Exit expectations in currency unions

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Abstract

The adoption of a common currency is not irreversible. In this paper, we develop a model of a small open economy which is initially part of a currency union. We show that, first, expectations of regime change arise necessarily in equilibrium, if fiscal policy fails to stabilize public debt. A regime change implies an alternative fiscal policy or, through exit from the union, monetary autonomy. Second, if monetary policy is expected to revalue debt after exit, yield spreads rise prior to exit, reflecting redenomination risk. We explore the macroeconomic implications of redenomination risk by calibrating the model to Greek data.

Keywords: Currency union, fiscal policy, regime change, exit, redenomination risk, euro, Greek crisis, Markov-switching linear rational expectations model

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1 Introduction

Currency unions provide a nominal anchor to inflation-prone member states (Alesina and Barro 2002). Delegating monetary policy to a hawkish central bank reduces inflation bias and thus differences in nominal interest rates across member states. The euro area is a case in point. Figure 1 displays monthly yield spreads on government bonds for Italy, Spain, Ireland, and Greece relative to Germany: they fell strongly in the run up to the creation of the euro in 1999 and stayed close to zero for about a decade. Their rise after 2009, at times of protracted budget deficits and large public liabilities, is often interpreted as a compensation for the possibility of an outright sovereign default (e.g. Lane 2012). Yet, in addition to credit risk, these yield spreads may also reflect "fears of a reversibility of the euro" (ECB 2013). Indeed, expectations of a member state's exit from the union may give rise to redenomination risk: if liabilities are expected to be converted into a new, weaker currency, their prices decline prior to exit, driving up yields.[1]

In this paper, we ask why redenomination risk may arise within a currency union and to what extent it differs from credit risk. We find that lack of fiscal discipline—typically considered a major cause for sovereign credit risk—may, in fact, also cause redenomination risk. Moreover, in terms of macroeconomic implications, redenomination risk, in contrast to credit risk, tends to undermine the stability gains of currency-union membership.

Building on the New Keynesian small open economy framework developed by Galí and Monacelli (2005) and others, we develop a model which allows policy regimes to change over time and assume that agents are fully aware of this possibility. Policy regimes are captured by simple feedback rules for monetary and fiscal policy. Initially, there is no independent monetary policy, as the economy is assumed to be part of a currency union. At the same time, it lacks fiscal discipline. In the terminology of Leeper (1991), fiscal policy is "active" as is it does not adjust (sufficiently) in a "passive" manner to stabilize debt. In principle, an active fiscal policy is sustainable as long as the price level is free to adjust in order to bring about a change in the value of government debt (Sims 1994, Woodford 1995, and Cochrane 2001). Yet, in a small open economy which is a member of a currency union, purchasing power parity ties down the domestic price level in the long-run.

Against this background and similar in spirit to Davig and Leeper (2007a), we establish our first result: under the fiscal rule in place, an equilibrium obtains only if market participants

[1]For the euro area, there is evidence of exit expectations from the online betting markets (Shambaugh 2012). In February 2012 Buiter and Rahbari (2012) coined the term "Grexit" and suggest a "likelihood of a Greek exit to 50% over the next 18 months". In May 2012 the German Ifo-think tank published a report on "Greece's exit from European Monetary Union: historical experience, macroeconomic implications and organisational implementation", see Born et al. (2012).

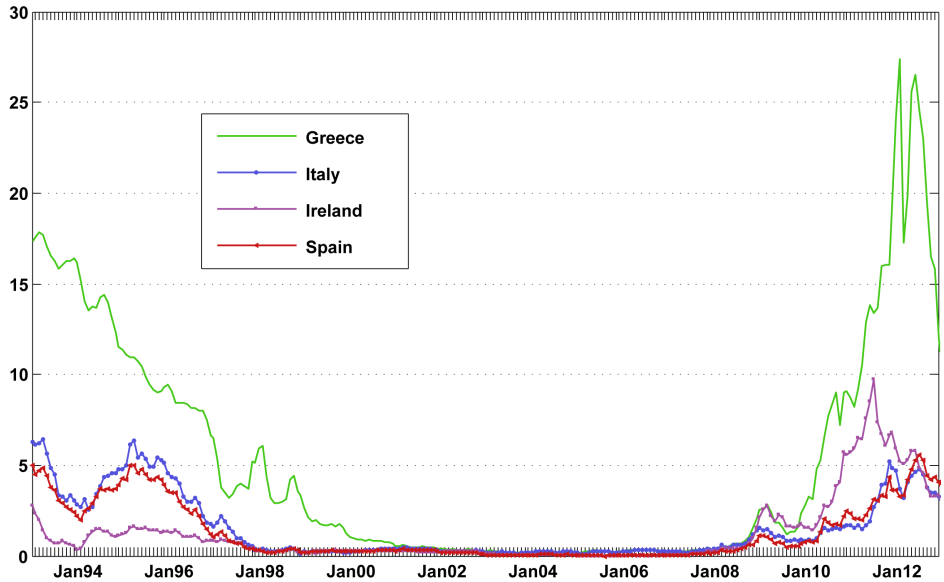

Figure 1: Interest rate spread vis-à-vis Germany. Notes: Long-term interest rates for convergence purposes, monthly observations 1993–2012; source: ECB.

expect a regime change to take place at some point.[2] Expectations about regime change arise necessarily in equilibrium, because active fiscal policy is inconsistent with permanent union membership. Regarding regime change, we consider two scenarios, allowing for expectations of either a change of the monetary or the fiscal regime.

Under the first scenario the country exits the currency union and starts operating an independent monetary policy which accommodates active fiscal policy. More precisely, it adjusts interest rates less than one-for-one to inflation thereby revaluing the debt stock which accumulated during union membership. This policy regime is inflationary, which we show, as a second result, to be necessary and sufficient for expectations of a depreciation to arise under the initial regime. Under the second scenario regarding regime change, the country remains part of the currency union, but alters its fiscal rule. The new fiscal rule is passive and ensures sufficient budget surpluses to service the outstanding debt. In addition, we assume that at the time of regime change there is a credit event, as a haircut is applied to outstanding government debt. This gives rise to credit risk while the government accumulates debt under the initial regime, providing a natural benchmark against which we assess the implications of redenomination risk.

[2]Formally, we allow for policy regimes to change within a Markov-Switching Linear Rational Expectations model. Davig and Leeper (2007a) use this framework to generalize the Taylor principle by showing that equilibrium determinacy obtains under a policy rule which would give rise to equilibrium indeterminacy in a fixed-regime model, provided there are expectations of a switch to a policy rule which is sufficiently aggressive towards inflation. In contrast, in our setup, the expected regime change ensures a mean square stable equilibrium as defined by Farmer et al. (2009) rather than determinacy.

Consider a surprise increase in the primary deficit (a "deficit shock"), due to a lump-sum tax cut under the initial regime. In the presence of redenomination risk, the shock is recessionary. Intuitively, as (real) interest rates rise, private consumption and output fall. Furthermore, inflation takes off already before the actual exit takes place due to forward-looking price-setting decision. Higher prices, in turn, crowd out net exports, which leads to a further decline in domestic output. Hence, reversibility risk induces stagflationary effects of budget deficits. It is reminiscent of the classic inflation bias: a fundamental inconsistency in the policy framework induces a lack of credibility thereby worsening the trade-off faced by policy makers (Barro and Gordon 1983). In case there is only credit risk, instead, deficits have no allocative consequences. Ricardian equivalence obtains as the accumulated debt stock is known to be serviced once the new fiscal regime is put in place. Also, while government yields rise in line with credit risk, effective savings conditions remain unchanged. As a result, deficits are neutral for the allocation even under the initial policy regime.

We also interpret the European sovereign debt crisis through the lens of our model, notably the macroeconomic developments in Greece between late 2009 and early 2012. The upward revision of the fiscal deficit at the beginning of this period presumably supports the notion of an active fiscal policy. In due course, the macroeconomic outlook deteriorated further, fueling speculation of a Grexit. Eventually, debt was restructured in early 2012, as fiscal reform was supposedly under way. We calibrate the model to account for these developments, exposing it to the time series of actual primary deficits. In addition, we rely on time-series data for private and sovereign yield spreads to identify market beliefs regarding regime change. We find that market beliefs about a Grexit have been small, and that risk premia due to redenomination risk account for merely 10% of the rise in sovereign spreads. Nevertheless, redenomination risk did have a strong bearing on the Greek economy, explaining about a quarter of the output decline during the period under consideration.

Our analysis relates to the literature on currency crises more generally. In fact, the notion that profligate fiscal policy fuels speculation regarding the duration of a fixed exchange rate regime dates back to at least Krugman (1979). In currency pegs, the finiteness of foreign currency reserves may give rise to expectations about currency revaluation. Within currency unions, this channel is absent by definition, but other factors may fuel speculation about exit and currency depreciation. We put forward one plausible channel: the inability of fiscal policy to sustain public debt at given prices. That said, we acknowledge the possibility that other factors may drive speculation of exit and depreciation and, hence, redenomination risk.

A number of papers have analyzed the conduct of fiscal policy in currency unions from the perspective of the fiscal theory of the price level, which is also operative in parts of our analysis. The focus of these contributions are the implications of the fiscal rule in one or several large member countries for the entire union (Woodford 1996, Sims 1997, Bergin 2000). One noteworthy result is that pursuing an active fiscal policy may be in a member state's interest, as it allows to attain a permanent increase in wealth at the expense of the rest of the union. In contrast, we analyze the case of a small open economy and abstract from developments in the rest of the union. In this regard, we find that an active fiscal policy gives rise to redenomination risk in equilibrium, inducing stagflationary effects to public debt and to deficit shocks.

The remainder of the paper is organized as follows. Section 2 presents the regime-switching model and characterizes the properties of a solution. Section 3 establishes our main results and illustrates the macroeconomic implications of redenomination risk. In Section 4, we apply the model to Greek data. Section 5 concludes.

2 The model

Our model builds on the New Keynesian small open economy framework (Galí and Monacelli 2005). We focus on a single country which is sufficiently small so as to have a negligible impact on the rest of the world. Within the country a representative household consumes, saves and works, while monopolistically competitive firms produce a variety of goods. They are constrained in their pricing-decisions à la Calvo. The country relates to the rest of the world insofar as consumption is a composite of goods produced at home and abroad and firms export part of their production. Furthermore, saving takes place via a complete set of internationally traded state-contingent securities. The government issues one period debt in order to finance lump-sum transfers. Government debt is nominally riskless in the baseline version of the model, an assumption which we relax in our analysis below. We capture monetary and fiscal policy through simple feedback rules, distinguishing two possibilities in each case. Regarding monetary policy, the options are either to maintain a currency union with the rest of the world or to operate an independent monetary policy. The fiscal rule either stabilizes public debt at given prices or fails to do so.

Our model permits these policy rules to change as part of the equilibrium process, in a way consistent with agents' expectations.[3] Indeed, as stressed by Davig and Leeper (2007a), once it is recognized that policy regimes may differ across time, it is desirable to endow agents in the model economy with this very insight. In order to keep the analysis tractable, we assume exogenously given beliefs of regime change within a Markov-Switching Linear Rational

[3]The framework underlying our model has been used extensively to contrast the properties of alternative policy rules within fixed-regime models (see, for instance, Galí and Monacelli 2005 and Corsetti et al. 2013b).

Expectations (MS-LRE) model.[4] In what follows, we directly present the model in MS-LRE form and delegate an exposition of the underlying non-linear framework to Appendix A.

2.1 The model

Our analysis is based on a first-order approximation to the optimality conditions of households and firms, the market clearing conditions as well as to the policy rules. The approximation is valid around a deterministic steady state, which is the same for every policy regime, with balanced trade, zero inflation and purchasing power parity. In what follows, we refer to variables in terms of deviation from this steady state using small-case letters. Note also that we only consider shocks which arise in the domestic economy, leaving the rest of the world unaffected.

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

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

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \kappa \left(\varphi + \frac{\gamma}{\varpi}\right) y_t. \tag{2.2}$$

Here $\pi_{H,t}$ denotes domestic (producer price) inflation ($\pi_{H,t} = p_{H,t} - p_{H,t-1}$), y_t denotes output and r_t is the nominal interest rate.[5] As for parameters, the discount factor of the household is given by β, the coefficient of constant relative risk aversion by γ and the inverse of the Frisch elasticity by φ. We further define $\varpi := 1 + \omega(2-\omega)(\sigma\gamma - 1)$ and $\kappa := (1-\beta\xi)(1-\xi)/\xi$, where σ denotes the trade price elasticity and ω the weight of imports in the production of final goods. $1-\xi$ is the fraction of firms which are randomly selected to adjust prices within a given period.

