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Sovereign Risk, Fiscal Policy, and Macroeconomic Stability

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Abstract

This paper analyzes the impact of strained government finances on macroeconomic stability and the transmission of fiscal policy. Using a variant of the model by Curdia and Woodford (2009), we study a "sovereign risk channel" through which sovereign default risk raises funding costs in the private sector. If monetary policy is constrained, the sovereign risk channel exacerbates indeterminacy problems: private-sector beliefs of a weakening economy may become self-fulfilling. In addition, sovereign risk amplifies the effects of negative cyclical shocks. Under those conditions, fiscal retrenchment can help curtail the risk of macroeconomic instability and, in extreme cases, even stimulate economic activity.

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1 Introduction

In the wake of the global financial crisis, sovereign risk premia have risen sharply in several countries, prompting policymakers to start fiscal tightening even as private demand remains weak. What are the likely consequences for economic activity? The present paper assesses this question quantitatively, starting from the observation that sovereign funding strains tend to spill over into private credit markets.[1] Through this sovereign risk channel, higher public indebtedness may adversely affect economic activity by raising private-sector financing costs. Conversely, upfront fiscal retrenchment may help improve credit conditions in the broader economy, thereby counteracting the direct contractionary effect of lower public spending.

Recent developments in Europe provide clear evidence in support of spillovers from sovereign risk to broader financial conditions. The panels in Figure 1 display time-series data on credit default swap (CDS) spreads for government debt and nonfinancial corporate debt.[2] The figure compares two sets of euro area countries: those with relatively low sovereign spreads (left panel) and those with relatively high sovereign spreads (Belgium, Greece, Ireland, Italy, Portugal, and Spain).[3] The series display substantial comovement, particularly in countries that face fiscal strain (right panel). For the time period shown, the daily correlation between corporate and sovereign CDS spreads in high-spread countries is 0.71. For the low-spread countries, it is lower, but still significantly positive at 0.36 percent.

In this paper, we formally explore the implications of the sovereign risk channel. We build on the model proposed by Cúrdia and Woodford (2009), in which heterogeneous households engage in borrowing and lending via financial intermediaries. Our variant of the model features two critical innovations. First, we allow for sovereign risk premia that respond to changes in the fiscal outlook of the country. Although the precise numerical relationship is uncertain and

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[1] This is prominently embedded in the notion of a "sovereign ceiling." In a strict interpretation, the sovereign ceiling posits that no debtor in a given country can have a better credit quality than the government, a primary reason being the state's capacity to extract private-sector resources through taxation. In reality, several authors, including Durbin and Ng (2005), have documented exceptions to this rule, notably for firms with substantial export earnings or foreign operations. Even then, however, sovereign and corporate bond yields tend to comove significantly (see the literature review in Cavallo and Valenzuela (2007) or Harjes (2011)). In the context of the global financial crisis, both the International Monetary Fund (2010a) and the European Central Bank (2010) have stressed that government bond yields typically have a strong influence on domestic corporate bond yields.

[2] A similar set of charts was first provided in International Monetary Fund (2011).

[3] We focus here on evidence for the euro area in order to control for the impact of monetary policy. Indeed, monetary policy is a key factor in determining the strength of the sovereign risk channel according to our analysis below.

Figure 1: Sovereign and nonfinancial corporate CDS spreads
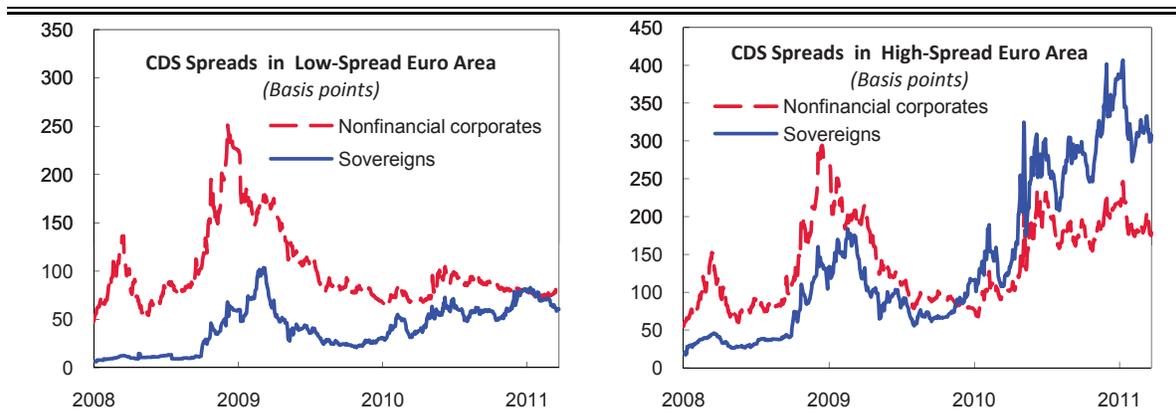
Notes: 5-year CDS spreads in low-spread and high-spread euro area countries, as well as for nonfinancial corporations headquartered there. Low-spread euro area includes Austria (number of firms in our sample: 1), Finland (1), France (24), Germany (18), and Netherlands (8). High-spread euro area includes Belgium (number of firms: 1), Greece (1), Ireland (0), Italy (4), Portugal (2), and Spain (4). The corporations in our sample are the constituents of the Itraxx Europe index. The same relative weights are adopted for the sovereign and corporate index series. For example, of the 52 firms in the low-spread euro area sample, 24 are headquartered in France. As a result, in the sovereign low-spread euro area series, France has a weight of 24/52. Data sources: Bloomberg; Markit.

likely to vary over time, the basic premise that risk premia are affected by fundamentals should be uncontroversial. Second, private credit spreads rise with sovereign risk because strained public finances raise the cost of financial intermediation. This way of modeling spillovers allows for a tractable representation of the sovereign risk channel within a simple variant of the canonical New Keynesian model. Consequently, we are in a position to supplement our numerical results with analytical solutions for interesting special cases.

The sovereign risk channel amplifies the transmission of shocks to aggregate demand, unless monetary policy manages to offset the spillover from sovereign default risk to private funding costs. Offsetting higher sovereign risk premia would typically require cuts in the policy rate. However, the central bank's capacity to enact such cuts may be hampered, most notably if the nominal interest rate is already at the zero lower bound (ZLB), as has been the case for several major central banks in recent years. Our model is developed with an explicit reference to this ZLB problem. Yet it is important to stress that the ZLB is but one prominent example of a constraint on central bank action. Monetary policy would be similarly constrained—and our analysis would carry through—under a currency peg or in other situations where political or institutional considerations prevent the central bank from counteracting a rise in sovereign risk premia.

Our analysis of the sovereign risk channel gives rise to two distinct sets of results for an environment where monetary policy is constrained. First, under these circumstances sovereign risk may give rise to indeterminacy, or belief-driven equilibria. Specifically, to the extent that a pessimistic shift in expectations (unrelated to fundamentals) implies an upward revision of the projected government deficit, the risk premium on public debt rises and, through the sovereign risk channel, spills over to private borrowing costs. Higher private funding costs, in turn, slow down activity, validating the initial adverse shift in expectations. Under normal circumstances, this scenario could be averted by the central bank's commitment to appropriately lower the policy rate. To the extent that monetary policy is constrained, however, expectations may become self-fulfilling, especially when sovereign risk is very high. In this scenario, we also find that the anticipation of a procyclical spending response—that is, fiscal tightening in response to a cyclical fall in tax revenue—can help to ensure determinacy.

Our second set of results suggests that (under equilibrium determinacy) the sign and the size of the government spending multiplier depend critically on the state of the economy. When the central bank is unconstrained, the sovereign risk channel is not operative in our model, as looser monetary policy can offset the impact of higher risk premia. By contrast, when the central bank is constrained, the sovereign risk channel typically reduces the spending multiplier. Fiscal retrenchment, by improving the outlook for public finances, may thus have less adverse effects on economic activity relative to a situation where sovereign risk is absent. These departures from standard macroeconomic results remain fairly modest as long as sovereign risk is contained. Only when public finances are very fragile, sovereign risk is high, *and* monetary policy is constrained for an extended period, does the sovereign risk channel unfold a sizeable impact on economic outcomes. The more severe the prevailing strain on public finances, the less fiscal retrenchment will weigh on growth. In relatively extreme cases, tighter fiscal policy may even stimulate economic activity.

As a caveat we emphasize that the present paper is not meant to add to the theory of sovereign default. Following Eaton and Gersovitz (1981), a number of authors, including Arellano (2008) and Mendoza and Yue (2010), have recently modeled default as a strategic decision of a sovereign that balances the gains from foregone debt service against the costs of exclusion from international credit markets. In equilibrium this implies that the probability of default increases in the level of debt. In order to maintain the tractability of our model for

business cycle analysis, we impose such a relationship without explicitly modeling a strategic default decision. Specifically, we link the sovereign risk premium to the expected path of public debt (or, alternatively, future fiscal deficits). We thereby abstract from a number of other factors that may also affect the market's assessment of sovereign risk, such as the quality of fiscal institutions or the composition of the investor base for government bonds. Implicit in our approach to modeling sovereign risk is the assumption that there are limits to credible commitment on the part of fiscal policymakers; otherwise, there would be no risk premium in the first place, and policymakers seeking to protect growth would arguably prefer to delay retrenchment until the economy is on a firm recovery path.

The remainder of the paper is structured as follows. Section 2 describes the model economy and presents our calibration. Sections 3 and 4 report analytical results and results from model simulations, respectively. Section 5 concludes.

2   The model

The key motivation for our model is the observation that sovereign risk systematically affects private-sector borrowing conditions. The model, therefore, needs to account for the possibility that private-sector borrowing and lending take place in equilibrium. We rely on the framework developed by Cúrdia and Woodford (2009) (CW, henceforth), which gives rise to an interest rate spread in an otherwise standard New Keynesian model. The spread emerges as a result of heterogeneity among households and because of costly financial intermediation. By assuming asymptotic risk sharing, CW are able to maintain the tractability of the New Keynesian baseline model. We add to their model a slightly richer specification of fiscal policy and allow the state of public finances to affect financial intermediation. In the following we briefly outline the model and stress the instances in which we depart from the original CW formulation.

2.1   Households

The economy is populated by a unit measure of households indexed by $i \in [0, 1]$. Household i is of one of two types, indexed by superscript $\tau_t(i) \in \{b, s\}$. In equilibrium, households of type $\tau_t(i) = b$ will be "borrowers," and households of type s will be "savers." Households infrequently change their type. In each period, the probability of redrawing a type is $1 - \delta$,

where $\delta \in (0,1)$. Conditional on redrawing, the household will end up being a borrower with probability π_b, and a saver with probability $\pi_s = 1 - \pi_b$. The objective of household $i \in [0,1]$ is given by

$$E_0 \sum_{t=0}^{\infty} (e_t \beta^t) \left[\frac{(\xi^\tau)^{\sigma_\tau^{-1}} [c_t(i)]^{1-\sigma_\tau^{-1}}}{1 - \sigma_\tau^{-1}} - \frac{\psi_\tau}{1+\nu} h_t(i)^{1+\nu} \right],$$

where $c_t(i)$ is an aggregate of household expenditures:

$$c_t(i) = \left[\int_0^1 c_t(j,i)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}} ; \quad \theta > 1. \tag{1}$$

Here $c_t(j,i)$ is a differentiated output good produced by firm $j \in [0,1]$. $h_t(i)$ denotes hours worked by the household. e_t is a unit-mean shock to the time-discount factor $\beta \in (0,1)$, and $\xi^\tau, \sigma_\tau, \psi_\tau$, and ν are positive parameters.

Households are able to insure against idiosyncratic risk through state-contingent contracts. Yet the resulting transfer payments are assumed to occur infrequently, namely only in those periods in which a household is assigned a new type. Meanwhile, households may borrow or save through financial intermediaries. The beginning-of-period wealth of household i is given by

$$A_t(i) = [B_{t-1}(i)]^+ (1+i_{t-1}^d) + [B_{t-1}(i)]^- (1+i_{t-1}^b) + (1-\vartheta_t) B_{t-1}^g(i)(1+i_{t-1}^g) + D_t^{int} + T_t(i) + T_t^c. \tag{2}$$

Here $[B_{t-1}(i)]^+$ denotes deposits at financial intermediaries at the end of the previous period, which earn the deposit rate i_{t-1}^d; $[B_{t-1}(i)]^-$ denotes debt at financial intermediaries, which charge the borrowing rate i_{t-1}^b. In equilibrium, household i is either borrowing or saving. In the case where it is saving, the household may also hold government debt $B_{t-1}^g(i) \geq 0$.

We depart from CW by assuming that government debt is not riskless: in any period, the government may honor its debt obligations, in which case $\vartheta_t = 0$; or it may partially default, in which case $\vartheta_t = \vartheta_{\text{def}}$, with $\vartheta_{\text{def}} \in [0,1)$ indicating the size of the haircut. i_{t-1}^g is the notional interest rate on government debt. D_t^{int} are profits from competitive financial intermediaries that are distributed across households in a lump-sum manner. $T_t(i)$ denotes transfers resulting from state-contingent contracts (which are zero for those households that do not redraw their type and are therefore temporarily without access to the payoff scheme implied by asymptotic risk sharing). T_t^c is a lump-sum transfer that, in case of a sovereign default, compensates bond

holders for losses associated with the sovereign default. Yet the payment is not proportional to the size of an individual's holdings of government debt (see Schabert and van Wijnbergen (2008) for a similar setup). This assumption, along with the risk of a haircut, drives a wedge between the risk-free rate, i_t^d, and the interest rate on government debt, i_t^g.

The end-of-period wealth of household i is given by

$$B_t(i) = A_t(i) - P_t c_t(i) + (1 - \tau_t^w)P_t w_t h_t(i) + D_t - T_t^g. \tag{3}$$

P_t denotes the consumption price index, τ_t^w is the labor tax rate, and w_t is the economy-wide real wage rate; D_t are profits earned by intermediary goods producers and $-T_t^g$ are lump-sum transfers by the government.

