Exit expectations and debt crises in currency unions

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Abstract

We study a sovereign debt crisis in a small member state of a currency union. If the country exits the currency union, it may redenominate its liabilities and reduce the real value of debt through depreciation and inflation. We analyze formally how the anticipation of this possibility, "exit expectations", impact the dynamics of the sovereign debt crisis. First, we show that public debt accumulates faster and sovereign yields increase more strongly because of redenomination risk. Second, we find that exit expectations induce public debt to be stagflationary. Last, we analyze Greek time-series data through the lens of our model and quantify the contribution of exit expectations to the Greek crisis.

Keywords: Currency union, exit, sovereign debt crisis, fiscal policy, redenomination risk, euro crisis, regime-switching model
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1 Introduction

An individual country within a currency union has limited control over inflation. Public debt, even if issued in nominal terms, is effectively real for such a country because the real value of public debt cannot be reduced unilaterally through inflation (Aguiar et al., 2013; De Grauwe, 2011). By exiting the currency union and introducing a new currency, governments regain control of inflation: debt becomes nominal—provided it is issued under domestic law and can be redenominated by fiat. For this reason, expectations of an exit from a currency union may arise in the context of a sovereign debt crisis.

The recent crisis in the euro area is a case in point. Figure 1 shows for the period 2009–2011 the probability of a sovereign default in Greece (dashed line) as implied by the price of credit default swap (CDS) spreads, jointly with the probability that a country exits the euro area before end-2014, as implied by the price of a bet offered by the online betting platform "intrade" (solid line).[1] Here we focus on the period from October 2009, after a newly elected Greek government revealed that the budget deficit was about twice as large as previously expected, until December 2011, that is, before actual default took place.[2]

These developments suggest that the monetary/fiscal regime in place as well as the probability of its demise and the options in the event of its demise are paramount for understanding economic outcomes in times of duress. Against this background, we take the perspective of a small member state of a currency union and ask how the possibility of an exit from the union impacts a sovereign debt crisis. We build a model of a small open economy which is (initially) operating within a currency union. We assume that the country experiences a sovereign debt crisis, as public debt is on an ever-rising, non sustainable trajectory. The crisis can be resolved via a fiscal reform, by outright default, or via an exit from the currency union. Exit from the union is inflationary, because the health of public finances is restored through currency depreciation.

Formally, we specify "simple rules" for monetary and fiscal policy as in Schmitt-Grohé and Uribe (2007), and let a Markov chain determine policy changes in a way consistent with

[1]The contract maturity of the CDS is five years (source: Datastream). We compute quarterly default probabilities as suggested by Hull (2017), chapters 24 and 25. We assume a time-varying haircut such that in the event of a default, debt would be reduced to 90 percent of GDP. Whether or not a currency redenomination would also trigger a credit event has been the subject of some controversy, see, for instance, Credit Suisse (2011). The wording of the exit bet was as follows: a "country currently using the Euro [is] to announce [its] intention to drop it before midnight ET 31 Dec 2014." While intrade itself closed down, data is still available from the following website: http://intrade-archive.appspot.com/event.jsp?event=79890. To compute the quarterly exit probability from the share price, we assume a flat yield curve over the horizon of the bet, that is we assume that at any given point in time, agents do not expect the quarterly exit probability to change going forward.

[2]The haircut was negotiated in March 2012. As CDS premiums rose very strongly in the run up to the event, we only display data up to December 2011 in Figure 1.

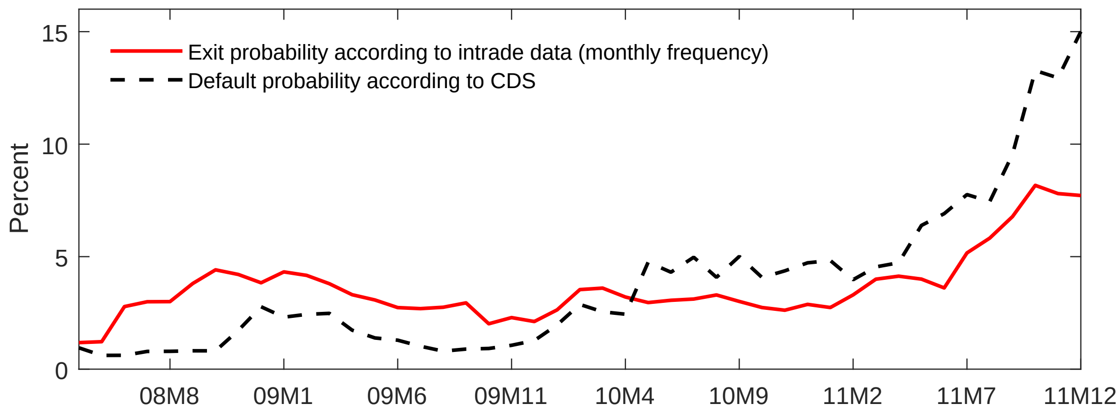

Figure 1: Quarterly probability of default and exit for Greece (2009M10-2011M12), computed on the basis of CDS spreads and the price of an online bet (see footnote 1 for details).

agents' expectations. Initially, fiscal policy is "active", as taxes do not systematically adjust to stabilize public debt. Because the country lacks monetary autonomy, public debt is on an explosive trajectory. Equilibrium default can restore public finances, as in the "fiscal theory of sovereign risk" (Uribe, 2006). As an alternative, the country may exit the union and adopt a "passive" monetary policy which accommodates the active fiscal policy. In this case, the price level and the exchange rate after exit are determined by the need to align the real value of public debt and future primary surpluses—an instance of the "fiscal theory of the price level" (Leeper, 1991; Sims, 2013; Woodford, 1995).[3]

Our methodological contribution is to introduce regime change in a New Keynesian model of a small open economy à la Galí and Monacelli (2005), which we extend to allow for dynamics of public debt. While New Keynesian models are frequently used to study the properties of alternative exchange rate regimes, the possibility of exchange-rate-regime change as part of the equilibrium process and the expectation thereof are commonly ignored, even though policy regime changes have been analyzed in other contexts (Bianchi, 2013; Davig and Leeper, 2007a).[4] Our analysis is focused on a situation where the country still operates within the currency union, but is subject to spillovers from the events after exit. In this regard, we follow the closed-economy analysis of Bianchi and Melosi (2017).

Because regime change is exogenous in our model, we maintain a high degree of tractability which allows us to derive our main results analytically. Our first result is that, even though active fiscal policy and currency union membership is not sustainable in the long run, this

[3]For contributions to the fiscal theory in an open-economy context, see Woodford (1996), Sims (1997), Bergin (2000), Dupor (2000) and Daniel (2001).

[4]See also Davig and Leeper (2007b, 2011). These authors put forward models where monetary and fiscal policy rules change over time. All these studies analyze closed-economy models.

policy mix may be sustained in equilibrium if the probability of regime change is sufficiently large. Yet exit expectations alter the dynamics of the debt crisis because investors anticipate losses due to depreciation and ask for higher yields prior to exit. Consequently, the refinancing costs of the government rise and the debt crisis is reinforced—as losses are proportional to outstanding debt, yields rise in sync with the debt level. In this respect, exit expectations are no different from expectations of outright sovereign default.

Our second result is that if public debt is high, exit expectations drive up interest rates for the sovereign, but also for private borrowers. This is because nominal depreciation after exit affects *all* assets denominated in the (new) domestic currency, not only public debt. This, in turn, has adverse effects on economic activity if prices adjust sluggishly. Moreover, inflation rises already (somewhat) before the exit takes place, due to forward-looking price-setting behavior by firms. As a result, competitiveness deteriorates and economic activity declines further. Hence, the adverse effect of exit expectations is not limited to public finances. It is felt in the economy at large: in the presence of exit expectations, public debt has a *stagflationary* effect on the economy. Instead, if exit is ruled out, public debt is neutral for the economy in our baseline model. In this respect, exit expectations differ fundamentally from expectations of outright sovereign default.

In a last step, we confront our model with Greek time-series data and estimate the realizations of the model's hidden states with a regime-switching Kalman filter. In the process we obtain estimates for the probability that a specific regime has been in place at a particular point in time. Overall we obtain estimates which appear quite plausible. For instance, we find a shift towards active fiscal policy is likely to have taken place around early 2010 and to have been reversed not before late 2015. We also compute counterfactual outcomes and find that exit expectations made a sizable contribution to the build-up of Greek sovereign debt through their impact on yields. Moreover, during the period 2010–2015, they slowed down the adjustment of the real exchange rate and caused an average output loss of some 4 percent.

Our finding that a policy mix of active fiscal policy and active monetary policy can give rise to stagflationary dynamics is not new. Bianchi and Ilut (2017) show that such a regime can account for the failure to reduce US inflation during the 1970s. In a more recent paper, Bianchi and Melosi (2018) model the lack of coordination between monetary and fiscal policy in a closed economy as an active-active regime and also obtain stagflationary dynamics. We show that this result carries over to an open-economy framework and highlight the pivotal role of the exchange rate regime. Benigno et al. (2007) establish that monetary policy can peg the exchange rate and achieve equilibrium determinacy via a simple instrument rule according to which interest rates respond to deviations of the exchange rate from target. In this sense monetary policy is active under a fixed exchange rate regime and hence unable to accommodate an active fiscal policy. The same holds in our model of a currency union. Here, we model membership in a currency union through a "targeting rule", fixing the exchange rate at unity. Effectively this implies an extremely large response of the interest rate to potential movements in the nominal exchange rate.

In our analysis, we consider outright default and exit as alternative outcomes of a sovereign debt crisis in a currency union. Yet, debt repudiation and devaluation often occur jointly (Reinhart, 2002). Na et al. (2018) 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, public debt is governed by domestic law, in line with actual practice in the euro area (Chamon et al., 2018), and may be redenominated upon exit.

Our model does not permit self-fulfilling exit as in the stylized models of Drazen and Masson (1994) and Obstfeld (1996), because we assume exogenous transition probabilities. We also abstract from contagion of exit across members states of a currency union, a possibility which is explored in Eijffinger et al. (2018). Instead, we study the impact of a non-sustainable fiscal/monetary policy mix within a regime-switching open economy model.

Our findings reiterate a theme which features prominently in classic studies of the stability of currency pegs, namely that a non-sustainable policy mix can be maintained only for a limited number of periods (Flood and Garber, 1984; Krugman, 1979). Also, our analysis reestablishes two results of earlier work on currency crises, namely that expected devaluation may raise the refinancing cost of governments, as well as induce a loss in competitiveness due to forward-looking price setting behavior (Obstfeld, 1994, 1997).

Lastly, our paper relates to work which accounts for important aspects of the recent euro-area crisis. Studies with a focus on outright sovereign default include Bi (2012), Daniel and Shiamptanis (2012) and Lorenzoni and Werning (2018), among others. In an influential empirical study Krishnamurthy et al. (2017) decompose yield spreads into a redenomination and a default premium. Gilchrist et al. (2018), Schmitt-Grohé and Uribe (2016) and Kuvshinov et al. (2016) analyze the sluggish adjustment of real exchange rates in the euro area.