Under complete international financial markets output is tied to the terms of trade s_t, the price of exports relative to imports,

$$y_t = -\frac{\varpi}{\gamma} s_t, \tag{2.3}$$

$$s_t = p_{H,t} + e_t. \tag{2.4}$$

The second equation relates the terms of trade to domestic producer prices and the variable e_t. It represents the nominal exchange rate in terms of deviation from steady state, defined as the price of domestic currency in terms of foreign currency. In case the country maintains

[4] In a stylized two-period model of exchange-rate policies, Drazen and Masson (1994) show beliefs of regime change to vary with the credibility of policy makers as well as with the state of the economy.

[5] More generally, while the country maintains membership to a currency union, it is the nominal interest rate on securities issued under domestic jurisdiction, see the discussion further below and in the beginning of section 3.1.

a currency union with the rest of the world, both share a common currency or, equivalently, the relative price of "currencies" is unity. Still, it is useful to distinguish between domestic and foreign "currency" as a way to keep track of the jurisdiction under which securities are issued. While all securities are denominated in common currency, "domestic securities" are understood to be issued under domestic jurisdiction and "foreign securities" issued under foreign jurisdiction. This distinction becomes relevant if the country exits the union. Upon exit, domestic securities are converted into new currency, whereas foreign securities are not.[6] More specifically, we assume that they are converted at par and that the price of the new currencies adjusts to clear the foreign exchange market.

As regards fiscal policy, we posit that the government levies lump sum taxes and issues one-period debt. Real public debt ($\hat{d}_t$) and tax receipts ($\hat{t}^r_t$) are both measured in terms of steady-state output, and expressed in percentage point deviation from steady state (indicated by a hat). ζ denotes the debt-to-GDP ratio in steady state. We assume that the government issues debt in its own currency, or equivalently, under domestic jurisdiction. Moreover, government debt is nominally riskless. The evolution of government debt is thus given by[7]

$$\beta \hat{d}^r_t \quad = \quad \hat{d}^r_{t-1} + \zeta(\beta r_t - \pi_{H,t}) - \hat{t}^r_t. \tag{2.5}$$

A second set of equilibrium relationships *varies across policy regimes.* Specifically, regarding tax collections we posit the following fiscal rule:

$$\hat{t}^r_t = \psi_{\varsigma_t} \hat{d}^r_{t-1} - \varepsilon^d_t, \tag{2.6}$$

where the ς_t indicates that the parameter ψ (which measures the responsiveness of taxes to the level of debt) follows a discrete-time Markov chain $\{\varsigma_t\}$ which determines the evolution of policy regimes over time. Monetary policy also possibly differs across regimes. In case of membership in the currency union, we impose $e_t = 0$. Alternatively, if monetary policy is independent, we assume it to follow an interest rate feedback rule, while the exchange rate adjusts to clear the foreign exchange market.

[6] In practice, the conversion of securities in the course of a national currency reform is likely to depend on the jurisdiction under which securities are issued. For instance, the discussion of a possible Grexit suggests that securities issued under Greek law are converted into new currency upon exit (see, for example, Buiter and Rahbari 2012). 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).

[7] We state real government debt in terms of producer prices, rather than consumer prices, in order to eliminate the terms of trade as another state variable in the model. This simplifies the solution considerably, while making a negligible quantitative difference, provided that home bias is strong (80% in our baseline calibration).

Altogether we consider the following three regimes, reflecting the particular interest of our analysis:

$$\text{Union AF:} \qquad e_t = 0, \qquad \psi < 1 - \beta \tag{2.8 - 1}$$

$$\text{Union PF:} \qquad e_t = 0, \qquad \psi > 1 - \beta \tag{2.8 - 2}$$

$$\text{Float AF:} \qquad r_t = \phi_\pi \pi_{H,t}, \quad \psi < 1 - \beta, \quad \phi_\pi < 1. \tag{2.8 - 3}$$

In the first and third regime, ψ is small such that taxes adjust not sufficiently to stabilize outstanding debt, that is, fiscal policy is active (AF). Instead, given the specific assumptions on the Markov chain that we impose below, tax collections suffice to stabilize the level of outstanding debt at given prices in the second regime, a situation of passive fiscal policy (PF). The "AF/PF" suffix thus characterizes the fiscal rule. The first two regimes are characterized by a membership in a currency union. In the third regime the country operates an independent, but passive monetary policy, accommodating active fiscal policy: it adjusts nominal interest rates less than one-for-one to inflation ($\phi_\pi < 1$).

2.2 Equilibrium and stability

We are now in a position to define an *equilibrium*, following Farmer et al. (2011). First, we restate equations (2.1) - (2.8) more compactly:

$$\mathit{\Gamma}_{\varsigma_t} x_t = E_t x_{t+1} + \mathit{\Psi}_{\varsigma_t} \varepsilon_t^d, \quad \varsigma_t \in \{\text{Union AF, Union PF, Float AF}\}, \tag{2.9}$$

where $x_t = (y_t, r_t, \pi_{H,t}, p_{H,t}, e_t, s_t, \hat{t}_t^r, \hat{d}_t^r)'$. The matrices $\mathit{\Gamma}_{\varsigma_t}$ and $\mathit{\Psi}_{\varsigma_t}$ contain the model's deep parameters and ς_t indicates that they are regime dependent. Regime transitions are governed by a matrix $P = [p_{ij}] = [Prob(\varsigma_t = j; \varsigma_{t-1} = i)]$ specified below.

Definition 1. A rational expectations equilibrium is a mean square stable (MSS) stochastic process that, given the Markov chain $\{\varsigma_t\}$, satisfies equation (2.9).

Definition 2. An $n-$dimensional process $\{x_t\}$ is MSS if there exists an $n-$vector μ and an $n \times n$ matrix $\mathit{\Sigma}$ such that

- $\lim\limits_{n\to\infty} E_t[x_{t+n}] = \mu$
- $\lim\limits_{n\to\infty} E_t[x_{t+n}\ x_{t+n}'] = \mathit{\Sigma}$.

Note that the concept of *stability* as defined above thus 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 be not globally explosive, which is captured by MSS. The duration of a regime is thus key for stability. It is governed by the transition matrix on which we impose a specific structure:

$$P = \begin{pmatrix} \mu & (1-\mu)\lambda & (1-\mu)(1-\lambda) \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}, \quad 0 \leq \mu \leq 1, \quad 0 < \lambda < 1. \tag{2.10}$$

It implies that regime one is transitory (unless $\mu = 1$), while regimes two and three are absorbing states. λ determines the likelihood of being absorbed into regime two, and we restrict it to the open interval $(0, 1)$. Graphically, our Markov chain prescribes the following sequence of regime transitions:

$$\text{Union AF}_{\circlearrowleft\mu} \qquad \longrightarrow_{1-\mu} \qquad \begin{cases} \lambda & \text{Union PF}_{\circlearrowleft 1} \\ 1-\lambda & \text{Float AF}_{\circlearrowleft 1} \end{cases}$$

Initially, there is thus membership in a monetary union paired with an active fiscal policy. In any period, the economy stays in Union AF with probability μ, and leaves this regime with probability $1-\mu$. λ, in turn, is the probability weight of a change in the fiscal rule. By contrast, a change in the conduct of monetary policy, that is, exit from the monetary union, is expected with a probability of $1-\lambda$. In this case, the fiscal rule is assumed to remain unchanged, which leads to "default by inflation", associated with a nominal depreciation. Importantly, both Union PF and Float AF are absorbing states, in the sense that the regimes will remain in place indefinitely.

Generally, the solution of MS-LRE models is obtained through specific algorithms (Farmer et al. 2011). Under our assumptions on the transitions probabilities, the problem simplifies considerably. Since the two target regimes are absorbing, we are able to solve the model backwards using the method of undetermined coefficients. This is particularly welcome, because we can thereby ensure the *uniqueness* of our solution, as the method of undetermined coefficients always delivers all candidate solutions. For the parameter specifications which we consider, we find that at most one of the candidate solutions satisfies mean square stability.[8] Appendix B solves the MS-LRE in its most general form, including credit risk as will be introduced in section 3.2.

[8]Note that in general MS-LRE models may have multiple fundamental ('non-sunspot') equilibria, see Farmer et al. (2011) for an example. In our analysis, we consider MSS solutions of the form $x_t = F_{\varsigma_t} x_{t-1} + G_{\varsigma_t} \varepsilon_t^d \ \forall \varsigma_t$.

3 Redenomination risk

We now investigate why redenomination risk may arise in a currency union and explore its consequences. In a nutshell, we show that it reflects an irreconcilability between profligate fiscal policy and maintaining currency union membership for a small open economy. In terms of consequences, redenomination risk turns out to have far reaching macroeconomic implications, as it induces budget deficits to be stagflationary.

3.1 Why redenomination risk arises

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

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

This condition holds under all policy regimes, but the case of a currency union is of particular interest. In this case $e_t = 0$ and $e_{t+1} \neq 0$ only in case the country exits the currency union. The nominal interest rate r_t corresponds to the yield of a one-period discount bond issued under domestic jurisdiction, which pays off one unit of common currency if no exit occurs, and one unit of new currency if exit does occur. More precisely, r_t is the spread in the yield of such a bond relative to one issued under foreign jurisdiction, where 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 measured in common currency are constant.[9]

Condition (3.1) holds in equilibrium and rules out arbitrage possibilities as market participants are able to trade both domestic as foreign securities. 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, domestic discount bonds must promise high returns in equilibrium, as foreign discount bonds pay off strictly better (in terms of new domestic currency) in those states of the world where exit and depreciation occurs. The level of r_t therefore measures redenomination risk. In our model, public debt beyond its steady state

[9] The relation which underlies equation (3.1) is given by $r_t - r_t^* = -E_t(\Delta e_{t+1})$, where r_t^* is the yield of a one-period discount bond issued under foreign jurisdiction (in terms of deviation from steady state). As returns in common currency are not influenced by developments in the small member state under consideration, we have $r_t^* = 0$. More fundamentally, (3.1) results from combining two Euler equations $\gamma c_t = \gamma c_{t+1} - (r_t - E_t\pi_{t+1})$ and $\gamma c_t = \gamma c_{t+1} - (r_t^* - E_t\Delta e_{t+1} - E_t\pi_{t+1})$, which in turn are linearizations of the two asset pricing equations $R_t^{-1} = E_t(\rho_{t,t+1})$ and $R_t^{*-1}/\mathcal{E}_t = E_t(\rho_{t,t+1}^*/\mathcal{E}_{t+1})$. Here $\mathcal{E}_t$ is the nominal exchange rate and R_t^{-1} and R_t^{*-1} denote the prices of discount bonds issued under domestic and foreign jurisdiction, respectively, with the payoff structure described in the main text above. ρ is the stochastic discount factor. See also Appendix A.

level gives rise to redenomination risk in regime Union AF, as we establish in the following proposition.

Proposition 1. *Given the transition matrix* (2.10)*, any rational expectations equilibrium satisfying the conditions summarized in system* (2.9) *features expectations of a policy regime change (that is, it requires* $\mu < 1$*). Moreover, expectations about currency depreciation upon exit increase in the level of outstanding public debt.*

Proof. We proof the first part by assuming to the contrary that there are no expectations of a regime change ($\mu = 1$). We show that in this case there is no rational expectations equilibrium, exploiting the fact that absent regime change the existence of a MSS process requires variables to be on non-explosive trajectories in each regime (Farmer et al. 2009). We proceed by showing that public debt is on an explosive trajectory in regime Union AF. First, absent expectations about regime change, $r_t = 0$ by (3.1). Second, combine (2.2),(2.3) and (2.4) to obtain

$$\beta E_t(p_{H,t+1}) = (1 + \beta + \frac{\kappa\varphi\varpi}{\gamma} + \kappa)p_{H,t} - p_{H,t-1}, \tag{3.2}$$

which has a unique non-explosive solution given by $p_{H,t} = \phi p_{H,t-1}$, where $\phi = \phi_{\text{aux}}/2\beta - \sqrt{\phi_{\text{aux}}^2/4\beta^2 - 1/\beta}$ with $\phi_{\text{aux}} = 1 + \beta + \kappa\varphi\varpi/\gamma + \kappa$, so that ϕ lies between zero and one. This expression illustrates that purchasing power parity pins down the domestic price level in the long run. Third, combine the equations for debt (2.5) and taxes (2.6) to obtain

$$\beta\hat{d}_t^r = (1 - \psi)\hat{d}_{t-1}^r + \zeta(\beta r_t - \pi_{H,t}) + \varepsilon_t^d. \tag{3.3}$$

The last equation shows that debt is on an explosive trajectory, as $1 - \psi > \beta$ and both the evolution of r_t and $\pi_{H,t}$ are isolated from the level of debt and of deficit shocks under Union AF. Thus, there is no equilibrium for $\mu = 1$.

