sum_{k=i}^{\infty} \xi^k E_t \left( \rho_{t,t+1} Y_{t,t+k}(j) \left[ \frac{P_{H,t}(j) P_{H,t-1}}{P_{H,t-1} P_{H,t+k}} - \frac{\gamma}{\gamma-1} \frac{W_{t+k}}{P_{H,t+k}} \right] \mid \text{U Def in } t+i \right) \\
&+ \sum_{i=1}^{\infty} (\lambda\xi)^{i-1} \varepsilon \xi_{\text{Exit}}^{1-i} \sum_{k=i}^{\infty} \xi_{\text{Exit}}^k E_t \left( \rho_{t,t+1} Y_{t,t+k}(j) \left[ \frac{P_{H,t}(j) P_{H,t-1}}{P_{H,t-1} P_{H,t+k}} - \frac{\gamma}{\gamma-1} \frac{W_{t+k}}{P_{H,t+k}} \right] \mid \text{Exit in } t+i \right).
\end{aligned}$$

We linearize the expressions inside the three sums running over  $k$  to obtain

$$\begin{aligned}
0 &= \frac{p_{H,t}^* - p_{H,t-1}}{1 - \beta\lambda\xi} - \sum_{k=0}^{\infty} (\beta\lambda\xi)^k E_t (m c_{t+k}^r + p_{H,t+k} - p_{H,t-1} \mid \text{Union}) \\
&+ \sum_{i=1}^{\infty} (\lambda\xi)^{i-1} \delta \xi^{1-i} \left( \frac{(\beta\xi)^i (p_{H,t}^* - p_{H,t-1})}{1 - \beta\xi} - \sum_{k=i}^{\infty} (\beta\xi)^k E_t (m c_{t+k}^r + p_{H,t+k} - p_{H,t-1} \mid \text{U Def in } t+i) \right) \\
&+ \sum_{i=1}^{\infty} (\lambda\xi)^{i-1} \varepsilon \xi_{\text{Exit}}^{1-i} \left( \frac{(\beta\xi_{\text{Exit}})^i (p_{H,t}^* - p_{H,t-1})}{1 - \beta\xi_{\text{Exit}}} - \sum_{k=i}^{\infty} (\beta\xi_{\text{Exit}})^k E_t (m c_{t+k}^r + p_{H,t+k} - p_{H,t-1} \mid \text{Exit in } t+i) \right),
\end{aligned}$$

where we write  $m c_t^r := w_t - p_{H,t}$  for brevity and  $P_{H,t}^* = P_{H,t}(j)$ , the latter using the fact that all resetting firms will choose the same reset price.

Next, we note that

$$\begin{aligned}
\frac{1}{1 - \beta\lambda\xi} + \frac{1}{1 - \beta\xi} \sum_{i=1}^{\infty} (\lambda\xi)^{i-1} \delta \xi^{1-i} (\beta\xi)^i + \frac{1}{1 - \beta\xi_{\text{Exit}}} \sum_{i=1}^{\infty} (\lambda\xi)^{i-1} \varepsilon \xi_{\text{Exit}}^{1-i} (\beta\xi_{\text{Exit}})^i \\
= \frac{(1 - \beta\xi)(1 - \beta\xi_{\text{Exit}}) + (1 - \beta\xi)\beta\varepsilon\xi_{\text{Exit}} + (1 - \beta\xi_{\text{Exit}})\beta\delta\xi}{(1 - \beta\lambda\xi)(1 - \beta\xi)(1 - \beta\xi_{\text{Exit}})} = \frac{1}{(1 - \beta\xi)\Lambda_1},
\end{aligned}$$

where  $\Lambda_1$  is defined as in the main text. This allows us to factor out  $p_{H,t}^* - p_{H,t-1}$ , leading to

