Exit expectations and debt crises in currency unions?

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Abstract

Membership in a currency union is not irreversible. Exit expectations may emerge during sovereign debt crises, because exit allows countries to reduce their liabilities through a currency redenomination. As market participants anticipate this possibility, sovereign debt crises intensify. 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 currency unions 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.

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

Jel codes: E52, E62, F41

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1 Introduction

Countries may join, but also exit currency unions, and 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).

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 the possibility of exit and currency redenomination impact the dynamics of sovereign debt crises? To address this question, we develop a model of a small open economy which is (initially) operating within a currency union. We assume that the government cannot commit to repaying its debt obligations in all states of the world. As sovereign default looms, the country experiences a sovereign debt crisis: a vicious circle of ever rising debt levels and sovereign yields. Moreover, the country may exit the currency union at any time, and in the process convert exiting liabilities at par value into a new currency. Market participants are fully aware of this possibility and ask for a redenomination premium, because they expect the new currency to depreciate. Expected depreciation after exit is larger, the more severe the sovereign debt crisis, because it is through redenomination and depreciation that the health of public finances can be restored.

Formally, we specify policies through simple feedback rules, which we permit to change over time in a way consistent with agents' expectations. Transitions are governed by a Markov

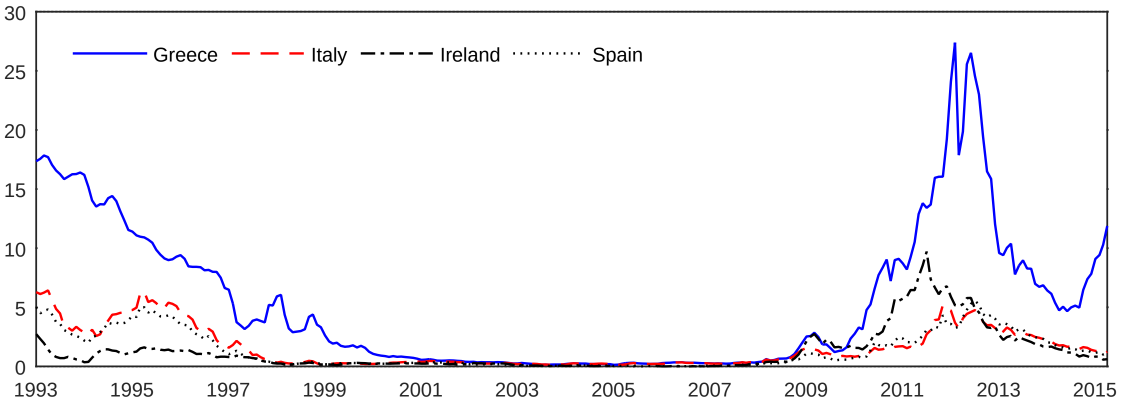

Figure 1: Interest rate spread vis-à-vis Germany for selected euro-area countries (percentage points). Data: monthly observations (1993M1–2015M4) for long-term interest rates for convergence purposes; source: ECB.

chain, such that exit and default are determined according to exogenous probabilities. Upon exit monetary policy is expected to be "passive", thereby accommodating an "active" fiscal policy (Leeper, 1991). As a result, the initial price level and, importantly, 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.[1] Hence, investors suffer losses upon exit which are proportional to outstanding government debt, such that redenomination premia prior to exit fluctuate endogenously over time.

In terms of methodological contribution, two aspects of our analysis are noteworthy. First, our model builds on the standard New Keynesian small open-economy framework à la Galí and Monacelli (2005), but features—as part of the equilibrium process—changing exchange-rate regimes. While New Keynesian models are frequently used to study the properties of alternative exchange-rate regimes, the possibility of regime change and the expectations thereof are commonly ignored, even though changing policy regimes have been analyzed in other contexts (Bianchi, 2013; Davig and Leeper, 2007a).[2] Second, because our model exhibits a high degree of tractability, we are able to obtain a number of closed-form results and yet,

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[1] For the fiscal theory in an open-economy context, see Woodford (1996), Sims (1997), Bergin (2000), Dupor (2000) and Daniel (2001). Our regime switching model builds on these contributions to the extent that the fiscal theory becomes operative after exit. Yet our focus is on the spillovers of the exit regime on the equilibrium outcome while the economy still operates in the currency union. Bianchi and Melosi (2014) rely on a similar mechanism, yet in a closed-economy context, as they explain the lack of disinflation in ths US during the Great Recession. Uribe (2006) studies sovereign default in a fiscal-theory environment.

[2] See also Bianchi and Ilut (2014); Davig and Leeper (2007b, 2011). These authors put forward models where monetary and fiscal policy rules change over time. Andolfatto and Gomme (2003) consider changes in money-growth rules under imperfect information. All these studies analyze closed-economy models.

as we demonstrate below, it is possible to interpret actual time series through the lens of (an extended version of) our model. However, these benefits come at a cost: because regime change is exogenous, our model is silent on why exit or default take place to begin with.

Our focus is therefore on how *expectations* of exit and default impact equilibrium dynamics within the New Keynesian open-economy model. Here we establish two results. First, exit expectations reinforce the adverse dynamics of a sovereign debt crisis while the country still operates within the currency union. Such a crisis arises if public debt is high and fiscal policy fails to generate sufficiently high budget surpluses, for given beliefs of a regime change. Beliefs about regime change matter, because they determine—for given levels of debt—the size of redenomination (and default) premia which, in turn, impact public finances adversely. As a result, a sovereign debt crisis is reinforced—or may even be caused—by an adverse shift in beliefs about exit. The effect of such a shift is stronger the more monetary policy is expected to tolerate inflation after exit in order to revalue the debt stock.[3]

Second, exit expectations which emerge during a sovereign debt crisis harm macroeconomic stability more generally. If public debt is high, expectations about exit drive up interest rates, not only for the sovereign, but also for private borrowers. This, in turn, 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. As a result, competitiveness deteriorates, leading to a further drop in economic activity. Importantly, in order to establish these results we permit the frequency of price adjustment to change with exit. This gives rise to a generalized Phillips curve. Here we find that, unless inflation moves one-for-one with the nominal exchange rate upon exit, exit expectations induce public debt and deficits to have stagflationary effects on the economy.

By way of contrast, if exit is ruled out, public debt and deficits are neutral in the baseline version of the model. Importantly, this is true even if there are expectations about outright default. Thus, expectations about exit and outright default affect the economy very differently in our analysis. Debt and deficits become recessionary in the presence of expectations about outright default, once we assume that sovereign default premia spill over into the private sector and impact borrowing conditions adversely (Bocola, 2015; Corsetti et al., 2013a), or

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[3] Note that our model does not feature full-fledged self-fulfilling crises, because we assume that probabilities of regime change are exogenous. Drazen and Masson (1994) consider a stylized two-period model in which exchange rate regimes may change depending on both the credibility of policy makers and the state of the economy. Calvo (1988) and Cole and Kehoe (2000) are classic references for self-fulfilling debt crises in the context of outright default. 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 expectations about regime change destabilize an existing regime (Flood and Garber, 1984; Krugman, 1979).

once we assume taxes to be distortionary. Yet, even in this case, default and exit expectations generally 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 arguably 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, and discussions of Greece exiting the Euro area started to look serious.[4] 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. Moreover, exit expectations account for about some ten percent of the output collapse as well as for a sizeable part of the (lack of) real exchange rate adjustment during our sample period. Overall, we thus find that the Greek crisis intensified considerably because of exit expectations.

In our analysis, we consider outright default and exit as alternative outcomes of a sovereign debt crisis in a currency union. 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 practice in the euro area (Chamon et al., 2015).[5] We also note that our analysis reestablishes—within the New Keyensian framework—two results of earlier work on currency crises, namely that expected devaluation may raise the refinancing cost of governments (Obstfeld, 1994) and induce a loss in competitiveness due to forward-looking price setting behaviour (Obstfeld, 1997).

Moreover, our paper relates to work which accounts for important aspects of 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

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[4] The term "Grexit" has been widely used only since February 2012 (Buiter and Rahbari, 2012); around that time the German Ifo-think tank prepared a report on "Greece's exit from European Monetary Union" (Born et al., 2012). Still, the possibility of a Greek exit from the euro area has been discussed earlier (see, for instance, Feldstein, 2010). Shambaugh (2012) reports evidence on exit expectations from online betting markets.

[5] 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.

CDS spreads, 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.

Finally, we stress that there are a number of influential studies on how government debt can be or has been reduced through inflation. On the theory side, we mostly borrow from the fiscal theory of the price level (as developed in Cochrane, 2001; Sims, 2013; Woodford, 1995). On the empirical side, Reinhart and Sbrancia (2011) provide an account of how advanced economies have actually relied on inflation to rebase outstanding nominal liabilities. Hilscher et al. (2014) study this possibility for the US as of today, and conclude that it is unlikely that future inflation will contribute significantly to a reduction in the US debt-to-GDP ratio.

The remainder of the paper is organized as follows. Section 2 presents the baseline model. Section 3 develops our results regarding the destabilizing effect of exit expectations. We discuss several model extensions as well as details and results of the estimation of the model in Section 4. Section 5 concludes.

2 The model

We consider 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.[6] 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 nominal debt 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. Importantly, in order to analyze the effect of exit expectations, we permit policy rules to change over time in a way consistent with agents' expectations. Formally, we draw on recent contributions which analyze discrete changes in structural parameters as well as in the conduct of policy within Markov-switching linear rational expectations models (Bianchi, 2013; Davig and Leeper, 2007a). This framework is well suited to analyze the extent to which market beliefs regarding regime change impact equilibrium outcomes before actual regime change

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[6] 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).

takes place.

In what follows, we outline the structure of the baseline model which features complete international financial markets, lump-sum taxation, one-period government debt and abstracts from spillovers of sovereign risk into the private sector. We use the baseline model to illustrate how exit expectations impact macroeconomic dynamics and contrast their effects to those of default expectations. The mechanisms which we identify remain operative, once we relax several simplifying assumptions in our empirical analysis below.

2.1 Setup

The household problem is standard and not directly affected by the possibility of regime change. The 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 φ^{-1} parameterizes the Frisch elasticity of labor supply. $E_0(\cdot)$ is the expectation operator which accounts for uncertainty due to fundamental shocks as well as possible changes of the policy regime.

Consumption is a composite of goods produced at Home, $C_{H,t}$, and imports, $C_{F,t}$, defined as follows

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

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

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

where $\gamma > 1$ measures the elasticity of substitution. $P_{H,t} = \left[\int_0^1 P_{H,t}(j)^{1-\gamma} dj \right]^{\frac{1}{1-\gamma}}$ and $P_{F,t} = \left[\int_0^1 P_{F,t}(j)^{1-\gamma} dj \right]^{\frac{1}{1-\gamma}}$ correspond to the price indices for goods produced at home and imported from abroad, respectively. $P_t = \left[(1-\omega) P_{H,t}^{1-\sigma} + \omega P_{F,t}^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$ denotes the consumer price index.