Now turn to the second part of the proposition. We focus on Float AF. As we establish in Appendix B, output and inflation in this regime evolve as

$$\begin{aligned}
\pi_{H,t} &= \phi_{\pi,d}\hat{d}_{t-1}^r + \phi_{\pi,\varepsilon}\varepsilon_t^d, \\
y_t &= \phi_{y,d}\hat{d}_{t-1}^r + \phi_{y,\varepsilon}\varepsilon_t^d,
\end{aligned}$$

where $\phi_{\pi,d}, \phi_{\pi,\varepsilon}, \phi_{y,d}$ and $\phi_{y,\varepsilon}$ are strictly positive coefficients. Combining (2.3) and (2.4), we solve for the nominal exchange rate as a function of the endogenous state variables $p_{H,t-1}$ and $\hat{d}_{t-1}^r$ and the shock ε_t^d:

$$\begin{aligned}
e_t &= -\frac{\gamma}{\varpi}y_t - p_{H,t} \\
&= -p_{H,t-1} - (\frac{\gamma}{\varpi}\phi_{y,d} + \phi_{\pi,d})\hat{d}_{t-1}^r - (\frac{\gamma}{\varpi}\phi_{y,\varepsilon} + \phi_{\pi,\varepsilon})\varepsilon_t^d.
\end{aligned}$$

Assuming that the economy operates under regime Union AF at time $t-1$, the nominal interest rate is given by

$$r_{t-1} = -E_{t-1}(\Delta e_t) = (1-\mu)(1-\lambda)\left(p_{H,t-1} + (\frac{\gamma}{\varpi}\phi_{y,d} + \phi_{\pi,d})\hat{d}^r_{t-1}\right).$$

Here we use $e_{t-1} = 0$, $E_{t-1}(\varepsilon^d_t) = 0$ and the fact that the exchange rate moves only in case of an exit from the currency union. Given that $\varpi > 0$ and $\varphi > 0$, expected depreciation (and therefore redenomination risk) increases in the level of outstanding public debt. $\square$

The above result rests on the fact that public debt is on an explosive trajectory in case permanent union membership is coupled with active fiscal policy.[10] Recalling the classic analysis of Leeper (1991), union membership for a small country thus appears as an instant of "active" monetary policy: it is not allowing the price level to adjust in order to stabilize public debt, because its conduct is decided at the union level and by assumption unresponsive to developments in a small member state. In this regard, Proposition 1 makes a positive statement: in case of union membership an active fiscal policy may still be consistent with an equilibrium, provided that market participants expect a regime change to take place at some point.[11] Recall that we assume whenever expectations of regime change arise, expectations about an exit cannot be ruled out ($\lambda < 1$). Hence, it follows immediately from Proposition 1 that exit must be possible for an equilibrium to obtain. At the same time, there will be expectations of a depreciation upon exit, as monetary policy is expected to revalue the debt stock upon exit.[12] Under Union AF, a build-up of public debt will therefore be accompanied by a rise in redenomination risk.

Our result hinges critically on the assumption that the domestic economy is small. Sims (1997, 1999) and Bergin (2000) analyze the implications of an active fiscal policy in large member states of a currency union. They are quite different. In fact, a large member state may sustain an active fiscal policy indefinitely, provided monetary is policy is passive at the union level, thereby allowing the inflationary consequences of a member state's active fiscal policy to be felt across the entire union. The resulting incentive of a member state to pursue an active fiscal policy provides a rationale for constraining the conduct of fiscal policy within

[10]We note that private sector transversality conditions do not constrain public debt to be on a non-explosive path in the present setup. Still, it is unappealing to allow governments to run Ponzi-schemes (Sims 1997). In any case, we restrict our analysis to (mean square) stable equilibria as defined above.

[11]Davig and Leeper (2011) also allow a policy regime which features active monetary and fiscal policy to be maintained for a limited period within a regime-switching model.

[12]It is here that our assumption that the government issues debt under domestic jurisdiction, thus being able to convert it into new currency upon exit, becomes essential. Foreign currency debt is like indexed debt, so expectations about inflation and currency depreciation upon exit would not arise. We note that there is no such assumption needed for the private sector of the economy. We further note that this assumption is in line with much of actual practise in the euro area, see section 4.

a currency union. Our analysis, instead, shows that pursing an active fiscal policy is not necessarily in the interest of a small member state to the extent that it may fuel speculation of an exit from the union.[13]

The above discussion highlights the fact that it is active fiscal policy, in combination with a passive monetary stance upon exit, the key driving factor for redenomination risk to arise in the initial regime. In the following we establish this formally. For this purpose, we consider an alternative scenario where fiscal policy is passive in all regimes. In this case, redenomination risk in the initial policy regime is absent in all equilibria. In addition, there is an equilibrium where exit is not expected.

Proposition 2. *Consider the equilibrium conditions summarized in system* (2.9)*, but assume that* $\psi > 1-\beta$ *in all regimes. Given the transition matrix* (2.10)*, there is an equilibrium where regime change is not expected* ($\mu = 1$)*. Moreover, expectations about currency depreciation upon exit are absent in all equilibria.*

Proof. We prove the first part of the proposition by recognizing that absent regime change ($\mu = 1$), the existence of an MSS process is equivalent to all variables being on non-explosive trajectories in all regimes in isolation. Start with union membership. Along the lines of the proof of Proposition 1, $r_t = 0$ by (3.1) and $p_{H,t} = \phi p_{H,t-1}$ with $0 < \phi < 1$. Given $1 - \psi < \beta$, the autoregressive root in equation (3.3) is strictly smaller than one. Hence, public debt is on a non-explosive trajectory. Next, we establish non-explosiveness under the float. Combining (2.1), (2.2) and the feedback rule for monetary policy implies

$$\begin{pmatrix} 1 & \frac{\varpi}{\gamma} \\ 0 & \beta \end{pmatrix} E_t \begin{pmatrix} y_{t+1} \\ \pi_{H,t+1} \end{pmatrix} = \begin{pmatrix} 1 & \frac{\varpi}{\gamma}\phi_\pi \\ -\kappa(\varphi + \frac{\gamma}{\varpi}) & 1 \end{pmatrix} \begin{pmatrix} y_t \\ \pi_{H,t} \end{pmatrix}. \tag{3.4}$$

The minimum state variable solution to (3.4) is given by $y_t = 0$ and $\pi_{H,t} = 0$. As a consequence, debt evolves as follows: $\beta \hat{d}^r_t = (1-\psi)\hat{d}^r_{t-1} + \varepsilon^d_t$. Again, it is non-explosive as fiscal policy is passive: $1 - \psi < \beta$.

Now turn to the second part of the proposition. Under the float we have $y_t = 0$ and $\pi_{H,t} = 0$ as part of all equilibria (that is: also for $\mu < 1$), and, by (2.3) and (2.4), $\Delta e_t = 0$. Hence, there is no expected depreciation prior to exit from the union. □

Taken together Propositions 1 and 2 show to what extent an active fiscal policy causes expectations of an exit and depreciation upon exit to arise within a small member state of a

[13] As a technical matter, the small open economy which we consider is of measure zero (Galí and Monacelli 2005) such that variables, even those on explosive trajectories, have no impact on the rest of the world. In the present context, one may question the small-open-economy assumption on conceptual grounds. Still, if we were to relax the assumption, the results in Bergin (2000) suggest that Proposition 1 still holds provided that monetary policy is active at the union level and permanent transfers across member states are ruled out.

currency union. Our argument hinges on the assumption that if a country exits the union for lack in fiscal discipline, it will likely accommodate active fiscal policy upon exit by means of its new monetary autonomy (passive monetary policy)—an assumption which strikes us plausible. That said, we stress that even though redenomination risk is fundamentally justified under Union AF, it also provokes a further deterioration of fundamentals through its impact on the government's financing cost (see Section 3.2). Thus, there is the possibility that an autonomous shift in expectations regarding regime change causes fiscal policy to become active, even if it is passive in the absence of such a shift. We do not analyze this possibility in the present paper.[14]

3.2 Redenomination risk vs credit risk

Redenomination risk arises as market participants expect domestic securities to be converted into new currency and, in addition, the new currency to depreciate upon exit. Depreciation, in turn, is expected whenever deficit shocks push public debt beyond its steady-steady level. In order to clarify how redenomination risk impacts the economy, we contrast it to credit risk, the latter arising if market participants expect the government to apply a haircut to its outstanding liabilities in some states of the world (see, e.g., Uribe 2006).[15]

We modify the model to account for this possibility. Specifically, we assume that a credit event takes place at the time of the switch to the new fiscal regime, thereby capturing a scenario of fiscal reform coupled with a one-time default.[16] Specifically, in case of a credit event, the government repudiates the amount $\delta_t > 0$ of its debt obligations, proportional to outstanding debt in excess of the steady-state level:

$$\delta_t = \zeta^{-1}\delta\hat{d}^r_{t-1}, \tag{3.5}$$

where $\delta \in [0, 1]$ is the haircut applied to excess debt. Otherwise, we assume $\delta_t = 0$. As a result, the flow budget constraint of the government is now given by

$$\begin{aligned} \beta\hat{d}^r_t &= \hat{d}^r_{t-1} + \zeta(\beta i_t - \delta_t - \pi_{H,t}) - \hat{t}^r_t && (3.6)\\ i_t &= r_t + E_t(\delta_{t+1}), && (3.7) \end{aligned}$$

[14]Specifically, in case of a membership in the currency union, condition $\psi > 1 - \beta$ is generally not sufficient for debt to be non-explosive, if expectations of an exit and depreciation arise. Because of the resulting risk premiums, the initial regime may become unsustainable, confirming expectations of the exit—the classic scenario of a self-fulfilling currency crisis (see, e.g., Obstfeld 1996). Above, however, we assume that fiscal policy is active independent of expectations regarding regime change.

[15]Uribe (2006) considers a scenario of active fiscal policy coupled with active monetary policy. As debt sets on an explosive path, expectations about partial repudiation adjust endogenously so as to satisfy the government's intertemporal budget constraint. As a result, credit risk rises in close sync with the debt level. The same holds in our analysis, though we simplify it by considering an exogenously given haircut parameter.

[16]Technically, the scenario of a one-time debt default at the time of the switch to Union PF introduces a new regime, see the solution to the full model in Appendix B.

where i_t is the nominal yield on government bonds, or the "sovereign yield spread". Insert (3.1) into (3.7) and apply the law of iterated expectations to obtain the following decomposition of sovereign yield spreads under Union AF:

$$i_t = -(1-\mu)(1-\lambda)E_t(e_{t+1}|\text{Float AF}) + (1-\mu)\lambda\delta_{t+1}. \tag{3.8}$$

The first term captures redenomination risk. It affects nominal interest rates of domestic securities, or "private yield spreads", in general. The second term captures credit risk which only affects the sovereign. Thus, sovereign yield spreads exceed private yield spreads to the extent that partial repudiation of public debt is expected.

We now explore the distinct roles of credit and redenomination risk in the transmission of deficit shocks while the economy operates under regime Union AF. For this purpose we rely on model simulations using parameter values in line with our calibration of the model to Greek data, detailed in Section 4.1 below. An exception are the parameters λ and δ which we vary in what follows. Figure 2 displays impulse responses of selected variables to a one-time deficit shock. While horizontal axes measure time in quarters, vertical axes measure deviations from steady-state, either in percent or percentage points of steady-state output. We show results for the two polar cases: a scenario where there is only redenomination risk ($\lambda = 0.5$, $\delta = 0$), represented by solid lines, and a scenario where there is only credit risk ($\delta = 0.5$, $\lambda \to 1$), represented by dashed lines. In each instant, market participants attach some probability on regime change taking place in the next period. Still, in the scenarios under consideration regime change does not actually materialize, such that Union AF is maintained for the entire period under consideration.[17]

The upper left panel displays the deficit shock. It is assumed to be purely transitory and equal to one percent of steady-state output. In response to the shock, public debt (upper right panel) and sovereign yields (2$^{\text{nd}}$ row left panel) rise steadily, irrespectively of whether there is only credit risk or only redenomination risk. This is because—under Union AF—neither taxes nor the price level adjust (sufficiently) to stabilize the real value of public debt. As debt builds up, expected losses to be realized in some states of the world also increase. Investors ask for compensation through lower bond prices, driving up sovereign yields and debt levels further. As a result, the size of the necessary adjustment, be it through outright default or through exit and inflation, increases in the duration of the initial regime.