Assuming identical initial wealth for all households, state-contingent contracts ensure that post-transfer wealth is identical for all households that are selected to redraw their type. It is given by

$$A_t = [d_{t-1}(1 + i_{t-1}^d) + (1 - \vartheta_t)b_{t-1}^g(1 + i_{t-1}^g) - b_{t-1}(1 + i_{t-1}^b)]P_{t-1} + D_t^{int} + T_t^c, \tag{4}$$

where b_t^g denotes government debt in real terms. d_t denotes aggregate savings deposited with intermediaries, and b_t denotes aggregate private borrowing, both in real terms. The latter evolves according to

$$
\begin{aligned}
b_t &= \delta b_{t-1}(1 + \omega_{t-1})(1 + i_{t-1}^d)/\Pi_t - \pi_b \omega_t b_t + \pi_b \left[\delta b_{t-1}^g(1 + i_{t-1}^g)/\Pi_t - b_t^g \right] \\
&\quad + \pi_b \pi_s [(c_t^b - c_t^s) - (1 - \tau_t^w)(w_t h_t^b - w_t h_t^s)].
\end{aligned} \tag{5}
$$

Intuitively, the accumulation of debt depends on four terms. The first term is the last period's private debt level plus interest (for those households that do not redraw their type). The second term, $-\pi_b \omega_t b_t$, is the gain accruing to borrowing households from fraudulent loans (discussed below). The third term captures whether sovereign indebtedness (suitably adjusted for the change in household types) falls. In order to reduce sovereign indebtedness, current taxes need to be relatively high, which increases the need for borrowing by borrowers. Put differently, if sovereign indebtedness falls, so that $\left[\delta b_{t-1}^g(1 + i_{t-1}^g)/\Pi_t - b_t^g \right] > 0$, more resources are made available by savers to borrowers since savers resort more to private sources

for storing value. The last term captures the difference in consumption levels relative to the difference in wage income across household types.

Turning to the intertemporal consumption decisions, note that, as a result of asymptotic risk sharing, all households of a specific type have a common marginal utility of real income, λ_t^τ, and choose the same level of expenditure:

$$c_t^s = \xi^s (\lambda_t^s)^{-\sigma_s} \tag{6}$$

$$c_t^b = \xi^b (\lambda_t^b)^{-\sigma_b}. \tag{7}$$

The optimal choices regarding borrowing from and lending to intermediaries, as well as to the government, are then governed by the following Euler equations:

$$e_t \lambda_t^s = \beta E_t \left[e_{t+1} \frac{1 + i_t^d}{\Pi_{t+1}} \left\{ (1 - \delta)\pi_b \lambda_{t+1}^b + [\delta + (1 - \delta)\pi_s] \lambda_{t+1}^s \right\} \right], \tag{8}$$

$$e_t \lambda_t^s = \beta E_t \left[e_{t+1} \frac{(1 - \vartheta_{t+1})(1 + i_t^g)}{\Pi_{t+1}} \left\{ (1 - \delta)\pi_b \lambda_{t+1}^b + [\delta + (1 - \delta)\pi_s] \lambda_{t+1}^s \right\} \right], \tag{9}$$

$$e_t \lambda_t^b = \beta E_t \left[e_{t+1} \frac{1 + i_t^b}{\Pi_{t+1}} \left\{ (1 - \delta)\pi_s \lambda_{t+1}^s + [\delta + (1 - \delta)\pi_b] \lambda_{t+1}^b \right\} \right]. \tag{10}$$

Optimal labor supply by households, in turn, is given by

$$h_t^s = \left(\frac{\lambda_t^s}{\psi_s} (1 - \tau_t^w) w_t \right)^{1/\nu}, \tag{11}$$

$$h_t^b = \left(\frac{\lambda_t^b}{\psi_b} (1 - \tau_t^w) w_t \right)^{1/\nu}. \tag{12}$$

Across household types, average labor supply, $h_t = \pi_b h_t^b + (1 - \pi_b) h_t^s$, is given by

$$h_t = \left(\frac{\Lambda_t}{\psi} (1 - \tau_t^w) w_t \right)^{1/\nu}, \tag{13}$$

where

$$\Lambda_t := \psi \left[\pi_b \left(\frac{\lambda_t^b}{\psi_b} \right)^{1/\nu} + \pi_s \left(\frac{\lambda_t^s}{\psi_s} \right)^{1/\nu} \right]^\nu \tag{14}$$

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and $\psi^{-1/\nu} = \pi_b \psi_b^{-1/\nu} + \pi_s \psi_s^{-1/\nu}$. Finally, for future reference we define

$$\lambda_t = \pi_b \lambda_t^b + (1 - \pi_b) \lambda_t^s \tag{15}$$

as the average marginal utility of real income across types.

2.2 Financial intermediaries

Saving and borrowing across households of different types takes place through perfectly competitive financial intermediaries. As in CW, we assume that an interest rate spread emerges because financial intermediation requires resources, $\Xi_t b_t$, and because in each period a fraction of loans, χ_t, cannot be recovered, irrespective of the characteristics of borrowers (due to, say, fraud). Moreover, deposits, d_t, are assumed to be riskless and intermediaries collect the largest quantity of deposits that can be repaid from the proceeds of the loans that they originate, that is, $(1 + i_t^d)d_t = (1 + i_t^b)b_t$. The cash flow in period t of a financial intermediary is thus given by $d_t - b_t - \chi_t b_t - \Xi_t b_t$. Using ω_t to define the spread between lending and deposit rates, we have

$$1 + \omega_t = \frac{1 + i_t^b}{1 + i_t^d}. \tag{16}$$

Substituting $d_t = (1 + \omega_t)b_t$, and choosing b_t to maximize the profits of the intermediary yields the first-order condition for loan origination

$$\omega_t = \chi_t + \Xi_t. \tag{17}$$

In departing from CW, we assume that either χ_t or Ξ_t depends on sovereign risk. This assumption captures the increased difficulties in monitoring and enforcing loan contracts in an economy under fiscal strain. Conceptually related is the notion that in case of a sovereign default, the government diverts funds from the repayments made by borrowers, see Mendoza and Yue (2010).

Costs $\chi_t b_t$ and $\Xi_t b_t$ differ in that only the latter are assumed to enter the economy's resource constraint. For the linearized version of the model, used in Section 3, we let loan origination costs be covered by $\chi_t > 0$, and set $\Xi_t = 0$, which facilitates deriving analytical results. For the dynamic simulations in Section 4 we set $\chi_t = 0$ and let $\Xi_t > 0$. Specifically, we assume

that either

$$\chi_t = \chi_\psi[(1 + i_t^g)/(1 + i_t^d)]^{\alpha_\psi} - 1 \text{ and } \Xi_t = 0, \tag{18}$$

or

$$\chi_t = 0 \text{ and } \Xi_t = \chi_\psi[(1 + i_t^g)/(1 + i_t^d)]^{\alpha_\psi} - 1, \tag{19}$$

where parameter $\chi_\psi > 0$ is used to scale the private spread in the steady state, and α_ψ measures the strength of the spillover from the (log) sovereign risk premium to the (log) private risk premium. Finally, transfers from intermediaries to households include loans that are not recovered by the intermediaries such that $D_t^{int} = P_t(\omega_t b_t - \Xi_t b_t)$.

2.3 Firms

There is a continuum of firms $j \in [0,1]$, each of which produces a differentiated good on the basis of the following technology

$$y_t(j) = z_t h(j)^{1/\phi}, \tag{20}$$

where z_t is an aggregate productivity shock. In each period only a fraction $(1 - \alpha)$ of firms is able to reoptimize its prices. Firms that do not reoptimize adjust their price by the steady-state rate of inflation, Π. Prices are set in period t to maximize expected discounted future profits.[4] The resulting first-order condition for a generic firm that adjusts its price, P_t^*, is

$$\left(\frac{P_t^*}{P_t}\right)^{1+\theta(\phi-1)} = \frac{K_t}{F_t}, \tag{21}$$

with

$$K_t = \lambda_t e_t \mu^p \phi w_t \left(\frac{y_t}{z_t}\right)^\phi + \alpha\beta E_t\left[\left(\frac{\Pi_{t+1}}{\Pi}\right)^{\theta\phi} K_{t+1}\right], \tag{22}$$

$$F_t = \lambda_t e_t y_t + \alpha\beta E_t\left[\left(\frac{\Pi_{t+1}}{\Pi}\right)^{(\theta-1)} F_{t+1}\right], \tag{23}$$

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[4]Future nominal profits are discounted with the factor $(\alpha\beta)^{T-t}\frac{\lambda_T}{\lambda_t}\frac{P_t}{P_T}$, taking into account that demand for product j is given by the demand function $y_t(j) = y_t(P_t(j)/P_t)^{-\theta}$, where $P_t(j)$ denotes the price of good j, and y_t is aggregate output.

where $\mu^p = \theta/(\theta - 1)$. The law of motion for prices (inflation) is given by

$$1 - \alpha \left(\frac{\Pi_t}{\Pi} \right)^{\theta - 1} = (1 - \alpha) \left(\frac{P_t^*}{P_t} \right)^{1 - \theta}. \tag{24}$$

For future reference it is also useful to define price dispersion $\Delta_t := \int_0^1 \left(\frac{P_{j,t}}{P_t} \right)^{-\theta\phi} dj$, which evolves as follows

$$\Delta_t = \alpha \Delta_{t-1} \left(\frac{\Pi_t}{\Pi} \right)^{\theta\phi} + (1 - \alpha) \left(\frac{1 - \alpha \left(\Pi_t/\Pi \right)^{\theta - 1}}{1 - \alpha} \right)^{\frac{\theta\phi}{\theta - 1}}. \tag{25}$$

Finally, profits distributed to households are given by $D_t = \int_0^1 P_t(j) y_t(j) - P_t w_t h_t(j) dj$; or, in equilibrium, $D_t = P_t \left(y_t - w_t \left(y_t/z_t \right)^\phi \Delta_t \right)$.

2.4 Government

Real government debt evolves as follows:

$$b_t^g = (1 - \vartheta_t) \frac{b_{t-1}^g (1 + i_{t-1}^g)}{\Pi_t} + g_t + \frac{T_t^c}{P_t} - \frac{T_t^g}{P_t} - \tau_t^w w_t h_t,$$

where g_t denotes government spending. Below we will consider different assumptions regarding the law of motion for government spending. As is customary, we assume throughout that the expenditure share of each particular differentiated good in government spending is the same as the share of that good in private consumption. By assumption, transfers T_t^c ensure that a sovereign default is neutral *ex post* in regard to any distributional consequences and the debt level. That is, under our assumptions, a sovereign default does not automatically ease the degree of fiscal strain. In particular, we set

$$T_t^c = P_t \vartheta_t \frac{b_{t-1}^g (1 + i_{t-1}^g)}{\Pi_t}.$$

The consolidated government flow budget constraint is thus given by

$$b_t^g = \frac{b_{t-1}^g (1 + i_{t-1}^g)}{\Pi_t} + g_t - \frac{T_t^g}{P_t} - \tau_t^w w_t h_t. \tag{26}$$

Letting

$$tr_t = \tau_t^w w_t h_t + T_t^g / P_t \tag{27}$$

denote the part of taxes that is related to the business cycle and to stabilization policy, we assume

$$(tr_t - t) = \left[\phi_{T,y}(y_t - y) + \phi_{T,b^g}(b_{t-1}^g - b^g) \right], \ \phi_{T,y} \geq 0, \ \phi_{T,b^g} > 0. \tag{28}$$

Throughout the paper, we assume that ϕ_{T,b^g} is large enough so as to eventually stabilize public debt.[5]

While *actual* default is neutral in the sense described above, the *probability* of default is crucial for the pricing of government debt, (i_t^g), and for real activity.[6] A fully specified model of sovereign default is beyond the scope of the present paper. Instead, we draw on earlier work in this area, which has pursued two distinct approaches. First, following Eaton and Gersovitz (1981), Arellano (2008) and others have modeled default as a strategic decision of the sovereign. Second, and more recently, Bi and Leeper (2010) and Juessen et al. (2011) consider default as the consequence of the government's inability to raise the funds necessary to honor its debt obligations. Under both approaches, the probability of sovereign default is closely and nonlinearly linked to the level of public debt.

In the current paper we operationalize sovereign default by appealing to the notion of a fiscal limit in a manner similar to Bi and Leeper (2010). Whenever the debt level rises above the fiscal limit, default will occur. The fiscal limit is determined stochastically, capturing the uncertainty that surrounds the political process in the context of sovereign default. Specifically, we assume that in each period the limit will be drawn from a generalized beta distribution with parameters α_{b^g}, β_{b^g}, and $\overline{b}^{\mathrm{g,max}}$. As a result, the *ex ante* probability of default, p_t, at a certain level of sovereign indebtedness, b_t^g, will be given by the cumulative distribution function of the (generalized) beta distribution:

$$p_t = F_{\mathrm{beta}} \left(\frac{b_t^g}{4y} \frac{1}{\overline{b}^{\mathrm{g,max}}}; \alpha_{b^g}, \beta_{b^g} \right). \tag{29}$$

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[5]We will also, for the most part, assume that the labor tax rate remains constant, $\tau_t^w = \tau^w$, and will state explicitly when we consider simulations in which this assumption is dropped.

[6]This implication of our setup is in line with evidence reported by Yeyati and Panizza (2011). Investigating output growth across a large number of episodes of sovereign default, they find that the output costs of default materialize in the run-up to defaults rather than at the time when the default actually takes place.

Note that $\overline{b}^{\text{g,max}}$ denotes the upper end of the support for the debt-to-GDP ratio. Since we keep the size of the haircut in case of default constant, we have

$$\vartheta_t = \begin{cases} \vartheta_{\text{def}} & \text{with probability } p_t, \\ 0 & \text{with probability } 1 - p_t. \end{cases} \tag{30}$$

Turning to monetary policy, we assume throughout that the central bank follows a Taylor-type interest rate rule that also seeks to insulate aggregate economic activity from fluctuations in risk spreads, at least to some degree. In particular, we assume:

$$\log(1 + i_t^{d,*}) = \log(1 + i^d) + \phi_\Pi \log(\Pi_t/\Pi) - \phi_\omega \log((1 + \omega_t)/(1 + \omega)). \tag{31}$$

Here, $i_t^{d,*}$ marks the target level for the deposit rate i_t^d, and $\phi_\Pi > 1$, $\phi_\omega > 0$. In deep recessions, however, the target level and the actual deposit rate can diverge. The reason is that in implementing rule (31), the central bank relies on steering the riskless nominal interest rate i_t^d, which cannot fall below zero. Therefore, $i_t^d = i_t^{d*}$ can only be implemented provided that $i_t^d \geq 0$. Otherwise, $i_t^d = 0$. As a result, an increase in the spread ω_t cannot be offset if monetary policy is constrained in lowering the policy rate.[7]

2.5 Market clearing and equilibrium

Good market clearing requires

$$y_t = \int_0^1 c_t(i)di + g_t + \Xi_t b_t = \pi_b c_t^b + \pi_s c_t^s + g_t + \Xi_t b_t. \tag{32}$$

The total supply of output is given by

$$y_t \Delta_t^{1/\phi} = z_t h_t^{1/\phi}. \tag{33}$$

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[7]Although we focus here on a simple representation of monetary policy, the model would, in principle, allow for more complicated types of monetary policy. For example, a central bank faced with the ZLB could promise low future real rates to help the economy ease out of the lower-bound situation; see Eggertsson and Woodford (2003). This would not only increase output relative to the current interest rate rule (31), but it would also raise tax revenues and therefore alleviate some of the fiscal strain. The question to what extent central banks can credibly engage in such forward guidance is not settled, however. Similarly, the effects of other unconventional monetary policy operations, such as quantitative easing, are uncertain and likely to be bounded in practice.