The remainder of the paper is organized as follows. Section 2 outlines our model structure. Section 3 presents our regime-switching model. We provide closed-form results in Section 4. Section 5 provides our quantitative analysis. Finally, Section 6 concludes. An accompanying Online Appendix provides proofs and additional derivations as well as more details on our quantitative analysis from Section 5.

2 A small open economy with sovereign debt

Our analysis is based on a New Keynesian model of a small open economy, as in Kollmann (2001), Galí and Monacelli (2005) or Corsetti et al. (2013b). An innovation relative to those studies is that our model features rich sovereign debt dynamics. We also allow the conduct of monetary and fiscal policy to change over time. In particular, there is the possibility that a member of a currency union exits the union in the future. This section outlines the economic environment. Section 3 introduces the regime switching model.

In what follows we briefly describe the behavior of households and firms which is standard. We provide more details on the economy's public sector, which is less standard. Regarding fiscal policy, the government may default outright on its liabilities, which we model following Uribe (2006). Regarding monetary policy, we model membership in the union as an exchange rate peg of unity. This is particularly convenient, as we study an exit from a currency union as a result of which the country will introduce an independent currency.

2.1 Households and firms

A representative household has preferences over aggregate consumption C_t and hours worked H_t. Let $\beta < 1$ denote the time discount factor, $1/\varphi > 0$ the Frisch elasticity of labor supply and E_t the expectation operator. The household maximizes

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

subject to a sequence of budget constraints

$$\int_0^1 P_{H,t}(i) C_{H,t}(i) di + \int_0^1 P_{F,t}(i) C_{F,t}(i) di + E_t \rho_{t,t+1} D_{t+1} = W_t H_t + \mathcal{Y}_t - P_t \tau_t + D_t$$

and subject to a no-Ponzi constraint. Here D_{t+1} is a portfolio of state contingent claims priced with the nominal stochastic discount factor $\rho_{t,t+1}$, W_t is the nominal wage, $\mathcal{Y}_t = \int_0^1 \mathcal{Y}_t(i) di$ are firm profits, τ_t are lump-sum taxes, and P_t is the consumer price index. In turn, $C_{H,t}(i)$ and $C_{F,t}(i)$ denotes consumption of domestically-produced and imported varieties with $i \in [0, 1]$, respectively. $P_{H,t}(i)$ and $P_{F,t}(i)$ is the (domestic-currency) price of each variety. Specifically, aggregate consumption C_t is a composite

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

where aggregate consumption of domestic goods $C_{H,t}$ consists of varieties

$$C_{H,t} = \left(\int_0^1 C_{H,t}(i)^{\frac{\gamma-1}{\gamma}} di \right)^{\frac{\gamma}{\gamma-1}},$$

and symmetrically for aggregate imports $C_{F,t}$. The import-weight of consumption is denoted $0 < \omega < 1$, $\sigma > 0$ is the elasticity between domestic goods and imports, and $\gamma > 1$ is the price elasticity of demand across varieties.

Minimizing expenditures yields the familiar demand functions

$$C_{H,t}(i) = (1-\omega)\left(\frac{P_{H,t}(i)}{P_{H,t}}\right)^{-\gamma}\left(\frac{P_{H,t}}{P_t}\right)^{-\sigma} C_t$$

for domestic varieties with price index $P_{H,t} = (\int_0^1 P_{H,t}(i)^{1-\gamma} di)^{1/(1-\gamma)}$, as well as

$$C_{F,t}(i) = \omega\left(\frac{P_{F,t}(i)}{P_{F,t}}\right)^{-\gamma}\left(\frac{P_{F,t}}{P_t}\right)^{-\sigma} C_t$$

for foreign varieties with price index $P_{F,t} = (\int_0^1 P_{F,t}(i)^{1-\gamma} di)^{1/(1-\gamma)}$. In turn, the consumer price index is $P_t = ((1-\omega)P_{H,t}^{1-\sigma} + \omega P_{F,t}^{1-\sigma})^{1/(1-\sigma)}$.

The household faces a consumption-savings problem in the presence of state-contingent assets. Optimality requires the following condition to be satisfied:

$$\rho_{t,t+1} = \beta\left(\frac{C_{t+1}}{C_t}\right)^{-1}\frac{P_t}{P_{t+1}}.$$

We may define the yield on a nominally riskless, domestic-currency bond from this expression as follows: $R_t \equiv 1/(E_t\rho_{t,t+1})$. The interest rate R_t is set by domestic monetary policy whenever the country operates outside the currency union.

Households in the rest of the world face a symmetric problem. This yields the condition $\rho_{t,t+1} = \beta(C^*_{t+1}/C^*_t)^{-1}(P^*_t/\mathcal{E}_{t+1})/(P^*_{t+1}/\mathcal{E}_t)$, where $\mathcal{E}_t$ is the price of foreign currency in terms of domestic currency (the nominal exchange rate). P^*_t is the consumer price index in the rest of the world. Combining this and the previous condition yields the risk sharing condition $C_t/C^*_t = \upsilon Q_t$, where $Q_t = (P^*_t\mathcal{E}_t)/P_t$ denotes the price of foreign consumption in terms of domestic consumption (the real exchange rate), and where $\upsilon = (C_{-1}/C^*_{-1})(P_{-1}/(\mathcal{E}_{-1}P^*_{-1}))$ is a constant capturing initial conditions (which we normalize to unity). Finally, first order conditions imply a conventional labor supply curve: $W_t/P_t = C_t N_t^{\varphi}$.

Firms produce varieties. They operate under monopolistic competition. They rely on a linear production technology $Y_t(j) = H_t(j)$ and face price adjustment frictions à la Calvo. Prices are set in the currency of the producer and the law of one price holds at the level of varieties. The demand faced by firm $i \in [0,1]$ at time $t+k$, given that it last reset its price in period t, is given by

$$Y_{t+k|t}(i) = \left(\frac{P_{H,t}(i)}{P_{H,t+k}}\right)^{-\gamma}\left((1-\omega)\left(\frac{P_{H,t+k}}{P_{t+k}}\right)^{-\sigma} C_{t+k} + \omega\left(\frac{P_{H,t+k}/\mathcal{E}_{t+k}}{P^*_{t+k}}\right)^{-\sigma} C^*_{t+k}\right).$$

The firms are owned by the domestic households. Let ξ denote the probability of keeping a posted price. A resetting firm at time t maximizes

$$E_t \sum_{k=0}^{\infty} \xi^k \rho_{t,t+k} \mathcal{Y}_{t+k|t}(i) = E_t \sum_{k=0}^{\infty} \xi^k \rho_{t,t+k} \left(P_{H,t}(i) Y_{t+k|t}(i) - \mathcal{C}(Y_{t+k|t}(i)) \right)$$

subject to the set of demand functions stated before. $\mathcal{C}(Y_{t+k|t}(i))$ denotes the (nominal) labor cost of producing $Y_{t+k|t}(i)$, given by $\mathcal{C}(Y_{t+k|t}(i)) = W_{t+k} Y_{t+k|t}(i)$. The first order condition is given by

$$\tilde{P}_{H,t} = \frac{\gamma}{\gamma - 1} \frac{E_t \sum_{k=0}^{\infty} (\beta\xi)^k P_{H,t+k}^{\gamma} C_{t+k}^{-1} MC_{t+k} Y_{t+k}}{E_t \sum_{k=0}^{\infty} (\beta\xi)^k P_{H,t+k}^{\gamma-1} C_{t+k}^{-1} Y_{t+k}}$$

where we denote aggregate output $Y_t = (\int_0^1 Y_t(i)^{(\gamma-1)/\gamma} di)^{\gamma/(\gamma-1)}$ and define real marginal costs $MC_t \equiv W_t / P_{H,t}$. Furthermore, we have exploited that all resetting firms choose the same reset price, $P_{H,t}(i) = \tilde{P}_{H,t}$ for all resetting firms. This also implies that domestic prices evolve as follows in equilibrium

$$P_{H,t}^{1-\gamma} = (1-\xi) \tilde{P}_{H,t}^{1-\gamma} + \xi P_{H,t-1}^{1-\gamma},$$

a well known property of Calvo pricing.

2.2 Monetary and fiscal policy

In case the country operates outside the currency union, we assume that monetary policy adjusts interest rates in response to producer-price inflation as follows:

$$R_t = \beta^{-1} \Pi_{H,t}^{\phi},$$

where $\phi > 0$ captures the feedback of inflation into the policy rate. In this case the nominal exchange rate is flexible. Alternatively, to capture the possibility that the country operates in a currency union with the rest of the world we impose:

$$\mathcal{E}_t = 1.$$

Hence, we model membership in a currency union as an exchange rate peg of unity, as for example in Galí and Monacelli (2016). Note that this implies that, formally, two currencies coexist even as the country is a member of the currency union. As long as the exchange rate is fixed, this model behaves exactly as if there were no independent currencies to begin with. Furthermore, this setup allows us to keep track of the denomination of assets once the country exits the currency union: assets which are “denominated” in “domestic currency” during union membership can be interpreted as “domestic law” securities—to be *redenominated* into new currency with a currency union exit.[5] As a result, changes in the price of those assets (changes in R_t, as we will see below) which reflect expected inflation and depreciation after exit from the union, may be interpreted as *redenomination risk*.[6]

The fiscal authority raises (real) lump sum taxes τ_t and issues short-term nominal bonds B_t at price I_t^{-1}. Government debt is risky, as in each period the government may renege on a fraction Θ_t of its liabilities. The budget constraint is given by:

$$I_t^{-1} B_{t+1} = B_t(1 - \Theta_t) - P_t \tau_t.$$

Implicit in this budget constraint is the assumption that government debt is denominated in domestic currency, or equivalently, is governed by domestic law. This assumption is key in our analysis, as it implies that outside the currency union the real value of debt can be reduced through inflation and depreciation. This assumption is in line with actual practice in the euro area.[7]

For optimizing households to be indifferent between state-contingent claims D_t and government debt B_t, the following no-arbitrage condition must be satisfied:

$$1 = I_t E_t \rho_{t,t+1}(1 - \Theta_{t+1}).$$

Recalling that the risk-free rate on domestic-currency assets equals $R_t = 1/(E_t \rho_{t,t+1})$, this equation shows that the sovereign bond yield exceeds the riskless rate once a haircut in the next period is expected. Optimality also requires the following transversality condition to be satisfied (Uribe 2006):

$$\lim_{j \to \infty} \beta^{j+1} E_t \left(\frac{C_{t+j+1}}{C_t} \right)^{-1} (1 - \Theta_{t+j+1}) \frac{B_{t+j+1}}{P_{t+j+1}} = 0.$$

By combining the previous equations and recalling the definition of $\rho_{t,t+1}$, we obtain the government's present value budget constraint (see Online Appendix A)

$$(1 - \Theta_t) \frac{B_t}{P_t} = \sum_{j=0}^{\infty} \beta^j E_t \left(\frac{C_{t+j}}{C_t} \right)^{-1} \tau_{t+j}.$$

[5]In the euro area crisis, market participants expected securities issued under Greek law to be converted into new currency in case of a Grexit (Buiter and Rahbari, 2012). Similarly, historical examples of "forcible conversions" of debt issued in foreign currency, but under home law, highlight the role of jurisdiction for currency conversions (Reinhart and Rogoff 2011).