$$\begin{aligned}
p_{H,t}^* - p_{H,t-1} &= (1 - \beta\xi)\Lambda_1 \{ \\
&\sum_{k=0}^{\infty} (\beta\lambda\xi)^k E_t (m c_{t+k}^r + p_{H,t+k} - p_{H,t-1} \mid \text{Union}) \\
&+ \sum_{i=1}^{\infty} (\lambda\xi)^{i-1} \delta \xi^{1-i} \sum_{k=i}^{\infty} (\beta\xi)^k E_t (m c_{t+k}^r + p_{H,t+k} - p_{H,t-1} \mid \text{U Def in } t+i) \\
&+ \sum_{i=1}^{\infty} (\lambda\xi)^{i-1} \varepsilon \xi_{\text{Exit}}^{1-i} \sum_{k=i}^{\infty} (\beta\xi_{\text{Exit}})^k E_t (m c_{t+k}^r + p_{H,t+k} - p_{H,t-1} \mid \text{Exit in } t+i) \}. \quad (\text{C.1})
\end{aligned}$$

We now write (C.1) recursively. In order to see how this works, assume that regime change occurs at time  $t+1$ . Consider the example of shifting to *Exit*. In this case, conditional on

the regime having changed, we obtain at  $t + 1$

$$p_{H,t+1}^* - p_{H,t} = (1 - \beta\xi_{\text{Exit}}) \sum_{k=0}^{\infty} (\beta\xi_{\text{Exit}})^k E_{t+1}(mc_{t+1+k}^r + p_{H,t+1+k} - p_{H,t} \mid \text{Exit in } t + 1)$$

and therefore, using the law of iterated expectations at time  $t$ ,

$$\begin{aligned} E_t(p_{H,t+1}^* - p_{H,t} \mid \text{Exit in } t + 1) \\ = (1 - \beta\xi_{\text{Exit}}) \sum_{k=0}^{\infty} (\beta\xi_{\text{Exit}})^k E_t(mc_{t+1+k}^r + p_{H,t+1+k} - p_{H,t} \mid \text{Exit in } t + 1). \end{aligned}$$

A similar equation holds for a shift to *Union Default*. Use this to rewrite (C.1) as

$$\begin{aligned} p_{H,t}^* - p_{H,t-1} &= \pi_{H,t} + (1 - \beta\xi)\Lambda_1 \{mc_t^r \\ &+ \frac{\delta\beta\xi}{1 - \beta\xi} [E_t(p_{H,t+1}^* - p_{H,t} \mid \text{U Def in } t + 1)] + \frac{\varepsilon\beta\xi_{\text{Exit}}}{1 - \beta\xi_{\text{Exit}}} [E_t(p_{H,t+1}^* - p_{H,t} \mid \text{Exit in } t + 1)] \\ &+ \beta\lambda\xi \left\{ \sum_{k=0}^{\infty} (\beta\lambda\xi)^k E_t(mc_{t+1+k}^r + p_{H,t+1+k} - p_{H,t} \mid \text{Union}) \right. \\ &+ \sum_{i=1}^{\infty} (\lambda\xi)^{i-1} \delta\xi^{1-i} \sum_{k=i}^{\infty} (\beta\xi)^k E_t(mc_{t+1+k}^r + p_{H,t+1+k} - p_{H,t} \mid \text{U Def in } t + 1 + i) \\ &\left. + \sum_{i=1}^{\infty} (\lambda\xi)^{i-1} \varepsilon\xi_{\text{Exit}}^{1-i} \sum_{k=i}^{\infty} (\beta\xi_{\text{Exit}})^k E_t(mc_{t+1+k}^r + p_{H,t+1+k} - p_{H,t} \mid \text{Exit in } t + 1 + i) \right\}. \end{aligned}$$