In order to describe the equilibrium, we use equations (5)-(15), which characterize the solution to the household problem; equations (16)-(19), which characterize financial intermediation; equations (21)-(25), which characterize optimal price setting behavior; equations (26)-(30), which characterize the behavior of fiscal policy; the assumption about the evolution of labor taxes; the interest rate target rule (31) and the lower-bound constraint; and finally the good market clearing conditions (32) and (33). For given exogenous realizations of $\{e_t, g_t, z_t\}$, these equations pin down a sequence for the endogenous variables

$$\left\{ b_t, b_t^g, c_t^b, c_t^s, \chi_t, \Delta_t, F_t, h_t, h_t^b, h_t^s, i_t^b, i_t^d, i_t^{d,*}, i_t^g, K_t, \lambda_t, \lambda_t^b, \lambda_t^s, \Lambda_t, \right.$$
$$\left. \omega_t, p_t, P_t^*/P_t, \Pi_t, \tau_t^w, T_t^g/P_t, tr_t, \vartheta_t, w_t, \Xi_t, y_t \right\}.$$

2.6 Calibration

In order to solve the model numerically, we assign parameter values on the basis of observations for U.S. data. The relationship between sovereign risk, private-sector spreads, and the debt level is calibrated based on cross-country evidence. A time period in the model is one quarter.

With respect to monetary policy, we assume an average inflation rate of 2 percent per year. The coefficient on inflation in the Taylor rule is set to a customary value of $\phi_\Pi = 1.5$. We consider different values for parameter ϕ_ω, the response of monetary policy to the interest rate spread. The specific parameterization will be discussed in the respective sections below. The steady-state level of government spending (consumption and investment) relative to GDP is $g/y = 0.2$. The level of gross public debt in the steady state is set to 60 percent of annual GDP. These values are broadly in line with U.S. averages over the last 20 years. In the baseline scenario, we set distortionary tax rates to zero and assume that the adjustment of taxes over the business cycle and in response to the debt level is achieved through lump-sum taxes. This assumption allows us to focus on the main channels of transmission in a transparent way while accounting for a feedback from economic activity to the fiscal outlook.[8] We assume that taxes react to debt sufficiently strongly (ϕ_{T,b^g} large enough) so as to ensure that the debt level remains bounded throughout and that $\phi_{T,y} = 0.34$. This value is reasonable for the U.S., but at the lower end of estimates for other OECD countries; compare Girouard and André (2005).

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[8]Below we explore the sensitivity of our results by also considering a distortionary tax rate on labor.

With regard to the preference parameters, we set the curvature of the disutility of work to $\nu = 1/1.9$, in line with the arguments provided by Hall (2009) regarding plausible values for the Frisch elasticity of labor supply. We set an elasticity of demand of $\theta = 7.6$ so as to generate a gross price markup of $\mu^p = 1.15$, which is in the range of customary values used in the literature. Finally, we assume that the average intertemporal elasticity of substitution $\overline{\sigma} = c/y$, where $\overline{\sigma} := \pi_b \cdot (c^b/y) \cdot \sigma_b + \pi_s \cdot (c^s/y) \cdot \sigma_s$. If the model had a representative household, this would correspond to the case of log-utility. Further, we assume that aggregate hours worked in the steady state are given by $h = 1/3$. We choose the relative values of the intertemporal elasticity of substitution for the two types of households (σ_b and σ_s) and of the scaling parameters for the disutility of work (ψ_b and ψ_s) such that the linearized model can be represented in the canonical three-equation New Keynesian format. This representation allows us to derive a number of analytical results in the next section. Importantly, under this calibration only the current value of the interest rate spread enters the dynamic IS-relationship and the New Keynesian Phillips curve. In addition, the evolution of output and inflation is independent of the level of private debt. Appendix A spells out in detail the conditions under which this representation is valid. Specifically, given the other parameter values, we set $\sigma_b/\sigma_s = 0.53$ and $\psi_b/\psi_s = 0.82$. We explore to sensitivity of our results with respect to these assumptions through numerical simulations in Section 4.

We target a ratio of private debt to annual GDP, $b/4y$, of 80 percent, in line with Great Moderation averages for the U.S. More precisely, the figure refers to nonfinancial, nonmortgage, nongovernment credit market debt outstanding recorded in the U.S. flow of funds accounts. The same target is used by Cúrdia and Woodford (2009). Along with the market clearing condition, this determines scaling parameters ξ^b and ξ^s. Next, as in Cúrdia and Woodford (2009), we assume that households redraw their type on average every 40 quarters, giving $\delta = 0.975$. This implies that the average time during which a specific type is without access to payoff streams from asymptotic risk sharing is 10 years.

A central element in our calibration is the share of borrowers in the economy, π_b. This determines the share of economic activity that is affected by an increase in the spread and therefore deserves some discussion. One possible calibration would refer to the (U.S.) Survey of Consumer Finances. Averaging over the latest surveys (1998, 2001, 2004, and 2007), the share of U.S. families that hold some kind of debt is 76 percent; compare Aizcorbe et al. (2003)

and Bucks et al. (2009). This suggests a value of $\pi_b = 0.76$, and of $\pi_s = 0.24$. However, loans secured by the primary residence make up a large share of that debt. This suggests that such a calibration for π_b might overstate the importance of borrowing and the related effect that an increase in borrowing spreads could have on economic activity. Another metric, also from the Survey of Consumer Finances, that is more directly related to the notion of "borrowers" and "savers" in our model is that on average 57 percent of families in the survey report that – over the year preceding each survey date – they have been spending less than their income, that is, they have saved. This suggests a value for π_b of $1 - 0.57$, or $\pi_b = 0.43$. That said, both of the aforementioned figures do not explicitly take into account the borrowing by firms in the economy (other than by single-owner firms). To the extent that households in our model own firms and also make the intertemporal decisions for these firms, any purely household-based measure of indebtedness is likely to underestimate the degree of indebtedness and thereby the importance of the borrowing spread. In particular, using the same measure of private borrowing as above (nonfinancial, nonmortgage, nongovernment credit market debt), 50 percent of private borrowing is accounted for by corporations rather than by households. To capture this, we set $\pi_b = (1 - 0.17) \cdot 0.43 + 0.17 \cdot 1 = 0.53$ in our baseline calibration. This formula hypothetically divides households into consumption entities, some of which are indebted, and investment entities, all of which have debt. In the calculations, 0.17 is the share of nonresidential private domestic fixed and inventory investment in private domestic economic activity.

In regard to the normal spread between deposit and lending rates, we target a steady-state value of 2.1 percent (annualized), in line with commercial and industrial loan rate spreads in the Federal Reserve's Survey of Terms of Business Lending. This pins down parameter χ_ψ. The steady-state level for the central bank's target interest rate, i^d, is set to 4.5 percent annualized, from which the time discount factor, β, follows.

Turning to the production parameters, we set $\phi = 1$, implying a linear production function. We furthermore target a unit value for steady-state output; this pins down productivity, z. We set parameter $\alpha = 0.9$ in order to generate a slope of the Phillips curve in line with the empirical evidence.[9]

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[9]Specifically, our parameterization implies a slope coefficient of $\kappa = 0.012$. Galí and Gertler (1999) report estimates for the slope of the Phillips curve, given by $(1 - \beta\theta)(1 - \theta)/\theta$, in the range between 0.007 and 0.047. More recently, Altig et al. (2010) report an estimate of 0.014.

Figure 2: Sovereign risk premia vs. debt
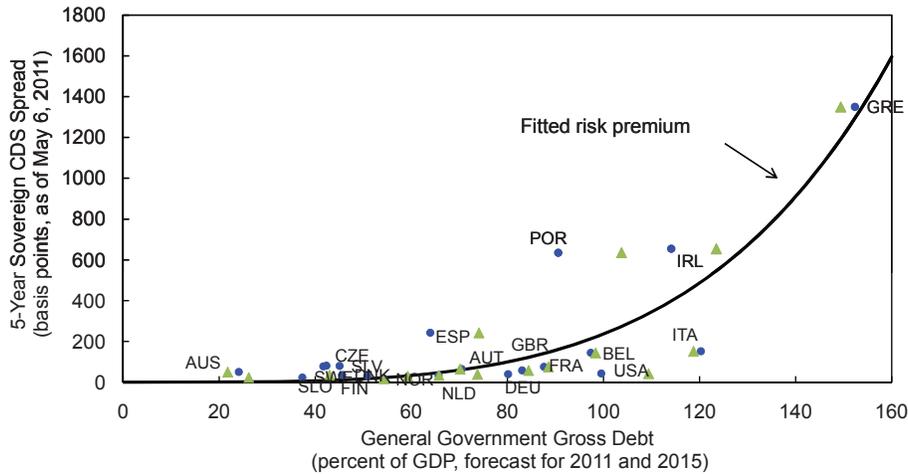
Notes: The figure shows 5-year sovereign CDS spreads against forecasts for end-2011 gross general government debt/GDP (blue circles) and end-2015 debt/GDP (green triangles). The countries shown are Australia, Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Portugal, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom, and United States. Excludes Japan. Forecasts are taken from the IMF World Economic Outlook April 2011.

Finally, it remains to determine the parameters that govern the spillover from sovereign risk premia to private-sector spreads. Actual haircuts in case of a sovereign default show large variation; see Panizza et al. (2009) and Moody's Investors Service (2011). $\vartheta_{\text{def}} = 0.5$ appears to be a reasonable average value. With respect to the specification of the fiscal limit, we seek to replicate the relationship between the sovereign risk premium and public debt shown in Figure 2. The figure plots CDS spreads of industrialized economies against the level of projected gross debt of the general government (relative to GDP). The projections are taken from the IMF's World Economic Outlook in April 2011. The blue dots show projections for the end of 2011. For comparison, the figure also plots IMF forecasts for the debt-to-GDP ratio by the end of 2015. For the countries shown in the figure, CDS spreads are systematically higher the higher the level of projected gross public debt.[10] In fact, the risk premium appears to rise

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[10]For a systematic empirical analysis of the relationship between fiscal variables and yields on government bonds, see, among others, Reinhart and Sack (2000), Ardagna et al. (2007), Baldacci et al. (2008), Haugh et al. (2009), Laubach (2009), Baldacci and Kumar (2010), or Borgy et al. (2011). Ardagna et al. (2007) explicitly focus on possible nonlinearities in the relationship and find that bond rates rise disproportionately for very high levels of debt. Note, however, that sovereign risk premia are bound to be affected by more than just one fiscal variable, including such factors as the quality of fiscal institutions or the composition of the investor base. We abstract from these complications to keep our exercise tractable and focus on the fact that high current and/or projected debt is consistently found to be a key determinant of government financing costs.

disproportionately as the debt level rises. We choose parameters $\alpha_{b^g} = 3.70$, $\beta_{b^g} = 0.54$, and $\overline{b}^{\,\mathrm{g,max}} = 2.56$ to match this empirical relationship. The black solid line displays the implied steady-state relationship between debt levels and the sovereign risk premium.

Regarding the spillovers from sovereign to private-sector risk, Figure 1 is suggestive of a sovereign risk channel that runs from sovereign spreads to spreads in the household and corporate sector. Of course, there might be other reasons for the observed comovement, too. In the present paper, we abstract from these and interpret the comovement as caused by sovereign risk, consistent with standard accounts of the sovereign debt crisis in parts of the euro area. In regard to α_ψ, Harjes (2011) finds for a sample of large, publicly traded euro area companies that a 100-basis-point increase in sovereign spreads raises private firms' credit spreads by about 50 to 60 basis points. As our baseline, we therefore set $\alpha_\psi = 0.55$. Although this value implies significant spillovers, it may still represent something closer to a lower bound for two reasons. First, it is based on credit spreads of companies that are large, with often sizeable export activities and access to international credit markets. Spillover effects from sovereign risk are likely to be more pronounced for smaller and less international companies that rely on local bank-based financing. Second, Figure 1 suggests that the comovement between spreads is considerably stronger in countries that face intense fiscal strain. Accordingly, the value of $\alpha_\psi = 0.55$ may understate the strength of the sovereign risk channel for highly indebted countries. For these reasons, we also consider higher values as we move through the simulations in the paper.

3   Sovereign risk, fiscal policy, and macroeconomic stability

In this section, we begin to analyze how sovereign risk affects macroeconomic dynamics and stabilization policy in the model outlined above. Our focus is on the stability properties of the economy, notably its vulnerability to self-fulfilling equilibria. In this context, we investigate in detail how the sovereign risk channel alters the transmission of fiscal policy. We show that monetary policy plays a key conditioning role, notably through its capacity to insulate private borrowing costs from fluctuations in sovereign risk premia. To capture this aspect we consider a scenario where monetary policy may be constrained by the ZLB. Our analysis proceeds in two steps. First, in this section, we consider a special case of our model for which we are able to obtain analytical solutions. For this case, we assume that the probability of

sovereign default depends on the expected primary deficit, rather than on the level of debt. In the next section, we will turn to simulation-based results for the full model.

3.1 A tractable special case of the model

In this section, we focus on a first-order approximation of the equilibrium conditions around the deterministic steady state. The aggregate equilibrium dynamics of the model can be represented by a variant of the New Keynesian Phillips curve and a dynamic IS relationship. The former relates inflation to expected inflation, output, and government purchases:

$$\widehat{\Pi}_t = \beta E_t \widehat{\Pi}_{t+1} + \kappa_y \tilde{y}_t - \kappa_g \tilde{g}_t, \tag{34}$$

where $\kappa_y = \kappa(\nu + \bar{\sigma}^{-1})$ and $\kappa_g = \kappa \bar{\sigma}^{-1}$, with $\kappa = \frac{(1-\alpha)(1-\alpha\beta)}{\alpha}$.[11] In terms of notation, $\tilde{y}_t = y_t - y$, $\tilde{g}_t = g_t - g$, and $\widehat{\Pi}_t = \log(\Pi_t/\Pi)$, where variables without a time subscript refer to steady-state values.