The dynamic adjustment of the economy differs fundamentally, however, depending on whether there is only credit risk or only redenomination risk. In the former case (dashed lines) the

[17] Put differently, yield spreads reflect expected losses which are not observed in the sample under consideration, as in the case of "peso problems". Conceptually related is the notion of a "rare disaster", which may account for within-sample deviation from interest rate parity (Barro 2006).

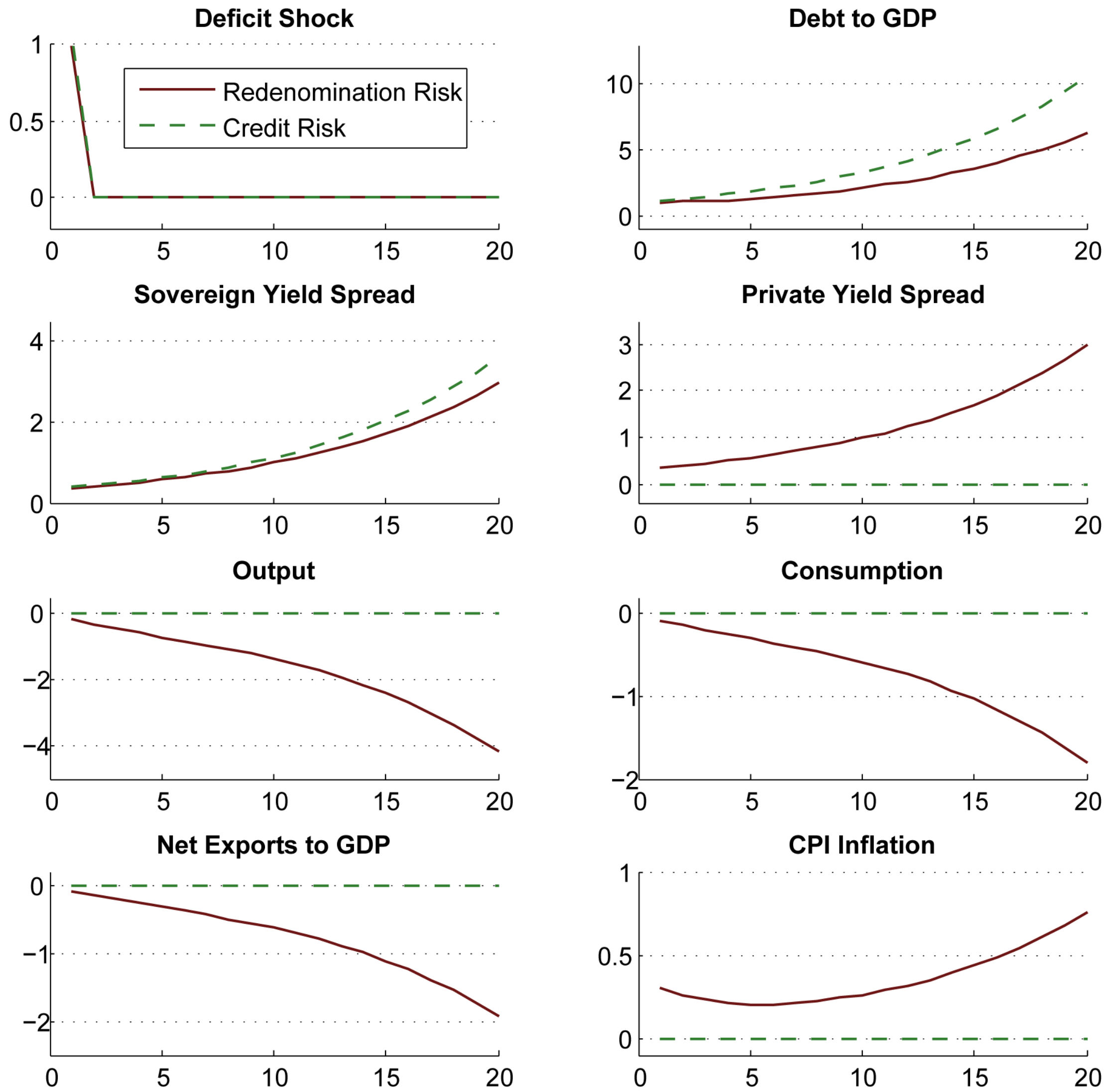

Figure 2: Impulse responses to deficit shock conditional on staying in regime Union AF. Notes: deficit shock equal to one percent of (annual) steady-state GDP. Horizontal axes measure quarters. Vertical axes measure deviations from steady state in percent, and percentage points in case of debt to GDP, net exports to GDP and the deficit shock (annual steady-state GDP in all cases). CPI inflation and the interest rates are annualized.

deficit shock has no bearing on the economy other than on public finances. Importantly, in the absence of redenomination risk, private yield spreads r_t are zero (2^{nd} row right panel). Thus, while the government's refinancing costs rise with credit risk, private-sector interest rates remain unaffected.[18] Furthermore, in the absence of redenomination risk, debt is known to be serviced eventually, once the switch to Union PF has taken place. Ricardian equivalence thus obtains even under the Union AF regime: deficits are neutral in the sense that they have no allocative consequences (Barro 1974).[19]

By contrast, in case there is only redenomination risk (solid lines), private yield spreads rise with the build-up in public debt (Proposition 1). In this case deficits have allocative consequences. Output (3^{rd} row left panel) declines along with consumption (3^{rd} row right panel) and net exports (lower left panel). At the same time, inflation rises (lower right panel). Deficit shocks turn out to be stagflationary in the presence of redenomination risk. Moreover, we note that a one-time deficit shock induces long-lasting effects—the model generates substantial internal propagation.

To better understand the economy's response to deficit shocks in the presence of redenomination risk, we conduct an additional experiment where exit from the currency union materializes in period 10. To simplify the discussion, we again assume that there is no credit risk ($\lambda = 0.5$, $\delta = 0$). Figure 3 shows the responses of selected variables. We contrast results for the baseline case (solid lines) with those for an alternative setup, where price rigidity upon exit declines to an intermediate level (solid lines with diamonds) or disappears altogether (solid line with squares).[20]

The upper left panel shows the response of the nominal exchange rate. Upon exit there is a discrete downward shift and further, more gradual depreciation thereafter. The exchange rate response is stronger, the more flexible prices are in the new regime. This is consistent with the response of inflation (upper right panel): it increases sharply in case prices are flexible after exit. While inflation also takes up in the baseline case, its response is muted relative to a scenario of more flexible prices. In fact, if prices are fully flexible after exit, the real exchange rate does adjust after exit (lower left panel). Instead, in the baseline case, the sluggish response of inflation after exit induces the real exchange rate to depreciate along with the nominal exchange rate. Importantly, large devaluations tend to be associated with a strong decline of the real exchange rate, as prices tend to adjust more sluggishly than

[18]Through a sovereign risk channel (Corsetti et al. 2013a) sovereign credit risk may affect the effective borrowing and savings conditions in the private sector, too. We also note that in our complete-markets setup there are no distributional effects associated with government default.

[19]As the government's financing costs rise, neutrality would break down if taxes were distortionary (Bi 2012).

[20]To allow for this possibility, we modify the Phillips curve in regime Union AF, given that firms anticipate that the frequency of price adjustment changes with a change in the regime. The derivation of the modified Phillips curve is available on request.

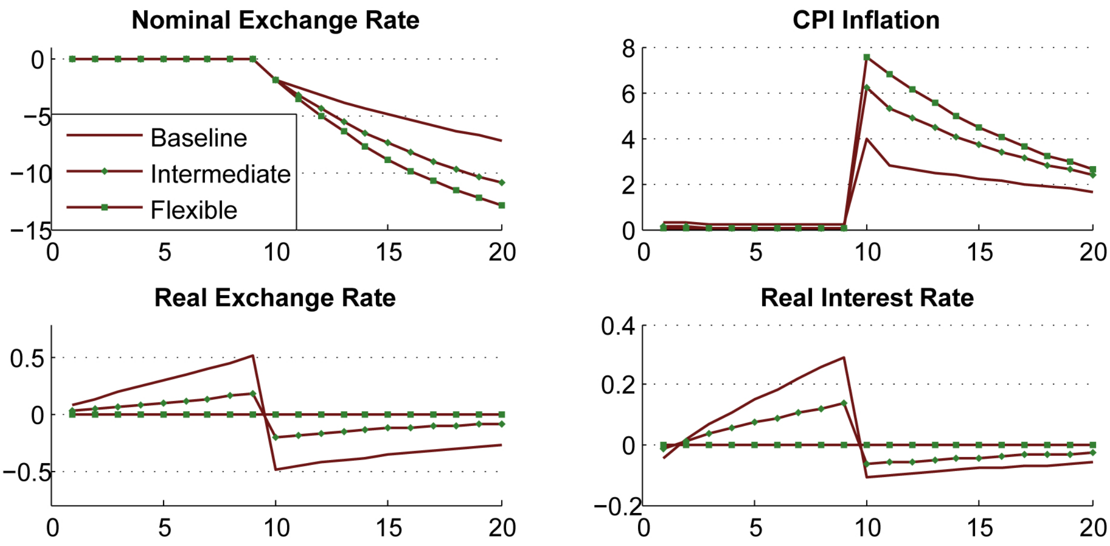

Figure 3: Impulse response to a deficit shock in regime Union AF, with exit from the currency union occuring in period 10, for different levels of price rigidity upon exit. Horizontal axes measure quarters. Vertical axes measure deviations from steady state in percent. The solid line corresponds to the baseline case (unchanged price rigidity); diamonds indicate an intermediate degree of price rigidity ($\xi = 0.75$), and squares indicate flexible prices after exit. CPI inflation and the real interest rate are annualized.

the nominal exchange rate—as in our baseline calibration (Burstein et al. 2005).[21] Prior to exit, equilibrium requires that an expected real depreciation is met by increased real interest rates (lower right panel).[22] Households thus postpone expenditure until after exit. Moreover, consumption is on a declining trajectory, since the size of adjustment increases the longer the initial regime lasts (see Figure 2). Finally, inflation rises prior to exit, implying an appreciation of the real exchange rate which, in turn, accounts for the decline of net exports. Intuitively, forward looking firms tend to raise prices, given that they expect inflation and depreciation upon exit which, in turn, will raise marginal costs.[23] Hence, the inflationary policies which are expected to take place after exit make themselves felt already prior to exit, as the current policy regime is bound to be abandoned for lack of consistency. In this sense, the implications of redenomination risk are reminiscent of the classic inflation bias (Barro and Gordon 1983).

[21] Burstein et al. 2005 consider five large devaluations and find that the real exchange rate response is on average about 90 percent of the nominal exchange rate response. In our baseline calibration, this ratio is a bit less than 50 percent, while in case prices become flexible upon exit it is zero, see Figure 3.

[22] This follows from condition (3.1), once it is expressed in real terms.

[23] In a closed-economy model, Davig and Leeper (2007b) find that deficit shocks are inflationary in a regime of passive fiscal policy, if agents anticipate a switch to a regime of active fiscal policy, where the latter regime is associated with high levels of inflation.

4 The case of Greece 2009–2012

In this section, we illustrate the empirical relevance of the mechanism analyzed above by applying the model to Greek data during the period 2009–2012. Specifically, according to our analysis, in the presence of market beliefs about regime change a build-up in public debt will be accompanied by a rise in credit and redenomination risk, the latter inducing a downturn in economic activity through a crowding out in consumption and a loss in competitiveness. In what follows we assess the quantitative contribution of this mechanism to macroeconomic outcomes in Greece.

As discussed in the introduction, the Greek government faced spiralling financing costs starting in late 2009, as did several other governments in the euro area (see Figure 1 above). Yet the experience of Greece is most dramatic in terms of sovereign yield spreads. In addition, the scenario of an exit from the euro area was arguably most plausible in the case of Greece.[24] Finally, the size and persistence of fiscal deficits arguably support the notion of an active fiscal policy, both prior to and during the crisis. This makes the case of Greece particularly suitable to be studied through the lens of our model.