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

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

where W_t denotes the nominal wage rate and $\mathcal{Y}_t = \int_0^1 \mathcal{Y}_t(j) dj$ are aggregate firm profits. T_t are taxes collected by the government in a lump-sum manner and Ξ_{t+1} is a portfolio of state-contingent assets traded on international financial markets. Finally, $\rho_{t,t+1}$ is the one-period nominal stochastic discount factor. For future reference we define the nominally risk-free interest rate as the yield on a bond which pays one unit of *domestic currency* in all states of the world: $R_t \equiv 1/\{E_t \rho_{t,t+1}\}$, and say this bond is issued under *domestic law* (see below). Households in the rest of the world face a symmetric problem such that in equilibrium, complete risk sharing ties relative consumption to the real exchange rate (see, for instance, Chari et al., 2002). Formally, using $\mathcal{E}_t$ to denote the nominal exchange rate—the price of one unit of foreign currency in terms of domestic currency—and an asterisk to denote variables in the rest of the world, we define the real exchange rate as the price of foreign consumption in terms of domestic consumption: $Q_t = \mathcal{E}_t P^*/P_t$. Assuming symmetric initial conditions across the two regions implies

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

Firms operate in a monopolistically competitive environment and rely on a linear production technology: $Y_t(j) = H_t(j)$. Moreover, while we assume that firms face price adjustment frictions à la Calvo, we permit the frequency of price adjustment to change with the monetary-policy/exchange-rate regime. This accommodates concerns that the Calvo parameter is not invariant vis-à-vis such fundamental policy changes and, hence, that there might be a structural break in the Phillips curve. In our rational expectations model, firms are fully aware of these complications.

Formally, at any time t, a resetting firm j chooses price $P_{H,t}(j)$ to satisfy the following objective

$$\max E_t \sum_{k=0}^{\infty} \left(\prod_{i=0}^{k} \xi_{\varsigma_{t+i}} \right) \rho_{t,t+k} \mathcal{Y}_{t+k}(j).$$

In this expression, $\xi_{\varsigma_{t+i}}$ is the per-period probability of not being able to reset a posted price. It is indexed to the policy regime in place at time $t+i$ by variable ς_{t+i}, the evolution of which is specified below. Prices are sticky in producer currency and the law of one price holds at the level of varieties. $\mathcal{Y}_{t+k}(j) = Y_{t,t+k}(j)(P_{H,t}(j) - W_{t+k})$ denotes profits in period $t+k$. Here $Y_{t,t+k}(j)$ is domestic and import demand for variety j at time $t+k$, given by[7]

$$Y_{t,t+k}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t+k}} \right)^{-\gamma} \left(\frac{P_{H,t+k}}{P_{t+k}} \right)^{-\sigma} \left[(1-\omega) C_{t+k} + \omega Q_{t+k}^{\sigma} C^* \right].$$

We define aggregate working hours as $H_t = \int_0^1 H_t(j)dj$ which—up to a factor capturing price dispersion—are linear in aggregate domestic output $Y_t = \int_0^1 Y_t(j) P_{H,t}(j)/P_{H,t} dj$.

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[7] 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).

The fiscal authority sells nominal debt to international investors. Its flow budget constraint is given by

$$(I_t)^{-1}D_t = D_{t-1}(1-\theta_t) - T_t.$$

Here, I_t denotes the gross yield of nominal government debt and D_{t-1} is debt which comes due in period t. 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 $\theta_t \in [0,1]$, which depends on the policy regime currently in place (see below).

International investors are risk neutral such that the absence of arbitrage possibilities requires the following condition for gross yields of government debt to be satisfied

$$(I_t)^{-1} = E_t\left((1-\theta_{t+1})\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}\right)(R^*)^{-1}.$$

Here, R^* is the opportunity cost of funds for international investors, namely, the nominal yield on a bond which pays one unit of *foreign currency* in all states of the world—we say it is issued under *foreign law*. When the domestic economy is part of a currency union, the currency denomination of foreign and domestic law securities coincides: both are issued in the common currency. By contrast, whenever the domestic economy is operating an independent monetary policy, assets issued under domestic (foreign) law are denominated in domestic (foreign) currency. By the same token, if exit from a currency union is possible, the law under which assets are issued cannot be ignored, as the currency in which they pay off is contingent on whether the economy remains part of the currency union in the future.[8]

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

2.2 Equilibrium with changing policy regimes

We conduct our analysis within a Markov-switching linear rational expectations (MS-LRE) model. For this purpose, we first specify the Markov chain which determines the evolution of policy regimes over time. In a second step we characterize the policy regime in terms of linear policy rules, and present the linearized equilibrium conditions which describe the behaviour of the private sector. In a last step, we define the equilibrium. Throughout we refer to variables in terms of (log-)deviations from steady state using lower-case letters. A lower-case letter

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[8] 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, Buiter 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 (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).

with a hat indicates deviations from steady state measured in percentage points of steady-state output. The steady state is assumed to be independent of policy regimes. There is no outright default and zero inflation in steady state and purchasing power parity holds.

Policy regimes are governed by the Markov chain $\{\varsigma_t\}$, which consists of the four states:

$$\varsigma_t \in \{Union,\ Union\ Default,\ Union\ Permanent,\ Exit\}.$$

Regimes differ in terms of parameters, as well as in terms of their (expected) duration. Formally, we define the transition matrix $\mathcal{P} = [\mathcal{P}_{lm}] = [Prob(\varsigma_t = m; \varsigma_{t-1} = l)]$ with

$$\mathcal{P} = \begin{pmatrix} \lambda & \delta & 0 & \epsilon \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix},$$

where $\epsilon \in [0,1]$, $\delta \in [0,1]$ and $\lambda := 1 - \epsilon - \delta$ denote the transition probabilities between policy regimes. Assuming $\varsigma_0 = Union$, we represent the sequence of regime transitions as follows

$$\begin{tikzcd} & Union\ Default \arrow[r, "1"'] & Union\ Permanent_{\circlearrowleft 1} \\ Union_{\circlearrowleft \lambda} \arrow[ur, "\delta"'] \arrow[dr, "\epsilon"] & & \\ & Exit_{\circlearrowleft 1}. & \end{tikzcd}$$

Hence, initially the economy is part of a currency union. *Union* persists with probability $\lambda = 1 - \epsilon - \delta$, where δ denotes the probability of moving to *Union Default* in the next period. As specified further below, a haircut on government debt is applied in this regime. Immediately thereafter the economy moves to *Union Permanent* for good: further regime change is ruled out. By contrast, ϵ denotes the probability of moving to *Exit*, that is, of leaving the currency union and subsequently operating an independent monetary policy. We assume that, just like *Union Permanent*, *Exit* is an absorbing state of the Markov chain.[9]

We specify policies in terms of simple rules and parameterize how they change across policy regimes. The government raises lump-sum taxes in order to service debt as follows

$$\hat{t}_t = \psi_{\varsigma_t} \hat{d}_{t-1} - \mu_t. \tag{2.1}$$

Here, μ_t denotes a "deficit shock", a one-time transfer of resources from the government to the representative household. Rules of this type have been popularized by Leeper (1991) and

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[9] 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.

are also recently used to characterize fiscal policy in the context of a sovereign debt crisis (e.g., Lorenzoni and Werning, 2013). The parameter ψ_{ς_t} captures the fiscal capacity of the country and/or its willingness to raise taxes in response to a build up of public debt. It varies across policy regimes. We do not restrict this parameter in regimes *Union* and *Exit*, but require $\psi_{\text{Union Default}} > 1-\beta$ as well as $\psi_{\text{Union Permanent}} > 1-\beta$. In the terminology of Leeper (1991), fiscal policy is "passive" in these regimes, as taxes are sufficiently responsive to debt.[10] Similarly, we posit a simple feedback rule for outright default

$$\theta_t = \zeta^{-1}\theta_{\varsigma_t}\hat{d}_{t-1}, \tag{2.2}$$

such that default only takes place in regimes where $\theta_{\varsigma_t} > 0$. Here parameter θ_{ς_t} captures the haircut applied to government debt in excess of its steady-state level. We allow for default in *Union Default*, such that $\theta_{\text{Union Default}} \geq 0$, and rule out default in all other regimes. Turning to monetary policy, we specify the following rule

$$\mathbb{1}_{\varsigma_t} e_t + (\mathbb{1}_{\varsigma_t} - 1)(r_t - \phi_\pi \pi_{H,t}) = 0. \tag{2.3}$$

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. In the second case, the central bank follows a Taylor-type rule which targets producer price inflation, with a feedback coefficient $\phi_\pi \geq 0$. Note that our assumptions regarding *Exit* imply that, in the period of exit, domestic prices (as well as 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 upon exit.

We close the model by describing linearized equilibrium conditions which determine the behaviour of the private sector (see Section 2.1). Appendices A and B provide details on the derivation. Using $\varpi := 1 + \omega(2-\omega)(\sigma - 1)$, we obtain a dynamic IS relation:

$$y_t = E_t y_{t+1} - \varpi(r_t - E_t \pi_{H,t+1}). \tag{2.4}$$

Under complete international financial markets output is tied to the real exchange rate q_t,

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[10] Intuitively, given that *Union Permanent* is an absorbing state of the Markov chain, for equilibrium to exist it is required that fiscal policy ensures intertemporal solvency in this regime (see below the definition of stability). Hence, strictly speaking, it is only required that $\psi_{\text{Union Permanent}} > 1-\beta$ for equilibrium to exist, given that *Union Permanent* is an absorbing state of the Markov chain. By contrast, *Union Default* is purely transitory such that the size of $\psi_{\text{Union Default}}$ does not impact equilibrium dynamics and stability. For simplicity, then, we restrict it to be the same as in *Union Permanent*.

the price of foreign consumption in terms of domestic consumption

$$(1-\omega)y_t = \varpi q_t, \tag{2.5}$$

$$q_t = (1-\omega)(e_t - p_{H,t}). \tag{2.6}$$

In introducing the firms' problem above, we explicitly considered the possibility that the frequency of price setting changes with a change in the monetary-policy/exchange-rate regime. Given our assumptions regarding regime transitions, this implies that parameter ξ_{Union} may differ from ξ_{Exit}.[11] We thus obtain a generalized New Keynesian Phillips curve for *Union*:

$$\begin{aligned}\pi_{H,t} &= \beta\left[\lambda E_t(\pi_{H,t+1}|\text{Union}) + \delta\Omega_1 E_t(\pi_{H,t+1}|\text{U Def}) + \epsilon\Omega_2 E_t(\pi_{H,t+1}|\text{Exit})\right] \\ &\quad +\kappa\left(\varphi + \varpi^{-1}\right)\Omega_1 y_t, \end{aligned} \tag{2.7}$$

where $\kappa := (1-\beta\xi)(1-\xi)/\xi$. The two factors Ω_1 and Ω_2 are given by

$$\begin{aligned}\Omega_1 &= \frac{(1-\beta\lambda\xi)(1-\beta\xi_{\text{Exit}})}{(1-\beta\xi)(1-\beta\xi_{\text{Exit}}) + (1-\beta\xi)\beta\epsilon\xi_{\text{Exit}} + (1-\beta\xi_{\text{Exit}})\beta\delta\xi} \\ \Omega_2 &= \frac{\xi_{\text{Exit}}}{\xi}\frac{1-\xi}{1-\xi_{\text{Exit}}}\frac{1-\beta\xi}{1-\beta\xi_{\text{Exit}}}\Omega_1.\end{aligned}$$

In expression (2.7), operator $E_t(\cdot|\cdot)$ denotes the expectation conditional on a particular regime being in place in the next period. In all other regimes, the Phillips curve is standard:

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \kappa_{\varsigma_t}\left(\varphi + \varpi^{-1}\right) y_t, \tag{2.7'}$$

where $\kappa_{\varsigma_t} = \kappa$ in *Union Default* and *Union Permanent*, and where $\kappa_{Exit} = (1-\beta\xi_{Exit})(1-\xi_{Exit})/\xi_{Exit}$.