Focus on the last three lines of this expression, more precisely on the sums multiplying  $\beta\lambda\xi$ . One can see that these sums correspond to the ones in (C.1), only at time  $t + 1$  and with a conditional time- $t$  expectations operator in front. Because (C.1) is conditional on being in *Union* at time  $t$ , we can write

$$\begin{aligned} p_{H,t}^* - p_{H,t-1} &= \pi_{H,t} + \beta\lambda\xi E_t(p_{H,t+1}^* - p_{H,t} \mid \text{Union}) + (1 - \beta\xi)\Lambda_1 \{mc_t^r \\ &+ \frac{\delta\beta\xi}{1 - \beta\xi} [E_t(p_{H,t+1}^* - p_{H,t} \mid \text{U Def})] \\ &+ \frac{\varepsilon\beta\xi_{\text{Exit}}}{1 - \beta\xi_{\text{Exit}}} [E_t(p_{H,t+1}^* - p_{H,t} \mid \text{Exit})] \}, \quad (\text{C.2}) \end{aligned}$$

where we have omitted the “in  $t + i$ ” because all expectations are now conditional on the shift occurring (or not occurring) at time  $t + 1$ . In a last step, we use a standard property of Calvo pricing, which is that

$$\pi_{H,t} = (1 - \xi_{\text{Exit}})(p_{H,t}^* - p_{H,t-1}), \quad \pi_{H,t} = (1 - \xi)(p_{H,t}^* - p_{H,t-1}),$$

the first term in *Exit*, the second term in all other regimes. Insert this into (C.2) and rearrange

to obtain the final expression

$$\pi_{H,t} = \beta [\lambda E_t(\pi_{H,t+1}|\text{Union}) + \delta \Lambda_1 E_t(\pi_{H,t+1}|\text{U Def}) + \epsilon \Lambda_2 E_t(\pi_{H,t+1}|\text{Exit})] + \frac{(1 - \beta\xi)(1 - \xi)}{\xi} \Lambda_1 m c_t^r,$$

where we define

$$\Lambda_2 = \frac{\xi_{\text{Exit}}}{\xi} \frac{1 - \xi}{1 - \xi_{\text{Exit}}} \frac{1 - \beta\xi}{1 - \beta\xi_{\text{Exit}}} \Lambda_1$$

as in the main text.

## D Data Appendix

The frequency of all data used is quarterly. The data has been obtained in August 2015.

**Sovereign bond yields** Long-term interest rates for convergence purposes. Reference area: Greece, Italy, Ireland, Spain and Germany. Spreads are computed as differences in yields (all vis-à-vis Germany). Quarterly data are obtained by taking averages of monthly data. Source: ECB Statistical Data Warehouse.

*<http://sdw.ecb.europa.eu>*

**Private sector yields** MFI interest rate statistics. Reference area: Greece and Germany. Credit and other institutions (MFI except MMFs and central banks); Balance sheet item: Deposits with agreed maturity; Original maturity: Up to 1 year; Amount category: Total ; BS counterpart sector: Non-Financial corporations and Households; IR business coverage: New business. Spreads are computed as differences in yields. Source: ECB Statistical Data Warehouse.

*<http://sdw.ecb.europa.eu>*

**Real GDP Growth** Real GDP growth rates are computed as the difference between GDP growth rates in Greece and Germany. For both countries we obtain GDP at market prices, Chain linked volumes, reference year 2005. Source: ECB's Statistical pocket book, Section 11.3.

*<http://sdw.ecb.europa.eu>*

**Consumer Price Inflation** Harmonized indexes of consumer prices. CPI inflation is computed as the difference between CPI growth rates in Greece and Germany. For both countries we obtain HICP data as 'prc hicp midx96' from Eurostat. We adjust the data for seasonal effects before computing growth rates. Source: Eurostat.

*<http://epp.eurostat.ec.europa.eu>*

**Primary surplus** This series is computed as the sum of Net Lending in units of GDP and Interest, payable, in units of GDP. Both are taken from the Quarterly non-financial accounts for general government [gov\_q\_ggnfa]. Source: Eurostat.