In what follows we focus on the period 2009Q4–2012Q1. The first quarter of this period coincides with the take-off of sovereign yield spreads, shortly after the incoming government announced a substantial overshooting in 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 an expected regime change, rather than of the regime change itself. Note that before the restructuring Greek public debt—in line with our modelling assumption—was issued almost exclusively under Greek jurisdiction (see, e.g., Buiter and Rahbari 2012 and Buchheit et al. 2013).

4.1 Calibration

We use observations for the Greek economy, if available, to pin down the parameter values of the model. They are displayed in Table 1. A period in the model corresponds to one quarter. The discount factor β is set to 0.99. We assume that the coefficient of relative risk aversion, γ, takes a value of one, consistent with balanced growth. We set $\varphi = 3$, implying a Frisch elasticity of labor supply of 1/3 in line with evidence provided by Domeij and Flodén (2006). The trade-price elasticity σ is set to 1.5, in line with estimates for Greece by Bennett et al. (2008), and ω to 0.2, corresponding to the 2009 export-to-GDP ratio in Greece.

[24]See footnote 1. Occasionally, commentators also contemplated an exit of Spain from the euro area, which was dubbed "Spexit".

Table 1: Model calibration

	Parameter description	Value	Target / Source
β	Discount factor (steady state)	0.99	Annual interest rate 4.1%
γ	risk aversion	1	Balanced growth
φ	Inverse Frisch elasticity	3	Domeij and Flodén (2006)
σ	Trade-price elasticity	1.5	Bennett et al. (2008)
ω	Home Bias	0.2	Export-to-GDP ratio 2009
ξ	Fraction of unchanged prices	0.9	Flat Phillips curve
ϵ	Elasticity of substitution	11	Mark-up 10%
ϕ_π	Taylor-rule coefficient	0.9	Passive monetary policy
ψ	Tax-rule coefficient	0.009/0.02	Active/Passive fiscal policy
ζ	Steady-state debt-to-GDP ratio	5.13	128.3% Debt 2009Q3
δ	Haircut	0.519	51.9% Haircut 2012Q1
μ	Probability of staying in initial regime	0.78	Δ Private yield spread
λ	Haircut vs exit	0.945	Δ Sovereign yield spread

To capture price rigidities we set $\xi = 0.9$, which conflicts with evidence from microeconomic studies such as Nakamura and Steinsson (2008) on the frequency of price adjustments. Nonetheless, the choice of a relatively high degree of price rigidity is appropriate in the context of our framework, as we abstract from frictions which induce a flatter Philips curve for any given value of ξ (see, e.g., Eichenbaum and Fisher 2007). Importantly, recent evidence suggests that Phillips curves indeed have been fairly flat in Greece in the time span under consideration (IMF 2013). Next, we set $\epsilon = 11$, such that the steady-state markup is equal to 10 percent. Regarding the conduct of monetary policy in case of an exit, we assume $\phi_\pi = 0.9$ such that monetary policy is passive. At the same time, we assume $\psi = 0.009$ in case fiscal policy is active, whereas we assume $\psi = 0.02$ for the regimes where fiscal policy is passive.
We pin down a last set of parameter values by matching key features of the Greek economy during the period 2009Q4–2012Q1. Specifically, given that sovereign yield spreads have been very low prior to 2009Q4, we assume that the model is in steady state prior to our sample period and set $\zeta = 5.13$ in order to match the debt-to-GDP ratio of 128.3 percent in 2009Q3. Finally, we set $\delta = 0.519$ implying an effective expected haircut of 51.9 percent, corresponding to the actual value in 2012Q1 according to calculations by Zettelmeyer et al. (2012).
Given parameter values, the model predicts an increase in sovereign and private yield spreads in response to deficit shocks ε_t^d. For each of the 10 quarters of the period under consideration, we specify a value for the deficit shock so as to generate a primary budget deficit in the model which is of the same size as the one observed for Greece. Figure 4 (left panel) displays the actual time series of primary budget deficits. The increase in interest rate spreads, in turn, is governed by the parameters μ and λ, which capture the beliefs regarding regime change. Importantly, while sovereign yield spreads increase in both credit and redenomination risk,

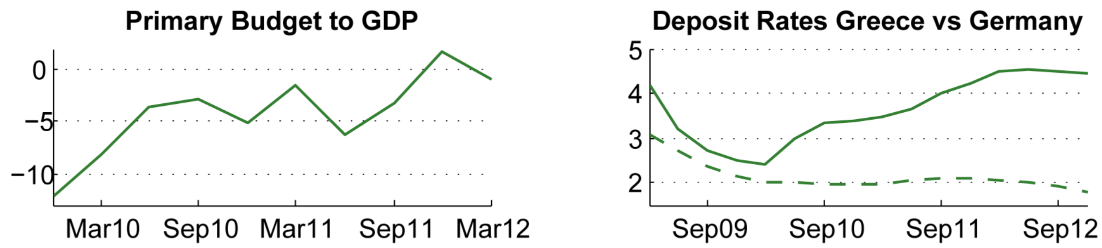

Figure 4: Primary budget balance in Greece. Nominal interest rates on deposits from non-financial institutions and household with local banks—Greece (solid lines) vs Germany (dashed lines). Notes: Horizontal axis measure quarters. Vertical axis measure percent of (annual) GDP for the primary deficit, percent annualized for the interest rates. Sources: Eurostat and ECB.

private yield spreads only increase in the latter. Targeting the actual increases in both variables during the sample period thus allows us to jointly identify the parameters μ and λ. For this purpose we rely on spread data vis-à-vis Germany both for the sovereign and for the private sector. Sovereign yield spreads are shown in Figure 1 above, while private sector yields in Greece and Germany are shown in the right panel of Figure 4.[25] Our calibration yields values for $\mu = 0.78$ and $\lambda = 0.945$, implying a probability of exit of 1.3 percent from one quarter to the next, and of 20.7 percent of an outright default.

4.2 Redenomination risk and credit risk in Greece

We now confront the predictions of the model with actual developments in Greece.[26] Recall that we permit only shocks to the government budget as exogenous source of variation and that, as argued above, they impact the allocation only in the presence of redenomination risk. The top row of Figure 5 displays the behavior of yield spreads: the evolution of sovereign and private yield spreads are shown in the left and right panel, respectively. While yield spreads in 2012Q1 serve as calibration targets, the model's prediction tracks the actual evolution of spreads rather closely. Moreover, comparing the evolution of sovereign and private yield spreads against the background of the decomposition of sovereign yield spreads given by expression (3.8), we highlight a first finding of our quantitative analysis: sovereign yield spreads in Greece appear to be mostly driven by credit risk, with redenomination risk accounting for merely 10 percent of the rise in spreads.

[25] As can be seen in Figure 4, spreads in deposit rates have indeed widened substantially during the period 2009Q3-2012Q1. Deposits with local banks would arguably be converted into new currency upon exit, thus proxying for "domestic securities" as defined above. We verify that a similar pattern in spreads obtains for other possible measures of domestic securities, such as within-country loans from local banks to non-financial institutions and to households.

[26] In what follows actual data are normalized in line with our assumption that the economy has been in steady state initially.

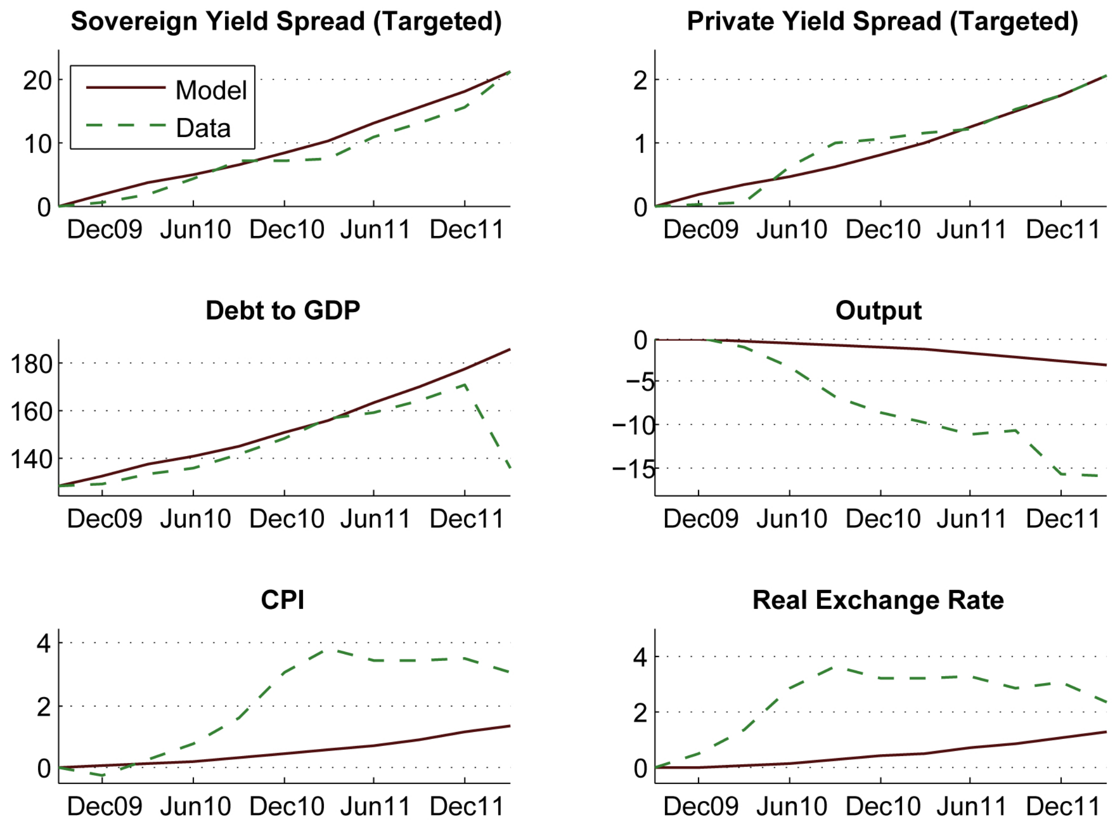

Figure 5: Key variables model versus Greek data. Notes: sovereign and private sector yield spreads in 2012Q1 serve as calibration target. Red solid lines: model prediction; green dashed lines: data. Horizontal axis measures quarters. Vertical axis measures change in percent, and percentage points in case of debt to GDP. CPI inflation and the interest rates are annualized. Data is normalized to zero in 2009Q3; first observation: 2009Q4. Data sources: ECB, Eurostat and IMF.

The middle and lower panels of Figure 5 contrast model predictions with actual data for key economic indicators. Starting with the model's prediction for public debt (2^{nd} row left panel), we note that it tracks actual developments rather closely.[27] The model's prediction for output (2^{nd} row right panel), the CPI (lower left panel) and the real exchange rate (lower right panel) fall short of actual developments. Still, the model accounts for about a quarter of the output decline observed during the sample period and for about a third of the loss of competitiveness, measured either by the CPI (relative to the euro area) or the real exchange rate. Taken together, these findings suggest that redenomination risk did have a rather strong

[27]As discussed above, the restructuring of Greek debt has taken place at the end of 2012Q1, which explains the drop in debt to GDP at the end of the sample. By contrast, the average sovereign spread in 2012Q1 did not decline (spreads were 24.1 percent in January, 27.4 percent in February and 17.2 percent in March, see Figure 1). The same is true for spreads in the private sector.

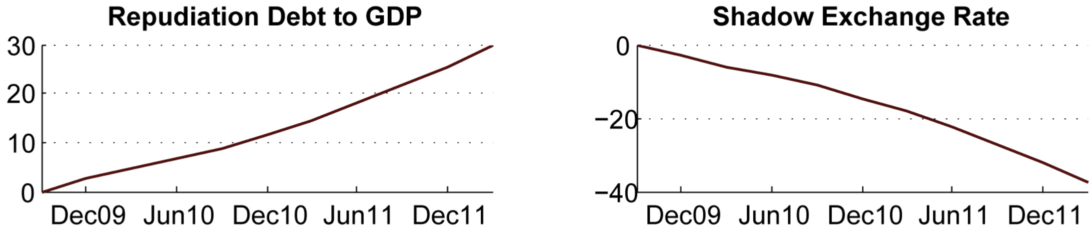

Figure 6: Debt repudiation and shadow exchange rate. Vertical axis measures percentage point changes for debt-to-GDP in haircut scenario, relative changes in percent for the nominal exchange rate; horizontal axis measures quarters.

adverse bearing on macroeconomic outcomes in Greece during the recent crisis.