The ratio of public debt to GDP evolves as

$$\beta\hat{d}_t = \hat{d}_{t-1} + \zeta(\beta i_t - \pi_{H,t} - \Delta y_t - \theta_t) - \hat{t}_t, \tag{2.8}$$

where i_t denotes the sovereign bond yield, $\hat{t}_t$ denote taxes in units of GDP and ζ parameterizes the public debt-to-GDP ratio in steady state. Lastly, the yield is related to the nominal interest rate and expected default as follows

$$i_t = r_t + E_t\theta_{t+1}. \tag{2.9}$$

We are now in the position to define an equilibrium. First, we restate equations (2.1) - (2.9) more compactly as follows

$$\mathit{\Gamma}_{\varsigma_t} x_t = \mathit{\Phi}_{\varsigma_t} E_t(x_{t+1}|\varsigma_{t+1}) + \Lambda_{\varsigma_t}\mu_t, \tag{2.10}$$

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[11] To simplify the exposition, in the following we omit subscripts *Union*, *Union Default* and *Union Permanent* for ξ, with the understanding that $\xi := \xi_{\text{Union}} = \xi_{\text{Union Default}} = \xi_{\text{Union Permanent}}$.

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 $\varGamma_{\varsigma_t}$, $\varPhi_{\varsigma_t}$ and Λ_{ς_t} contain the parameters of the model and ς_t indicates that they are regime dependent. Our equilibrium definition follows Farmer et al. (2011).

Definition 1. A rational expectations equilibrium is a mean square stable (MSS) stochastic process that, given the Markov chain $\{\varsigma_t\}$, satisfies (2.10).

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

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

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.[12]

3 Results

We now establish how exit expectations destabilize the economy while the country still operates in the initial regime. In this regime, the country is part of a currency union but membership is imperfectly credible. First, we show that exit expectations may reinforce or even induce a sovereign debt crisis—a vicious circle of ever growing debt and yield spreads. Second, we illustrate that exit expectations harm macroeconomic stability more generally. Throughout we contrast the effects of exit expectations and default expectations.

3.1 Exit expectations reinforce sovereign debt crises

In this subsection, we assume prices to be perfectly flexible, both before and after exit ($\xi = \xi_{Exit} = 0$). This assumption, combined with our assumptions on the transition probabilities,

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[12] In general, a minimum state variable solution is mean square stable whenever the eigenvalues of $(\mathcal{P}' \otimes I_{n^2})\text{diag}(F_{\varsigma_1} \otimes F_{\varsigma_1}, ..., F_{\varsigma_h} \otimes F_{\varsigma_h})$ 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. $x_t = F_{\varsigma_h} x_{t-1} + G_{\varsigma_h} \mu_t$ (Farmer et al. 2009). 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.

permits us to solve the model in closed form. Specifically, because the two target regimes are absorbing, we solve the model backwards using the method of undetermined coefficients.[13]

In all regimes, flexible prices imply constant output $y_t = 0$ by equations (2.7) and (2.7'). Given equation (2.4), 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 (2.5)). The latter, in turn, requires $p_{H,t} = e_t$ by (2.6), such that prices move one-for-one with the nominal exchange rate after exit. Hence, in the flexible-price case under consideration, public debt and deficits do not affect any variables in real terms even as yields carry a redenomination premium which, in turn, affects public finances adversely.

To see this, start from the observation that interest rates reflect expectations of future policies via a version of the uncovered interest parity (UIP) condition. Combine equations (2.4), (2.5) and (2.6) to obtain

$$r_t = E_t \Delta e_{t+1}. \tag{3.1}$$

In the initial regime, $e_t = 0$, while $e_{t+1} \neq 0$ is possible only if the country exits the currency union. 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 law. 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-law bond must offer a higher interest rate, because a foreign-law bond pays off strictly better (in terms of new domestic currency) in those states of the world where exit and depreciation occur. Given that r_t corresponds to the yield of a one-period bond issued under domestic jurisdiction, it represents the "redenomination premium". Equivalently, r_t captures the *spread* of the yield of a domestic-law bond relative to that of a bond issued under foreign jurisdiction.[14]

To determine the redenomination premium, we solve for the change of 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 depends primarily on how strongly the newly independent monetary policy raises nominal interest rates in response to inflation, as captured by parameter ϕ_π. Recall 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, minus

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[13] All derivations can be found in Appendix C. The analytical solution presented in Section 3.1 is the unique mean square stable minimum state variable solution of the model, provided $\lambda \left((1-\psi_{\text{Union}})\Theta^d\right)^2 < 1$, where Θ^d is defined below. If the latter condition is violated, no solution exists. The condition holds unless either ϵ or $\delta\theta$ are close to unity, and unless δ and ϵ are both close to zero while $\psi_{\text{Union}} < 1 - \beta$.

[14] Recall that 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.

the price level which prevailed in terms of old currency, the period before exit. We obtain the following solution for nominal depreciation in *Exit*

$$\Delta e_t = \Theta^e \left[(1-\psi_{\text{Exit}})\hat{d}_{t-1} + \mu_t\right], \tag{3.2}$$

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

Hence, in case monetary policy satisfies the Taylor principle ($\phi_\pi > 1$), the exchange rate will remain unchanged upon exit. 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 Θ^e attains a maximum at $\phi_\pi = 0$).[15] 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 the amount of outstanding debt and the larger the current budget deficit. The fiscal theory of the price level applies, such that the initial price level as well as the exchange rate adjust after exit in order to align the real value of debt with the expected sequence of real primary surpluses. Note that $\phi_\pi \leq 1$ is required for equilibrium to exist if ψ_{Exit} is sufficiently small; and that, conversely, $\phi_\pi > 1$ is possible only if the fiscal authority adjusts taxes sufficiently strongly after exit.[16]

Combining (3.1) and (3.2) determines the redenomination premium in *Union* which, in turn, impacts public finances adversely through sovereign yields. Sovereign yields carry a redonomination premium, because government debt is issued under domestic law, see equation (2.9). Higher debt service, all else equal, contributes to rising debt levels, see equation (2.8). As a result, there may be a vicious circle: rising debt levels raise expectations of a depreciation upon exit and vice versa. To see this formally, we state the solution for public debt in *Union*

$$\hat{d}_t = \Theta^d \left[(1-\psi_{\text{Union}})\hat{d}_{t-1} + \mu_t\right], \tag{3.3}$$

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

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[15] Furthermore, one can show that the solution for public debt in *Exit* is given by the following expression

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

Thus, the (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 at all ($\phi_\pi = 0$).

[16] More formally, 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 ϕ_π, we assume ψ_{Exit} satisfies these assumptions throughout.

We note that $\Theta^d(1-\psi_{\text{Union}})$, the autoregressive root on debt in equation (3.3), 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 ($\epsilon = \theta = 0$), we have $\Theta^d = \beta^{-1}$, that is, 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.

The above expression shows that exit expectations may reinforce—or even induce—sovereign debt crises. Specifically, all else equal, Θ^d increases in ϵ. Hence, if—for a given fiscal policy parameter ψ_{Union}—public debt is on explosive trajectory, the rate at which debt accumulates increases further as $\epsilon > 0$. Moreover, debt may be on a stable trajectory in the absence of exit expectations, but become explosive as ϵ is raised sufficiently.[17] In this regard, exit expectations impact public finances in a way which is comparable to expectations about outright default: as with ϵ, Θ^d increases in $\delta\theta$, that is, as the expected losses due to a haircut become larger. Finally note that, for given expectations about exit or default, a sufficiently aggressive fiscal stance in *Union* may shield the economy from explosive dynamics.[18]

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

$$i_t = \left(\Theta^\theta + \Theta^r\right)\left[(1-\psi_{\text{Union}})\hat{d}_{t-1} + \mu_t\right], \tag{3.4}$$
$$\text{where } \Theta^\theta = \delta\theta\frac{\Theta^d}{\zeta} > 0 \quad \text{and} \quad \Theta^r = \epsilon\left(\frac{1-\psi_{\text{Exit}}-\beta\phi_\pi}{1-\beta\phi_\pi}\right)\frac{\Theta^d}{\zeta} > 0.$$

This closes the vicious circle described above: 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. Both exit and default expectations may drive such a vicious circle, as can be observed from equation (3.4): it decomposes sovereign yields into a redenomination premium and a default premium, as captured by the two parameters Θ^r and Θ^θ.[19]

3.2 Exit expectations harm macroeconomic stability

With sticky prices ($\xi > 0$ and $\xi_{\text{Exit}} > 0$), exit expectations matter for how 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 a version of the algorithm

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[17] Note also that for any given probability of exit, debt becomes more explosive as monetary and fiscal policy are expected to be more accommodative upon exit (as ϕ_π or ψ_{Exit} decline).

[18] 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 results show that this insight carries over to the case of exit expectations.

[19] One can further show that, in the initial regime, $r_t = \Theta^r\left[(1-\psi_{\text{Union}})\hat{d}_{t-1} + \mu_t\right]$ 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'.

developed in 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 ϵ, δ, θ and ξ_{Exit} 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 both cases, we assume price stickiness is not expected to change with an exit from the currency union ($\xi_{\text{Exit}} = \xi$).

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 and sovereign yield spreads 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 the presence of exit expectations (solid lines), deficits harm macroeconomic stability. Private yield spreads rise along with sovereign yield spreads. As the ex ante real interest rate rises, output collapses with domestic demand. At the same time, (producer-price) inflation rises, while the nominal exchange rate remains flat. This appreciates the real exchange rate thereby making the domestic economy less competitive, which contributes to a further drop in domestic output.[20] Overall, exit expectations destabilize the economy by making debt and deficits stagflationary.

Instead, in the presence 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, the private yield spread r_t is zero. 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.[21]

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[20] 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 (2.6).

[21] 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).