[6]One consequence of our modeling two currencies even under union membership is that, with an exit from the union, we implicitly assume conversion at par from common into new currency. However, this assumption does not affect our results. What matters for the effects of exit expectations is the price of the new currency in terms of the old currency in the exit period. Whether this price is the result of an at-par conversion coupled with a large subsequent nominal depreciation of the new currency, or a different conversion rate coupled with a smaller subsequent nominal depreciation, is irrelevant for our conclusions. At the same time, we acknowledge that our formulation abstracts from direct costs of a currency conversion.

[7]During 2003–2014, most (many) European countries issued more than 60-70 (90) percent of their public debt under domestic law (Buchheit et al., 2013; Chamon et al., 2018).

This equation is satisfied under the common assumption that the government raises enough (future) taxes to redeem its debt without default and at given prices. In other words, fiscal policy is assumed to be "passive" (Leeper, 1991). Yet, alternatively, if the government fails to do so and instead pursues an "active" fiscal policy, the expression above may be also satisfied because the default rate Θ_t or, alternatively, the price level P_t respond accordingly.

Below we study a sovereign debt crisis and consider these possibilities explicitly. First, as in the "fiscal theory of sovereign risk" (Uribe, 2006), we consider outright default: Θ_t adjusts such that the present value budget constraint is satisfied. As a consequence, in our analysis a default is always partial: the size of the haircut is determined endogenously reflecting the shortfall of forthcoming future taxes. Second, prices may adjust to reduce the real value of debt—a "default by inflation". This is therefore an instance of the "fiscal theory of the price level" (Sims, 2013; Woodford, 1995).

We capture the possibility of active versus passive fiscal policy by positing a rule for how the fiscal authority sets taxes, following Leeper (1991) and Schmitt-Grohé and Uribe (2007):

$$\tau_t - \tau = \psi \left(\frac{B_t}{P_t} - \frac{\tau}{1-\beta} \right).$$

This equation implies that, if the government perpetually raises an amount $\tau_t = \tau \geq 0$ of taxes, it sustains a steady-state real stock of debt $B_t/P_t = \tau/(1-\beta) \geq 0$. The parameter τ therefore determines the level for public debt that is sustainable. Moreover, this rule implies that as long as debt levels exceed this threshold, taxes adjust with slope coefficient $\psi \geq 0$. For large ψ, debt levels converge back to the steady state and fiscal policy is passive. In contrast, if ψ is sufficiently low, fiscal policy is active.

2.3 Market clearing

The good market clears as

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

where we use that $P_{F,t}$ equals the domestic-currency price of the foreign consumption basket, $P_{F,t} = \mathcal{E}_t P_t^*$, reflecting that the domestic country is small (De Paoli, 2009). The labor market clears as $H_t = \int_0^1 H_t(i)di = \int_0^1 Y_t(i)di = Y_t \int_0^1 (P_{H,t}(i)/P_{H,t})^{-\gamma} di = Y_t \Delta_t$, where Δ_t is price dispersion which is equal to one up to a first order approximation of the model. The asset market clears residually:

$$E_t \rho_{t,t+1} D_{t+1} - D_t = I_t^{-1} B_{t+1} - (1-\Theta_t) B_t + P_{H,t} Y_t - P_t C_t.$$

This equation shows that household savings (left hand side) equal newly issued public debt (first term right hand side) plus new foreign assets that result from a trade surplus.

3 A model of changing policy regimes

We study the dynamics of a sovereign debt crisis in a small member state of a currency union. In particular, we ask how expectations of a future shift in the policy regime—most notably, an exit from the union coupled with a subsequent inflationary policy—affects the sovereign debt crisis while the country is still part of the currency union. We ask this question in light of the actual developments in the euro area: as public debt started to rise sharply in Greece, there was widespread speculation about an exit from the euro zone, alongside speculation about an outright sovereign default.

Specifically, we have in mind the following sequence of regime transitions

$$\text{Sovereign debt crisis} \quad \begin{array}{ll} \nearrow & \text{Fiscal reform} \\ \rightarrow & \text{Default} \\ \searrow & \text{Exit the currency union.} \end{array}$$

Initially, the country is a member of a currency union. Yet, fiscal policy is active, triggering—as we will show below—a sovereign debt crisis. By this we mean that public debt is on an unsustainable trajectory: without a change in policy, public debt grows at an ever faster rate. The change in policy can occur in three different ways. First, there may be a fiscal reform as a result of which fiscal policy turns passive. Second, there may be a default, bringing public debt back to a sustainable level. Third, there may be an exit from the currency union, coupled with an inflationary monetary stance.

To capture this formally, we now introduce our Markov-switching linear rational expectations (MS-LRE) model. In a closed-economy context, this framework has been used extensively to study the implications of discrete shifts in a country's policy regime (e.g., Bianchi, 2013; Davig and Leeper, 2007a). Here we use this framework to model an exit of a country from a currency union.

One key benefit from using a Markov-switching framework, where transition probabilities are exogenous, is tractability. Specifically, we are able to derive conditions under which the model has a well defined equilibrium, even as the country experiences a sovereign debt crisis. Moreover, we are able to solve the model analytically for some special cases. This allows us to explore the economic mechanism that operates at the heart of our model in some depth. Also on the applied side, the Markov assumption has important benefits: in our application to Greece in Section 5, we exploit the quasi-linearity of the model in order to estimate the probability that a particular policy regimes was in place at a given point in time.

The MS-LRE model is cast in terms of the linearized equilibrium conditions associated with the optimization problems of households and firms introduced in the previous section.

We linearize these equilibrium conditions around a steady state that is independent of policy regimes. Moreover, we consider a steady state where purchasing power parity holds, there is zero inflation and zero default. Lower-case letters refer to variables in terms of deviations from steady state.[8] We identify a number of equilibrium conditions which are *invariant* across policy regimes. First, the behavior of the private sector is captured by a dynamic IS relation and a New Keynesian Phillips curve

$$y_t = E_t y_{t+1} - \varpi(r_t - E_t \pi_{H,t+1}), \tag{3.1}$$

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \kappa \left(\varphi + \varpi^{-1}\right) y_t, \tag{3.2}$$

where we define $\varpi := 1 + \omega(2-\omega)(\sigma-1)$ and $\kappa := (1-\beta\xi)(1-\xi)/\xi$. Second, under complete financial markets output is tied to the real exchange rate as follows:

$$y_t = \frac{\varpi}{1-\omega} q_t, \tag{3.3}$$

$$q_t = (1-\omega)(e_t - p_{H,t}). \tag{3.4}$$

In contrast, the equilibrium conditions that capture the behavior of the public sector are generally *regime dependent*. First of all, under our assumed fiscal rule, public debt evolves as

$$\beta b_{t+1} = (1 - \psi_{\varsigma_t}) b_t + \lambda(\beta i_t - \pi_{H,t} - \theta_t), \tag{3.5}$$

where we define $\lambda := \tau/(1-\beta)$ as the level of debt in steady state and ς_t is an index of the policy regime or, formally, the state of the Markov chain: $\varsigma_t \in \{\text{Crisis}, \text{Reform}, \text{Default}, \text{Exit}\}$. Here, $\psi_{\text{Reform}} > 1-\beta$, while all other regimes are characterized by active fiscal policy, $\psi_{\varsigma_t} < 1-\beta$. The sovereign bond yield is not regime dependent. It can be written as

$$i_t = r_t + E_t \theta_{t+1}. \tag{3.6}$$

Monetary policy is characterized by the following equation:

$$\mathbb{1}_{\varsigma_t}(r_t - \phi \pi_{H,t}) + (1 - \mathbb{1}_{\varsigma_t}) e_t = 0, \tag{3.7}$$

where the indicator variable $\mathbb{1}_{\varsigma_t}$ takes the value of one in regime Exit and the value of zero otherwise. We note that monetary policy must persistently violate the Taylor principle after exit, $\phi < 1$, for it is required to "accommodate" the active fiscal policy. If it refused to do so, the equilibrium after exit would be characterized by a hyper-inflation (e.g., Bianchi and Melosi, 2018; Loyo, 2000).

A similar regime-dependent equation governs the dynamics of a sovereign default:

$$\mathbb{1}'_{\varsigma_t} b_{t+1} + (1 - \mathbb{1}'_{\varsigma_t}) \theta_t = 0. \tag{3.8}$$

[8]Details on the linearization can be found in Online Appendix A.

Table 1: Regime-dependent parameters

	Crisis	Reform	Default	Exit
ψ	$\psi_{\text{Crisis}} < 1 - \beta$	$\psi_{\text{Reform}} > 1 - \beta$	$\psi_{\text{Default}} = \psi_{\text{Crisis}}$	$\psi_{\text{Exit}} = \psi_{\text{Crisis}}$
$\mathbb{1}$	$\mathbb{1}_{\text{Crisis}} = 0$	$\mathbb{1}_{\text{Reform}} = 0$	$\mathbb{1}_{\text{Default}} = 0$	$\mathbb{1}_{\text{Exit}} = 1$
$\mathbb{1}'$	$\mathbb{1}'_{\text{Crisis}} = 0$	$\mathbb{1}'_{\text{Reform}} = 0$	$\mathbb{1}'_{\text{Default}} = 1$	$\mathbb{1}'_{\text{Exit}} = 0$

Here, a second indicator variable $\mathbb{1}'_{\varsigma_t}$ takes the value of one in regime Default and zero otherwise. The haircut is such that public debt is reduced to its sustainable level (the steady state) because fiscal policy remains active in regime Default. Hence $b_{t+1} = 0$ in this regime and θ_t adjusts endogenously (Uribe, 2006). Note also that the size of the haircut (and therefore the default premium on sovereign debt) depend endogenously on the level of debt because the higher the level of debt, the larger the haircut.

We define equilibrium as follows. First, we restate conditions (3.1)-(3.8) and the definition for inflation $\pi_{H,t} = p_{H,t} - p_{H,t-1}$ more compactly as

$$\Gamma_{\varsigma_t} x_t = E_t x_{t+1}, \tag{3.9}$$

where $x_t = (y_t, r_t, i_t, \pi_{H,t}, p_{H,t}, e_t, q_t, b_{t+1})'$. The matrix Γ_{ς_t} contains the parameters and ς_t indicates that they may be regime dependent; an overview of the regime dependent parameters is given in Table 1. The expectations operator E_t captures the uncertainty induced by the possibility of a policy regime change. Therefore, second, we specify the Markov chain. The Markov chain is summarized by a transition matrix

$$\mathcal{P} = [P(i,j)] = [P(\varsigma_{t+1} = j | \varsigma_t = i)], \quad i, j \in \{\text{Crisis}, \text{Reform}, \text{Default}, \text{Exit}\}. \tag{3.10}$$

Third, we state the definition of equilibrium, following Farmer et al. (2011).