This last finding may seem puzzling, given that, according to our calibration, market beliefs about exit have been small. Yet it is important to keep in mind that both credit and redenomination risk rise endogenously as long as the initial regime persists and, hence, adjustment is delayed. In order to quantify this effect we compute the expected losses in the event of an outright default and in the event of an exit. Figure 6 shows the results. In the left panel, we report the percentage-point reduction in the debt-to-GDP ratio had the Greek government applied a haircut to its outstanding liabilities. It rises in close sync with the rise in the debt level, pushing up credit risk premiums. By the same token, the right panel in Figure 6 shows the source of redenomination risk. It reports the "shadow exchange rate", that is, the depreciation of the "new Drachma" vis-à-vis the euro had Greece exited the currency union (Flood and Garber 1984). Again, it rises over time in close sync with the evolution of debt, as inflation upon exit is expected to be higher, the higher the current debt level—in line with the fundamental insight of the fiscal theory of the price level.

5 Conclusion

In this paper, building on the standard New Keynesian small open economy framework, we have developed a Markov-Switching Linear Rational Expectations model of changing policy regimes. In particular, policy regimes differ in terms of government budget policies as in terms of the exchange rate regime. As a first result, we show that fiscal policy which does not sustain public debt at given prices is incompatible with permanent union membership. However, an equilibrium may obtain nonetheless to the extent that market participants expect a regime change to take place at some point.

Expectations about a shift in either the fiscal or the exchange rate regime give rise to credit risk and redenomination risk, respectively. In our setup, credit risk emerges because of a possible haircut on outstanding public debt. Redenomination risk, instead, emerges because of a large scale depreciation in case the country exits the currency union. We find that the macroeconomic implications of the two sources of risk differ fundamentally. If only credit risk is present, a deficit shock affects the borrowing conditions of the government, but has no further bearing on the equilibrium outcome. Instead, deficit shocks are stagflationary in the presence of redenomination risk.

We analyze key developments in Greece during the period 2009Q4–2012Q1 through the lens of the model. Specifically, the fact that sovereign yield spreads increase in both credit and redenomination risk, while private yield spreads only increase in the latter, allows us to identify market beliefs about regime change. We find that markets attached a per-quarter-probability of 1.3% to a Grexit and of 20.7% to a credit event. Accordingly, our results suggest a limited role for redenomination risk in accounting for Greek yield spreads. This result is particularly noteworthy in light of the rationale provided by the ECB for its promise of unlimited purchases in secondary sovereign bond market ("Outright monetary transactions" or OMT, for short), namely to restore the monetary transmission mechanism by confronting "fears of a reversibility of the euro". Nevertheless, we stress that redenomination risk did have a strong bearing on the Greek economy: the emergence of private yield spreads explains about a quarter of the output decline during the period under consideration. However, we leave a more detailed analysis of this policy, as well as of the developments in other European countries for future research.

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A Model

In what follows, we present the non-linear model, along with first order and market clearing conditions, as well as details on the log-linearization. Our exposition draws on Corsetti et al. (2013b), focusing on the domestic economy and its interaction with the rest of the world, ROW, for short.

A.1 Non-linear model

Final Good Firms The final consumption good, C_t, is a composite of intermediate goods produced by a continuum of monopolistically competitive firms both at home and abroad. We use $j \in [0,1]$ to index intermediate good firms as well as their products and prices. Final good firms operate under perfect competition and purchase domestically produced intermediate goods, $Y_{H,t}(j)$, as well as imported intermediate goods, $Y_{F,t}(j)$. Final good firms minimize expenditures subject to the following aggregation technology

$$C_t = \left[(1-\omega)^{\frac{1}{\sigma}} \left(\left[\int_0^1 Y_{H,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}} \right)^{\frac{\sigma-1}{\sigma}} + \omega^{\frac{1}{\sigma}} \left(\left[\int_0^1 Y_{F,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \quad (A.1)$$

where σ measures the trade price elasticity. The parameter $\epsilon > 1$ measures the price elasticity across intermediate goods produced within the same country, while ω measures the weight of imports in the production of final consumption goods—a value lower than one corresponds to home bias in consumption.

Expenditure minimization implies the following price indices for domestically produced intermediate goods and imported intermediate goods, respectively,

$$P_{H,t} = \left(\int_0^1 P_{H,t}(j)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}, \qquad P_{F,t} = \left(\int_0^1 P_{F,t}(j)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}. \quad (A.2)$$

By the same token, the consumption price index is

$$P_t = \left((1-\omega) P_{H,t}^{1-\sigma} + \omega P_{F,t}^{1-\sigma} \right)^{\frac{1}{1-\sigma}}. \quad (A.3)$$

Regarding the ROW, we assume an isomorphic aggregation technology. Further, the law of one price is assumed to hold at the level of intermediate goods such that

$$P_{F,t} \mathcal{E}_t = P_t^*, \quad (A.4)$$

where $\mathcal{E}_t$ is the nominal exchange rate (the price of domestic currency in terms of foreign currency). P_t^* denotes the price index of imports measured in foreign currency. It corresponds to the foreign price level, as imports account for a negligible fraction of ROW consumption. We also define the terms of trade and the real exchange rate as

$$S_t = \frac{P_{H,t}}{P_{F,t}}, \; Q_t = \frac{P_t \mathcal{E}_t}{P_t^*} \tag{A.5}$$

respectively. Note that while the law of one price holds throughout, deviations from purchasing power parity (PPP) are possible in the short run, due to home bias in consumption.

Intermediate Good Firms Intermediate goods are produced on the basis of the following production function: $Y_t(j) = H_t(j)$, where $H_t(j)$ measures the amount of labor employed by firm j. Intermediate good firms operate under imperfect competition. We assume that price setting is constrained exogenously à la Calvo. Each firm has the opportunity to change its price with a given probability $1-\xi$. Given this possibility, a generic firm j will set $P_{H,t}(j)$ in order to solve

$$\max E_t \sum_{k=0}^{\infty} \xi^k \rho_{t,t+k} \left[Y_{t,t+k}(j) P_{H,t}(j) - W_{t+k} H_{t+k}(j) \right], \tag{A.6}$$

where $\rho_{t,t+k}$ denotes the stochastic discount factor and $Y_{t,t+k}(j)$ denotes demand in period $t+k$, given that prices have been set optimally in period t.

Households The domestic economy is inhabited by a representative household that ranks sequences of consumption and labour effort, $H_t = \int_0^1 H_t(j)dj$, according to the following criterion

$$E_t \sum_{k=0}^{\infty} \beta^k \left(\frac{C_{t+k}^{1-\gamma}}{1-\gamma} - \frac{H_{t+k}^{1+\varphi}}{1+\varphi} \right). \tag{A.7}$$

The household trades a complete set of state-contingent securities with the rest of the world. Letting Ξ_{t+1} denote the payoff in units of domestic currency in period $t+1$ of the portfolio held at the end of period t, the budget constraint of the household is given by

$$W_t H_t + \Upsilon_t - T_t - P_t C_t = E_t \left\{ \rho_{t,t+1} \Xi_{t+1} \right\} - \Xi_t, \tag{A.8}$$

where T_t and Υ_t denotes lump-sum taxes and profits of intermediate good firms, respectively.

Monetary and Fiscal Policy In case the economy is not part of a currency union, domestic monetary policy is specified by an interest rate feedback rule. Defining the riskless one period interest rate as $R_t \equiv 1/E_t(\rho_{t,t+1})$, we posit

$$\log(R_t) = \log(R) + \phi_\pi (\Pi_{H,t} - \Pi_H), \tag{A.9}$$

where $\Pi_{H,t} = P_{H,t}/P_{H,t-1}$ measures domestic inflation and (here as well as in the following) variables without a time subscript refer to the steady-state value of a variable. Conversely, if the country is part of a currency union the exchange rate is exogenously fixed at unity, $\mathcal{E}_t = 1$.

As regards fiscal and budget policy, we posit that the government levies lump sum taxes, T_t, and issues one-period nominal debt in home currency, D_t. Debt is risky as in any period, the government may default on a fraction $\delta_t \in [0, 1]$ of its outstanding liabilities. The period budget constraint of the government then reads as follows:

$$I_t^{-1} D_t = (1 - \delta_t) D_{t-1} - T_t, \tag{A.10}$$

where I_t denotes the gross interest rate which the government pays on newly issued debt. The following no-arbitrage condition must hold in equilibrium:

$$I_t^{-1} = E_t(\rho_{t,t+1}(1 - \delta_{t+1})). \tag{A.11}$$

It links the interest rate to the expected loss due to default. Next, defining $D_t^r := D_t/P_{H,t}Y$ and $T_t^r := T_t/P_{H,t}Y$ as a measure of real debt and tax revenues to steady state GDP, we posit that

$$T_t^r - T^r = \psi(D_{t-1}^r - D^r) - \varepsilon_t^d. \tag{A.12}$$

ε_t^d measures an exogenous iid shock to tax collections, or, equivalently a "deficit shock".

Market clearing At the level of each intermediate good, supply equals demand stemming from final good firms and the ROW:

$$Y_t(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\epsilon} \left((1 - \omega)\left(\frac{P_{H,t}}{P_t}\right)^{-\sigma} C_t + \omega \left(\frac{P_{H,t}^*}{P_t^*}\right)^{-\sigma} C_t^*\right), \tag{A.13}$$

where $P_{H,t}^*$ and C_t^* denote the price index of domestic goods expressed in foreign currency and ROW consumption, respectively. It is convenient to define an index for aggregate domestic output: $Y_t = \left(\int_0^1 Y_t(j)^{\frac{\epsilon-1}{\epsilon}} dj\right)^{\frac{\epsilon}{\epsilon-1}}$. Substituting for $Y_t(j)$ using (A.13) gives the aggregate relationship

$$Y_t = (1 - \omega)\left(\frac{P_{H,t}}{P_t}\right)^{-\sigma} C_t + \omega \left(\frac{P_{H,t}^*}{P_t^*}\right)^{-\sigma} C_t^*. \tag{A.14}$$

We also define net exports in terms of steady-state output as follows:

$$\frac{1}{Y}\left(Y_t - \frac{P_t}{P_{H,t}} C_t\right). \tag{A.15}$$

A.2 Equilibrium Conditions and the Linearized Model

In the following, lower-case letters denote relative deviation in percent from steady-state values, 'hats' denote (percentage point) deviations from steady-state scaled by steady state output. Variables in the ROW are assumed constant.

Price indices The terms of trade, the law of one price, the CPI, CPI inflation and the real exchange rate can be written as

$$s_t = p_{H,t} - p_{F,t} \tag{A.16}$$

$$p_{F,t} = -e_t \tag{A.17}$$

$$p_t = (1-\omega)p_{H,t} + \omega p_{F,t} = p_{H,t} - \omega s_t \tag{A.18}$$

$$\pi_t = \pi_{H,t} - \omega \Delta s_t \tag{A.19}$$

$$q_t = (1-\omega)s_t \tag{A.20}$$

Intermediate good firms The demand for a generic good (j) is given by

$$Y_t(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\varepsilon} Y_t, \tag{A.21}$$

so that

$$\int_0^1 Y_t(j)dj = \zeta_t Y_t, \tag{A.22}$$

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

$$\zeta_t Y_t = \int_0^1 H_t(j)dj = H_t. \tag{A.23}$$

A first order approximation is given by $y_t = h_t$.

The first order condition to the price setting problem is given by

$$E_t \sum_{k=0}^{\infty} \xi^k \rho_{t,t+k} \left[Y_{t,t+k}(j) P_{H,t}(j) - \frac{\varepsilon}{\varepsilon - 1} W_{t+k} H_{t+k} \right] = 0. \tag{A.24}$$

In the steady state, we have a symmetric equilibrium:

$$P_H = \frac{\varepsilon}{\varepsilon-1}\frac{WH}{Y} = \frac{\varepsilon}{\varepsilon-1} MC^n, \tag{A.25}$$

where the second equation defines nominal marginal costs.

Linearizing (A.24) and using the definition of price indices, one obtains a variant of the New Keynesian Phillips curve (see, e.g., Galí and Monacelli, 2005):

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \kappa mc_t^r, \tag{A.26}$$

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

$$mc_t^r = w_t - p_{H,t} = w_t^r - \omega s_t. \tag{A.27}$$

Here $w_t^r = w_t - p_t$ is the real wage (deflated with the CPI).