The dynamic IS-relationship links output to real government spending and the effective real interest rate through

$$\tilde{y}_t - \tilde{g}_t = E_t \tilde{y}_{t+1} - E_t \tilde{g}_{t+1} - \bar{\sigma} \left[\widehat{i}_t^d + (\pi_b + s_\Omega) \widehat{\omega}_t - E_t \widehat{\Pi}_{t+1} + \Gamma_t \right], \tag{35}$$

where $\widehat{\omega}_t := \log((1+\omega_t)/(1+\omega))$, $\widehat{i}_t^d := \log((1+i_t^d)/(1+i^d))$, and $\Gamma_t := E_t \log(e_{t+1}) - \log(e_t)$. From the IS relationship, it is clear that fluctuations in the private-sector spread can influence economic activity unless they are neutralized by monetary policy. The degree to which the private-sector spread affects economic activity, for a given policy rate, is determined by parameters $\pi_b + s_\Omega$. As discussed in Cúrdia and Woodford (2009), parameter $s_\Omega := \pi_b \pi_s (\sigma_b c_b/y - \sigma_s c_s/y)/\bar{\sigma}$ indicates the extent to which interest rate increases affect the aggregate demand by borrowers more adversely than that of savers. In our calibration, $c_b > c_s$ and $s_\Omega > 0$.

As regards monetary policy, equation (31) implies that during normal times (in deviations from steady state):

$$\widehat{i}_t^d = \phi_\pi \widehat{\Pi}_t - \phi_\omega \widehat{\omega}_t. \tag{36}$$

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[11] Here, as in the following linearizations, we abstract from fluctuations in productivity, z_t.

For the analytical results, we initially consider the case $\phi_\omega = (\pi_b + s_\Omega)$, in which the central bank fully neutralizes the effect of the sovereign risk premium on aggregate economic outcomes, as apparent from the IS equation (35). However, monetary policy may not always be able to do so. In particular, we assume below that monetary policy becomes constrained such that the nominal interest rate is stuck at the lower bound of zero in the initial period of our simulations. This means that the central bank can no longer offset a rise in the interest rate spread. We follow Christiano et al. (2011) and Woodford (2011) in assuming that monetary policy will return to Taylor rule (36) in the next period and be unconstrained thereafter with probability $1 - \mu$, where $\mu \in (0,1)$. Otherwise, the zero interest rate persists into the next period. The same Markov structure applies for the remaining periods. As a result, the expected length of the ZLB episode is given by $1/(1-\mu)$. Shocks to the time discount factor, Γ_t, follow the same Markov structure.[12] Given that there are no endogenous state variables in the special case of our model considered here, once the ZLB situation ceases to persist, the economy immediately reverts to the steady state.

As indicated above, we make one further simplifying assumption in this section that allows us to derive analytical results. Specifically, we assume that the probability of sovereign default—and thus the sovereign risk premium—depends on the expected primary deficit rather than the level of public debt as in the full model. Consequently, the interest rate spread also depends on the expected deficit. We postulate a linear relationship of the form

$$\widehat{\varpi}_t = \xi E_t(\tilde{g}_{t+1} - \phi_{T,y}\tilde{y}_{t+1}), \tag{37}$$

where, in order to ease the burden on notation, we have defined the spread that enters the IS relationship over and above the risk-free deposit rate as $\widehat{\varpi}_t := (\pi_b + s_\Omega)\widehat{\omega}_t$. Parameter $\xi \geq 0$ indicates the extent to which fiscal strain—as measured by primary deficits—spills over to private-sector spreads. Parameter $\phi_{T,y} \in [0,1)$ measures the sensitivity of tax revenue with respect to economic activity.

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[12]Specifically, we assume a temporary increase in the effective discount factor, triggered by $0 < e_t = e_L < 1$ while at the ZLB, so $\Gamma_t = \mu \log(e_L) - \log(e_L) = -(1-\mu)\log(e_L) \geq 0$.

Debt/GDP	ξ'	ξ by length of ZLB episode (qtrs)		
		6	7	8
60 percent	0.0005	0.004	0.005	0.005
90 percent	0.0016	0.014	0.015	0.017
110 percent	0.0030	0.025	0.028	0.031
130 percent	0.0051	0.042	0.047	0.052
140 percent	0.0065	0.054	0.060	0.066
150 percent	0.0083	0.068	0.076	0.084

Notes: The table presents estimates for the slope of the average private interest rate with respect to the fiscal deficit, ξ, for different average lengths (in quarters) of the ZLB episode and for different debt/GDP ratios. The entries in the columns "ξ by length of ZLB episode (qtrs)" are based on the formula $\xi = \frac{1+\mu(1-\mu)}{\mu(1-\mu)}\xi'$ that is explained in detail in the main text and in Appendix B.

3.2 The size of the spillover from public to private risk premia

To appreciate our results below, it is useful to discuss the range of plausible values for ξ in equation (37), which—through a sequence of back-of-the-envelope calculations—links to the fundamental parameters of the model. Let ξ' be the slope of the risk premium with respect to debt at a specific debt level, evaluated in the steady state. Our assumptions regarding the sovereign spread in Section 2, in particular equation (29), imply that

$$\xi' = \alpha_\psi \frac{(\pi_b + s_\Omega)\,\vartheta_{\text{def}}}{1 - \vartheta_{\text{def}}\, F_{\text{beta}}\left(\frac{b^g}{4y}\frac{1}{\bar{b}^{\text{g,max}}};\, \alpha_{b^g}, \beta_{b^g}\right)} \frac{1}{4y}\frac{1}{\bar{b}^{\text{g,max}}} f_{\text{beta}}\left(\frac{b}{4y}\frac{1}{\bar{b}^{\text{g,max}}};\, \alpha_b, \beta_b\right). \qquad (38)$$

The first column of Table 1 reports the resulting values for ξ' at different debt levels using the calibration of the fiscal limit distribution discussed in Subsection 2.6.

These values appear to be fairly small. It needs to be borne in mind, however, that the relationship in equation (37) links the interest rate spread to the expected deficit, whereas the full model implies a link between the interest rate spread and the expected level of debt, i.e., the result of a series of accumulated deficits. The values for ξ' are thus bound to understate the sensitivity of the interest rate spread to a persistent fiscal deficit. More precisely, an appropriate mapping from the slope of the risk premium into the simplified model environment needs to take into account the horizon over which deficits accumulate. The following expression is meant to capture this fact for empirically reasonable values of

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$\mu > 0.5$ (so the ZLB is expected to be binding for at least two periods):[13]

$$\xi = \frac{1 + \mu(1 - \mu)}{\mu(1 - \mu)} \xi'. \tag{39}$$

The columns under "ξ by length of ZLB period" in Table 1 report the corresponding values of ξ for different initial debt levels if the ZLB has an expected duration of six, seven, or eight quarters. These calculations suggest that a value of ξ as high as 0.1 cannot be ruled out if the initial debt stock is large and the recessionary shock persists for an extended period. In particular, recall from Figure 1 that the spillovers may be noticeably stronger than usual for countries that face intense fiscal strain. A bigger spillover parameter, α_ψ, would scale up linearly the entries in Table 1.

3.3 Sovereign risk channel and equilibrium determinacy

Assume, as a baseline scenario, that the level of government spending is exogenously given. For this case, we find that the sovereign risk channel significantly alters the determinacy properties of the model while the ZLB is binding. Specifically, the range of parameters that ensure determinacy shrinks in the presence of sovereign risk. In the following, we establish distinct restrictions on parameters that yield a (locally) determinate equilibrium.[14]

Proposition 1 *In the economy summarized by equations (34) – (37), let the interest rate be equal to zero in the initial period. In each subsequent period, let the interest rate remain at zero with probability $\mu \in (0, 1)$. Otherwise, let monetary policy be able to permanently return to Taylor rule (36). There is a locally unique bounded equilibrium if and only if*

$$a) \quad a < 1/(\beta\mu), \quad and \quad b) \quad (1 - \beta\mu)(1 - a) > \mu\bar{\sigma}\kappa_y,$$

where $a := \mu + \mu\xi\phi_{T,y}\bar{\sigma}$ and $\kappa_y := \kappa[\nu + 1/\bar{\sigma}]$.

Proof. See Appendix C. ∎

In the absence of an endogenous risk premium (i.e., for $\xi = 0$) as in Christiano et al. (2011) and Woodford (2011), condition a) is always satisfied. Hence there will be a unique bounded

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[13] Appendix B presents a more detailed motivation of the following formula.

[14] We focus on local determinacy once the economy has reached the ZLB. A separate strand of the literature examines global determinacy in the New Keynesian model. Benhabib et al. (2002), for example, propose a fiscal policy setup that rules out liquidity traps by making the low-inflation steady state fiscally unsustainable. Mertens and Ravn (2011) study the efficacy of fiscal policy in belief-driven equilibria.

equilibrium if and only if condition b) holds. If $\xi = 0$, condition b) is given by $(1 - \beta\mu)(1 - \mu) > \mu\bar{\sigma}\kappa_y$. The previous literature has shown that the set of "fundamental" parameters for which this condition holds is larger (i) the less persistent the ZLB situation (in our parameterization, the smaller μ); (ii) the lower the interest sensitivity of demand (the smaller $\bar{\sigma}$); and (iii) the flatter the Phillips curve (the smaller κ_y). In addition to these findings, our analysis shows that the range of parameters for which the equilibrium is determinate shrinks in the presence of a sovereign risk channel. Specifically, with $\xi > 0$, condition a) is violated if either the interest rate spread is sufficiently responsive to the deficit or if tax revenue is sufficiently responsive to output ($\phi_{T,y}$ is large enough). Note that the same parameters are also key determinants for whether condition b) is satisfied.[15]

It is instructive to contrast this baseline result with a situation where government spending adjusts endogenously to output while the economy is at the ZLB. The following proposition summarizes the pertinent conditions for the existence of a unique bounded equilibrium.

Proposition 2 *In the economy specified in Proposition 1, let government spending $\tilde{g}_t$ take on a value of $\tilde{g}_t = \varphi\tilde{y}_t$ when the economy is at the ZLB, and $\tilde{g}_t = 0$ otherwise. Suppose further that $\varphi < 1$. Define $a^* := \mu + \mu\xi\phi_{T,y}^*\bar{\sigma}^*$; $\kappa_y^* = \kappa_y - \varphi\kappa_g$; $\phi_{T,y}^* := \phi_{T,y} - \varphi$; and $\bar{\sigma}^* = \bar{\sigma}/(1 - \varphi)$. There exists a locally unique bounded equilibrium if and only if:*

1. *with $a^* > 0$*

$$a) \quad a^* < 1/(\beta\mu), \quad and \quad b) \quad (1 - \beta\mu)(1 - a^*) > \mu\bar{\sigma}^*\kappa_y^*,$$

2. *with $a^* < 0$:*

$$a) \quad (1 + \beta\mu)(1 + a^*) > -\mu\bar{\sigma}^*\kappa_y^* \quad and \quad b) \quad (1 - \beta\mu)(1 - a^*) > \mu\bar{\sigma}^*\kappa_y^*.$$

Proof. See Appendix C. ∎

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[15]The analytical results in Proposition 1 do not depend on the strength of the response to inflation, ϕ_π, once the economy has left the ZLB (apart from whether the parameter satisfies the Taylor principle). At first glance this seems to contradict the results in Davig and Leeper (2007). Yet, these authors study an economy with monetary regime changes in which the Taylor principle is satisfied in one regime but not the other. They show that the equilibrium may remain locally determinate in both regimes if the "passive regime" is not too persistent and if—in addition—monetary policy is sufficiently responsive to inflation in the "active" regime. This suggests that the monetary response to inflation should enter the determinacy conditions. Their calculations, however, explicitly exclude the possibility that the passive regime entails a ZLB scenario in which monetary policy does not react at all to inflation. Instead, they assume some reaction of monetary policy to inflation in both regimes. If one of the regimes entails a ZLB situation, the precise strength of the response to inflation in the active regime does not feature in the determinacy conditions.

To appreciate the implications of this proposition, consider first the possibility that there is no sovereign risk channel ($\xi = 0$). In this case the range of parameters for which the equilibrium is determinate is larger if spending is countercyclical ($\varphi < 0$). With an endogenous risk premium, however, the opposite may hold. More precisely, if $\xi > 0$ and if, in addition, the conditions of Item 1 of Proposition 2 hold, then subject to some limits on the elasticity of taxes with respect to output, namely, $\phi_{T,y} < 1 - \frac{\kappa\nu}{(1-\beta\mu)\xi}$, the range of fundamental parameters for which the equilibrium is determinate is at least as large with a procyclical spending response, $\varphi \in (0,1)$, as without any response; indeed the range can even be larger. Note that this case is more likely the lower the elasticity of tax revenue to economic activity (the smaller $\phi_{T,y}$), and the more strongly the interest rate spread responds to the deficit (the larger ξ). The main conclusion is straightforward, if unconventional: a procyclical fiscal stance may reduce the risk of equilibrium indeterminacy in the presence of sovereign risk.[16]

The two propositions above deserve some further discussion. While previous work has focused on the case in which government debt and a rising risk premium imply explosive debt, we consider a situation in which debt ultimately will always be stabilized through one-off tax measures (although sovereign default can still occur). In such an environment, we find that an economy with an endogenous risk premium and a constrained central bank can be prone to belief-driven equilibria. Moreover, we find that systematic spending cuts during recessions (when the ZLB is binding) may actually help to anchor expectations to a unique equilibrium. To see why, assume that during the ZLB period agents expect some drop in output. Lower output means less tax revenue and, in the absence of a fiscal response, higher deficits, which in turn imply a higher interest rate spread. As the widening of the interest rate spread cannot be offset by monetary policy at the ZLB, the real interest rate rises. Consequently, expectations of adverse output developments can become self-fulfilling in high-debt economies where a high and rising interest rate spread weighs heavily on output, thus confirming agents' beliefs in equilibrium. By contrast, a procyclical fiscal stance may be sufficient to prevent an adverse expectational shock from confirming itself, because public spending cuts would offset the expected decline in tax revenue triggered by a fall in output.

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[16](See Appendix D, Corollary 4 for details). It bears stressing that we focus here on very simple fiscal and monetary rules in order to maintain analytical tractability. More complicated rules that would make future monetary or fiscal behavior depend on past developments might, in principle, help overcome problems of indeterminacy.