Definition 1. A rational expectations equilibrium is a mean square stable (MSS) stochastic process that, given the Markov chain (3.10), satisfies (3.9) in all regimes $\{\varsigma_t\}$ at all times.

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

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

Key in this definition is the notion of stability, which is different in a regime switching model from what is commonly used in models where the policy regime is fixed. Intuitively, an explosive debt trajectory in some regimes is possible in equilibrium, if the economy moves sufficiently quickly to another regime where debt is stabilized. Therefore, the expected duration of the "explosive" regimes is key for stability (Bianchi and Melosi, 2018).

4 Theoretical analysis

We now derive a number of closed-form results in order to shed light on the economics of the model. First, we show that an active fiscal policy coupled with membership in a currency union induces a sovereign debt crisis—that is, public debt follows an explosive trajectory. This policy mix is therefore not sustainable. Moreover, we show that while an exit from the union may resolve the debt crisis, expectations of an exit reinforce the debt crisis while the country is still a member of the currency union. In this respect, exit expectations are no different from expectations of an outright sovereign default. Second, we show that exit expectations—unlike expectations of outright default—harm macroeconomic stability more generally: they induce public debt to be stagflationary.

For the theoretical analysis in this section, we use a specific form for the transition matrix (3.10), in line with the graphical representation at the beginning of Section 3

$$\mathcal{P} = \begin{pmatrix} 1-f-\delta-\epsilon & f & \delta & \epsilon \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}. \tag{4.1}$$

We assume that the initial regime is Crisis. This regime persists with probability $1-f-\delta-\epsilon \geq 0$, where $f \geq 0$ denotes the probability of a fiscal reform, $\delta \geq 0$ the probability of default, and $\epsilon \geq 0$ the probability of an exit from the union. Specification (4.1) assumes that all regimes except Crisis are absorbing regimes. This assumption simplifies the algebra considerably. We relax it in our numerical analysis in Section 5 below. To simplify the algebra, we also assume that taxes are invariant to the level of outstanding debt in the active fiscal regimes, that is, $\psi_{\text{Crisis}} = 0$.

4.1 Exit expectations reinforce sovereign debt crises

In this subsection, we assume prices to be perfectly flexible ($\xi = 0$). In this case, public debt is the only state variable in the model, making a closed-form solution particularly tractable.[9] In a first step, we establish a condition for which an equilibrium of the model exists, according to Definitions 1 and 2 above, given transition matrix (4.1).

[9]Because the three target regimes are absorbing, we solve the model backwards using the method of undetermined coefficients. All derivations are detailed in Online Appendix B.

Proposition 1. *Assuming that prices are perfectly flexible ($\xi = 0$), an equilibrium of the regime switching model exists if and only if the following condition for (mean square) stability is satisfied:*

$$(1 - f - \delta - \epsilon) \left(\frac{1}{\beta(1 - \epsilon - \delta)} \right)^2 < 1. \tag{4.2}$$

Proof. In Online Appendix B. □

Intuitively, the way to verify (mean square) stability is to make sure that first, variables remain bounded once the regime shift has occurred (as the three target regimes are absorbing) and that second, the switch to these "stable" regimes occurs sufficiently quickly—which is condition (4.2).[10]

Proposition 1 implies that if the first regime lasts forever ($f = \delta = \epsilon = 0$), no equilibrium exists as in this case $(1/\beta)^2 > 1$. This shows that an active fiscal policy in a small open economy is inconsistent with permanent membership in a currency union. Intuitively, for a small union member, public debt, even if issued in nominal terms, is effectively real because the country lacks control of inflation (Aguiar et al., 2013; De Grauwe, 2011). As a result, an explosive path is inevitable for public debt unless it is stabilized by fiscal policy.[11]

It follows that an equilibrium can exist only if there is a possibility of regime change. Expectations of fiscal reform are particularly helpful in this regard: assuming $\epsilon = \delta = 0$, a probability of fiscal reform $f > 1 - \beta^2 > 0$ is sufficient for an equilibrium to exist, see equation (4.2). In contrast, while ϵ and δ enter the numerator of (4.2) in the same way as f, their influence is not unambiguous for stability: both also enter negatively in the denominator. Hence, they may actually *reduce* stability.[12]

To understand this result, we characterize explicitly the equilibrium in the initial regime. Note first that, in all regimes, flexible prices imply constant output $y_t = 0$ by equation (3.2). By equation (3.1), this implies a constant real interest rate, $r_t - E_t \pi_{H,t+1} = 0$, and a constant real exchange rate $q_t = 0$ by equation (3.3). The latter, in turn, requires $p_{H,t} = e_t$ by equation (3.4), such that prices move one-for-one with the nominal exchange rate after exit. Prior to exit, debt is on an explosive trajectory. This is because fiscal policy is active, but also because

[10] A formal criterion for verifying mean square stability is provided in Farmer et al. (2009). All eigenvalues of $(\mathcal{P}' \otimes I_{n^2})\text{diag}(F_{\varsigma_1} \otimes F_{\varsigma_1}, ..., F_{\varsigma_h} \otimes F_{\varsigma_h})$ must lie within 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, that is, $x_t = F_{\varsigma_i} x_{t-1}$ for $i \in \{1, ..., h\}$. This criterion reduces to the criterion for stability in Blanchard and Kahn (1980) in absorbing states of the Markov chain.

[11] Instead, if the country is large, running an active fiscal policy may impact union-wide inflation (Bergin, 2000; Sims, 1999).

[12] As is easy to verify, the derivative of equation (4.2) with respect to ϵ is positive for ϵ below $\bar{\epsilon} = 1 - 2f - \delta$, but negative above this threshold (and symmetrically for δ). Hence, as ϵ and δ rise stability tends initially to be reduced, whereas once both are large enough, stability tends to be increased.

there are expectations of exit and default. Furthermore, sovereign yields evolve in sync with public debt, as stated in the following proposition.

Proposition 2. *Assume that prices are perfectly flexible ($\xi = 0$). In this case, the solution for public debt and the sovereign yield in the initial regime are given by*

$$b_{t+1} = \frac{1}{\beta(1-\delta-\epsilon)} b_t, \qquad i_t = \frac{\delta+\epsilon}{\beta\lambda(1-\delta-\epsilon)} b_t. \tag{4.3}$$

Proof. In Online Appendix B. □

The autoregressive root in the solution for debt is larger than unity and increases in ϵ, the probability of exit: exit expectations reinforce crisis dynamics. Observe that the probability of exit enters the solution in exactly the same way as the probability of default δ. This is because investors suffer equally in the event of exit and in the event of default. Ex-ante, they ask for higher yields as they expect these events to materialize. Consequently, for as long as the economy continues to operate in the initial regime, higher interest rate expenditures induce public debt to grow faster.

To dig deeper into the mechanics, we decompose the sovereign yield into the premiums which reflect, in turn, default and exit expectations. By equation (3.6), we see that sovereign yields increase directly in expected losses due to default: $i_t = r_t + E_t\theta_{t+1}$. This expression also shows that sovereign yields move one-for-one with the nominal interest rate r_t, the yield on a domestic-currency (equivalently, domestic-law) security. Exit expectations operate along this margin. To see this, combine equations (3.1), (3.3) and (3.4) to obtain for r_t in the initial regime:

$$r_t = E_t\Delta e_{t+1} = \epsilon e_{t+1}|\text{Exit}, \tag{4.4}$$

where we have evaluated E_t on the basis of the Markov chain. Expression (4.4) is the uncovered interest parity (UIP) condition. It shows that, to the extent that the nominal exchange rate depreciates after exit, r_t must rise in the initial regime. We solve for the nominal exchange rate after exit to obtain

$$\pi_{H,t}|\text{Exit} = \Delta e_t|\text{Exit} = \lambda^{-1} b_t, \tag{4.5}$$

which shows that there is depreciation—reflecting inflation—whenever outstanding debt exceeds its sustainable level (scaled by the steady-state level of debt). Inflation and depreciation in regime Exit reflect an accommodating monetary stance which ensures that the real value of debt is reduced:

$$b_{t+1}|\text{Exit} = \phi b_t. \tag{4.6}$$

If monetary policy after exit does not respond at all to inflation ($\phi = 0$), public debt is reduced to its steady state level immediately upon exit. Otherwise, inflation (and nominal depreciation) are spread over time, and public debt converges back to steady state only slowly ($0 < \phi < 1$). In either case, the level of debt determines the equilibrium price level and the nominal exchange rate after exit.

Turning back to the initial regime, it is now clear why exit and default expectations impact public finances symmetrically: investors suffer losses in both instances. However, there is also an important difference: exit expectations impact sovereign yields by altering interest rates on *all* domestic-law assets whereas default expectations exclusively impact sovereign yields. This is because, after exit, all domestic-law assets—private and public—are affected by nominal depreciation. This has two important implications. First, the nominal interest rate r_t which reflects exit expectations enters the IS curve of the economy (see equation (3.1)). Second, as a result, exit expectations have consequences for the real economy if prices are not fully flexible ($\xi > 0$), a case which we analyze next.

4.2 Exit expectations make public debt stagflationary

If prices are sticky, exit expectations matter for how debt dynamics feed back into the economy. To show this analytically, in this subsection we make the following additional parametric assumptions: we assume that the disutility of work is linear ($\varphi = 0$) and we restrict the slope of the Phillips curve to $\kappa = 1 - \beta$. These assumptions simplify the algebra considerably. Moreover, we make one additional assumption which is critical for obtaining analytical expressions. We assume that the sovereign debt crisis is expected to last for only a single period: $f + \delta + \epsilon = 1$.

If prices are sticky, the real exchange rate is a state variable for as long as the country is a member of the currency union. This gives rise to richer equilibrium dynamics. The following proposition states the solution for output and the price level in regime Crisis.

Proposition 3. *Assume that $\varphi = 0$, $\kappa = 1 - \beta$ and that $f + \delta + \epsilon = 1$. In this case, the solution for output and the domestic price level in the initial regime are given by*

$$y_t = \frac{\xi\varpi(1-\epsilon-\delta)}{(1-\omega)\Lambda} q_{t-1} - \frac{\epsilon\xi\varpi\sqrt{\kappa/(1-\beta\phi)}}{\lambda\Lambda} b_t, \tag{4.7}$$

and $p_{H,t} = -\varpi^{-1} y_t$, where $\Lambda =: (1-\epsilon-\delta)(1-\beta\epsilon\xi(1-\xi)) - \epsilon\sqrt{\kappa/(1-\beta\phi)}(1-\xi(1-\beta\epsilon\xi))$ is positive for ϵ sufficiently below unity.[13]

Proof. In Online Appendix B. □

[13]We find numerically that in the region where $\Lambda < 0$, the solution is no longer mean square stable, that is, the model ceases to have an equilibrium. If prices are sticky, the condition for mean square stability can only be checked numerically.