Households The first order conditions in deviations from steady state are familiar

$$\begin{aligned} w_t^r = w_t - p_t &= \gamma c_t + \varphi h_t, && \text{(A.28)} \\ c_t &= E_t c_{t+1} - \frac{1}{\gamma}(r_t - E_t \pi_{t+1}). && \text{(A.29)} \end{aligned}$$

Risk sharing implies that consumption is tightly linked to the real exchange rate (see, e.g., Galí and Monacelli, 2005)

$$\gamma c_t = -q_t. \tag{A.30}$$

Government Rewriting the interest rate feedback rule gives immediately

$$r_t = \phi \pi_{H,t}, \tag{A.31}$$

and similarly for the case of currency union membership, where $e_t = 0$.
Equivalently, rewriting the the tax rule (A.12) gives immediately

$$\hat{t}_t^r = \psi \hat{d}_{t-1}^r - \varepsilon_t^d. \tag{A.32}$$

Scale the flow budget constraint (A.10) by producer prices and steady state output, and linearize around zero default to obtain

$$\beta \hat{d}_t^r = \hat{d}_{t-1}^r + \zeta(\beta i_t - \delta_t - \pi_{H,t}) - \hat{t}_t^r, \tag{A.33}$$

where $\zeta := \frac{D}{PY}$ defines debt in steady state.
Next, using that $\rho_{t,t+1} = \beta \left(\frac{C_{t+1}}{C_t}\right)^{-\gamma} \frac{P_t}{P_{t+1}}$, linearize the no-arbitrage condition (A.11) to obtain

$$c_t = E_t c_{t+1} - \frac{1}{\gamma}(i_t - E_t \delta_{t+1} - E_t \pi_{t+1}), \tag{A.34}$$

which, together with (A.29), establishes that $i_t = r_t + E_t(\delta_{t+1})$.

Equilibrium Linearizing the good market clearing condition (A.14) yields

$$y_t = -(2-\omega)\sigma\omega s_t + (1-\omega)c_t, \tag{A.35}$$

where we use the definition of the terms of trade (A.19) and the fact that variables in the ROW are constant. Net exports to GDP become

$$\hat{tb}_t = y_t - c_t + \omega s_t. \tag{A.36}$$

Some key equations We finally show how to obtain equations (2.1)-(2.3) from the main text (which are the dynamic IS curve, the New Keynesian Phillips curve and a risk sharing condition).

Combine good market clearing (A.35), risk sharing (A.30) and the definition of the real exchange rate (A.20) to obtain

$$y_t = -\frac{1}{\gamma}\underbrace{(1+\omega(2-\omega)(\sigma\gamma-1))}_{:=\varpi} s_t. \tag{A.37}$$

Rearrange to obtain

$$s_t = -\frac{\gamma}{\varpi} y_t, \tag{A.38}$$

which is (2.3) in the main text.
Rewrite the Euler equation (A.29)

$$\begin{aligned} c_t &= E_t c_{t+1} - \frac{1}{\gamma}(r_t - E_t(\pi_{H.t+1} - \omega \Delta s_{t+1})) &\text{(A.39)}\\ &= E_t c_{t+1} - \frac{1}{\gamma}(r_t - E_t \pi_{H,t+1} - \frac{\omega\gamma}{\varpi} E_t \Delta y_{t+1}), &\text{(A.40)} \end{aligned}$$

where we use $\pi_t = \pi_{H,t} - \omega \Delta s_t$ in the first line and (A.38) in the second.
Combine (A.38) with (A.30) and (A.20) to obtain

$$c_t = \frac{1-\omega}{\varpi} y_t. \tag{A.41}$$

Use this expression to substitute for consumption in (A.40)

$$y_t = E_t y_{t+1} - \frac{\varpi}{\gamma}(r_t - E_t \pi_{H,t+1}), \tag{A.42}$$

which is (2.1) in the main text.
Finally, use (A.28), (A.38), (A.41) and production technology $y_t = h_t$ to rewrite marginal cost

$$mc_t^r = w_t^r - \omega s_t = \gamma c_t + \varphi h_t - \omega s_t = (\frac{\gamma}{\varpi} + \varphi) y_t. \tag{A.43}$$

Insert into the Phillips curve (A.26) to obtain (2.2) in the main text.

B Model solution

In what follows, we present details regarding the model solution. Markov-Switching Linear Rational Expectations models (MS-LRE) in general are discussed in Farmer et al. (2009) and Farmer et al. (2011). We consider mean square stable solutions which we obtain by applying the method of undetermined coefficients.

An MS-LRE in general has the following structure:

$$\Gamma_{\varsigma_t} x_t = E_t x_{t+1} + \Psi_{\varsigma_t} \varepsilon_t \ \ \forall \varsigma_t, \tag{B.1}$$

with x_t being a vector of endogenous random variables, ε_t being a vector of white noise structural errors, and where Γ_{ς_t} and Ψ_{ς_t} are matrices containing the model's deep parameters. They evolve over time, following a discrete time Markov Chain $\{\varsigma_t\}$, with transition matrix $P = [p_{ij}] = [Prob(\varsigma_t = j; \varsigma_{t-1} = i)]$.

A candidate solution looks as follows:

$$x_t = F_{\varsigma_t} x_{t-1} + G_{\varsigma_t} \varepsilon_t \ \ \forall \varsigma_t, \tag{B.2}$$

and it is mean square stable (thus constitutes a rational expectations equilibrium to (B.1)) if and only if all eigenvalues of

$$(P' \otimes I_{n^2}) \mathrm{diag}(F_{\varsigma_1} \otimes F_{\varsigma_1}, ..., F_{\varsigma_h} \otimes F_{\varsigma_h}) \tag{B.3}$$

lie within the unit circle. Here n is the number of variables considered, h denotes the number of regimes, $\otimes$ is the Kronecker-product and "diag" stacks matrices in a bigger diagonal matrix. Specifically, in the full model with default there are four distinct regimes, with transitions governed by

$$P = \begin{pmatrix} \mu & (1-\mu)\lambda & 0 & (1-\mu)(1-\lambda) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}. \tag{B.4}$$

Union PF is divided into two regimes (call them "Union PF - Default" and "Union PF"), the former being purely transitory to be left for the latter immediately. Recall that the model features two endogenous state variables ($\hat{d}_t^r$ and $p_{H,t}$) and one shock (ε_t^d). In what follows we outline the derivation of the solution (B.2) for the state variables only, so that $n = 2$.

We repeat the model equilibrium conditions for convenience

$$\begin{aligned}
y_t &= E_t y_{t+1} - \frac{\varpi}{\gamma}(r_t - E_t \pi_{H,t+1}) && \text{(B.5)}\\
\pi_{H,t} &= \beta E_t \pi_{H,t+1} + \kappa\left(\varphi + \frac{\gamma}{\varpi}\right) y_t && \text{(B.6)}\\
y_t &= -\frac{\varpi}{\gamma} s_t && \text{(B.7)}\\
s_t &= p_{H,t} + e_t && \text{(B.8)}\\
\beta \hat{d}_t^r &= \hat{d}_{t-1}^r + \zeta(\beta i_t - \pi_{H,t} - \delta_t) - \hat{t}_t^r && \text{(B.9)}\\
i_t &= r_t + E_t(\delta_{t+1}) && \text{(B.10)}\\
\hat{t}_t^r &= \psi_{\varsigma_t} \hat{d}_{t-1}^r - \varepsilon_t^d && \text{(B.11)}\\
\delta_t &= \zeta^{-1} \delta_{\varsigma_t}\ \hat{d}_{t-1}^r && \text{(B.12)}\\
r_t &= \phi_\pi \pi_{H,t} \ \text{ or } \ e_t = 0, && \text{(B.13)}
\end{aligned}$$

with inflation being defined by $\pi_{H,t} = p_{H,t} - p_{H,t-1}$.

Union PF We start by obtaining F_{ς_3} and G_{ς_3}, which is Union PF. Combine equations (B.5),(B.7),(B.8) to obtain the UIP-condition, combine equations (B.6),(B.7),(B.8) to obtain a second order difference equation in the producer price:

$$\begin{aligned}
r_t &= -E_t(\Delta e_{t+1}) && \text{(B.14)}\\
\beta E_t(p_{H,t+1}) &= \underbrace{(1 + \beta + \frac{\kappa\varphi\varpi}{\gamma} + \kappa)}_{\phi_{aux}} p_{H,t} - p_{H,t-1}. && \text{(B.15)}
\end{aligned}$$

Union PF is absorbing, thus $E_t(\Delta e_{t+1}) = 0$ and so $r_t = 0$. Prices are solved by $p_{H,t} = \phi p_{H,t-1}$, with $\phi = \phi_{aux}/2\beta - \sqrt{\phi_{aux}^2/4\beta^2 - 1/\beta} \in (0,1)$, where ϕ_{aux} is specified in (B.15). As there is no default in Union PF, $i_t = r_t = 0$ (B.10), and so

$$\beta \hat{d}_t^r = (1-\psi)\hat{d}_{t-1}^r - \zeta \pi_{H,t} + \varepsilon_t^d,$$

where we suppress the regime-dependence of ψ for expositional clarity (thus $\psi_{\varsigma_2} = \psi$, and accordingly for the other regimes below).

More compactly:

$$\underbrace{\begin{bmatrix} p_{H,t} \\ \hat{d}_t^r \end{bmatrix}}_{x_t} = \underbrace{\begin{bmatrix} \phi & 0 \\ \frac{\zeta(1-\phi)}{\beta} & \frac{1-\psi}{\beta} \end{bmatrix}}_{F_{\varsigma_3}} \underbrace{\begin{bmatrix} p_{H,t-1} \\ \hat{d}_{t-1}^r \end{bmatrix}}_{x_{t-1}} + \underbrace{\begin{bmatrix} 0 \\ \frac{1}{\beta} \end{bmatrix}}_{G_{\varsigma_3}} \varepsilon_t^d.$$

Union PF - Default Regime Union PF - Default is purely transitory, and so $E_t(\delta_{t+1}) = 0$ also here (yielding again $i_t = 0$). Accordingly, Union PF and Union PF - Default differ only in the law of motion for public debt:

$$\underbrace{\begin{bmatrix} p_{H,t} \\ \hat{d}^r_t \end{bmatrix}}_{x_t} = \underbrace{\begin{bmatrix} \phi & 0 \\ \frac{\zeta(1-\phi)}{\beta} & \frac{1-\psi-\delta}{\beta} \end{bmatrix}}_{F_{\varsigma_2}} \underbrace{\begin{bmatrix} p_{H,t-1} \\ \hat{d}^r_{t-1} \end{bmatrix}}_{x_{t-1}} + \underbrace{\begin{bmatrix} 0 \\ \frac{1}{\beta} \end{bmatrix}}_{G_{\varsigma_2}} \varepsilon^d_t.$$

Float AF In regime Float AF, there is an independent central bank and no outright default ($i_t = r_t$). Insert the Taylor-rule into (B.5) and (B.9) to obtain a three-by-three system in $(y_t, \pi_{H,t}, \hat{d}^r_t)$:

$$\begin{aligned} y_t &= E_t y_{t+1} - \frac{\varpi}{\gamma}(\phi_\pi \pi_{H,t} - E_t \pi_{H,t+1}) \\ \pi_{H,t} &= \beta E_t \pi_{H,t+1} + \kappa(\varphi + \frac{\gamma}{\varpi}) y_t \\ \beta \hat{d}^r_t &= (1-\psi)\hat{d}^r_{t-1} + \zeta(\beta\phi_\pi - 1)\pi_{H,t} + \varepsilon^d_t. \end{aligned}$$