Figure 3: Determinacy regions with endogenous response of government spending

Different expected durations of the ZLB episode
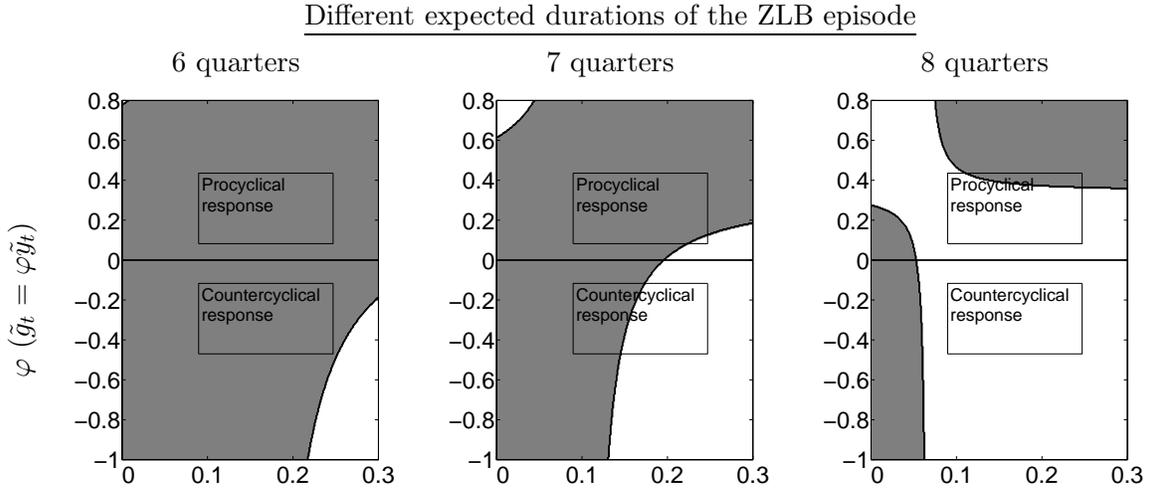
Notes: Determinacy regions with endogenous response of government spending to economic activity during a deep recession. Grey areas mark parameterizations that imply determinacy. y-axis: response of government spending to output, φ ($\tilde{g}_t = \varphi \tilde{y}_t$). x-axis: response of the interest rate spread to the deficit, ξ. From left to right: ZLB is expected to bind for 6, 7, or 8 quarters ($\mu = 5/6, 6/7, 7/8$).

Figure 3 illustrates the results of Propositions 1 and 2 for the baseline parameterization. Each panel of the figure displays results for a different value of μ implying, from left to right, an expected duration of the ZLB episode of 6, 7, and 8 quarters, respectively. We evaluate whether a unique equilibrium exists for different values of the slope of the risk premium, ξ, measured on the horizontal axis, and the response of government spending to output, φ, measured on the vertical axis. Grey areas indicate determinacy regions, while white areas indicate equilibrium indeterminacy. In the case of protracted ZLB episodes (right panel) with a steep slope of the risk premium, we find that there may be no countercyclical spending policy—of the simple form analyzed here—that ensures determinacy. However, a policy of procyclical spending cuts is not a panacea either; although it is helpful under the circumstances detailed above in reducing the risk of belief-driven equilibria, it does not ensure determinacy for all values of ξ under consideration.

On a final note, we have made the risk premium depend on the expected next-period deficit in this section, as apparent from (37). This conforms to the notion that sovereign spreads reflect a forward-looking assessment of the fiscal position. Quantitatively, however, it turns out that our results would be very similar if we had assumed that the sovereign spread depends on the current period's deficit.

3.4 Output effects of government spending cuts

In the following we shift our focus to the output effects of exogenous government spending cuts. To that end, we limit our analysis to parameterizations for which a stable and unique equilibrium exists. Our results suggest that sovereign risk is a key determinant for the size, and even sign, of the fiscal multiplier. In the simplified model setup that we consider at the moment, the sovereign risk channel is governed by parameter ξ. However, since monetary policy may neutralize the effects of the sovereign risk channel outside the ZLB episode, parameter μ plays a key role in our analysis as well.

Following Woodford (2011) and Christiano et al. (2011), we focus on an economy at the ZLB and assume that government spending deviates from its steady-state level during the ZLB episode only, i.e., by taking on a value of $\tilde{g}_t = g_L$. Otherwise government spending is set to its steady-state level. Our key result is summarized by the following proposition.

Proposition 3 *Under the conditions spelled out by Proposition 1 (which ensure that a locally unique bounded equilibrium exists), let shock Γ_t take on a value of Γ for as long as monetary policy is constrained to zero interest rates, and a value of 0 otherwise. Similarly, let government spending take on a value of g_L when the economy is at the ZLB, and 0 otherwise. As before, define $a = \mu + \mu\xi\phi_{T,y}\bar{\sigma}$, and $b = \mu + \mu\bar{\sigma}\xi$. Then, while monetary policy is constrained, output is given by*

$$y_L = \vartheta_r(\log(1 + i^d) - \Gamma) + \vartheta_g \, g_L,$$

where

$$\vartheta_r = \frac{\bar{\sigma}(1 - \beta\mu)}{(1 - \beta\mu)(1 - a) - \mu\bar{\sigma}\kappa_y} > 0 \tag{40}$$

and

$$\vartheta_g = \frac{(1 - \beta\mu)(1 - b) - \mu\bar{\sigma}\kappa_g}{(1 - \beta\mu)(1 - a) - \mu\bar{\sigma}\kappa_y}. \tag{41}$$

Proof. See Appendix C. ∎

Note that ϑ_g provides a measure for the government spending multiplier on output at the ZLB. It is characterized in more detail by Corollary 5 in Appendix D.2. Specifically, under the determinacy conditions established above, equation (41) implies that the multiplier is positive if and only if

$$(1 - \mu) - \frac{\mu\bar{\sigma}\kappa_g}{1 - \beta\mu} > \mu\xi\bar{\sigma}. \tag{42}$$

If this condition is satisfied, a spending cut at the ZLB will reduce output, in line with conventional wisdom. If $\xi = 0$, i.e., in the absence of a sovereign risk channel, this will always

Figure 4: Effects of early retrenchment
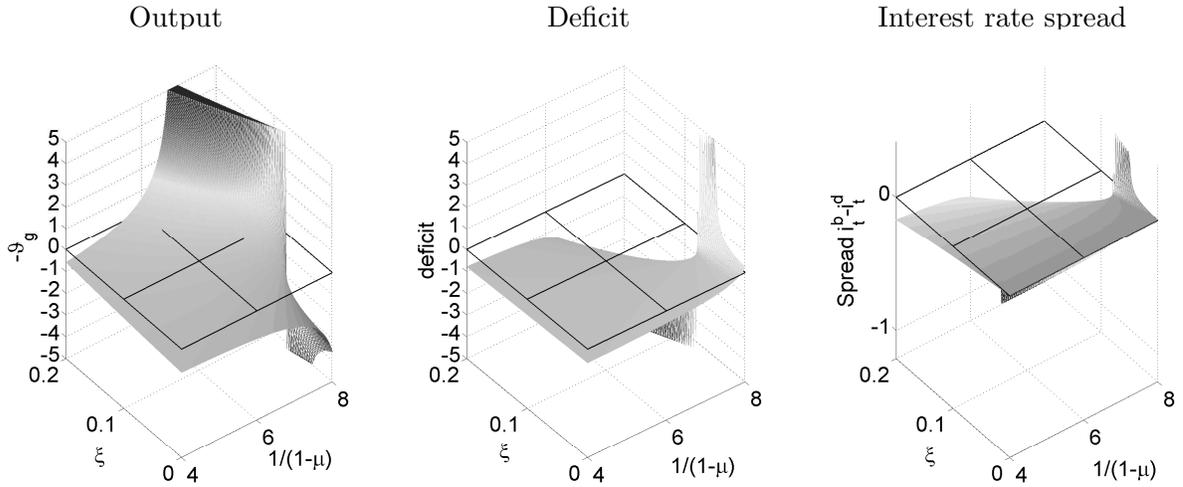
Notes: The figure shows the effects of a unit cut in government spending for the length of the ZLB episode. Effect on output (left panel), on the deficit (middle panel: negative means the deficit shrinks), and on the interest rate spread (right panel). On the axes: responsiveness of interest spread to expected deficit, ξ, and expected duration of ZLB episode: $1/(1-\mu)$. Only parameterizations that imply determinacy are shown. For better readability, multipliers and deficits are capped at the maximum level indicated in the charts.

be the case. Moreover, the government spending multiplier will be strictly greater than one, consistent with the analysis of Christiano et al. (2011) and Woodford (2011). In contrast, if $\xi > 0$, the government spending multiplier at the ZLB may actually become negative, such that spending cuts *raise* output.

The left panel of Figure 4 illustrates this result. It displays the output effect of a government spending cut during the ZLB episode for different levels of spillovers from sovereign risk, as measured by alternative values for ξ, and for different assumptions regarding the expected length of the recession, as measured by alternative values for $1/(1-\mu)$. The other parameters underlying these computations remain fixed as laid out earlier. In the same figure we also show the response of the budget deficit (middle panel) and the interest rate spread (right panel).

The figure shows that the fiscal multiplier depends crucially on both dimensions under consideration. Consider first the case where $\xi = 0$, that is, a situation when there is no sovereign risk channel. In this case, a spending cut invariably causes a sizeable decline in output. In fact, for an expected duration of the ZLB episode of eight quarters, the government spending multiplier on output reaches a value as high as 3, a result recently stressed in Christiano

et al. (2011). The underlying mechanism is well understood: the deflationary effect of spending cuts cannot be counteracted by a reduction in policy rates, thus causing an increase in the real interest rate which crowds out private demand. The effect is stronger the longer the expected duration of the ZLB episode, as private demand is determined by the expected path of current *and future* short-term real interest rates.

Turning to the scenario of an active sovereign risk channel, we focus first on a case where the ZLB period is expected to be short, namely four quarters only. In this case, as the interest rate spread becomes more responsive to the fiscal deficit, i.e., as ξ takes on bigger values, the fiscal multiplier tends to decline. In other words, output falls by less in response to a public spending cut. Still, the role of the sovereign risk channel is limited, even for very high values of ξ. This is due to the fact that monetary policy is expected to be able to offset the effect of sovereign risk on private interest rates in the near future.

The picture changes significantly if monetary policy is expected to be constrained for an extended period. Under those circumstances, the sovereign risk channel has a strong bearing on the fiscal transmission mechanism. In fact, if ξ and μ both take on sufficiently high values, the sign of the output multiplier turns negative, implying that a spending cut during the ZLB episode becomes expansionary. To understand this finding, it is useful to consider the responses of the deficit and the risk premium. Note that for almost all parameterizations, a cut in government spending reduces the deficit (see also Erceg and Lindé (2010b)). If fiscal strain is severe at the outset, the lower deficit leads to a considerable decline in the risk premium. This, in turn, reduces the interest rate spread, stimulates private demand, and raises tax revenue. The result is a virtuous cycle of an additional decline in interest rate spreads, increased economic activity, and a further improvement of the fiscal outlook.[17]

In sum, our simplified model setup reveals a potentially important role for the sovereign risk channel. Although the model implies standard positive multipliers under normal conditions (i.e., public spending cuts depress short-term output), fiscal retrenchment may become less contractionary, and even turn expansionary, in the presence of severe fiscal strain if monetary policy is unable to cushion the adverse effects of sovereign risk on private-sector borrowing conditions.

As such, our results shed some fresh light on the theoretical possibility of "expansionary fis-

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[17]Contrary to the first impression given by Figure 4, conditional on the length of the ZLB episode the size of the multiplier is monotone in the responsiveness of the spread to the deficit, as measured by parameter ξ.

cal contractions," which has attracted significant attention following the prominent study by Giavazzi and Pagano (1990), who consider the experience of Denmark and Ireland during the 1980s.[18] In order to rationalize expansionary consolidations, previous theoretical accounts have often focused on the "expectations view," whereby immediate fiscal retrenchment triggers a shift in expectations regarding the long-run level of spending, and thus a downward revision of the anticipated tax burden (Bertola and Drazen 1993, Sutherland 1997, and Perotti 1999). In a similar vein, Blanchard (1990) formalizes the idea that early consolidation may reduce the likelihood of more disruptive future adjustment, thus boosting current private spending. Giavazzi and Pagano themselves stress that monetary policy may also have played an important role in the Danish and Irish episodes. Specifically, both episodes were marked by credible exchange rate pegs, which arguably led to declining country risk premia and lower real interest rates. More recently, Erceg and Lindé (2010a) have analyzed government spending cuts in a model of a currency union where country risk is a function of the state of public finances.[19] Our own analysis provides a novel contribution to this literature by highlighting a distinct set of economic conditions—high sovereign risk and a constrained central bank—under which spending cuts may have non-standard effects.[20]

4   Dynamic analysis

We now turn to a numerical analysis of the full model as outlined in Section 2 above. This allows us to revisit our analytical results while accounting for the possibility that sovereign risk depends on the expected debt level rather than the expected deficit. In order to highlight the role of monetary policy, we focus again on a ZLB scenario. However, we depart from the

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[18]The evidence on expansionary consolidations remains controversial. For a positive assessment, see, for example, Alesina and Perotti (1995) or Alesina and Ardagna (2010). A skeptical view is presented by International Monetary Fund (2010b). Perotti (2011) provides a reassessment.

[19]In simulations, they find that output always falls in the initial periods of a persistent spending cut but that the effects may eventually turn positive during the dynamic adjustment process. For high levels of debt we obtain even stronger results—notably positive impact effects—as we consider a wider range of parameterizations and allow for a nonlinear relationship between the risk premium and the level of public debt.

[20]Earlier papers have also shown that the *expectation* of persistent fiscal retrenchment after the ZLB episode can stimulate economic activity while the economy is still at the ZLB; see, for example, Corsetti et al. (2010) and Woodford (2011). Appendix E discusses how the sovereign risk channel affects those results. For the scenarios under consideration, we find that there are parameterizations for which expected future retrenchment increases output at the ZLB in the presence of a sovereign risk channel, while it crowds out output in the absence of such a channel. The reverse does not hold. In particular, whenever a future retrenchment package is found to boost output at the ZLB in the absence of sovereign risk, it also boosts output at the ZLB in the presence of sovereign risk. Indeed, any positive output effect caused by expected future retrenchment is even stronger if the sovereign risk channel is active.

simplifying assumption that the expected duration of the ZLB episode is constant. Instead, we envisage a scenario in which a) the initial debt level matters for the depth of the recession; and b) fiscal retrenchment may alter the length of the ZLB episode.[21]

4.1 Deep recessions and sovereign risk

To set the stage for our analysis, we subject the model economy to a large shock that pushes monetary policy to the ZLB. Specifically, we consider a first-order autoregressive process for $\hat{e}_t$ to capture in a stylized manner the output loss in the U.S. during the 2007–2009 recession. The Congressional Budget Office (2011) estimates that the output gap reached 6.7 percent in 2009 and that it will still be at a 1.7 percent level in 2014 and at 0.5 percent in 2015.[22] For the simulations, we also assume that taxes stabilize the debt level, if only very gradually.[23] While the simulations for the baseline scenario assume that taxes are raised in a lump-sum manner, Subsection 4.3 assesses the extent to which distortionary taxation would affect our conclusions.