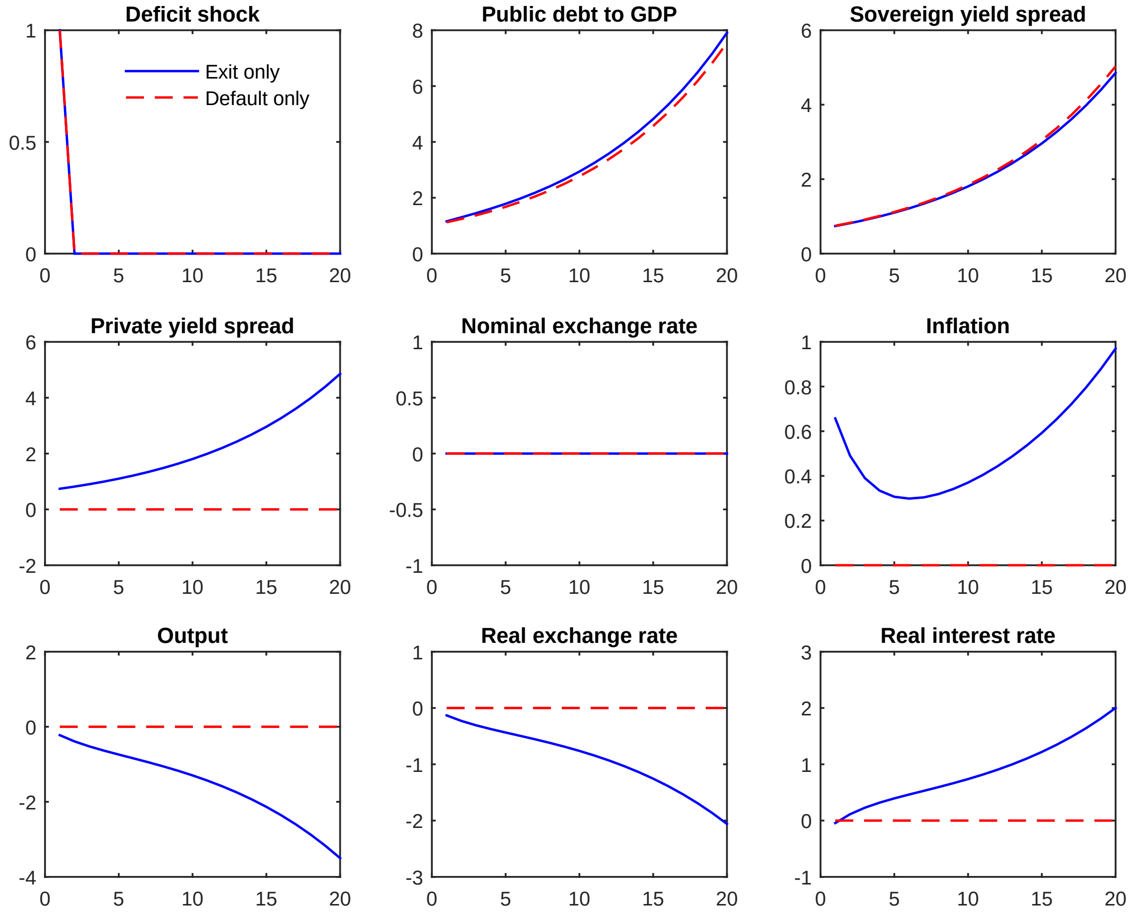

Figure 2: Impulse responses to a deficit shock in *Union*, conditional on staying in *Union*. Notes: Solid (dashed) lines represent exit-only (default-only) scenario; horizontal axes measure time in quarters; vertical axes measure deviations from steady state in percent, and percentage points in case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

To provide intuition on why exit expectations harm macroeconomic stability in the initial regime, we conduct an additional experiment where exit actually realizes in period 10 after the deficit shock. To simplify the discussion, we rule out outright default for this experiment ($\epsilon = 0.1, \delta = 0.1, \theta = 0$). By contrast, we now allow for the possibility that price stickiness changes with an exit from the currency union. In particular, we contrast the case of unchanged rigidity ($\xi_{\text{Exit}} = \xi$) to a scenario of flexible prices after exit ($\xi_{\text{Exit}} = 0$).[22] Formally, note that

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[22] As far as the dynamics in *Union* are concerned, this is equivalent to a scenario of a one-time reset of prices upon exit and renewed stickiness thereafter.

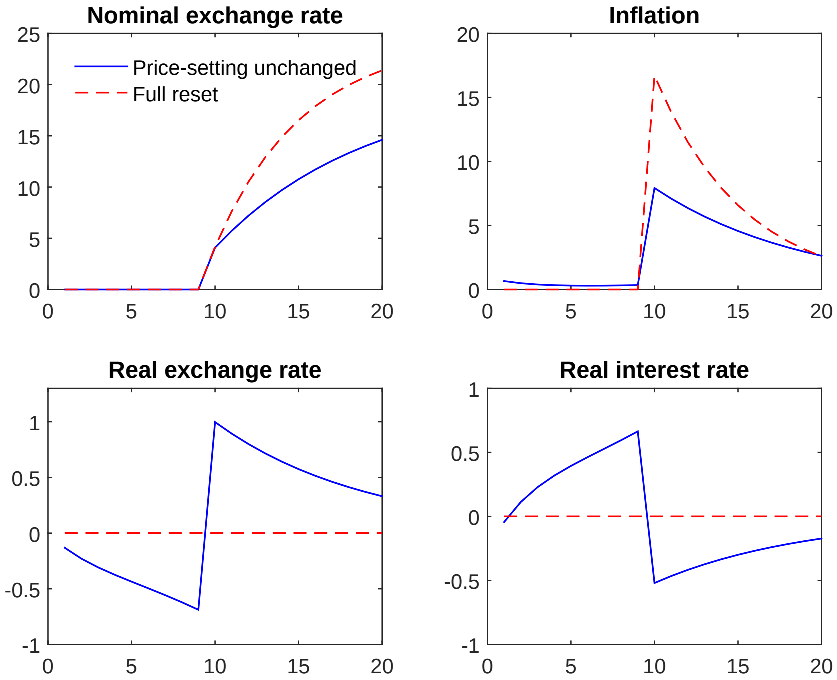

Figure 3: Impulse responses to a deficit shock in *Union* and actual exit in period 10 for different levels of rigidity in *Exit*. Solid line corresponds to unchanged rigidity ($\xi = \xi_{\text{Exit}} = 0.85$), dashed line assumes flexible prices after exit; horizontal axes measure time in quarters;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

in case of $\xi_{\text{Exit}} = 0$, $\Omega_1 = \frac{1-\beta\lambda\xi}{1-\beta(\lambda+\epsilon)\xi}$ and $\Omega_2 = 0$ such that (2.7) collapses to

$$\pi_{H,t} = \beta\left[\lambda E_t(\pi_{H,t+1}|\text{Union}) + \delta\frac{1-\beta\lambda\xi}{1-\beta(\lambda+\epsilon)\xi}E_t(\pi_{H,t+1}|\text{U Def})\right] + \kappa\left(\varphi+\varpi^{-1}\right)\frac{1-\beta\lambda\xi}{1-\beta(\lambda+\epsilon)\xi}y_t. \quad (3.5)$$

That is, the Phillips curve in *Union* becomes steeper, the larger the probability of an exit (as ϵ increases)—as this effectively reduces price stickiness. At the same time, firms' pricing decisions in *Union* are unaffected by developments after exit, as firms anticipate that once the exit occurs, they will be able to optimally re-adjust their prices. Figure 3 shows results of this additional experiment, namely the response of selected variables to the deficit shock under the assumption that exit actually takes place in period 10 after the shock. In the figure, solid lines correspond to the case of unchanged rigidity, and dashed lines correspond to the case of flexible prices after exit.

The upper-left panel shows the response of the nominal exchange rate. In the case of unchanged rigidity, there is a discrete upward shift upon exit and further, more gradual depreciation thereafter. Overall, the response of the exchange rate is quite similar under flexible prices after exit, yet in the long run it depreciates by more in this case.[23] 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 case of unchanged rigidity, its response is muted relative to the scenario of flexible prices. Moreover, if prices are flexible after exit, the real exchange rate does not adjust after exit (bottom-left panel). Instead, in the case of unchanged rigidity, the sluggish response of inflation after exit induces the real exchange rate to depreciate upon exit, along with the nominal exchange rate.

The lower-right panel shows the ex ante real interest rate, which governs the intertemporal allocation of private domestic expenditure and, hence, the recessionary impact of the deficit shock in the presence of exit expectations illustrated in Figure 2 above. The ex ante real rate relates to the real exchange rate as follows

$$r_t - E_t \pi_{H,t+1} = E_t(\Delta e_{t+1} - \pi_{H,t+1}) = (1-\omega)^{-1} E_t \Delta q_{t+1}, \tag{3.6}$$

where the above relation follows from combining the UIP condition (3.1) and the definition of the real exchange rate (2.6). Thus, equilibrium requires that an expected real depreciation is met by increased real interest rates. If prices are flexible throughout (see Section 3.1), 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 the same result to obtain in the sticky-price model.

We conclude that exit expectations harm macroeconomic stability to the extent that (some) price stickiness is expected to persist beyond exit.[24] Under the same condition, 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 if they expect real depreciation upon exit which, in turn, will raise marginal costs. Empirically, large devaluations tend to be associated with sizeable real depreciations (Burstein et al., 2005). To allow for this possibility, as well as for the possibility of a structural break in the Phillips curve upon exit, we let the parameter ξ_{Exit} be determined in the estimation in our empirical analysis below.

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[23] Under $\phi_\pi = 0$, the exchange rate jumps to its long-run value straight away upon exit. By contrast, as $\phi_\pi > 0$ in our simulations, nominal interest rates increase with inflation in *Exit* such that as a result, the nominal exchange rate adjusts gradually—in line with UIP condition (3.1).

[24] For $0 < \xi_{\text{Exit}} < \xi$, the responses of all variables fall in between the cases displayed in Figure 3.

4 Greece 2009–2012

In this section we quantify the contribution of exit expectations to the 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 expectations of exit and default, rather than of 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, 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.[25] We also allow for taxes

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[25] In the absence of complete international financial markets small open economy models 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 during 2009–2012 (Buiter and Rahbari, 2012).

to be distortionary, namely proportional to the output of firms.[26]

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

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

Here R_t (R^*), as before, denotes the nominally risk-free interest rate on a bond issued under domestic (foreign) law, that is, on a bond that pays one unit of domestic (foreign) currency in all states of the world.[27] Following Corsetti et al. (2013a) we rationalize a value of χ 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.[28]

The dynamics of sovereign debt are a key feature of our analysis. Therefore, in the extended model, we account for the fact that public debt is long-term following Woodford (2001). The government's flow budget constraint changes to

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

where $\iota \geq 0$ parameterizes the maturity of debt. Ψ_t denotes the price of government debt, which solves

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

and which relates to the (gross) sovereign bond yield via

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

In the government's budget, τ_t is the tax rate proportional to output, which, as before, may depend on the size of public debt through the feedback parameter ψ_{ς_t}. Furthermore, we allow the rest of the world to subsidize the domestic government through a transfer payment Z_t, 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.