Equation (4.7) shows that output rises in the real exchange rate q_{t-1}: a weaker exchange rate boosts output. At the same time, because output and domestic prices are strictly negatively related, a weaker exchange rate puts upward pressure on domestic prices, in order to restore purchasing power parity. Besides these conventional effects, importantly, the expressions in Proposition 3 show that output and domestic prices also depend on public debt—but only to the extent that there are exit expectations ($\epsilon > 0$). In this regard, exit and default expectations differ fundamentally.[14]

While default expectations alter sovereign yields directly, via equation (3.6), they have no bearing on the nominal interest rate r_t which matters for the intertemporal allocation of household expenditures. For this reason default expectations are neutral for the allocation in our model. Intuitively, because in equilibrium, private agents are *indifferent* between saving in state contingent claims and government debt, the *expected* return from saving in government debt is exactly *equal* to the nominally riskless rate (Uribe, 2006). In our complete-markets setup, default also leaves the households' balance sheet unaffected. For default expectations to impact economic activity, additional frictions are thus required, for example a "sovereign risk channel" by which expectations of default impact the riskless rate r_t directly (Bocola, 2016; Corsetti et al., 2013a), or alternatively, a channel through which sovereign default impacts the households' balance sheet adversely.[15]

Exit expectations, in contrast, alter the nominal interest rate r_t, see equation (4.4), and, if prices are sticky, also the real interest rate. To see this, we subtract expected inflation on both sides of (4.4) and use equation (3.4):

$$\begin{aligned} r_t - E_t \pi_{H,t+1} &= (1-\omega)^{-1} E_t \Delta q_{t+1} \\ &= (1-\omega)^{-1} [f \Delta q_{t+1} | \text{Reform} + \delta \Delta q_{t+1} | \text{Default} + \epsilon \Delta q_{t+1} | \text{Exit}], \end{aligned} \tag{4.8}$$

where in the second line we have evaluated E_t using the Markov chain. This expression reveals that the *real* interest rate—the rate which governs intertemporal expenditure decisions—is determined by the expected *real* depreciation of the exchange rate after exit, as well as the *real* depreciation of the exchange rate conditional on staying in the currency union.

To proceed further, we derive analytical expressions for the real exchange rate response. We obtain $\Delta q_t | \text{Reform} = \Delta q_t | \text{Default} = -(1-\xi) q_{t-1}$. That is, if the country stays a union member, the speed with which deviations of the real exchange rate from purchasing power

[14]When $\epsilon = 0$, equation (4.7) reduces to $y_t = \xi \varpi (1-\omega)^{-1} q_{t-1}$, where q_t evolves as $q_t = \xi q_{t-1}$ (to obtain the solution for the real exchange rate, we have used equation (3.3)). Clearly, this solution is entirely independent of default expectations.

[15]Incomplete asset markets *per se* are not sufficient to generate a balance sheet effect of sovereign default. This is because, as long as sovereign debt is held exclusively domestically, the loss in assets by households due to default is exactly offset by a decline in expected forthcoming taxation. Therefore, our neutrality result would continue to hold in this alternative environment.

parity are corrected depends on the Calvo parameter only: more price stickiness implies a slower reversion of the real exchange rate. In the case of exit, the result is

$$q_t|\text{Exit} = (1 - \omega)\lambda^{-1}b_t. \tag{4.9}$$

Upon exit, the real exchange rate is determined by the outstanding debt—a higher debt level implying a more depreciated real exchange rate.

To summarize, if prices are flexible (the previous subsection), there is a nominal depreciation after exit. This drives up the nominal interest rate in regime Crisis. If prices are sticky, the real exchange rate depreciates *alongside* the nominal exchange rate after exit. Prior to exit, the real interest rate rises which, in turn, induces a decline of economic activity.

Proposition 3 also reveals that in the presence of exit expectations, sovereign debt raises domestic prices. Intuitively, forward looking firms set their prices while considering current demand as well as expected future inflation. In turn, future inflation is determined by expectations of future policies. We have seen in the previous subsection that, after exit, nominal depreciation induces a rise in inflation. Therefore, inflation may rise already in the initial regime, reflecting the expected inflation after exit which raises future marginal costs. This result is in line with earlier studies, which have emphasized that expected devaluation in fixed exchange rate arrangements tends to erode competitiveness (Obstfeld, 1994, 1997).

We conclude that exit expectations are recessionary to the extent that the real exchange rate is expected to depreciate after exit. At the same time, inflation rises somewhat already prior to exit, implying an erosion of competitiveness in the initial regime. By how much the real exchange rate depreciates after exit depends on the extent of price stickiness after exit. This is, ultimately, an empirical question. Here we notice that empirical studies tend to find that large devaluations tend to be associated with sizable real depreciations (e.g., Burstein et al., 2005).

5 Quantitative analysis

Exit and default expectations have been a major concern in Greece in the period after the global financial crisis, recall Figure 1. We now analyze the Greek experience through the lens of our model. We consider time-series data for the period since Greece joined the euro area in 2001Q1, but our focus is on the more recent sovereign debt crisis. The purpose of our analysis is twofold. First, we show that the model is able to capture key features of the data. Second, we quantify the role of exit expectations for macroeconomic performance in Greece through counterfactual experiments. Throughout we rely on a regime-switching Kalman filter which allows us to determine a) the probability that a specific regime has been in place at a given point in time, b) the dynamics of the model's hidden states and c) counterfactual dynamics of the variables of interest in the absence of exit expectations.

5.1 Macroeconomic performance in Greece

To set the stage, Figure 2 displays key macroeconomic indicators for Greece during 2001Q1-2018Q1. The red solid lines represent actual data. The black dashed lines are the predictions of the model, the gray area represents the time span when exit expectations affected macroeconomic performance according to our estimates, both to be discussed below. From top to bottom we show the debt-to-GDP ratio (in percent), the deficit-to-GDP ratio (in percent), the sovereign yield (in percentage points), and indexes for real GDP as well as the real effective exchange rate vis-à-vis the euro area.[16]

We observe that during the first half of the sample, the developments in Greece were rather benign. While budget deficits were high, debt remained stable relative to GDP because of a strong growth performance during this period. Also, sovereign yields were close to zero. The real exchange rate appreciated steadily.

The picture changed rapidly in the aftermath of the global financial crisis of 2007–2008. In October 2009, the incoming government revealed 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). This set in motion what has become known as the Greek sovereign debt crisis. Sovereign yields started to take off and public debt rose quickly. Deficits remained high for an extended period, and output tanked. The behavior of the real exchange rate is also noteworthy. It continued to appreciate until mid-2010. Only afterwards there was a reversal of the previous trend, but this reversal was rather moderate and very slow. In March 2012 public debt amounted to 175 percent of GDP. At this point debt was restructured and investors suffered a haircut of about 50 percent (Zettelmeyer et al., 2013).

However, after the restructuring the crisis lingered on. In the process Greek banks were recapitalized and, as a result, the debt ratio climbed back to 157 percent until the end of 2012. In fact, by 2013 the debt ratio was back to the pre-haircut level. For the end of the sample period, we observe that output has been stabilized, there is a small budget surplus and public debt seems to have plateaued at about 180 percent of GDP.

[16]We obtain data from Eurostat, except for data on sovereign yields. Here we rely on the Bank of Greece. The Bank of Greece does not report data for the period after the haircut until early 2014. Greece did not have market access during this period. We normalize the index for real GDP and the exchange rate so that their values coincide with the model predictions in 2001Q1.

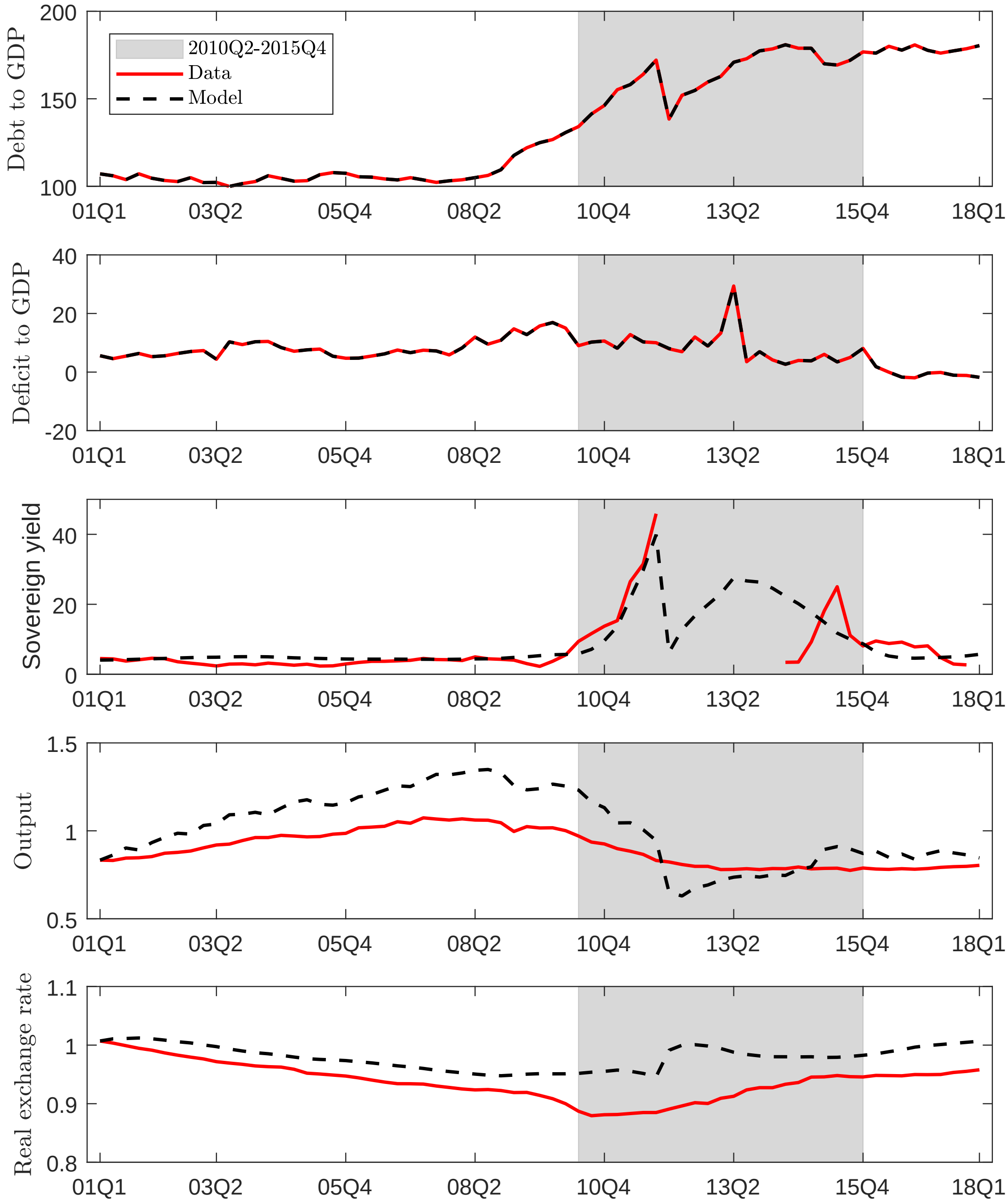

Figure 2: Macroeconomic performance in Greece 2001Q1-2018Q1, actual time-series data (solid red lines) vs model prediction (dashed black lines). The gray area represents the time span when exit expectations affected macroeconomic performance according to our estimates. Public debt and deficits (annualized) are measured in percent of GDP, sovereign yields are on short-term debt (annualized, in percentage points), real GDP and the real exchange rate are indexes. Yield data is not available after the time of the haircut: 2012Q1-2014Q1. Source: Eurostat and Bank of Greece.