Figure 5 shows the evolution of output, the interest rate spread, and the policy rate in response to the recessionary shock. It displays the behavior of the economy in the absence of any discretionary fiscal policy measure for three different initial levels of government debt: 60 percent of GDP (black solid line), 90 percent (blue dashed line), and 115 percent (red dots). The adjustment dynamics differ substantially in that the decline in output and the rise of the interest rate spread are much stronger if initial debt is high. To understand this result, note that the shock induces an increase in the budget deficit, which leads to a build-up of public debt and thus an increase in the sovereign risk premium. Moreover, since the shock pushes the economy to the ZLB, monetary policy is unable to offset the spillover from sovereign risk to private interest rates. Private expenditure thus falls further, compounding the initial decline in output. This effect is stronger the higher the initial debt level, because the relationship

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[21]We solve the model economy under perfect foresight using standard techniques.

[22]Given the process $\log(e_t) = \rho_e \log(e_{t-1}) + u_t$, we set $u_0 = -0.1525$ (with $u_t = 0$ for all other periods) and $\rho_e = 0.93$ to roughly replicate those values for our baseline economy with a debt-to-GDP ratio of 60 percent. At the time of writing, the CBO had not yet published output gap estimates and forecasts based on the revision to the national income and product accounts released by the BEA on July 29, 2011.

[23]In particular, unless noted otherwise, we set the response parameter $\phi_{T,b^g} = 0.014$ for the first 30 quarters. This response is twice as large as would be required to ensure stable debt dynamics in the absence of adverse movements in the risk premium. At the same time, the adjustment of taxes is slow enough that without government spending cuts, the debt burden would stabilize in a very gradual manner only. Beyond quarter 30, ϕ_{T,b^g} rises to twice the previous value, ensuring that government debt will eventually be stabilized even for the higher level of indebtedness (and a correspondingly higher risk premium) prevailing at that point.

Figure 5: Deep recession with different initial levels of government debt

| Output (% from ss) | Interest rate spread (bps) | Policy rate (%) |
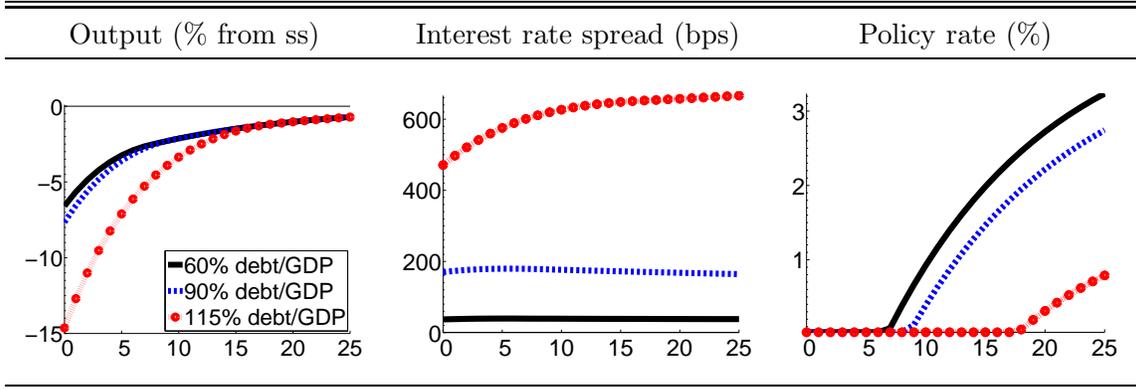
Notes: The figure shows responses to the recessionary shock for different initial debt levels. Black solid line: 60 percent debt-to-GDP, blue dashed: 90 percent, red dots: 115 percent. Output is expressed in terms of percent deviations from the steady state, the risk premium in annualized basis points, and the interest rate in annualized percentage rates.
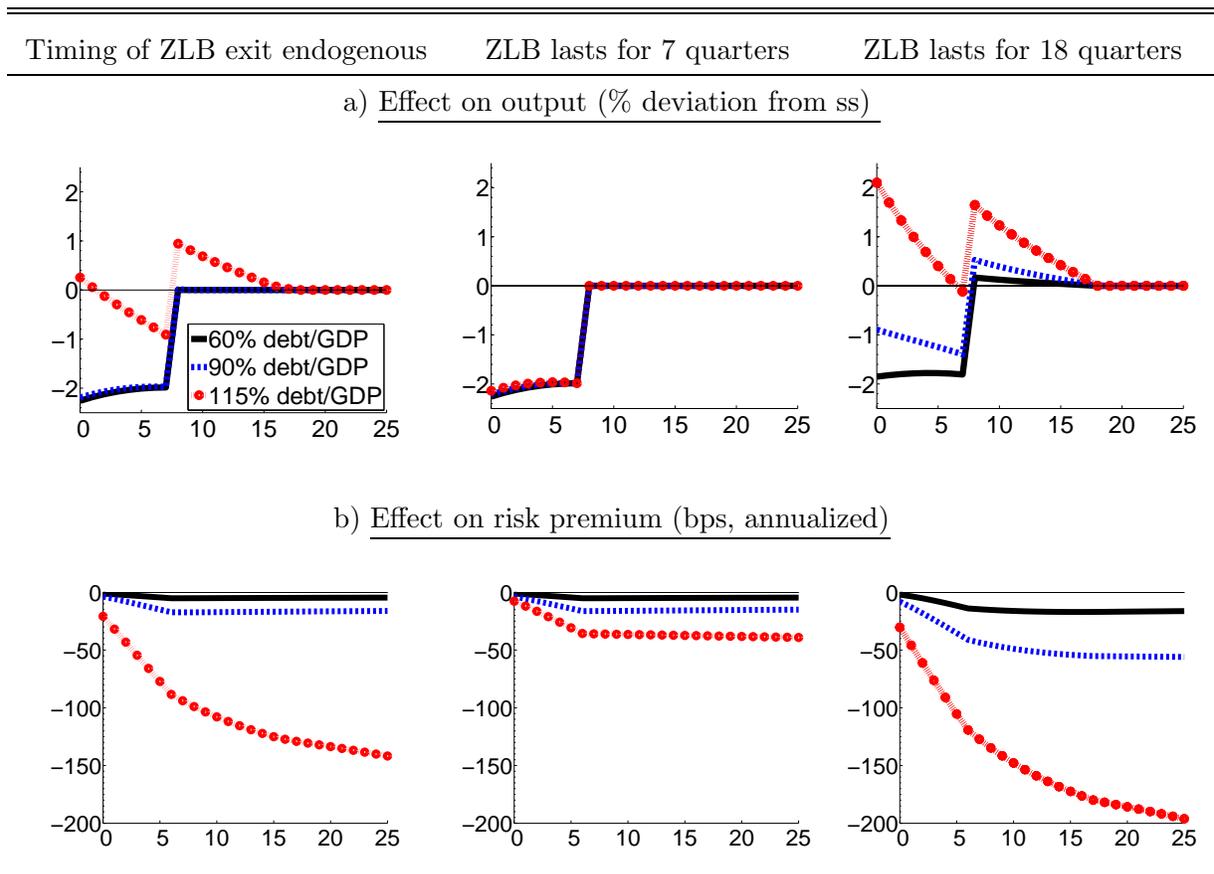
between public debt and sovereign risk is fundamentally nonlinear.

In our simulations, a persistently high risk premium also lengthens the time span over which the ZLB remains binding. This result is apparent from the dynamics of the policy rate shown in the right panel of Figure 5: the ZLB episode is extended by as much as 11 quarters if government debt is high. Hence, our dynamic analysis delivers a first additional insight: not only does the importance of the sovereign risk channel depend on whether the central bank is constrained in steering interest rates, but sovereign risk may itself be an important determinant for how severely monetary policy is constrained in the face of certain shocks.

4.2 Fiscal retrenchment during deep recessions

What are the effects of government spending cuts in the recessionary environment just described? In order to mimic the setup of Section 3, we consider an episode of fiscal restraint that lasts for two years and starts at the onset of the recession, that is, we consider an "immediate retrenchment" scenario. We discuss alternative timing assumptions in Subsection 4.3. During the episode of fiscal restraint, government spending falls below its steady-state level by 2 percent of (steady-state) GDP. Figure 6 depicts the resulting dynamics relative to the baseline scenario. The panels on the left show the response of output (top) and the interest rate spread (bottom). In order to isolate the effect of a binding ZLB, the panels in the middle and on the right show the response of the same variables under the assumption that the exit

Figure 6: The impact—relative to the baseline—of immediate retrenchment

| Timing of ZLB exit endogenous | ZLB lasts for 7 quarters | ZLB lasts for 18 quarters |

a) Effect on output (% deviation from ss)

b) Effect on risk premium (bps, annualized)

Notes: The panels show the effects of an immediate retrenchment in government spending by 2 percent of steady-state output for 8 quarters on output (top) and the risk premium (bottom). Solid black line: 60% initial debt-to-GDP ratio, dashed blue line 90%, dotted red line: 115%. Left panel: the effect of the retrenchment when the timing of the exit from the ZLB is endogenously determined according to equation (36). Other panels: for each initial debt level, the depth of the recession without retrenchment is calibrated such that it implies a binding ZLB for 7 quarters (middle) and 18 quarters (right). For the middle and rightmost panels, regardless of the austerity package being implemented, monetary policy is assumed to keep the nominal rate at zero for that time period (7 and 18 quarters, respectively).

from the ZLB is not endogenous, but fixed exogenously at 7 and 18 quarters. These lengths correspond, respectively, to the duration of the ZLB episode for debt-to-GDP ratios of 60 percent and 115 percent in Figure 5.[24]

We find, first, that for all initial debt levels, the retrenchment package is effective in reducing the deficit (not shown). Thus, the level of government debt and the risk premium (consistent with Figure 4) decline. In addition, monetary policy escapes from the ZLB constraint somewhat earlier for all debt levels (not shown). However, the spending cuts have quite different effects on output across our different scenarios. If initial debt is low, the spending cuts prompt an initial output decline of more than 2 percent, as private expenditure also falls. In contrast, if initial debt is high, the initial output response is actually positive, reflecting a strong increase in private expenditure. To understand this finding, recall that spending cuts affect real interest rates through two channels. On the one hand, the deflationary effect of lower public spending raises, all else equal, real interest rates as it cannot be offset by a reduction in policy rates at the ZLB. On the other hand, the reduction of public debt reduces sovereign risk, thereby lowering private interest rate spreads. The strength of the effect operating through the second channel increases in the initial level of debt, as the postulated relationship between public debt and sovereign risk is nonlinear. In our simulations, this sovereign risk channel turns out to be dominant if we assume an initial debt level of 115 percent of GDP.

As stressed above, the impact of the recessionary shock and the period of time for which monetary policy is constrained depend on the initial level of debt. In addition, the initial level of debt also determines the quantitative importance of the sovereign risk channel. To isolate the latter dimension, the panels in the middle and right columns of Figure 6 show the effect of the austerity packages on output for different debt levels, but fixing the length of the ZLB episode exogenously. If the lower bound is expected to be binding only for a short period of time (middle panels), the effect of the spending cuts hardly varies with the debt level. In other words, the importance of sovereign risk appears limited. However, in line with our earlier results in Section 3, the picture changes quite dramatically if the lower bound is expected to be binding for an extended period of time (right panels). In this case, we find that spending cuts have a positive and lasting effect on economic activity at high initial levels of debt, which under our specification imply elevated sovereign risk premia (dotted red line, right

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[24]In the underlying computations, for each debt level, we rescale the initial recessionary shock such that the ZLB binds for the desired length of time.

panel). Moreover, the "output costs" of public spending cuts are noticeably lower than usual even for the intermediate, 90 percent, level of debt to GDP (dashed blue line in the rightmost panel). Overall, we thus find our earlier analytical results confirmed by the simulations of the full-fledged model: fiscal strain alters the fiscal transmission mechanism through the sovereign risk channel, provided that monetary policy is constrained for an extended period.

4.3 Further considerations

This section assesses the sensitivity of the previous results with respect to some modifications that may have a bearing on the sovereign risk channel. We start by assessing how an alternative timing of spending cuts affects the impact of fiscal retrenchment. We then explore alternative assumptions on the tax system and on the conduct of monetary policy.

4.3.1 The timing of spending cuts

So far, we have focused on spending cuts that take place immediately, i.e., at the time the recessionary shock hits the economy. This scenario reflects an important premise guiding the analysis in this paper: namely that policymakers facing nonnegligible sovereign risk premia will generally find it difficult to improve investor confidence solely by announcing future austerity. More likely, investors concerned about default risk will expect to see some immediate proof of policymakers' readiness to cut deficits, thus prompting upfront tightening measures. Nevertheless, it is worth contrasting the effect of such immediate tightening programs with examples of more backloaded deficit reduction. We now assess the role of such timing decisions on the basis of model simulations. The left panels of Figure 7 reproduce the results for an immediate retrenchment that were reported in the left column of Figure 6. The remaining columns report the impact of two alternatively timed (and sized) consolidation packages. The middle panels display the response of the economy to a package of spending cuts of 2 percent of steady-state GDP that starts two years after the initial recessionary impact and that lasts for 10 years (a "medium-term retrenchment"). The right panels, in turn, show results for a combination of the previous two packages (a "persistent retrenchment," that sees spending cuts start immediately and last for 12 years in total). As before, the figures report the effect of these different packages depending on the initial level of debt (the range of the axes has been rescaled to accommodate the range implied by these simulations).