*<http://epp.eurostat.ec.europa.eu>*

**Transfers** We compute transfers in units of GDP from the two time series Interest, payable, in units of GDP (see item Primary surplus above) and the sovereign yield spread (see item Sovereign bond yields above). The (model-implied) quarterly interest payment to GDP (which is the interest payment that would be implied by market interest rate)

is given by  $\zeta \cdot \text{sovereign yield spread}/4$ , where  $\zeta$  measures the debt-to-quarterly-GDP ratio (see main text). Transfers are thus given by the difference between actual interest payments to GDP and market-rate implied interest payments to GDP: ‘Transfer =  $\zeta \cdot \text{sovereign yield spread}/4$  - Interest, payable, in units of GDP’.

**Further adjustments** A few further adjustment are required in order to make the data model consistent. Annualized data are divided by four to obtain quarterly data (Sovereign bond yields and Private sector yields). We correct the primary surplus to GDP ratio for its model-implied value in steady state, given by  $(1 - \beta)\zeta$ .

## E Additional Figures

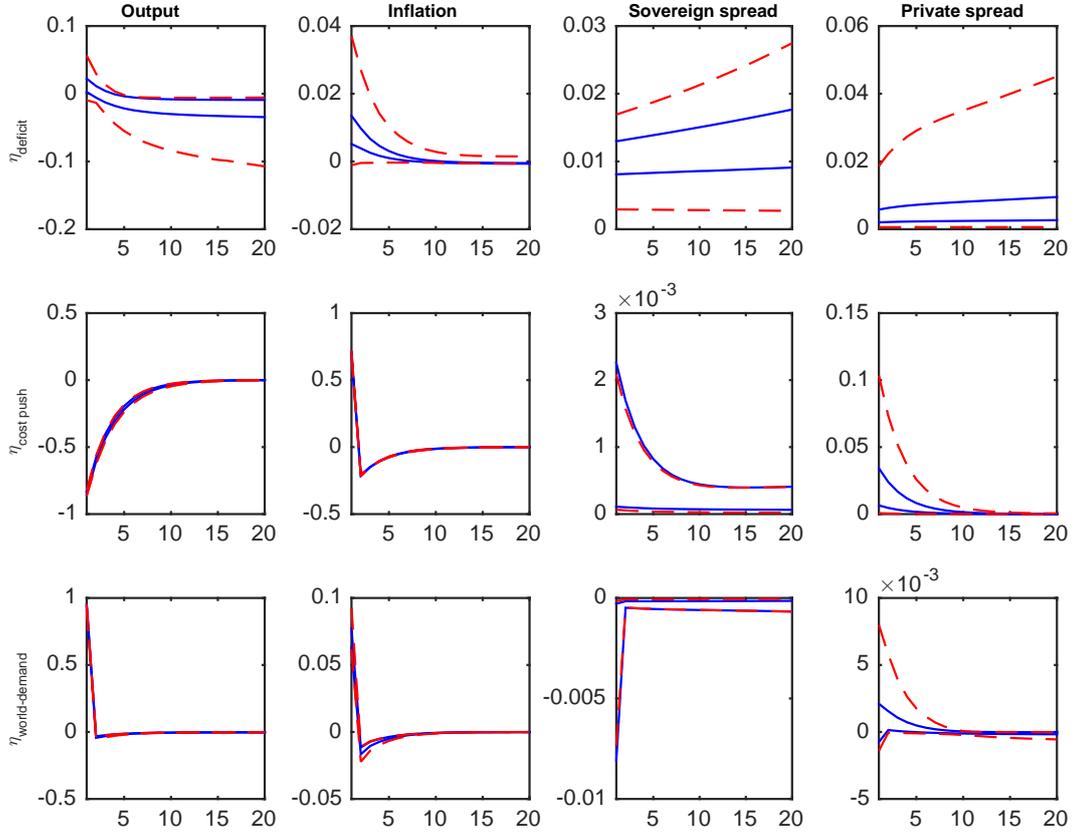
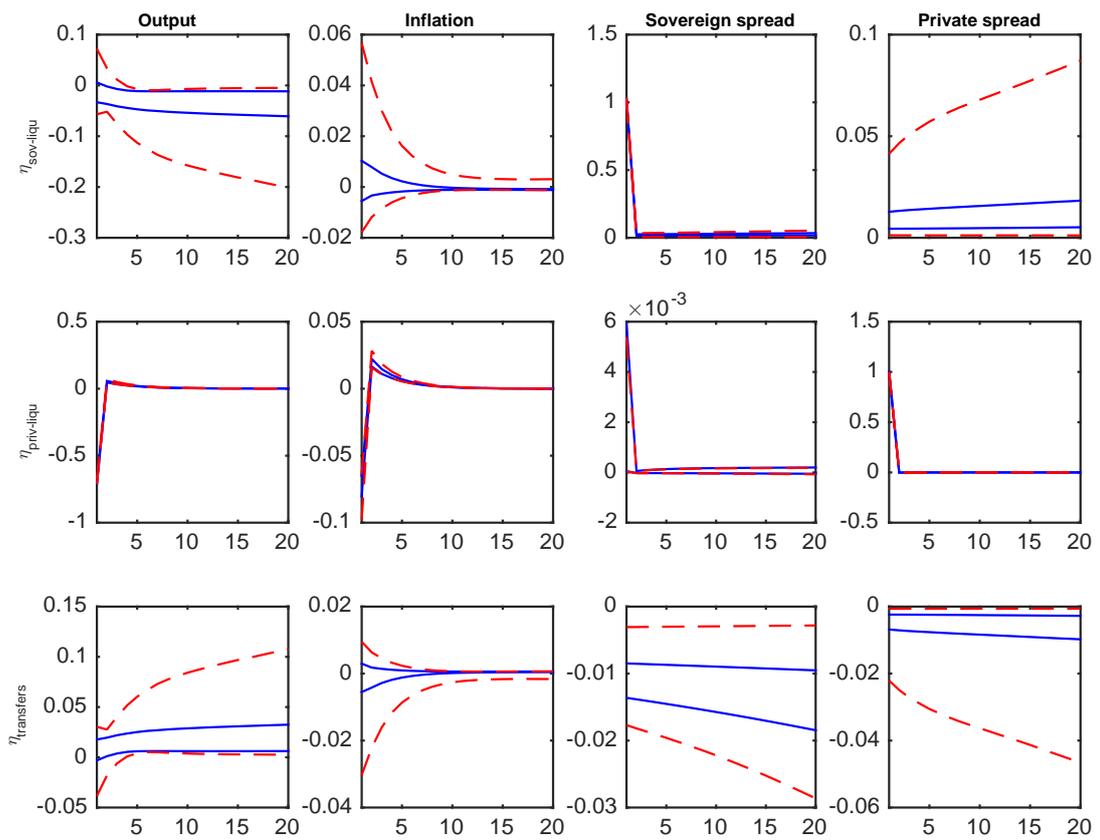