5.2 A model-based account

We analyze the Greek experience on the basis of our model as introduced in Section 2 above. For this purpose we proceed in three steps. First, we make the model amenable for quantitative analysis by introducing shocks. We also specify the transmission matrix in such a way that it allows for repeated regime change. Second, we calibrate the model. Last, we apply a regime-switching version of the Kalman filter in order to bring the model to the data. As a result we uncover the regimes and hidden state variables in the model that capture best the Greek experience.

5.2.1 Shocks and transitions

In Section 4 we restricted regime transitions to ensure that all regimes but Crisis are absorbing states of the Markov chain, see equation (4.1). This allowed us to obtain a number of closed-form results. Now we use a more general setup. It permits repeated regime change such that there is a possibility of multiple haircuts and crises. Specifically, we assume for the transition matrix (3.10):

$$\mathcal{P} = \begin{pmatrix} 1-f-\delta-\epsilon & f & \delta & \epsilon \\ c & 1-c & 0 & 0 \\ (1-\epsilon)/2 & (1-\epsilon)/2 & 0 & \epsilon \\ 0 & 0 & 0 & 1 \end{pmatrix}. \tag{5.1}$$

Recall that in a given row of $\mathcal{P}$, the entries in each column are the probabilities of switching to one of the following regimes: Crisis, Reform, Default, Exit, respectively. Each row, in turn, represents one of these regimes (same order, from top to bottom). Parameter $c \geq 0$ (second row) thus captures the probability of entering regime Crisis, conditional on currently being in regime Reform. Accordingly, $1-c$ is the probability of staying in Reform. As before, we assume that a switch to either Default or Exit requires the economy to be in Crisis in the first place. Still, in contrast to Section 4, we no longer assume Default to be absorbing. Instead, once in Default, the economy exits with probability ϵ, but may also switch to Crisis or to Reform with equal probability (third row). Finally, we maintain that Exit is an absorbing state (last row). This is justified because for reasonable probabilities of reentering the union in the future, the effects on agents' expectations are sufficiently small to make no difference for the dynamics inside the currency union.

We introduce two stochastic disturbances. The first disturbance is a *deficit shock*, η_t. It enters the government's budget and we replace equation (3.5) with the following equation:

$$\beta b_{t+1} = (1-\psi_{\varsigma_t})b_t + \lambda(\beta i_t - \pi_{H,t} - \theta_t) + \eta_t. \tag{5.2}$$

The deficit shock captures variation in public debt that is independent of debt service and the systematic feedback of debt into taxation. This may capture surprise deficits in the primary balance, but also favorable borrowing conditions granted to Greece by official foreign lenders such as the European Stability Mechanism (ESM).

The second disturbance is a *demand shock*, μ_t. It allows for the possibility that output rises even though the real exchange rate does not depreciate, a key feature of the Greek data prior to the crisis, see Figure 2. Yet in our baseline model output and the real exchange rate are tightly linked via the risk sharing condition, see equation (3.3) above. In what follows we replace this condition with the following equation:

$$y_t = \frac{\varpi}{1-\omega} q_t + \mu_t. \tag{5.3}$$

As we show shortly, these two modifications are sufficient for our model to capture some key aspects of the Greek data. In our baseline specification, we thus abstract from any further modifications in the interest of transparency, as well as to ensure that the theoretical insights gained in Section 4 are still valid under the model extension.

5.2.2 Calibration

In what follows we calibrate model parameters in order to solve and simulate the model numerically. In principle, a full-blown estimation of regime-switching models is feasible (Bianchi, 2013). The benefit of performing an estimation is that one can learn about key parameters that are difficult to calibrate, and that one obtains a sense of precision of the quantitative results. Still, in what follows we refrain from full-blown estimation, for two reasons. First, we kept our model deliberately stylized in order to perform the theoretical analysis in Section 4 above. Estimation would require us to introduce additional shocks and frictions into the model. As a consequence our quantitative analysis would be less transparent about the key mechanisms that drive our results. Second, in the context of our analysis, the key parameters of interest such as the probability of exit ϵ and the degree of monetary accommodation after exit ϕ are likely to be weakly identified, because exit has never materialized in sample. Similarly, default has occurred only once such that λ (which measures the safe level of debt) as well as the default probability δ are also unlikely to be well identified.[17]

[17] Of course, there is a trade-off between the ability of a model to capture various aspects of the data, that is, its complexity, and the transparency of its mechanics. How one evaluates this trade-off depends perhaps as much on taste as on the issue at hand. In fact, in an earlier version of the paper, we do carry out a full-blown estimation of an extended model version (Kriwoluzky et al., 2015). For this purpose we added a number of features/frictions to the model at the expense of a certain disconnect between the transmission mechanism of the basic and of the estimated model. For the present version of the paper, we choose to carry out the quantitative analysis on the basis of the parsimonious version of the model for the sake of transparency.

Table 2: Model parameters

	Parameter description	Value	Target / Source
β	Time discount factor	0.99	Annual interest rate 4.1%
φ	Inverse Frisch elasticity	4	Chetty et al. (2011)
σ	Trade-price elasticity	1.5	Bennett et al. (2008)
ω	Home bias	0.26	Average exports to GDP
γ	Elasticity of substitution	11	Mark-up 10%
ξ	Calvo parameter	0.875	IMF (2013)
λ	Steady-state real debt	3.532	Reinhart and Rogoff (2011)
ϕ	Taylor rule	0.64	Bianchi and Melosi (2017)
ψ_{Crisis}	Tax parameter	0	Bianchi and Melosi (2017)
ψ_{Reform}	Tax parameter	0.073	MSS equilibrium
ϵ	Probability Exit	0.039	Intrade (Figure 1)
δ	Probability Default	0.052	CDS (Figure 1)
c	Probability Crisis	0.029	See the main text
f	Probability Reform	0.158	See the main text

We report parameter values in Table 2. We assume a discount factor β of 0.99 because a period in the model corresponds to one quarter. We set $\varphi = 4$. This implies a moderate Frisch elasticity of labor supply (Chetty et al., 2011). We set the trade-price elasticity to 1.5, in line with estimates for Greece by Bennett et al. (2008). For the export share in steady state we assume a value of $\omega = 0.26$, corresponding to the average export-to-GDP ratio of Greece in our sample period. We set $\gamma = 11$ such that the steady-state mark up is 10 percent. To account for the slow movements of the Greek real exchange rate in our sample period (Figure 2) indicating a flat Phillips curve, we assume a relatively high degree of price stickiness $\xi = 0.875$, implying that prices are reset on average every two years. Here we stress that our model lacks frictions other than price rigidity that induce nominal inertia (such as wage rigidity). We assume that the sustainable level of debt in steady state is 90 percent of GDP (Reinhart and Rogoff, 2011). This implies $\lambda = 3.532$.[18]

The policy parameters are more difficult to determine. The degree of monetary accommodation after exit ϕ has no empirical counterpart, because Greece has never left the euro area. Since Exit in our model is a regime of "active fiscal and passive monetary policy", we

[18] Recall that $\lambda = B/P$ corresponds to the real stock of debt in steady state. Quarterly output in steady state is $Y = ((\gamma - 1)/\gamma)^{1+\varphi}$. We therefore set $\lambda = 0.9 \cdot 4 \cdot Y = 3.532$.

fix $\phi = 0.64$ in line with estimates by Bianchi and Melosi (2017) for the US at times when this regime was in place. Following Bianchi and Melosi (2017), we also restrict the tax parameter to be zero in the active fiscal regime, $\psi_{\text{Crisis}} = 0$. Instead, for Reform we set $\psi_{\text{Reform}} = 0.073$. This is the lowest number which still ensures a mean square stable equilibrium in our model (taking as given the other parameter values). This number is also in line with estimates for this parameter for the US in passive fiscal regimes (Bianchi and Melosi, 2017).

Regarding the model's stochastic structure, we assume that η_t and μ_t are independent and Normal distributed, with variance $\sigma_\eta^2 = 0.03$ and $\sigma_\mu^2 = 0.01$, thereby giving more weight to deficit shocks. While the solution of the model itself does not depend on these parameters, the Kalman filter output does. Picking these two values guarantees that the rise of debt-to-GDP after the haircut in 2012Q1 is attributed to fresh deficits (a large positive deficit shock) rather than to a drop in GDP (a large negative demand shock). Other than that, the filter prediction is rather robust to variation in the values of the two variances.

Lastly, we determine the parameters in the transition matrix $\mathcal{P}$. We impute the probabilities of default δ and exit ϵ from the CDS and intrade data shown in Figure 1. Because ϵ and δ are constant in our analysis, while the two probabilities display a slight upward trend in Figure 1, we calibrate $\delta = 0.052$ and $\epsilon = 0.039$ as the *average* of the probabilities of default and exit during this period.[19] Regarding the probability of transitioning from Reform to Crisis we assume that $c = 0.029$. This reflects that the developments in Greece were benign after it joined the euro area until the start of the sovereign debt crisis.[20]

Finally, we determine the probability of fiscal reform f as we target an average duration of regime Crisis of four quarters. This target accounts for the recent European experience. The crisis started to unfold in the euro area at large in the second half of 2010 as sovereign spreads vis-à-vis German bunds took off in a number of euro countries, in addition to those of Greece. The policy responses across countries differed considerably, both in terms of speed and intensity. Still, most euro countries implemented far-reaching reforms during the course of 2011.[21] Formally, we impose $1/(1 - f - \epsilon - \delta) = 4$, such that, given the values for ϵ and δ,

[19]Of course, these numbers are merely suggestive. First, these probabilities are assumed to be constant in our analysis. Second, the intrade bet covers an exit scenario of *any* euro country, not just of Greece, although it seems reasonable to assume that a Grexit has been by far the most likely exit event. Third, it has been argued that the CDS on Greek sovereign debt may be triggered by a Grexit, even in the absence of outright default. In this case, the "hazard" probability reflects both the probability of exit and the probability of default.