Figure 7: The timing of retrenchment
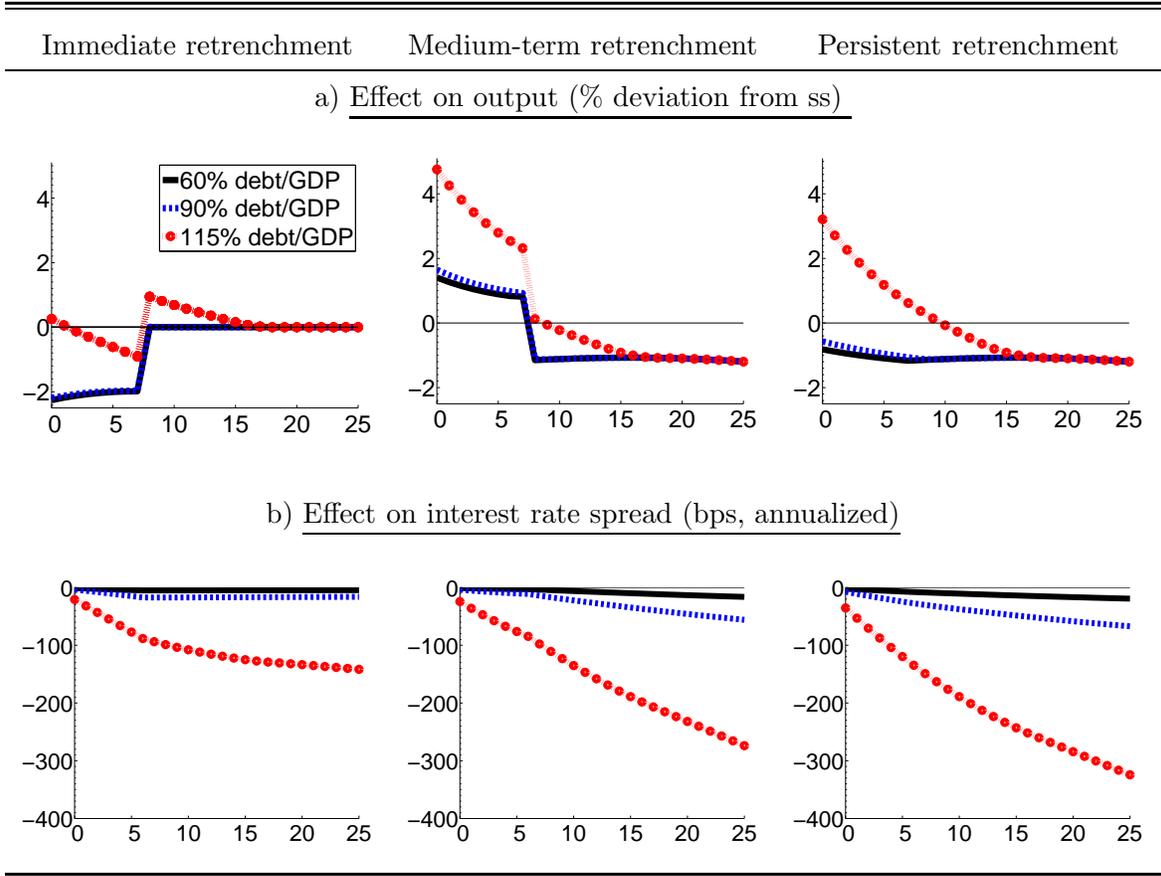
Notes: The panels show the effect of a retrenchment in government spending by 2 percent of steady-state output on output (top) and the risk premium (bottom) for different assumptions on the timing of the austerity episode. Left panels: immediate retrenchment for first 2 years; middle: medium-term retrenchment (during years 3 through 12), right: persistent retrenchment for 12 years. Solid black line: 60% initial debt-to-GDP ratio, dashed blue line 90%, dotted red line: 115%. For all the panels the timing of the exit from the ZLB is endogenously determined according to equation (36).

Under medium-term retrenchment (middle panels), there are immediate output gains from fiscal forward guidance, in line with the results in Corsetti et al. (2010). Specifically, most or all of the spending cuts are implemented when monetary policy has escaped from the ZLB constraint and regained its ability to contribute to economic stabilization. When the spending cuts occur, they reduce contemporaneous demand and inflation, causing the central bank to lower the real interest rate. The prospect of a lower future real rate already crowds in consumption, and thus output, during the early periods of the recession, i.e., before the government spending cuts occur. This leads to higher tax revenue and implies an immediate reduction in the sovereign risk premium, which further stimulates demand through reduced

interest rate spreads facing the private sector. Note that such anticipated medium-term retrenchment unfolds a stronger expansionary effect upfront, the weaker the initial fiscal situation (dotted red line vs dashed blue line in the central panels).

The persistent retrenchment scenario, in turn, is a combination of the two previous scenarios. In the simulations shown in the right column of Figure 7, persistent retrenchment has the strongest effect on the risk premium (red dotted line), reflecting the larger overall cut to spending. However, its output effects are generally somewhat smaller than in the medium-term retrenchment scenario. For the highest level of debt under consideration (i.e., 115 percent of GDP), the persistent retrenchment still crowds in economic activity for most of the time that the economy remains constrained by the ZLB. However, the initial boost to output is more subdued than under medium-term retrenchment, because the impact from the additional reduction in debt—and hence the risk premium—is more than offset by the immediate contractionary effect of upfront spending cuts.

Together, our simulations using alternative timing assumptions underscore the theoretical benefit of delaying fiscal adjustment until after the economy has recovered from the worst of the initial recession. However, the simulations strictly depend on the credibility of pre-announced consolidation plans. If private agents harbor any doubts about the likelihood of implementation, they will expect a less benign path for deficits and debt than has been announced, and the sovereign risk premium will be correspondingly higher. In this sense, the medium-term retrenchment scenario considered here may not actually be available as a credible policy option, notably at times of significant concern about sovereign risk. This notion is an important motivation for the present paper and explains the focus of most of our analysis on fiscal adjustment scenarios that involve immediate spending cuts. That being said, it bears repeating a key result of our earlier work in Corsetti et al. (2010): to the extent that policymakers can credibly commit to future austerity, backloaded consolidation strategies will generally garner superior outcomes in terms of near-term growth, as they avoid tightening fiscal policy at a time when the central bank is unable to offset the contractionary fiscal impulse.

4.3.2 Distortionary taxation

Distortionary taxes generally weigh on economic activity. To the extent that an early re-
trenchment reduces the need for distortionary taxation in the future, such a policy would
appear to be less harmful to growth than we have reported so far. Figure 8 assesses this
hypothesis, focusing again on results for three different levels of initial debt.[25]

Figure 8: Effects of retrenchment on output depending on taxation
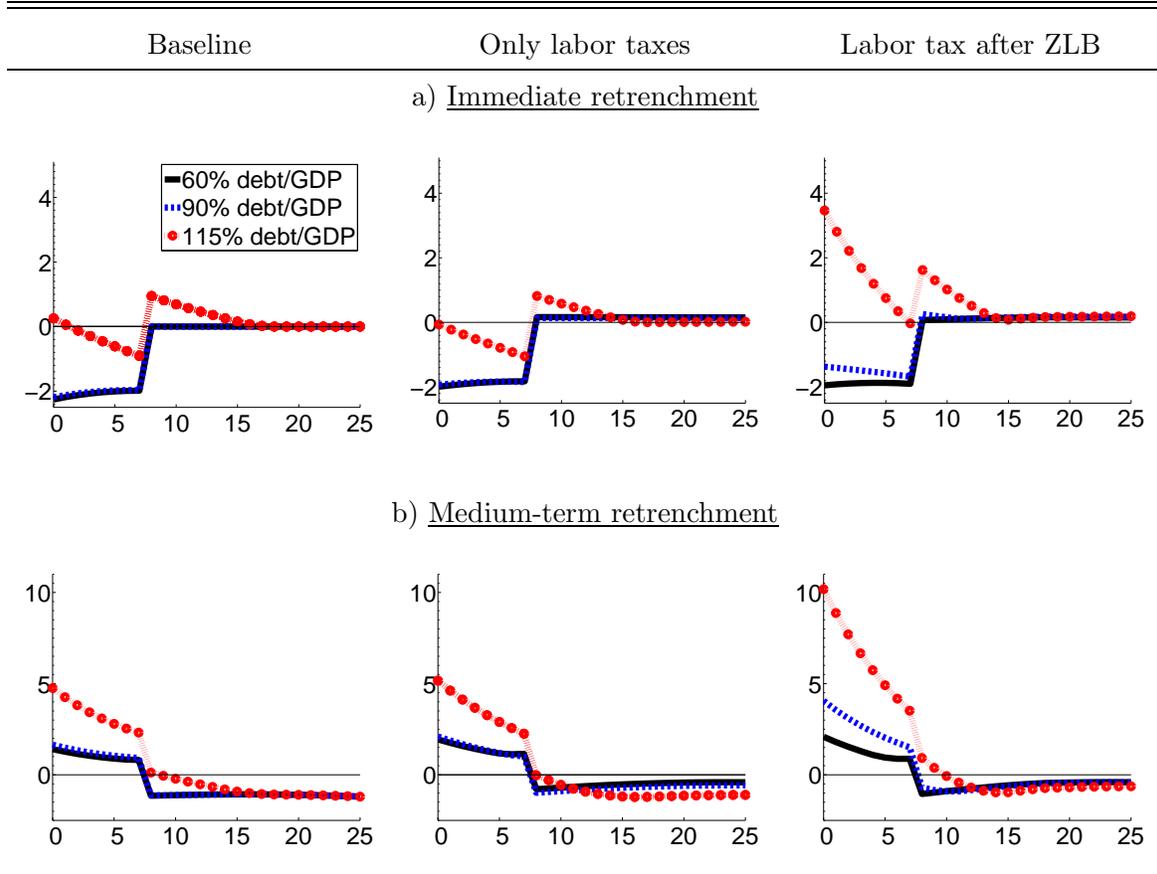
Notes: The panels show the effect of retrenchment on output for different assumptions about taxation. The
left column reproduces the effect of retrenchment with lump-sum taxes (as in the baseline). The middle panel
shows the effect of retrenchment when labor taxes are used throughout. The right column shows the effect of
retrenchment if taxes are lump-sum for the first 18 quarters but distortionary thereafter. For the simulations
in which labor taxes are used the initial shock has been rescaled such that for each debt level the severity of
the recession and the length of the ZLB episode without retrenchment are roughly comparable to the baseline
responses shown in Figure 5.

The first column reproduces the responses for the baseline case, in which only lump-sum

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[25]For this exercise, we fix the labor tax rate at 35 percent in the steady state, in line with the 2006 average
U.S. marginal income tax rate reported by Barro and Redlick (2011). Fluctuations in labor taxes ensure that
(28) holds. For the scenarios with labor taxes, we set $\phi_{T,b^g} = 0.0193$ for all periods.

taxes are used. The second column shows how distortionary taxation alters the effect of the spending cuts. In the simulations, distortionary taxes, if used throughout, have little bearing on how fiscal retrenchment affects output. While lower future distortionary taxation stimulates future economic activity, and thus current demand, a second, countervailing effect is present. Without retrenchment, distortionary tax rates rise more strongly, with a view toward stabilizing the rising debt burden. As stressed by Eggertsson (2011), to the extent that higher labor tax rates raise inflation, they may help to stabilize output if the economy is stuck at the ZLB. By contrast, an early retrenchment reduces the labor tax burden and exerts a negative effect on activity. In the simulations shown here, this effect outweighs the beneficial impact arising from the reduced tax burden in later periods.

One may argue, of course, about the likelihood that taxes would actually be raised while the economy remains stuck at the ZLB. Since the timing of taxation is important for the aforementioned finding, the rightmost column of Figure 8 shows the results for a different taxation scenario. The goal is to disentangle the impact of fiscal retrenchment from the specific effects that labor taxes have in a ZLB situation. Thus, the responses in the right column are based on the assumption that lump-sum taxes are used for the first 18 quarters to prevent debt from exploding. Only after these 18 quarters, and hence well after the end of the ZLB episode, do labor taxes take over. For the 60 percent debt level, the difference relative to the case of lump-sum taxation is small, and the effects are very similar to the baseline. For the 90 percent debt level, the output effects of retrenchment turn more favorable. However, this mostly affects the medium-term retrenchment package. Finally, results for the highest debt level shown here, i.e., 115 percent of debt to GDP, illustrate that the sovereign risk channel may be stronger in the case with distortionary taxation, provided that changes in distortionary tax rates materialize only after the ZLB has ceased to bind. Intuitively, for this level of sovereign indebtedness, the heightened risk premium demands relatively strong increases in distortionary taxes to finance the debt burden, which by itself worsens the recession. As a result, an early retrenchment now crowds in output, and much more strongly so than in the case with lump-sum taxes only.

4.3.3 Degree of monetary policy offset for risk premia

Next, we consider the sensitivity of our results with regard to the extent to which the central bank is able to neutralize the effect of sovereign risk on private borrowing rates. Our baseline simulations have assumed that once the economy has exited from the ZLB situation, the central bank can set interest rates in a way that prevents sovereign risk from affecting economic activity in any way.

Figure 9: Effects of retrenchment on output when CB cannot fully neutralize risk premia
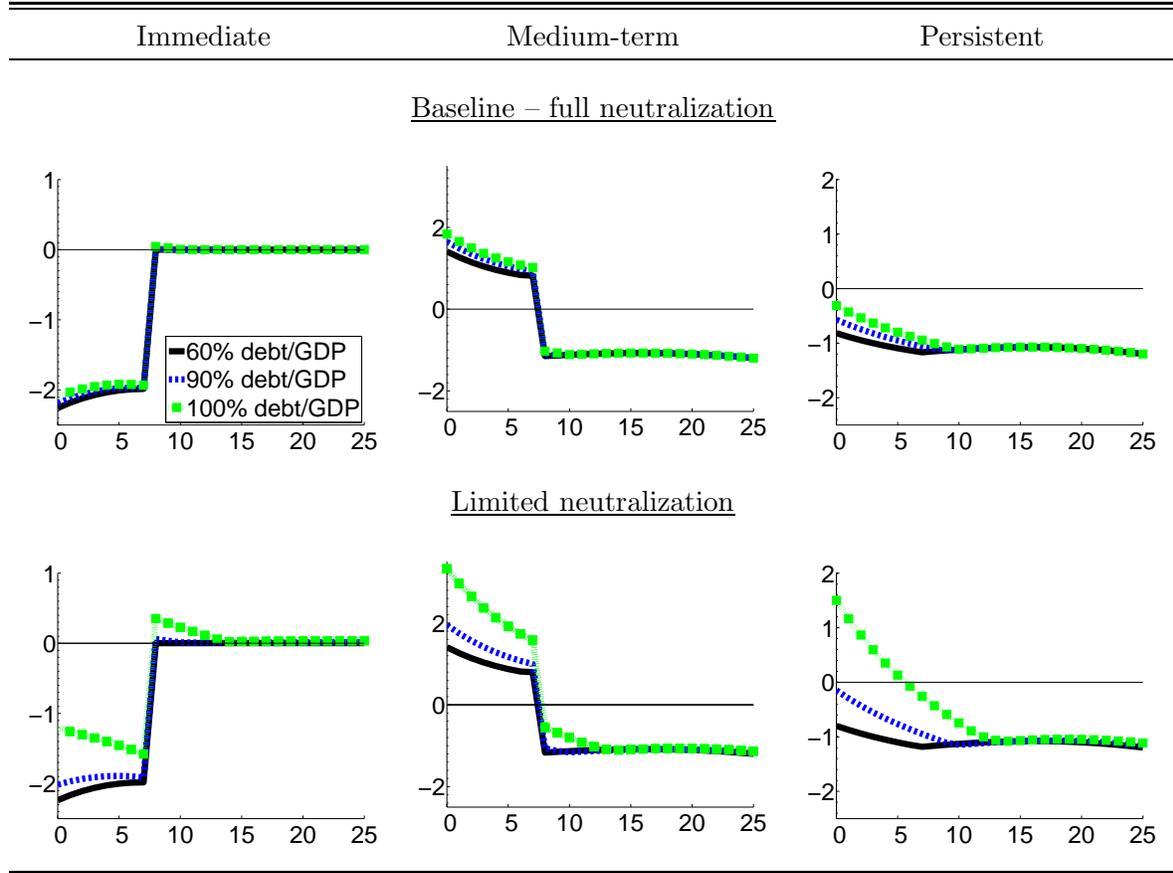
Notes: The figure shows the effect of the three retrenchment packages (described in the notes to Figure 7) for the case where the central bank does not fully offset the risk premium even once the economy has left the ZLB. Top row shows the baseline responses for 60, 90, and 100 percent initial debt-to-GDP ratio. Bottom row shows the case when the response coefficient ϕ_ω is only 3/4 of the size of the benchmark calibration.