Figure E.1: Impulse responses of selected variables, given prior (dashed) and posterior (solid) distributions of model parameters. Notes: lines indicate 98% probability bands while drawing from the distributions of  $\epsilon, \delta, \chi$  and  $\xi_{\text{Exit}}$ ; shocks are normalized to one percent.



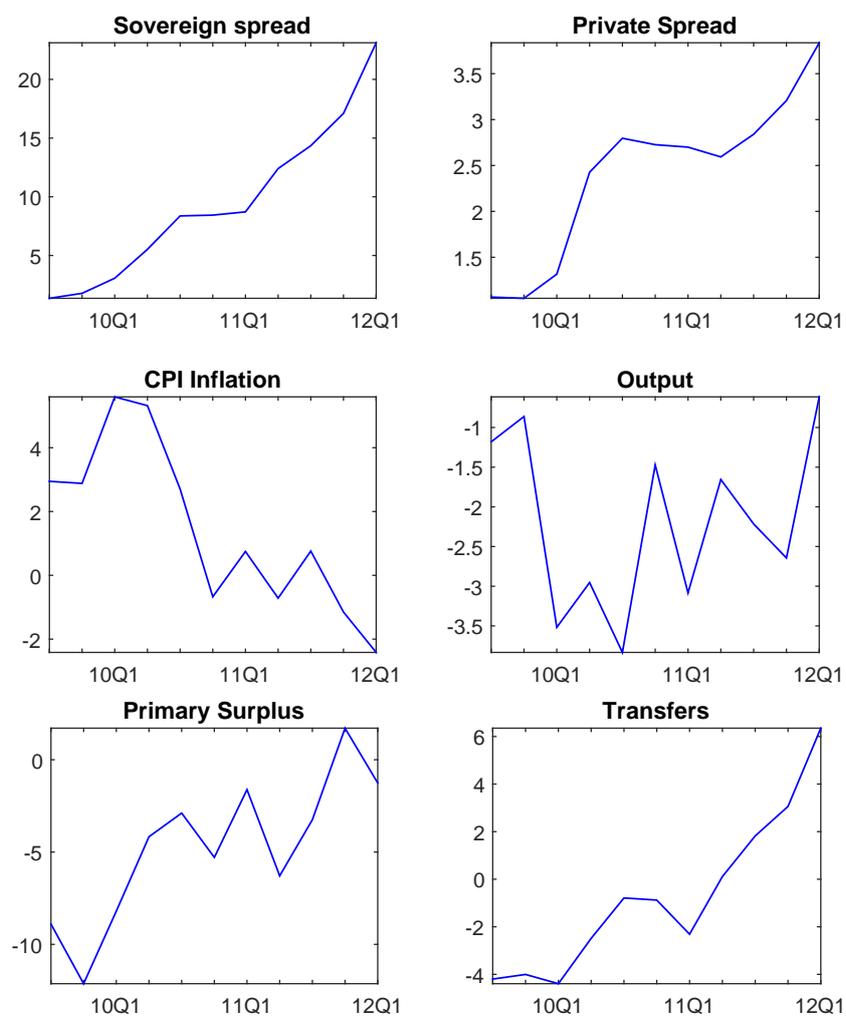


Figure E.3: Greek time-series data 2009Q3–2012Q1. Notes: vertical axes measure percent/percentage points; spreads (annualized), inflation (CPI-based, annualized), and output growth all measured relative to Germany; primary surplus is measured relative to GDP; transfers are computed as difference between market interest rates and actual interest payments.