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[26] Hence the term T_t does not appear in the household budget constraint any longer. The deficit shock, μ_t, however, continues to appear as it represents a lump-sum transfer to the household.

[27] 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.

[28] 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.

Finally, we introduce four 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.[29] 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). All shocks in the model are i.i.d. 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 observations 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 displays 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 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. 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 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 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 had to be refinanced.

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[29] 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 %
ϵ	Gamma	0.055	0.05	0.034	0.011	0.022	0.048
δ	Gamma	0.055	0.05	0.058	0.051	0.008	0.126
χ	Beta	0.2	0.1	0.123	0.067	0.048	0.213
ξ_{Exit}	Beta	0.66	0.1	0.836	0.095	0.692	0.925
σ_{deficit}	Inverse-G.	0.01	∞	0.097	0.022	0.073	0.125
$\sigma_{\text{cost-push}}$	Inverse-G.	0.01	∞	0.008	0.003	0.006	0.013
$\sigma_{\text{world-demand}}$	Inverse-G.	0.01	∞	0.073	0.019	0.052	0.097
$\sigma_{\text{sov-liqu}}$	Inverse-G.	0.01	∞	0.013	0.003	0.009	0.017
$\sigma_{\text{priv-liqu}}$	Inverse-G.	0.01	∞	0.003	0.001	0.002	0.004
$\sigma_{\text{transfers}}$	Inverse-G.	0.01	∞	0.032	0.007	0.025	0.041

Notes: exit probability measured by ϵ, probability of outright default measured by δ, χ parameterizes pass-through of sovereign risk into private yields, ξ_{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.

Given that our sample is short, we only estimate a subset of model parameters. Specifically, we estimate the probability of exit and default, ϵ and δ, as well as parameter χ which captures the strength of the sovereign risk channel. Moreover, we estimate the degree of price rigidity after exit, captured by ξ_{Exit}. As discussed above, this parameter also determines how strongly exit expectations impact the allocation in the initial regime. Lastly, we estimate the standard deviation of all six disturbances.

As prior distributions we choose a Gamma distribution with mean 0.055 and standard deviation 0.05 for both ϵ and δ. 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., Buiter and Rahbari, 2012 and UBS, 2010). Regarding χ, 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 ξ_{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 β is set to 0.99. We set $\varphi = 4$, implying a moderate Frisch elasticity of labor supply (Chetty et al., 2011). The trade-price elasticity σ is set to 2, in line with estimates for Southern European countries reported by European Commission (2014). For ω 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 $\theta = 0.64$.

Regarding fiscal policy we assume $\psi_{\text{Union}} = \psi_{\text{U Per}} = 0.015$. Given $\beta = 0.99$, this value 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 $\phi_\pi = 0.83$ 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 debt-feedback of taxes and public expenditures very close to zero. Finally, given ζ, 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 estimated 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 somewhat above the prior mean in the case of δ and

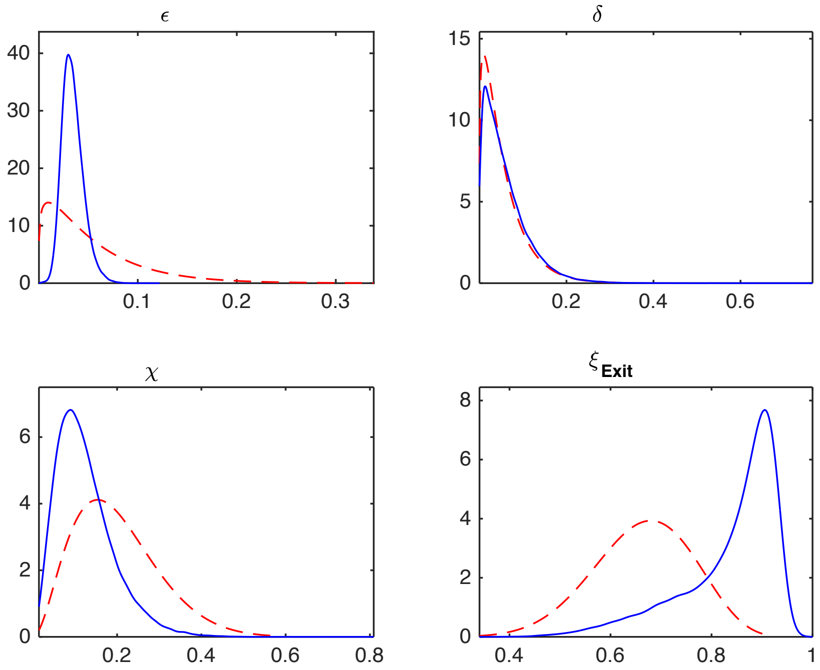

Figure 4: Prior (dashed) and posterior (solid) distribution of model parameters. Notes: exit probability measured by ϵ, probability of outright default measured by δ, χ parameterizes pass-through of sovereign risk into private yields, ξ_{Exit} captures price rigidities after exit.

below the prior mean in the case of ϵ. At the same time, probability bands are quite large for δ. The posterior mean for χ implies that only 12% 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 ξ_{Exit} suggests that nominal rigidities are expected to decline only moderately upon exit. Figure 4 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). For three of the four parameters, the posterior distribution tightens considerably. We apply a Kalman smoother to reconstruct the sequences of unobserved shocks at the posterior mean and show the results in Figure E.5 of 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 and contrast the outcome to two counterfactuals. First, we isolate the effect of exit expectations by running a simulation as in the estimated model, except that expectations of exit are ruled out ($\epsilon = 0$). Second, we also rule out outright default by setting the haircut parameter to

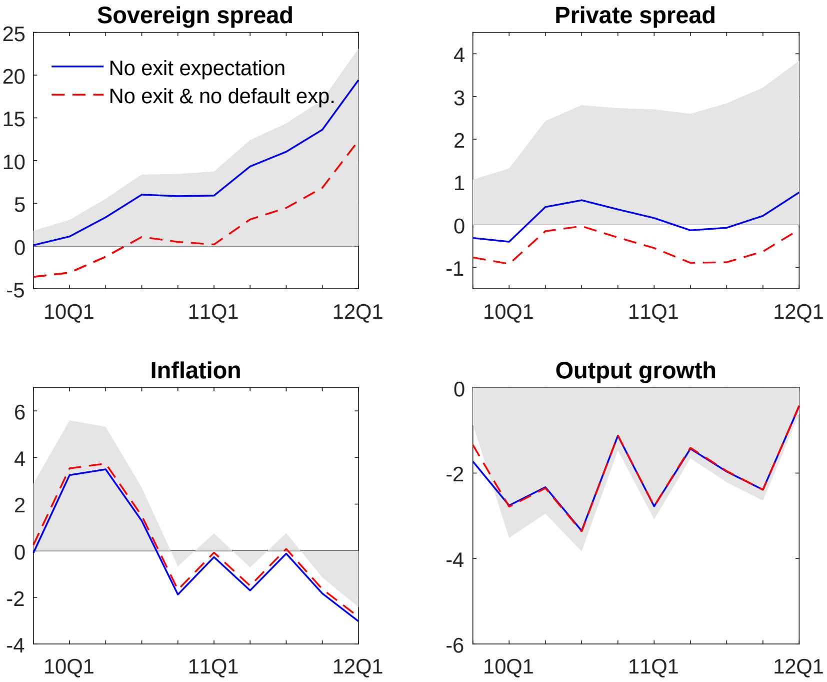

Figure 5: Counterfactual (vs actual) outcome of observed variables. Notes: shaded area indicates actual time series/prediction of estimated model; counterfactuals: solid line corresponds to scenario where exit is ruled out ($\epsilon = 0$), dashed line represents dynamics in the absence of exit and default expectations ($\epsilon = \theta = 0$). Interest rates are annualized and in percentage points. Inflation is annualized and measured in percent, quarterly output growth is measured in percent.

zero ($\theta = 0$). Figure 5 shows the result. In the figure, the grey area corresponds to the actual outcome, 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 the period 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 sample, respectively. At the height of the crisis, the redenomination premium thus accounts for more than 15 percent of the yield spread. Our result that exit expectations reinforce sovereign debt crises is thus quantitatively relevant for Greece. 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" is 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 5 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 the sovereign risk channel (parameter χ). Note that spreads may be negative because of liquidity shocks.

Exit expectations harm macroeconomic stability more generally. We contrast actual and counterfactual outcomes of CPI inflation and output growth in the bottom panels of Figure 5. We find that in the absence of exit expectations inflation is strongly reduced and particularly so in the early stage of the crisis period, that is, exit expectations are inflationary—in line with the discussion above. The effect of exit expectations on output turns out to be sizeable as well: the cumulative effect on output growth amounts to about 2.5 percentage points during our sample period and hence for some 12 percent of the total output loss.[30]

In order to assess the contribution of exit (and default) expectations to the sovereign debt crisis in Greece, we compute the model prediction of the debt-to-GDP ratio for the estimated model as well as for the two counterfactual scenarios. The upper-left panel of Figure 6 shows

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[30] During the first quarter of our sample, output growth would have been lower in the absence of exit expectations. This is surprising in light of our discussion from Section 3.2, where we found exit expectations to be unambiguously contractionary. However, as we assume international financial markets to be incomplete in the estimated model, this is not necessarily the case. Exit, in this case, 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.

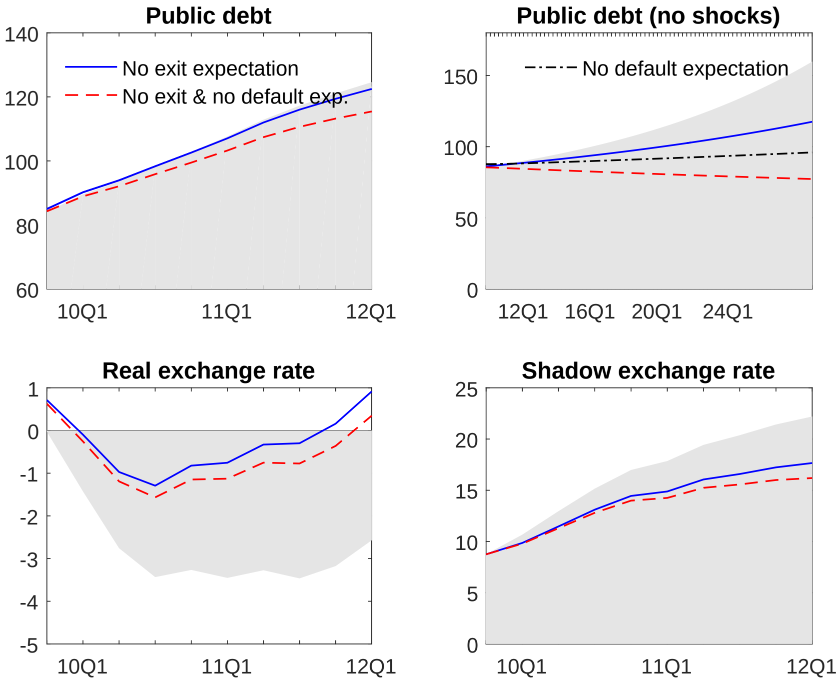

Figure 6: Counterfactual (vs actual) outcomes of additional variables. Notes: shaded areas indicate time series predicted by estimated model; counterfactuals: solid (dashed, dashed-dotted) line captures scenario w/o exit (w/o exit and w/o default, w/o default). Upper row shows public debt (percentage points of GDP), w/ and w/o shocks. Lower row shows shadow exchange rate—nominal exchange rate if exit were to take place—and real exchange rate, both in percent.

the results. The shaded area corresponds to the prediction of the estimated model, which captures the actual increase by some 40 percentage points during the sample period very well.[31] At the same time, our counterfactual simulations show that expectations of exit and default contributed only moderately to the build-up of debt during 2009–2012 (solid and dashed line). In fact, during our sample period the bulk of the debt increase is due to persistently negative primary surpluses and the strong drop in output at the time.