[20]Greece joined the euro area in 2001Q1, and the sovereign debt crisis started in 2009Q4. The time in between those two events is 35 quarters. We thus calibrate c to solve $1/(1 - c) = 35$.

[21]In response to a IMF-EU bailout package, Portugal implemented far reaching austerity measures and structural reforms under socialist PM Coehlo and his finance minister Victor Gaspar. In Spain, the outgoing socialist prime minister Zappatero pushed through a constitutional reform putting in place a "golden rule" deficit cap in September. In Italy, PM Mario Monti unveiled a 30-billion-euro package of austerity measures in December. Also in December the European Union's six-pack legislation came into force. Among other things, it strengthened the procedures to reduce fiscal deficits.

we obtain $f = 0.158$.

5.2.3 Filtering and results

We use a Kalman filter to uncover the model's hidden state variables lagged real exchange rate, public debt as well as shocks, that can best account for the Greek experience: $\{q_{t-1}, b_t, \eta_t, \mu_t\}$. For this purpose we specify as observable variables the debt-to-GDP and the deficit-to-GDP ratios, shown in the top panels of Figure 2 above.[22] One complication when using the Kalman filter in the context of a regime-switching model is that the regime is another unobserved state, and in fact one that evolves non-linearly. Hence, we may not rely on the conventional filter, but resort to a "switching" Kalman filter instead (Kim and Nelson, 1999). We implement the filter numerically following the steps described in Murphy (1998).

As explained in Bianchi (2013), agents in regime-switching models might form expectations by using a different transition matrix $\mathcal{P}$ than the one used ex-post by the econometrician. This might reflect, for instance, knowledge of the econometrician that one of the regimes has never materialized, in which case one may impose zero transition probability to this regime in the filter. This is useful in our application, because we know, for example, that regime Exit has never materialized. We therefore impose the following additional information in the filter: regime Default has been visited in 2012Q1 and *only then*; Exit has never materialized; and finally, at the start of the sample in 2001Q1, the economy was in regime Reform.[23] For all other periods, the filter uses the transition matrix (5.1).

We now turn to the results. The top panel of Figure 3 displays the (smoothed) probabilities assigned to regime Crisis and Default by the Kalman filter. To understand this graph, recall that the regime is an unobserved state. As a result, the Kalman filter attaches a probability that the economy has visited a particular regime at a given point in time. By construction, the probability of Default is one in 2012Q1 and zero otherwise. We find that in mid-2010, the probability of being in regime Crisis starts to rise sharply. Moreover we find a very high probability that the economy has switched back to regime Crisis after the haircut in 2012Q1. The probability of Crisis then declines slowly until 2015Q4.

The bottom panel of Figure 3 displays, for each quarter, the probability assigned by the

[22] In the model, debt to (annual) GDP is given by $(b_{t+1} - \lambda y_t)/(4Y)$, and (annualized) deficits to (annual) GDP are $(b_{t+1} - b_t)/Y$ (both in deviation from steady state). A complication arises in regime Default. In the budget deficit data, the 2012 Greek haircut is not counted as a surplus, whereas in our observation equation for deficits it is counted as such. Therefore, in this regime we correct the budget deficit for the realized haircut. Furthermore, we have to decide whether the deficit shock η_t realizes before or after the haircut. We assume it realizes after, such that in regime Default $\beta b_{t+1} = \eta_t$ (recall equation (3.8)). This allows us to capture the refinancing of Greek banks which happened right after the Greek haircut, shows appears as a large η_t in the default period.

[23] We thank one anonymous referee for pointing this strategy out to us.

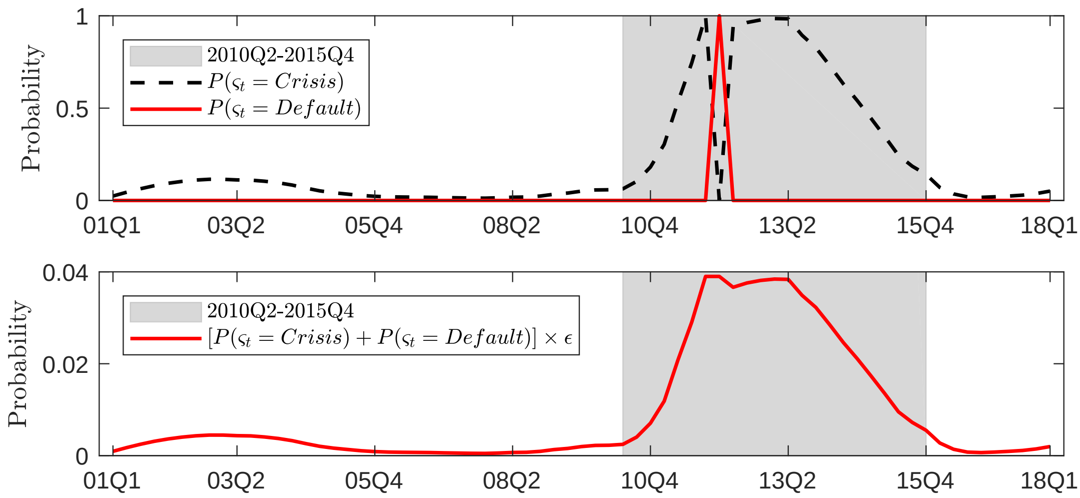

Figure 3: Model predictions. Top: smoothed probability of economy being in regime Crisis (red solid lines) and Default (black dashed lines), as implied by the Kalman filter. Bottom: smoothed probability of economy being in regime Crisis or Default as implied by the Kalman filter, times the exit probability ϵ.

Kalman filter of exiting the currency union in the next quarter. This probability fluctuates over time because an exit may happen only if the economy is either in regime Default or Crisis (whereas conditional on being in these regimes, the exit probability is ϵ) and because the probability of being in these regimes fluctuates, as shown in the upper panel of the figure. Hence, according to our estimates, exit expectations affected macroeconomic outcomes during the period 2010Q2-2015Q4, which in our figures we mark in gray.

We stress, however, that the time variation in the exit probability in Figure 3 is entirely due to the uncertainty about which regime has been in place at a given point in time. This uncertainty is one of the *econometrician*. The agents in the model, instead, know the current regime and understand that—conditional on each regime—the probability of regime change is constant. Bianchi and Melosi (2016) discuss models where *agents in the model* attach a time-varying probability to regime change.

Last, we consider the model predictions for the variables shown in Figure 2. Recall that the figure displays actual data (red solid lines) next to the model predictions for the same variables (black dashed lines). We stress that while debt and deficit data has been fed into the regime-switching Kalman filter, the other variables have not been targeted. And yet we find that the model accounts reasonably well for the actual developments. The model captures the output expansion before 2009 as well as the long-lasting contraction after 2009. The same holds for the dynamics of the real exchange rate: the model predicts the real appreciation until 2009 as well as the reversal after 2010. Finally, the model matches very well the path for sovereign yields, and here in particular the spike preceding the haircut in 2012Q1. Overall we find that our model is able to account for some key features of the data.

5.3 Counterfactual dynamics

We next rely on model simulations to conduct counterfactual experiments. The purpose of these experiments is to quantify the role of exit expectations for macroeconomic performance in Greece. We specify two counterfactuals, each of which assumes alternative regime switching probabilities.

First, we set $f' = f + \epsilon$ and $\epsilon = 0$, that is, we assume that agents attach zero probability to an exit but instead consider Reform more likely once the economy is in Crisis. For these alternative parameter values we simulate the model using the innovations and initial states that we obtain as Kalman filter output for the baseline. For the second counterfactual, we set $\delta' = \delta + \epsilon$ and $\epsilon = 0$. Here the probability of Exit is shifted to Default. As we consider both counterfactuals jointly we are able to isolate two distinct effects of exit expectations: a) they foreshadow an implicit default and hence induce a faster accumulation of debt due to higher yields (eliminated in the first counterfactual), and b) they induce stagflationary dynamics (eliminated in both counterfactuals).

Figure 4 shows the results. The red solid lines show the baseline, the black dashed lines show the first counterfactual (higher probability of Reform), the black dotted lines show the second counterfactual (higher probability of Default). During the first half of the sample, the baseline and counterfactual dynamics coincide because exit expectations were virtually zero during this period (recall Figure 3). Instead, notable differences start to develop after 2010. For both counterfactuals, the output collapse would have been smaller and the real exchange rate would have depreciated more quickly had there been no speculation about a Grexit. The difference relative to the baseline illustrates the quantitative importance of the stagflationary effect of exit expectations during the Greek crisis. We find that, during the period when exit expectations impacted macroeconomic outcomes (the gray area), output was on average 4.4% lower due to exit expectations.

Instead, differences between the two counterfactuals arise when looking at the dynamics of debt, deficits, and sovereign yields. Indeed, under the first counterfactual sovereign yields flatten substantially, because redenomination risk ceases to be a driver of sovereign yields. As a consequence of lower interest rate payments, the debt ratio increases by less. This reduces the probability of outright sovereign default inducing a further reduction in yields and the debt ratio, and so on. Overall, in the absence of redenomination risk, the debt ratio remains