Now guess that $\pi_{H,t} = \phi_{\pi,d}\hat{d}^r_{t-1} + \phi_{\pi,\varepsilon}\varepsilon^d_t$ and $y_t = \phi_{y,d}\hat{d}^r_{t-1} + \phi_{y,\varepsilon}\varepsilon^d_t$:

$$\pi_{H,t} = \underbrace{\frac{\phi_{\pi,d}(1-\psi) + \phi_{y,d}\kappa(\varphi + \frac{\gamma}{\varpi})}{1 - \phi_{\pi,d}\zeta(\beta\phi_\pi - 1)}}_{=\phi_{\pi,d}} \hat{d}^r_{t-1} + \underbrace{\frac{\phi_{\pi,d} + \phi_{y,\varepsilon}\kappa(\varphi + \frac{\gamma}{\varpi})}{1 - \phi_{\pi,d}\zeta(\beta\phi_\pi - 1)}}_{=\phi_{\pi,\varepsilon}} \varepsilon^d_t$$

$$y_t = \underbrace{\frac{\phi_{y,d}(\frac{1-\psi}{\beta} + \frac{\phi_{\pi,d}\zeta}{\beta}(\beta\phi_\pi - 1)) - \frac{\phi_{\pi,d}\varpi}{\gamma\beta}(\beta\phi_\pi - 1)}{1 + \frac{\varpi}{\gamma}\frac{\kappa}{\beta}(\varphi + \frac{\gamma}{\varpi})}}_{=\phi_{y,d}} \hat{d}^r_{t-1} + \underbrace{\frac{\phi_{y,d}(\frac{1}{\beta} + \frac{\phi_{\pi,\varepsilon}\zeta}{\beta}(\beta\phi_\pi - 1)) - \frac{\phi_{\pi,\varepsilon}\varpi}{\gamma\beta}(\beta\phi_\pi - 1)}{1 + \frac{\varpi}{\gamma}\frac{\kappa}{\beta}(\varphi + \frac{\gamma}{\varpi})}}_{=\phi_{y,\varepsilon}} \varepsilon^d_t.$$

Verify the guess first for $\phi_{\pi,d}$ and $\phi_{y,d}$ to obtain a quadratic equation in $\phi_{\pi,d}$. The root which implies stable dynamics is given by $\phi_{\pi,d} = -p/2 + \sqrt{p^2/4 - q}$, where

$$\begin{aligned} p &= -\left(\frac{1}{\beta}(\beta - 1 + 2\psi) + \frac{\varpi\kappa}{\gamma\beta}(\varphi + \frac{\gamma}{\varpi})\right) / \frac{\zeta(\beta\phi_\pi - 1)}{\beta} \\ q &= \left(\frac{\psi}{\beta}(\beta - 1 + \psi) + \frac{\varpi\kappa}{\gamma\beta}(\varphi + \frac{\gamma}{\varpi})(\beta\phi_\pi - 1 + \psi)\right) / \frac{\zeta^2(\beta\phi_\pi - 1)^2}{\beta}. \end{aligned}$$

Second, verify the guess for $\phi_{y,d}$ to arrive at

$$\phi_{y,d} = \frac{\phi_{\pi,d}\varpi(1 - \beta\phi_\pi)}{\varpi\kappa(\varphi + \gamma/\varpi) + \gamma(\beta - 1 + \psi) + \phi_{\pi,d}\zeta\gamma(1 - \beta\phi_\pi)}. \tag{B.16}$$

Finally, conjecture that $(1-\psi)\phi_{\pi,\varepsilon} = \phi_{\pi,d}$, and similarly, $(1-\psi)\phi_{y,\varepsilon} = \phi_{y,d}$. To check this, insert both expressions into the verified guess from the previous page.

More compactly:

$$\underbrace{\begin{bmatrix} p_{H,t} \\ \hat{d}_t^r \end{bmatrix}}_{x_t} = \underbrace{\begin{bmatrix} 1 & \phi_{\pi,d} \\ 0 & \frac{1-\psi+\zeta(\beta\phi_\pi-1)\phi_{\pi,d}}{\beta} \end{bmatrix}}_{F_{\varsigma 4}} \underbrace{\begin{bmatrix} p_{H,t-1} \\ \hat{d}_{t-1}^r \end{bmatrix}}_{x_{t-1}} + \underbrace{\begin{bmatrix} \phi_{\pi,\varepsilon} \\ \frac{\zeta(\beta\phi_\pi-1)\phi_{\pi,\varepsilon}+1}{\beta} \end{bmatrix}}_{G_{\varsigma 4}} \varepsilon_t^d.$$

Proposition 3. *Under Float AF:* $\phi_{\pi,d}, \phi_{\pi,\varepsilon}, \phi_{y,d}$ *and* $\phi_{y,\varepsilon}$ *are all strictly positive.*

Proof. We now prove that $(\phi_{\pi,d}, \phi_{\pi,\varepsilon}, \phi_{y,d}, \phi_{y,\varepsilon}) > 0$, as we use this result in Proposition 1 in the main text. Remember that all deep parameters in the model are positive, and that under Float AF: $\psi < 1-\beta$ and $\phi_\pi < 1$. Start with $\phi_{\pi,d}$. We note that $q < 0$ and thus, by the monotonicity of the square-root function, $\phi_{\pi,d} = -p/2 + \sqrt{p^2/4 - q} > 0$. Now turn to $\phi_{y,d}$ in equation (B.16). We note that the numerator is positive because $\phi_{\pi,d} > 0$ as shown above (remember that $\phi_\pi < 1$). However, the denominator could possibly be negative because $\psi < 1-\beta$. We thus need to show that

$$\varpi\kappa(\varphi + \gamma/\varpi) + \gamma(\beta - 1 + \psi) + \phi_{\pi,d}\zeta\gamma(1-\beta\phi_\pi) > 0. \tag{B.17}$$

We proceed by inserting directly $\phi_{\pi,d}$ into (B.17). Cancel terms to obtain

$$\begin{aligned} &= \frac{\gamma}{2}\left\{\tilde{\kappa} + \beta - 1 + \sqrt{((\beta - 1 + 2\psi) + \tilde{\kappa})^2 - 4\left(\psi(\beta - 1 + \psi) + \tilde{\kappa}(\beta\phi_\pi - 1 + \psi)\right)}\right\} \\ &= \frac{\gamma}{2}\left\{\tilde{\kappa} + \beta - 1 + \sqrt{(\tilde{\kappa} + \beta - 1)^2 + 4\tilde{\kappa}(1-\beta\phi_\pi)}\right\} \\ &> 0, \end{aligned}$$

where we abbreviate $\tilde{\kappa} := \frac{\varpi\kappa}{\gamma}(\varphi + \frac{\gamma}{\varpi})$. $\phi_\pi < 1$ guarantees that $\phi_{y,d} > 0$, again using the monotonicity of the square-root function. Finally, $(\phi_{\pi,\varepsilon}, \phi_{y,\varepsilon}) > 0$ follows immediately from $(1-\psi)_{\pi,\varepsilon} = \phi_{\pi,d}$, and similarly, $(1-\psi)\phi_{y,\varepsilon} = \phi_{y,d}$, as established above. □

Union AF Given the closed-form expressions of the solutions for all target regimes, we now solve for regime Union AF. As in Union PF above, the equilibrium is characterised by the second order difference equation in prices (B.15). Split up $E_t(p_{H,t+1})$ into conditional expectations and evaluate each of them in turn:

$$E_t(p_{H,t+1}|\text{Union PF - Default}) = \phi p_{H,t} \tag{B.18}$$

$$E_t(p_{H,t+1}|\text{Float AF}) = p_{H,t} + \phi_{\pi,d}\hat{d}_t^r \tag{B.19}$$

$$E_t(p_{H,t+1}|\text{Union AF}) = ? \tag{B.20}$$

The third conditional expectation depends on the solution of regime Union AF which we have not yet worked out. First, to obtain an expression for bond yields, use the law of iterated expectations and combine (B.10) and (B.12):

$$i_t = -(1-\mu)(1-\lambda)E_t(e_{t+1}|\text{Float AF}) + (1-\mu)\lambda\zeta^{-1}\delta\hat{d}_t^r. \tag{B.21}$$

Replace $E_t(e_{t+1}|\text{Float AF})$ by combining (B.7) and (B.8):

$$i_t = (1-\mu)(1-\lambda)\left(E_t(p_{H,t+1}|\text{Float AF}) + \frac{\gamma}{\varpi}\phi_{y,d}\hat{d}_t^r\right) + (1-\mu)\lambda\zeta^{-1}\delta\hat{d}_t^r. \tag{B.22}$$

Now insert (B.19) into (B.22) and set $\hat{d}_t^r = \beta^{-1}\left((1-\psi)\hat{d}_{t-1}^r + \zeta(\beta i_t - (p_{H,t} - p_{H,t-1})) + \varepsilon_t^d\right)$ to obtain an expression for the yield i_t purely as a function of today's producer price and the relevant state variables $(p_{H,t-1}, \hat{d}_{t-1}^r, \varepsilon_t^d)$:

$$i_t = \vartheta_1 p_{H,t} + \vartheta_2 p_{H,t-1} + \vartheta_3 \hat{d}_{t-1}^r + \vartheta_4 \varepsilon_t^d, \tag{B.23}$$

with $\vartheta_1, ..., \vartheta_4$ being coefficient functions of the structural parameters. Plugging back (B.23) into (B.19) yields a similar expression for $E_t(p_{H,t+1}|\text{Float AF})$:

$$E_t(p_{H,t+1}|\text{Float AF}) = \eta_1 p_{H,t} + \eta_2 p_{H,t-1} + \eta_3 \hat{d}_{t-1}^r + \eta_4 \varepsilon_t^d, \tag{B.24}$$

with, again, $\eta_1, ..., \eta_4$ being coefficient functions of the structural parameters.

We are now in the position to apply the guess-and-verify method. Guess that, while in regime Union AF, producer prices evolve as $p_{H,t} = \phi_p p_{H,t-1} + \phi_d \hat{d}_{t-1}^r + \phi_\varepsilon \varepsilon_t^d$ and solve (B.20):

$$E_t(p_{H,t+1}|\text{Union AF}) = \phi_p p_{H,t} + \frac{\phi_d}{\beta}\left((1-\psi)\hat{d}_{t-1}^r + \zeta(\beta i_t - (p_{H,t} - p_{H,t-1})) + \varepsilon_t^d\right),$$

the third conditional expectation needed to evaluate the full of $E_t(p_{H,t+1})$. Finally, replace i_t by (B.23) and rearrange (B.15) to verify the guess:

$$\begin{aligned} p_{H,t} = {} & \underbrace{\frac{-(\mu\phi_d\zeta(\beta\vartheta_2+1) + (1-\mu)(1-\lambda)\beta\eta_2 + 1)}{\mu(\beta\phi_p + \phi_d\zeta(\beta\vartheta_1 - 1)) + (1-\mu)(\beta\lambda\phi + \beta(1-\lambda)\eta_1) - \phi_{aux}}}_{=\phi_p} p_{H,t-1} \\ & + \underbrace{\frac{-(\mu\phi_d(1-\psi+\zeta\beta\vartheta_3) + \beta(1-\mu)(1-\lambda)\eta_3)}{\mu(\beta\phi_p + \phi_d\zeta(\beta\vartheta_1 - 1)) + (1-\mu)(\beta\lambda\phi + \beta(1-\lambda)\eta_1) - \phi_{aux}}}_{=\phi_d} \hat{d}_{t-1}^r \\ & + \underbrace{\frac{-(\mu\phi_d(\beta\zeta\vartheta_4+1) + (1-\mu)(1-\lambda)\beta\eta_4)}{\mu(\beta\phi_p + \phi_d\zeta(\beta\vartheta_1 - 1)) + (1-\mu)(\beta\lambda\phi + \beta(1-\lambda)\eta_1) - \phi_{aux}}}_{=\phi_\varepsilon} \varepsilon_t^d. \end{aligned}$$

Verify the guess first for ϕ_p and ϕ_d to obtain a cubic polynomial in ϕ_d. The polynomial has three real roots, all of which imply explosive paths for the state variables while in Union AF. However, for the calibrated model we verify that at most one of these solution candidates satisfies mean square stability (the root in the interval [0,0.5]). The coefficients ϕ_p and ϕ_ε then follow unambiguously from ϕ_d.

We thus obtain:

$$\underbrace{\begin{bmatrix} p_{H,t} \\ \hat{d}^r_t \end{bmatrix}}_{x_t} = \underbrace{\begin{bmatrix} \phi_p & \phi_d \\ \frac{\zeta(\beta(\vartheta_1\phi_p+\vartheta_2)-(\phi_p-1))}{\beta} & \frac{1-\psi+\zeta(\beta(\vartheta_1\phi_d+\vartheta_3)-\phi_d)}{\beta} \end{bmatrix}}_{F_{\varsigma_1}} \underbrace{\begin{bmatrix} p_{H,t-1} \\ \hat{d}^r_{t-1} \end{bmatrix}}_{x_{t-1}} + \underbrace{\begin{bmatrix} \phi_\varepsilon \\ \frac{\zeta(\beta(\vartheta_1\phi_\varepsilon+\vartheta_4)-\phi_\varepsilon)+1}{\beta} \end{bmatrix}}_{G_{\varsigma_1}} \varepsilon^d_t.$$