The destabilizing role of exit and default expectations becomes clear, once we abstract from shocks, and let the simulation run over a somewhat longer horizon, namely over 15 years. This is illustrated in the upper-right panel of Figure 6. It turns out that—given conditions in 2009Q3 for the estimated model (shaded area)—public debt is on an explosive trajectory. Exit expectations are to a large extent responsible, as our counterfactual simulation (solid line) illustrates. More than that, exit expectations alone suffice to generate an explosive

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[31] 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.

trajectory in debt-to-GDP (dashed-dotted line). Only if both exit and default expectations are ruled out (dashed line), we observe that debt converges back to its steady state level in the long run.

Finally, we also report model predictions for the exchange rate. The lower-left panel of Figure 6 shows the real exchange rate, predicted to appreciate in the early stage of the crisis (as before, the shaded area corresponds to the prediction of the estimated model). We find that competitiveness does not start to improve before 2011, in line with actual developments. To a large extent this is due to exit expectations. In the counterfactual simulation without exit expectations (solid line), the real exchange rate hardly moves. The effect of default expectations on the exchange rate is small and of the opposite sign.

The lower right panel of Figure 6 shows the shadow exchange rate: 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. Absent exit or default expectations, the shadow exchange rate is lower than in the estimated model. Note that in principle, depreciation in the event of exit can be due to an appreciated real exchange rate or due to an accommodating monetary-fiscal policy mix after exit whenever public debt is high. Our analysis has highlighted the mechanisms which underlie 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 according to our estimates, 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 by exiting countries can redenominate their liabilities. The real value of debt will then decline with the value of the new 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 which may exit or, alternatively, apply a haircut to its outstanding liabilities while remaining part of the union.

Market participants are aware of these possibilities and expectations of exit and default matter for the equilibrium outcome. In particular, 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. As a result, the sovereign debt crisis intensifies in the presence of exit expectations along two dimensions. First, exit expectations reinforce the adverse debt dynamics through their impact on yields and public finances. Second, exit expectations make public debt and deficits stagflationary.

In order to assess the quantitative importance of exit expectations, we estimate an extended version of the model on Greek times series 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 exit expectations have an adverse and sizeable impact on economic outcomes in Greece during our sample period. Redenomination premia account for a significant fraction of sovereign yield spreads, and for almost all the spread observed in private-sector yields. Exit expectations also account for a large fraction of the loss in competitiveness and for more than 10 percent of the output loss during our sample period.

While our analysis is silent on the benefits and costs of an actual exit, it makes transparent how the adverse dynamics of a sovereign debt crisis within a currency union may intensify in the presence of exit expectations. Our findings are thus in line with a more general insight: policy frameworks which lack credibility tend to generate inferior outcomes.

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A Model appendix

A.1 Baseline model

Here we present details on the baseline model outlined in Section 2. In the following, lowercase 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 derivation of the New Keynesian Phillips curve in *Union* is delegated to Appendix B. In all other regimes, the first order condition of the price setting problem is given by

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

By linearizing this expression and using the definition of price indices, one obtains a variant of the New Keynesian Phillips curve (see, e.g., Galí and Monacelli, 2005):

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \kappa_{\varsigma_t} mc_t^r, \tag{A.4}$$

where $\kappa_{\varsigma_t} := (1 - \xi_{\varsigma_t})(1 - \beta \xi_{\varsigma_t})/\xi_{\varsigma_t}$, for $\xi_{\varsigma_t} = \xi_{\text{Exit}}$ in regime *Exit*, and $\xi_{\varsigma_t} = \xi$ in regimes *Union Default* and *Union Permanent*. Marginal costs defined in real terms, deflated with the domestic price index, are given by

$$mc_t^r = w_t - p_{H,t} = w_t^r - (p_{H,t} - p_t). \tag{A.5}$$

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

$$q_t = e_t - p_t \tag{A.6}$$

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

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

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

The key equations in the main text are obtained as follows. Combining equations (A.6) and (A.7) yields equation (2.6). Insert risk sharing (A.3) into goods market clearing (A.8) to obtain equation (2.5) 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 (2.5) and (2.6) from the main text in the second line. Combine (A.3) and (2.5) 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 (2.4) 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 the Phillips curve to obtain (2.7)-(2.7') in the main text.

Sovereign yields and debt. The government's flow budget constraint can be written as

$$\beta \frac{(I_t)^{-1}}{\beta} \frac{D_t}{P_{H,t} Y_t} \frac{D_{t-1}}{P_{H,t-1} Y_{t-1}} \frac{Y_{t-1}}{Y_t} \frac{P_{H,t-1}}{P_{H,t}} (1 - \theta_t) - \frac{T_t}{P_{H,t} Y_t}.$$

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 ζ the level of debt to GDP in steady state. Furthermore, we denote i_t the log-deviation of the gross yield I_t from steady state (which is $1/\beta$).

Linearize the bond price schedule from the main text to obtain

$$i_t = E_t \Delta e_{t+1} + E_t \theta_{t+1},$$

where we have used that $R^* = 1/\beta$ and that $\theta = 0$ in steady state. Insert (3.1) from the main text to obtain (2.9) from the main text.

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, ζ_{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. η_t is a shock affecting the household's disutility of labour, which acts as a cost-push shock to firms. α is a (small) positive constant, which induces stationarity to the model.

First order conditions are given by

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

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

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

In these expressions, ν_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[1]

$$c_t = E_t c_{t+1} - (r_t - E_t \pi_{t+1} + \chi E_t \theta_{t+1} + \nu_t - \alpha \hat{b}_t^*) \tag{A.9}$$

$$r_t = E_t e_{t+1} - e_t. \tag{A.10}$$

Note that the effective ex ante real interest rate depends on sovereign risk if $\chi > 0$, by the private sector liquidity shock ν_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

$$w_t - p_t = c_t + \varphi h_t + \eta_t. \tag{A.11}$$

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 $W_t H_t + \mathcal{Y}_t = (1 - \tau_t) P_{H,t} Y_t$ (see the firm's problem below), and that $B_t = 0$ in equilibrium. Here, τ_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 $\zeta_c := C/Y$.[2] Linearization gives

$$\beta \hat{b}_t^* + \zeta_c (c_t - y_t + (p_t - p_{H,t})) = -\tilde{\tau}_t + \hat{b}_{t-1}^* + \zeta_{B^*} (\beta (\chi E_t \theta_{t+1} + \nu_{B,t}) + \Delta e_t - \pi_{H,t} - \Delta y_t) + \mu_t, \tag{A.12}$$

where $\tilde{\tau}_t$ denotes the deviation of the sales tax rate τ_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 face the same problem as in the baseline model, with the exception that profits now comprise sales taxes τ_t as follows

$$\mathcal{Y}_t(j) = Y_t(j)(1 - \tau_t)(P_{H,t}(j) - W_t).$$

As a result, the derivation of the Phillips curves is unchanged from before, but marginal costs now read

$$mc_t^r = w_t^r - (p_{H,t} - p_t) - \tilde{\tau}_t/(1 - \tau). \tag{A.13}$$

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[1] 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.

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

Similarly, technology is the same as in the baseline model above, such that up to first order, output corresponds to working hours of the households

$$y_t = h_t. \tag{A.14}$$

In turn, aggregate period profits are given by

$$\begin{aligned} \mathcal{Y}_t &= \int_0^1 ((1-\tau_t)P_{H,t}(j)Y_t(j) - W_t H_t(j))dj \\ &= (1-\tau_t)\int_0^1 P_{H,t}(j)Y_t(j)dj - W_t H_t \\ &= \frac{Y_t}{P_{H,t}^{-\gamma}}(1-\tau_t)\int_0^1 P_{H,t}(j)^{1-\gamma}dj - W_t H_t \\ &= (1-\tau_t)P_{H,t}Y_t - W_t H_t, \end{aligned}$$

where we have used $\int_0^1 H_t(j)dj = H_t$ in the second equality, demand function $Y_t(j) = (P_{H,t}(j)/P_{H,t})^{-\gamma} Y_t$ in the third equality, and the definition of price index $P_{H,t}^{1-\gamma} = \int_0^1 P_{H,t}(j)^{1-\gamma}$ in the last equality.

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 $\zeta_{c^*} := C^*/Y = (1-(1-\omega)\zeta_c)/\omega$.[3] Linearization gives

$$y_t = -\sigma(p_{H,t} - p_t) + (1-\omega)\zeta_c c_t + \omega\zeta_{c^*}(\sigma q_t + c_t^*). \tag{A.15}$$

The price of government debt is given by

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

where $\varkappa_t$ is a shock affecting the price of government debt directly, which we call a "sovereign liquidity shock". Define the gross yield of government debt as

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

and linearize to obtain

$$i_t = -(1-\iota\beta)\log\left(\Psi_t/\Psi\right), \tag{A.16}$$

where $\Psi = \frac{\beta}{1-\iota\beta}$ is the price of debt in steady state (this follows from the bond price schedule above, using that $R^* = 1/\beta$ and that $\varkappa_t = 1$ in steady state). Linearize the bond price schedule, and combine with (A.16) to obtain

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

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[3] 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.10) to replace $E_t \Delta e_{t+1}$.

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 μ_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

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

where we have used (A.16) to replace the price of government debt by the sovereign yield i_t. Lastly, we posit a policy rule for the tax rate equivalent to the one in our baseline model, such that

$$\tilde{\tau}_t = \psi_{\varsigma_t}\hat{d}_{t-1}, \tag{A.19}$$

where the feedback parameter ψ_{ς_t} may vary with the policy regime. Similarly, the policy for default is the same as before

$$\theta_t = \zeta^{-1}\theta_{\varsigma_t}\hat{d}_{t-1}, \tag{A.20}$$

where θ_{ς_t} 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.9)-(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 Generalized Phillips curve

Here we provide details on the derivation of the generalized Phillips curve, which we refer to in the main text. We consider a Calvo setup and denote with ξ_{Exit} the probability that a firm may not adjust its price in *Exit*, while ξ denotes this probability in all other regimes.