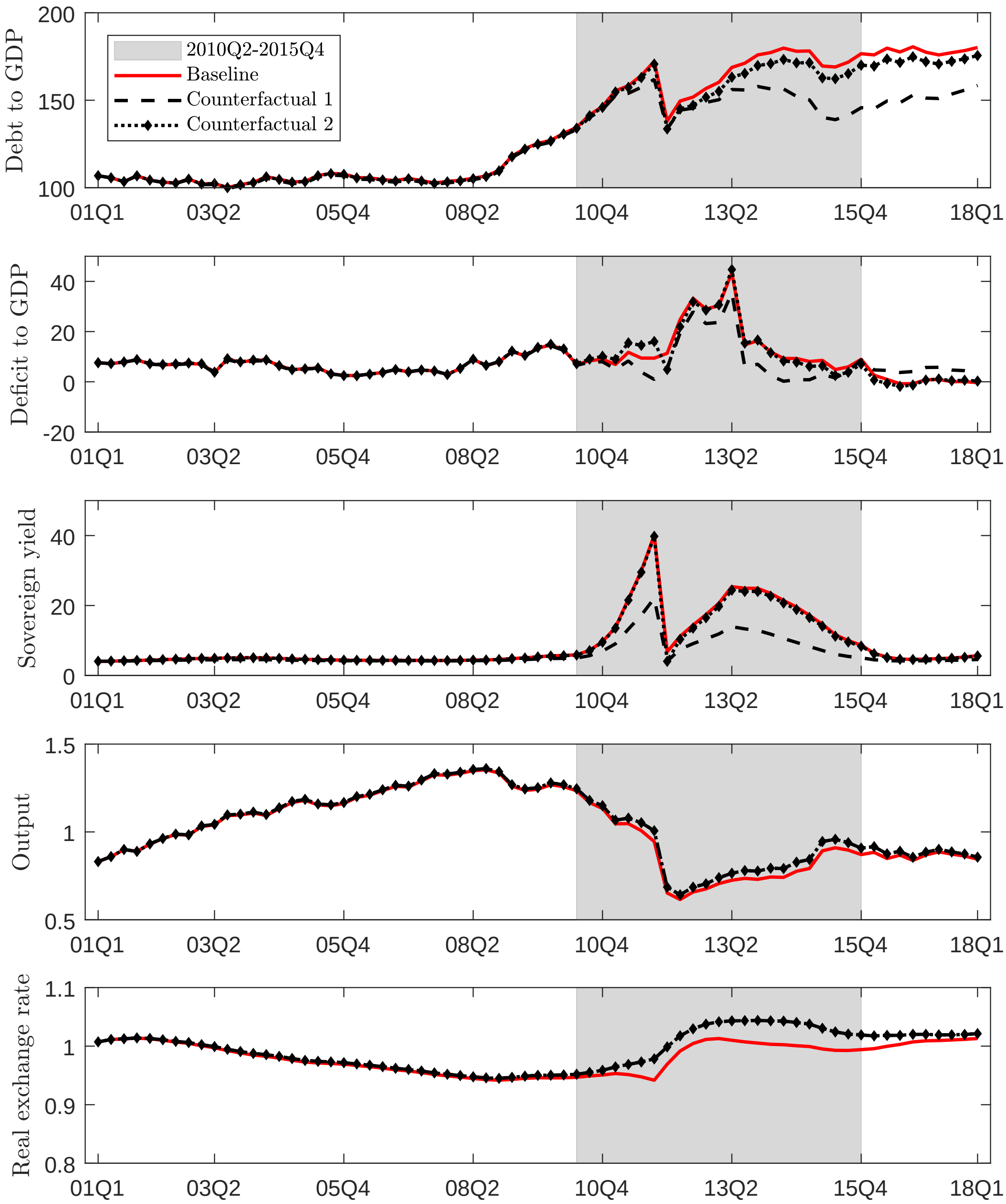

Figure 4: Macroeconomic performance in Greece, baseline (red solid line) and counterfactuals. Counterfactual 1: set $f' = f + \epsilon$ and $\epsilon = 0$ (black dashed line). Counterfactual 2: set $\delta' = \delta + \epsilon$ and $\epsilon = 0$ (black dotted line with diamonds).

stable and the budget deficit declines relative to GDP. In contrast, this effect is absent in the second counterfactual: the decline in redenomination risk is matched by a corresponding increase in the risk of outright sovereign default. As a result, the dynamics of debt, deficits and sovereign yields remain largely unchanged relative to the baseline scenario.

5.4 Robustness and extension

In this section we assess the robustness of our results as we consider several modifications of our model. They concern the specification of, in turn, the policy mix after exit, the nature of international financial markets, and the ergodic probability of regime Exit. Moreover, in Online Appendix C we report results for two additional model variations. They concern a possible output cost of sovereign default and a possible response of union-wide interest rates to the developments in Greece.

First, under our baseline scenario we assume for regime Exit that the country permanently maintains an inflationary policy mix, as an active fiscal policy is paired with a central bank that persistently violates the Taylor principle. We now consider an alternative scenario for which we continue to assume that monetary policy accommodates an active fiscal policy after exit. However, this policy mix now has a limited duration: for regime Exit we assume there is a probability of 25% that the country moves on to a new regime where passive fiscal policy is coupled with active monetary policy. Agents in the model thus expect the inflationary stance after exit to last only for about one year. The (black) dashed lines in Figure 5 show the result. The effects of redenomination risk are dampened relative to the baseline (solid lines), because inflation and depreciation after exit are reduced. Sovereign yields respond less and hence, the build-up of debt after the haircut in 2012Q1 is smaller. Also the stagflationary effects of exit expectations are weaker: in particular, the real exchange rate depreciates faster after the haircut.

In a second experiment we relax the assumption of complete financial markets. Instead, we assume that agents have access to a one-period nominal bond that is traded internationally. We assume that after exit, the bond is traded in foreign currency, and we assume a negative net foreign asset position in steady state—minus 30% of annual GDP, corresponding to Greece's NIIP position in the early years after joining the euro area. Taken together, these assumptions imply that nominal depreciation after exit generates a negative balance-sheet effect for domestic households. Still, we find that the model predictions under incomplete markets, shown by the (black) dotted lines with diamonds in Figure 5, are very close to the baseline.[24] The notable difference relative to the complete-markets case is that the dynamics of the real exchange rate are now more pronounced: the real exchange rate appreciates more

[24] In the case of incomplete markets, we conduct the robustness analysis by running again the Kalman filter. This is because with incomplete markets, the model has an additional state variable (net foreign assets), which needs to be uncovered as a hidden state by the filter. Under incomplete markets, we also reduce the standard deviation of demand shocks μ_t to obtain reasonable predictions for the output series.

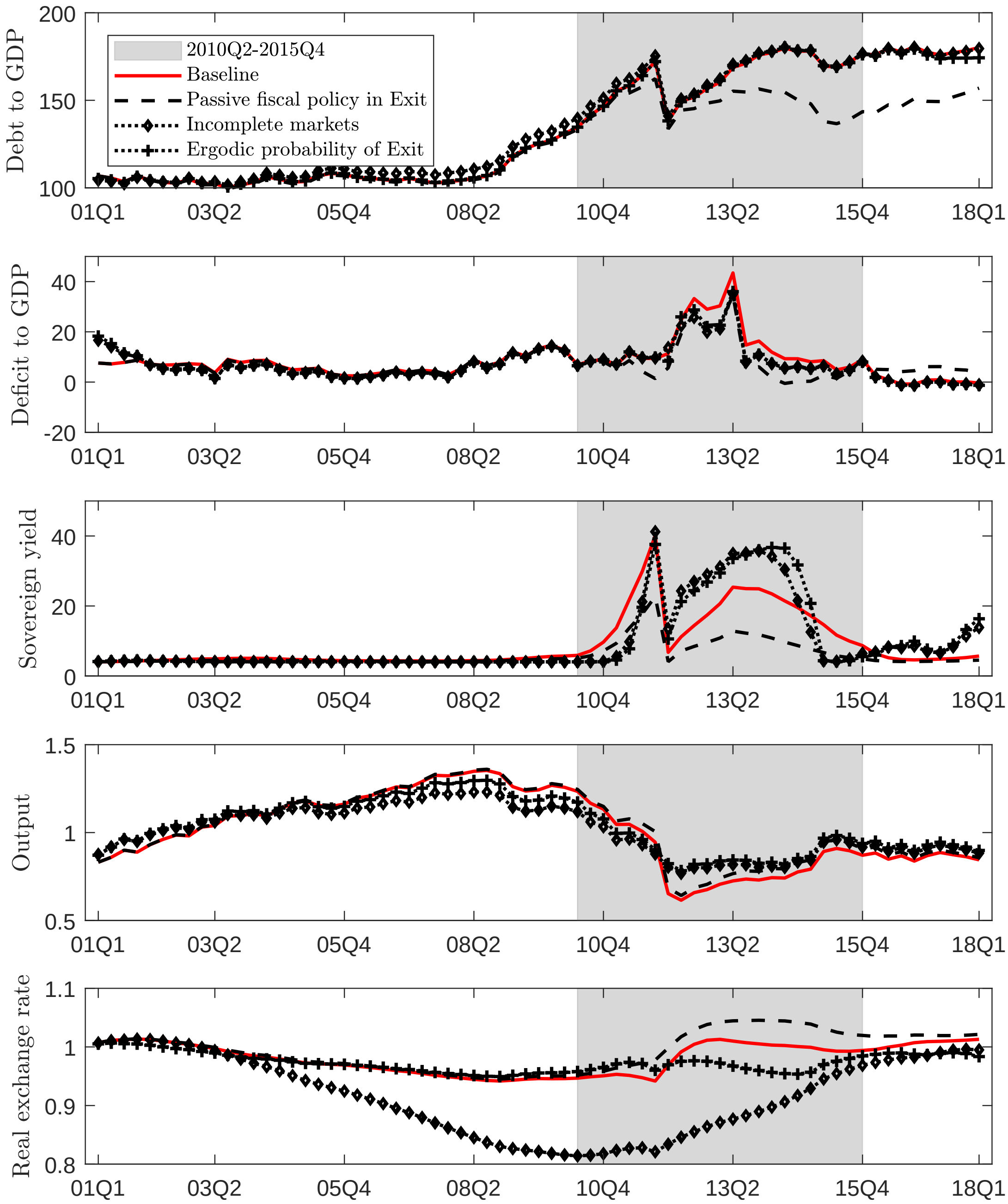

Figure 5: Macroeconomic performance in Greece, baseline (red solid line) and robustness. Robustness exercise 1: switch to passive fiscal policy after exit (black dashed line). Robustness exercise 2: incomplete markets (black dotted line with diamonds). Robustness exercise 3: smaller ergodic probability of Exit (black dotted line with pluses).

strongly prior to the crisis, and it depreciates more sharply after the crisis. Moreover, the output boom and bust are somewhat reduced relative to the baseline.

Third, in the baseline scenario we implicitly assume that the ergodic probability of regime

Exit is equal to one—see Markov chain (5.1). This is because, by making regime Reform transitory relative to the theoretical analysis in Section 4, Exit is the only absorbing state of the Markov chain. We now relax this assumption and assume instead that, conditional on being in Reform, the economy may move on to a further regime which is characterized by identical parameter values as Reform. However, the new regime differs from Reform in that it is an absorbing state of the Markov chain. We set the probability of transition to this additional regime to be such that the ergodic probability of regime Exit implied by the Markov chain is 25%. Again, we find that the model predictions under this alternative Markov chain, shown by the (black) dotted lines with pluses in Figure 5, are very close to what we obtain for the baseline.

6 Conclusion

Membership in a currency union is not irreversible. Expectations of an exit may arise during sovereign debt crises, because exit allows countries to reduce their liabilities through currency redenomination, inflation, and depreciation. In this paper, we ask how this possibility impacts a sovereign debt crisis and macroeconomic performance more generally. In our model we show that, as market participants anticipate the possibility of exit and depreciation, the debt crisis intensifies, and public debt has a stagflationary impact on the economy.

We also analyze Greek time-series data through the lens of our model. In doing so, we obtain an estimate that is was likely that Greece pursued an active fiscal policy from 2010 to 2015, which in our model is associated with exit expectations during this period. Moreover, we quantify the contribution of exit expectations to macroeconomic performance in Greece and find non-trivial effects for sovereign yields, but also for the real exchange rate and output. In particular, we find that exit expectations caused an average contraction of output of more than 4 percent during the period from mid-2010 until end-2015.

In concluding we stress that while our analysis is silent on the benefits and costs of an actual exit, it makes transparent that exit expectations can amplify the adverse dynamics of a sovereign debt crisis within a currency union. 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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