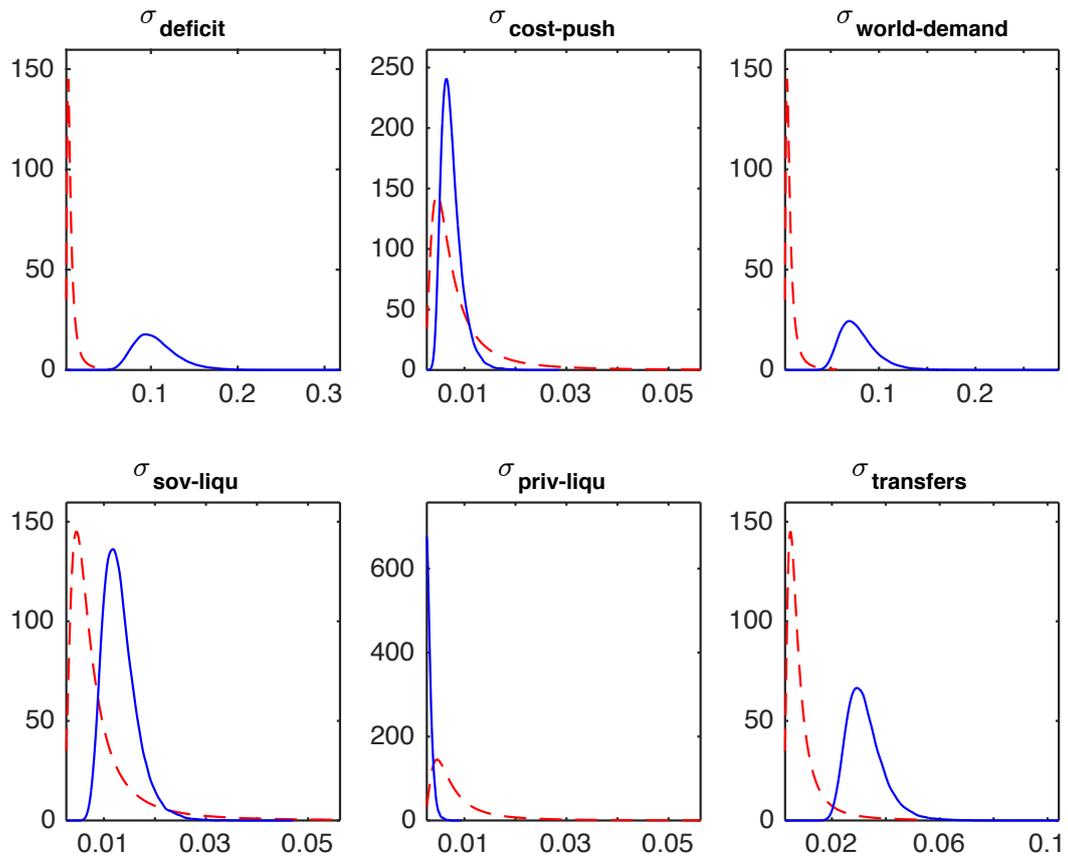


Figure E.4: Prior (dashed) vs. Posterior (solid) distribution of standard errors of shocks.

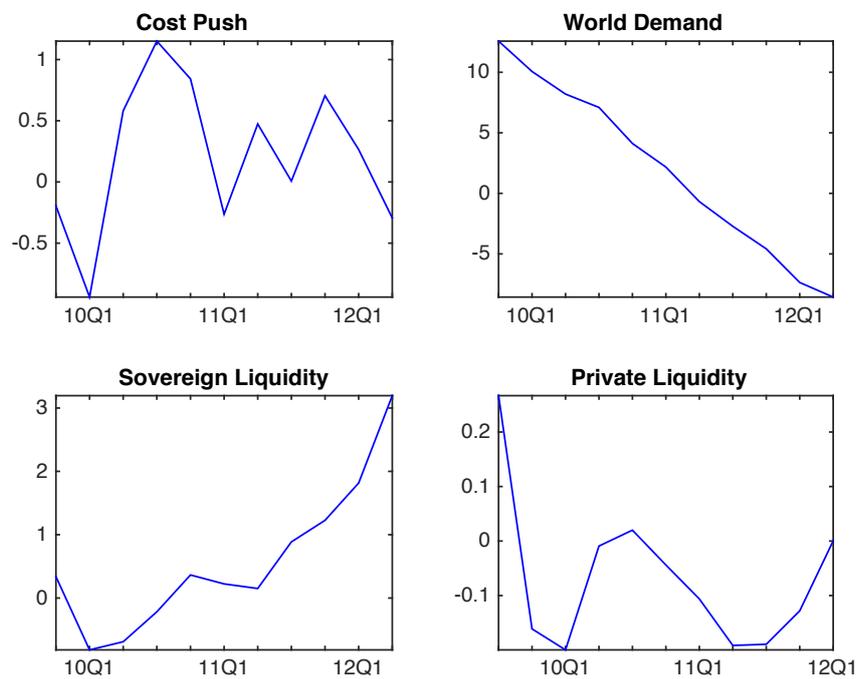


Figure E.5: Estimated sequence of unobserved shocks 2009Q1–2012Q1. Note: shock sequences are obtained by applying Kalman smoother at the posterior mean; vertical axes measure percent.