For simplicity, we only present the case without distortionary taxation (Section 2). The firm maximization problem in *Union* can be written as

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

where we have split the expectation operator into expectations conditional on realizations of the Markov chain. More precisely, expectations are conditional on still being in the first regime, or on having switched regimes at time $t+i$. The maximization is subject to the conventional demand constraints given in the main text. 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

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

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

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

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

We note that

$$\frac{1}{1-\beta\lambda\xi} + \frac{1}{1-\beta\xi}\sum_{i=1}^{\infty}(\lambda\xi)^{i-1}\delta\xi^{1-i}(\beta\xi)^i + \frac{1}{1-\beta\xi_{\text{Exit}}}\sum_{i=1}^{\infty}(\lambda\xi)^{i-1}\varepsilon\xi_{\text{Exit}}^{1-i}(\beta\xi_{\text{Exit}})^i$$
$$= \frac{(1-\beta\xi)(1-\beta\xi_{\text{Exit}}) + (1-\beta\xi)\beta\varepsilon\xi_{\text{Exit}} + (1-\beta\xi_{\text{Exit}})\beta\delta\xi}{(1-\beta\lambda\xi)(1-\beta\xi)(1-\beta\xi_{\text{Exit}})} = \frac{1}{(1-\beta\xi)\Omega_1},$$

where Ω_1 is defined as in the main text. This allows us to factor out $p_{H,t}^* - p_{H,t-1}$ from the linearized first order condition above, leading to

$$\begin{aligned} p_{H,t}^* - p_{H,t-1} = (1-\beta\xi)\Omega_1 \{ & \\ & \sum_{k=0}^{\infty}(\beta\lambda\xi)^k E_t(mc_{t+k}^r + p_{H,t+k} - p_{H,t-1} \; | \text{Union}) \\ & + \sum_{i=1}^{\infty}(\lambda\xi)^{i-1}\delta\xi^{1-i}\sum_{k=i}^{\infty}(\beta\xi)^k E_t(mc_{t+k}^r + p_{H,t+k} - p_{H,t-1} \; | \text{U Def in } t+i) \\ & + \sum_{i=1}^{\infty}(\lambda\xi)^{i-1}\varepsilon\xi_{\text{Exit}}^{1-i}\sum_{k=i}^{\infty}(\beta\xi_{\text{Exit}})^k E_t(mc_{t+k}^r + p_{H,t+k} - p_{H,t-1} \; | \text{Exit in } t+i) \}. \end{aligned} \tag{B.1}$$

We now write (B.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 $t+1$

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

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

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

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

$$
\begin{aligned}
p^*_{H,t} - p_{H,t-1} = \pi_{H,t} + (1-\beta\xi)\Omega_1 \ \{ & mc^r_t \\
+ \frac{\delta\beta\xi}{1-\beta\xi}[E_t(p^*_{H,t+1} - p_{H,t} \ |\text{U Def in } t+1)] &+ \frac{\varepsilon\beta\xi_{\text{Exit}}}{1-\beta\xi_{\text{Exit}}}[E_t(p^*_{H,t+1} - p_{H,t} \ |\text{Exit in } t+1)] \\
+ \beta\lambda\xi \ \{ & \sum_{k=0}^{\infty}(\beta\lambda\xi)^k E_t(mc^r_{t+1+k} + p_{H,t+1+k} - p_{H,t} \ |\text{Union}) \\
+ \sum_{i=1}^{\infty}(\lambda\xi)^{i-1}\delta\xi^{1-i} & \sum_{k=i}^{\infty}(\beta\xi)^k E_t(mc^r_{t+1+k} + p_{H,t+1+k} - p_{H,t} \ |\text{U Def in } t+1+i) \\
+ \sum_{i=1}^{\infty}(\lambda\xi)^{i-1}\varepsilon\xi^{1-i}_{\text{Exit}} & \sum_{k=i}^{\infty}(\beta\xi_{\text{Exit}})^k E_t(mc^r_{t+1+k} + p_{H,t+1+k} - p_{H,t} \ |\text{Exit in } t+1+i) \ \} \ \}.
\end{aligned}
$$

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 (B.1), only at time $t+1$ and with a conditional time-t expectations operator in front. Because (B.1) is conditional on being in *Union* at time t, we can write

$$
\begin{aligned}
p^*_{H,t} - p_{H,t-1} = \pi_{H,t} + \beta\lambda\xi E_t(p^*_{H,t+1} - p_{H,t} \ |\text{Union}) + (1-\beta\xi)\Omega_1 \ \{ & mc^r_t \\
+ \frac{\delta\beta\xi}{1-\beta\xi}[E_t(p^*_{H,t+1} - p_{H,t} \ |\text{U Def})] & \\
+ \frac{\varepsilon\beta\xi_{\text{Exit}}}{1-\beta\xi_{\text{Exit}}}[E_t(p^*_{H,t+1} - p_{H,t} \ |\text{Exit})] \ \}, & \quad \text{(B.2)}
\end{aligned}
$$

where we have omitted the "in $t+i$" because all expectations are now conditional on the shift ocurring (or not ocurring) 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 equation in *Exit*, the second in all other regimes. Insert this into (B.2) and rearrange to obtain the final expression

$$
\begin{aligned}
\pi_{H,t} = \beta\,[\lambda E_t(\pi_{H,t+1}|\text{Union}) + \delta\Omega_1 E_t(\pi_{H,t+1}|\text{U Def}) + \epsilon\Omega_2 E_t(\pi_{H,t+1}|\text{Exit})] & \\
+ \frac{(1-\beta\xi)(1-\xi)}{\xi}\Omega_1 mc^r_t, & \quad \text{(B.3)}
\end{aligned}
$$

where we define

$$
\Omega_2 = \frac{\xi_{\text{Exit}}}{\xi}\frac{1-\xi}{1-\xi_{\text{Exit}}}\frac{1-\beta\xi}{1-\beta\xi_{\text{Exit}}}\Omega_1
$$

as in the main text.

C Closed-form solution of special case (Section 3.1)

Here we provide details on the closed-form solution of the special case which we study in detail in Section 3.1. In this case, we consider the baseline model, but let $\xi = \xi_{\text{Exit}} = 0$. 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 $\xi = \xi_{\text{Exit}} = 0$, the model collapses to

$$r_t = E_t \pi_{H,t+1} \tag{C.1}$$

$$e_t = p_{H,t} \tag{C.2}$$

$$\beta \hat{d}_t = (1 - \psi_{\varsigma_t}) \hat{d}_{t-1} + \zeta(\beta i_t - \pi_{H,t} - \theta_t) + \mu_t \tag{C.3}$$

$$i_t = r_t + E_t \theta_{t+1} \tag{C.4}$$

$$\theta_t = \zeta^{-1} \theta_{\varsigma_t} \hat{d}_{t-1} \tag{C.5}$$

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 (C.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 (C.1) and (C.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 (C.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 (C.4). By contrast, generally $e_t = p_{H,t} \neq 0$ in this regime. The system (C.1)-(C.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 (C.2). However, generally $r_t \neq 0$ because of expected changes in inflation and nominal depreciation (equations (C.1) and (C.2)), and $i_t \neq 0$ because of (in addition to the variation in r_t) expected outright default (equation (C.4)). Moreover, movements in i_t feed back into $\hat{d}_t$ through equation (C.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 (C.3) as

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

where ε denotes the probability of moving to *Exit*, and δ denotes the probability of moving to *Union Default*, see sequence (2.2) in the main. Insert this into (C.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 (3.3) from the main text. Substitute back the result for $\hat{d}_t$ into (C.6) to obtain (3.4) from 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 ζ*sovereign yield spread/4, where ζ 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 = ζ*sovereign yield spread/4 - Interest, payable, in units of GDP'.

Further adjustments A few further adjustments 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

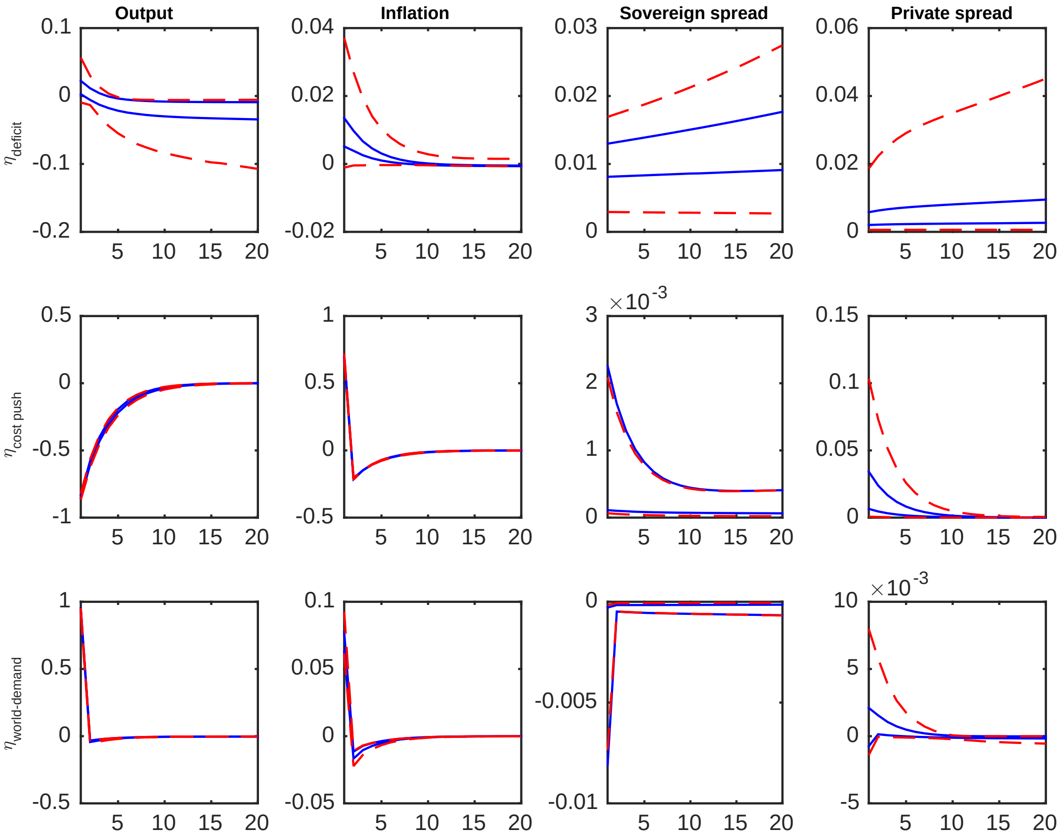

Figure E.1: Impulse responses of selected variables, given prior (dashed) and posterior (solid) distributions of model parameters. Notes: lines indicate maximum and minimum in each period. We consider 50.000 draws from the distributions of ϵ, δ, χ and ξ_{Exit}; shocks are normalized to one percent.

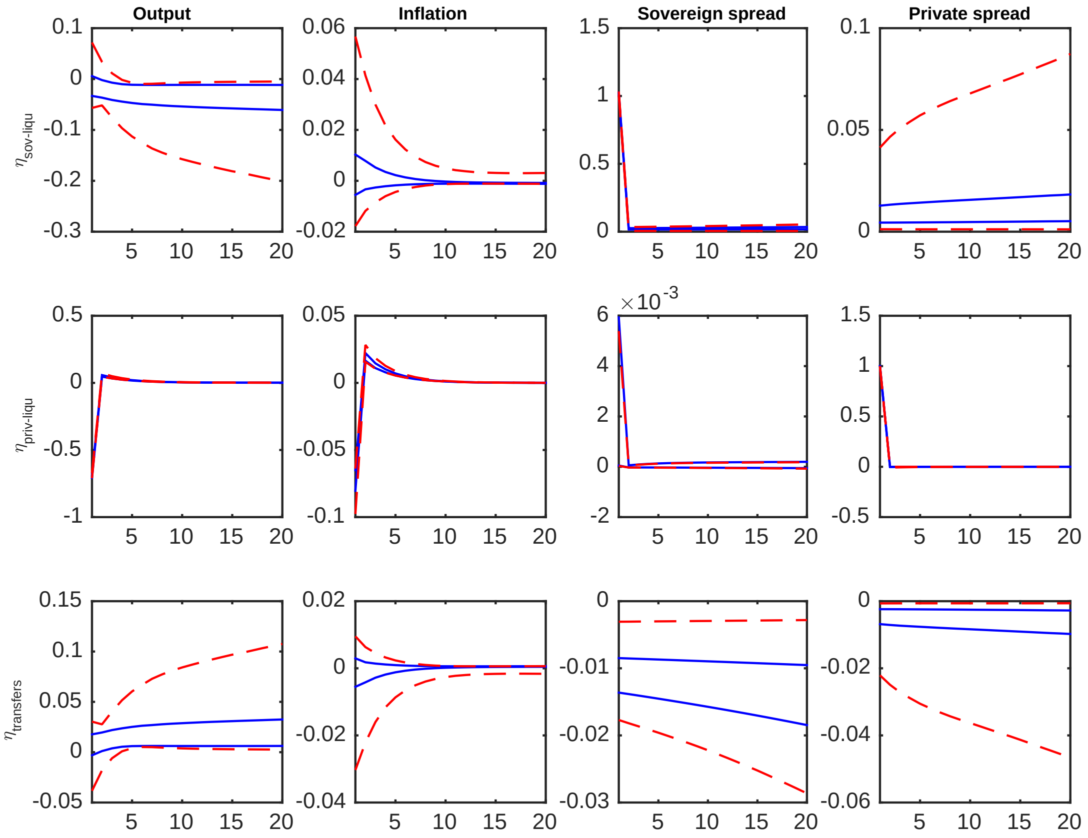

Figure E.2: Impulse responses of selected variables, given prior (dashed) and posterior (solid) distributions of model parameters. Notes: lines indicate maximum and minimum in each period. We consider 50.000 draws from the distributions of ϵ, δ, χ and ξ_{Exit}; shocks are normalized to one percent.

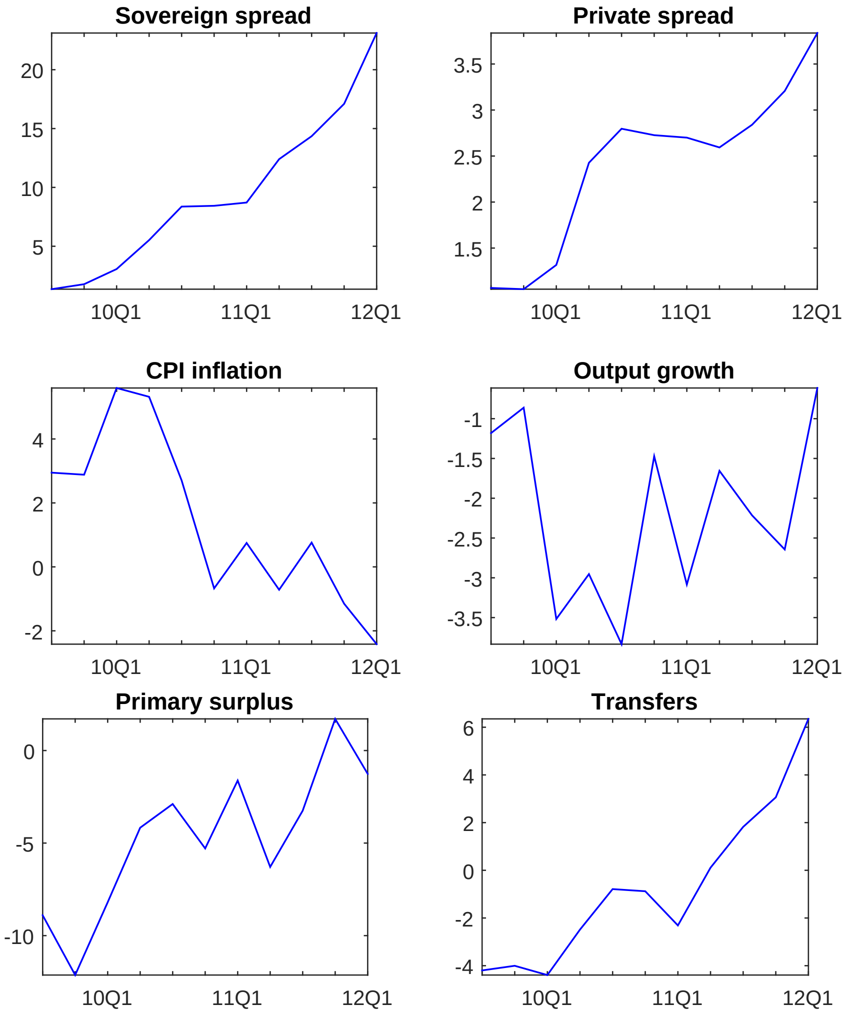

Figure E.3: Greek time-series data 2009Q3–2012Q1. Notes: vertical axes measure percent/percentage points; spreads (annualized), inflation (CPI-based, annualized), and output growth all measured relative to Germany; primary surplus is measured relative to GDP; transfers are computed as difference between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

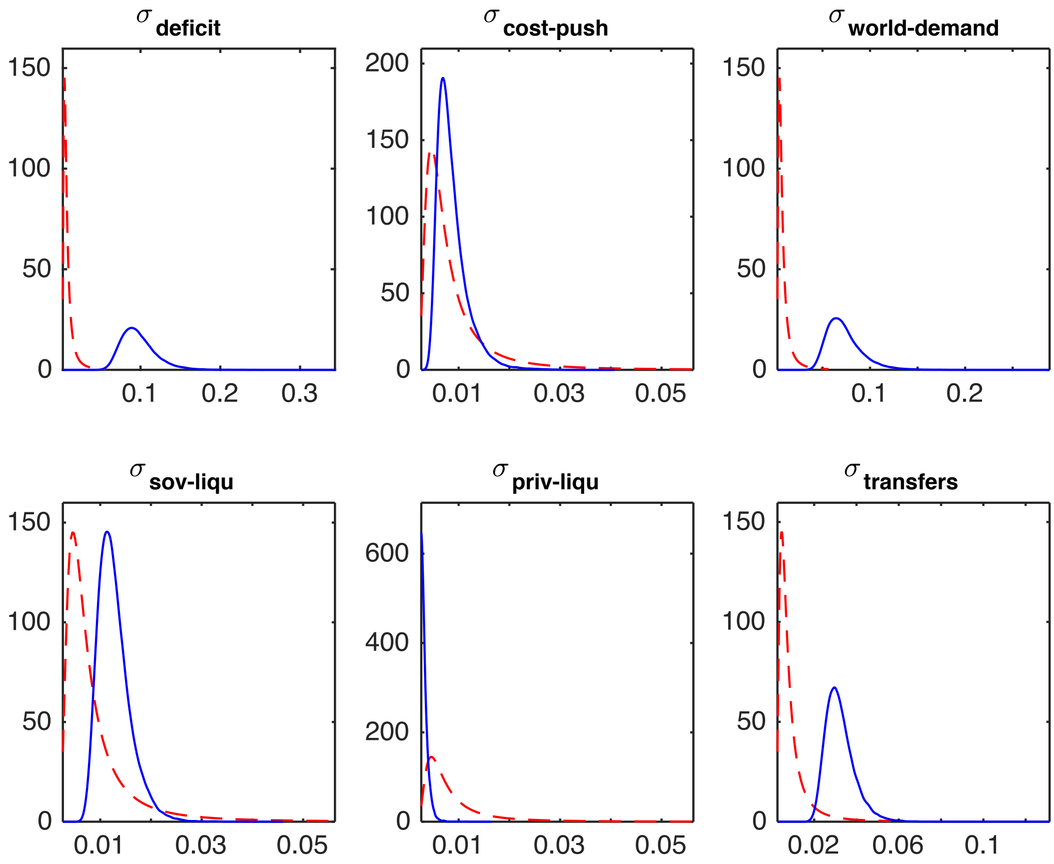

Figure E.4: Prior (dashed) vs. Posterior (solid) distribution of standard errors of shocks.

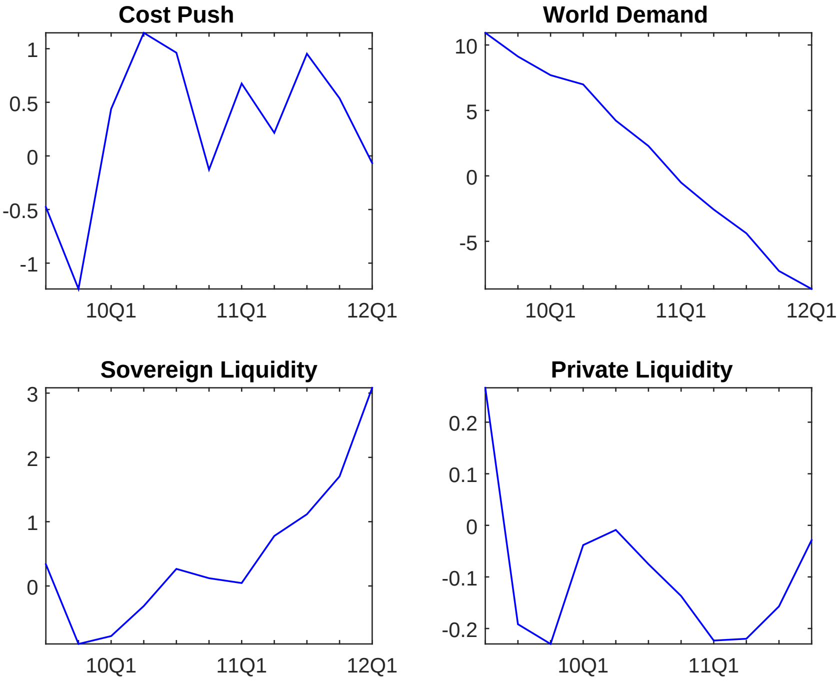

Figure E.5: Estimated sequence of unobserved shocks 2009Q3–2012Q1. Note: shock sequences are obtained by applying Kalman smoother at the posterior mean; vertical axes measure percent.