We now assess, instead, the effect of spending cuts if the central bank does not, or cannot, fully neutralize the sovereign spread. In particular, we assume that the central bank's response is only three-quarters the size of the value of ϕ_ω that we used in the previous simulations. To this end, we set $\phi_\omega = 0.75(\pi_b + s_\Omega)$. The first point to note about this scenario is that the baseline

recession is deeper, reflecting the stronger headwinds from persistently high risk premia. The lower panels of Figure 9 show the effects of fiscal retrenchment relative to that new baseline. By comparison, the upper panel revisits the baseline in which the central bank fully offsets higher sovereign risk premia after the ZLB episode. As it turns out, early retrenchment is less detrimental to economic activity at high initial debt levels in the lower panels. Intuitively, the central bank's limited willingness (or capacity) to neutralize higher spreads in the future raises the benefit of fiscal retrenchment as a way to bring down long-term real interest rates via the sovereign risk channel.

5   Conclusion

The present paper analyzes how the "sovereign risk channel" affects macroeconomic dynamics and stabilization policy. Through this channel, rising sovereign risk drives up private-sector borrowing costs, unless higher risk premia are offset by looser monetary policy. If the central bank is constrained in counteracting higher risk premia, sovereign risk becomes a critical determinant of macroeconomic outcomes. Its implications for stabilization policy have not been fully appreciated in earlier formal analyses, although they are likely to be of great importance for many advanced economies currently facing intense fiscal strain.

Building on the model proposed by Cúrdia and Woodford (2009), we show that the sovereign risk channel makes the economy (more) vulnerable to problems of indeterminacy. In particular, private-sector beliefs about a weakening economy can become self-fulfilling, driving up risk premia and choking off demand. In this environment, a procyclical fiscal stance—that is, tighter fiscal policy during economic downturns–can help to ensure determinacy.

Further, we find that sovereign risk tends to exacerbate the effects of negative cyclical shocks: recessionary episodes will be deeper the stronger the sovereign risk channel, which in our specification is a nonlinear function of public-sector indebtedness. Moreover, in deep recessions that force the central bank down to the zero lower bound (ZLB) for nominal interest rates, sovereign risk delays the exit from the ZLB, hence prolonging macroeconomic distress. The sovereign risk channel also has a significant bearing on fiscal multipliers. Specifically, the effect of government spending on aggregate output hinges on (i) the responsiveness of private-sector risk premia to indicators of fiscal strain; and (ii) the length of time during which monetary policy is expected to be constrained. Our analysis suggests that upfront

fiscal retrenchment is less detrimental to economic activity (i.e., multipliers are smaller) in the presence of significant sovereign risk, as lower public deficits improve private-sector financing conditions. In relatively extreme cases where fiscal strains are severe and monetary policy is constrained for an extended period, fiscal tightening may even exert an expansionary effect. That being said, fiscal retrenchment is no miracle cure. Indeed, all our simulations feature a deep recession even if tighter fiscal policy, under the aforementioned conditions, may stimulate economic activity relative to an even bleaker baseline.

As an additional caveat, we note that our analysis has focused on fiscal multipliers under a go-it-alone policy that does not involve external financial support at below-market rates. Availability of such support could allow countries to stretch out the necessary fiscal adjustment as they benefit from lower funding costs and, possibly, positive credibility effects. Indeed, if and where announcements of future fiscal adjustment are credible, delaying some of the planned spending cuts remains a superior strategy in terms of protecting short-term growth. How countries end up dealing with the challenges summarized here may prove to be a defining feature of global economic developments over the coming years.

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A   Three-equation representation of the aggregate economy

The following IS curve can be derived for the linearized model:

$$\widehat{y}_t = \widehat{y}_{t+1} - (\tilde{g}_{t+1} - \tilde{g}_t) - \left[\Xi(\tilde{b}_{t+1} - \tilde{b}_t) + b(\tilde{\Xi}_{t+1} - \tilde{\Xi}_t)\right]$$
$$-\bar{\sigma}\left[\widehat{i}_t^d - \widehat{\Pi}_{t+1} + \widehat{\Gamma}_t + (\pi_b + s_\Omega)\widehat{\omega}_t - [\psi_\Omega + s_\Omega(1 - \bar{\delta})]\widehat{\Omega}_{t+1}\right],$$

where

$$\widehat{\Omega}_t = \widehat{\omega}_t + \bar{\delta}\,\widehat{\Omega}_{t+1}.$$

The New Keynesian Phillips curve reads as follows:

$$\widehat{\Pi}_t = \beta\,\widehat{\Pi}_{t+1}$$
$$+\kappa\left[(\phi(1 + \nu) + 1/\bar{\sigma} - 1)\widehat{y}_t - \phi(1 + \nu)\widehat{z}_t - 1/\bar{\sigma}[\tilde{g}_t + \Xi\,\tilde{b}_t + b\,\tilde{\Xi}_t] - \widehat{\tau}_t^w + [s_\Omega + \pi_b - \gamma_b]\widehat{\Omega}_t\right];$$

and the Taylor rule reads is given by:

$$\widehat{i}_t^{d,*} = \phi_\Pi\widehat{\Pi}_t - \phi_\omega\widehat{\omega}_t.$$

$$\widehat{i}_t^d = \max\left\{\widehat{i}_t^{d,*}, -(1 + i^{d,*})\right\}.$$

This three-equation system, together with an assumption about the evolution of the spread $\widehat{\omega}_t$, describes the dynamics of output, inflation, and interest rates (independently of private debt) if

1. $\Xi = 0$, that is, no aggregate resource costs of loan origination.

2. $[\psi_\Omega + s_\Omega(1 - \bar{\delta})] = 0$.

3. $\widehat{\tau}_t^w = 0$, that is, distortionary taxes do not move or are nonexistent.

4. $[s_\Omega + \pi_b - \gamma_b] = 0$.

The parameters and laws of motion chosen in the paper satisfy these conditions.

B   Linking ξ and ξ'

This appendix provides the foundation for equation (39) in the main text. The formula is motivated through a sequence of back-of-the-envelope calculations. Focus on the interest rate

spread in the IS curve, neglecting other terms. Assume that initially, in period t, the economy is at the ZLB. This gives a relationship of

$$\tilde{y}_t = E_t \tilde{y}_{t+1} - \bar{\sigma}\widehat{\varpi}_t + \ldots.$$

Iterating forward, we have

$$\tilde{y}_t = -\bar{\sigma} E_t \left\{ \sum_{j=0}^{\infty} \widehat{\varpi}_{t+j} \, I(\text{economy at ZLB in period } t+j) \right\},$$

where $I()$ is the indicator function. If the spread depends on the future debt level, as in the full version of the model presented in Section 2, we have

$$\widehat{\varpi}_{t+j} = \xi' E_{t+j} \tilde{b}^g_{t+j+1},$$

so

$$\tilde{y}_t = -\bar{\sigma} E_t \left\{ \sum_{j=0}^{\infty} I(\text{economy at ZLB in period } t+j) \, \xi' \, E_{t+j} \tilde{b}^g_{t+j+1} \right\}.$$

Abstracting from the effect of interest payments and the valuation of debt, $\tilde{b}^g_{t+j+1}$ is roughly the sum of initial debt in $t-1$ (assumed to be zero without loss of generality in the following exposition) and the deficits accumulated in period t through $t+j+1$. Let $deficit$ be the primary deficit. Following the Markov structure, we assume that the primary deficit (before extraordinary debt-stabilization measures) is the same in every period at the ZLB. With the same abstraction as above, conditional on being at the ZLB in $t+j$,

$$E_{t+j} \tilde{b}^g_{t+j+1} = \tilde{b}^g_{t+j} + \mu \cdot deficit = (j+1+\mu) \, deficit.$$

Then,

$$\tilde{y}_t = -\bar{\sigma}\xi' E_t \left\{ \sum_{j=0}^{\infty} I(\text{economy at ZLB in period } t+j)(j+1+\mu)deficit \right\}.$$

And so

$$\tilde{y}_t = -\bar{\sigma}\, \xi'\, deficit \sum_{j=0}^{\infty} \mu^j (j+1+\mu),$$

or, equivalently.

$$\tilde{y}_t = -\bar{\sigma}\, \xi'\, \frac{1 + \mu(1-\mu)}{(1-\mu)^2} \, deficit. \tag{43}$$

In contrast, the analytical version of the model in Section 3 has

$$\tilde{y}_t = -\bar{\sigma} E_t \left\{ \sum_{j=0}^{\infty} I(\text{economy at ZLB in period } t+j) \xi \; deficit \; E_{t+j}[I(\text{at ZLB in } t+j+1)] \right\},$$

which boils down to

$$\tilde{y}_t = -\bar{\sigma}\, \xi \sum_{j=0}^{\infty} \mu^j \; deficit \; \mu.$$

Or, equivalently,

$$\tilde{y}_t = -\bar{\sigma}\, \xi\, \frac{\mu}{1-\mu} \; deficit. \tag{44}$$

Comparing (43) and (44) leads to the relationship in the main text, namely, equation (39):

$$\xi = \frac{1+\mu(1-\mu)}{\mu(1-\mu)} \xi'.$$

C   Proofs of propositions

C.1   Proof of Proposition 1

The economy, stripped from exogenous variables, is given by

$$E_t z_{t+1} = A z_t,$$

where $z_t = [\tilde{y}_t; \hat{\pi}_t]$ and

$$A = \frac{1}{a\mu\beta} \begin{bmatrix} \mu\beta + \bar{\sigma}\mu\kappa_y & -\bar{\sigma}\mu \\ -a\kappa_y & a \end{bmatrix},$$

where $a = (\mu + \mu\bar{\sigma}\xi\phi_{T,y})$. The Blanchard-Kahn conditions for determinacy require that matrix A have two roots outside the unit circle. Woodford (2003), pp. 670f., gives the following necessary and sufficient conditions for determinacy:
either (Case I): (i) $det(A) > 1$, (ii) $det(A) - tr(A) > -1$, and (iii) $det(A) + tr(A) > -1$,
or (Case II): (i) $det(A) - tr(A) < -1$ and (ii) $det(A) + tr(A) < -1$.

In the current case, $det(A) = \frac{1}{a\mu\beta}$ and $tr(A) = \frac{1}{a\mu\beta}[\mu\beta + \bar{\sigma}\mu\kappa_y + a]$. Since both $det(A) > 0$ and $tr(A) > 0$ Case II cannot be satisfied. Checking Case I, condition (iii) holds since both terms are positive. Condition (i) of Case I is equivalent to condition a) in the proposition. Condition (ii) of Case I is equivalent to condition b) in the proposition. ∎

C.2   Proof of Proposition 2

In this case

$$A = \frac{1}{a^*\mu\beta} \begin{bmatrix} \mu\beta + \bar{\sigma}^*\mu\kappa_y^* & -\bar{\sigma}^*\mu \\ -a^*\kappa_y^* & a^* \end{bmatrix},$$

where a^*, $\bar{\sigma}^*$ and κ_y^* are defined in the proposition.

1. Note that under the restriction that $a^* > 0$, $det(A) > 0$. Therefore it cannot be the case that $det(A) - tr(A) < -1$ and $det(A) + tr(A) < -1$. This means that determinacy can only obtain under the conditions of Case I spelled out in the proof of Proposition 1. Conditions (i) and (ii) of that case correspond to conditions a) and b) in Proposition 2. In addition, if $\varphi < 1$ (as assumed), then $tr(A) > 0$, so $det(A) + tr(A) > -1$. Condition (iii) of Case I is therefore obsolete.

2. For $a^* < 0$, $det(A) < 0$, so Case I cannot hold. The conditions given in the proposition are those pertaining to Case II. $\square$

C.3   Proof of Proposition 3

The assumed Markov structure means that output, inflation, and government spending (in deviations from the steady state) will take on the same respective values, y_L, π_L, and g_L, in every period in which monetary policy is constrained, and values of zero thereafter. The IS curve thus implies

$$y_L - g_L = \mu(y_L - g_L) - \bar{\sigma}[-\log(1 + i^d) + \Gamma + \mu\xi(g_L - \phi_{T,y}y_L) - \mu\pi_L],$$

while the Phillips curve gives

$$\pi_L = \mu\beta\pi_L + \kappa_y y_L - \kappa_g g_L.$$

Solving these equations for y_L and π_L yields:

$$y_L = \vartheta_r[\log(1 + i^d) - \Gamma] + \vartheta_g g_L,$$

where ϑ_r and ϑ_g take on the values given in the proposition. In addition, $\vartheta_r > 0$: the numerator is positive, and so is the denominator, per condition b) for determinacy in Proposition 1. $\blacksquare$

D   Two corollaries

D.1   Statement and proof of Corollary 4

Corollary 4 *Under the conditions of Proposition 2, the following special cases obtain:*

1. *With no endogenous risk premium ($\xi = 0$), the range of parameters for which the equilibrium is determinate is larger if government spending is countercyclical ($\varphi < 0$), rather*

than acyclical. In addition, the range of fundamental parameters implying determinacy of the equilibrium is larger the more negative φ.

2. *With an endogenous risk premium $\xi > 0$, instead, the range of parameters for which the equilibrium is determinate is often larger if government spending is procyclical, that is, if spending is cut systematically during a deep recession. More precisely: Under the conditions of Proposition 2, if $a^* > 0$, $\varphi \in (0,1)$, and $\phi_{T,y} < 1 - \frac{\kappa\nu}{(1-\beta\mu)\xi}$, then the range of fundamental parameters for which the equilibrium is determinate is at least as large as in the absence of an endogenous spending response and can be larger. Note that this case is more likely the less tax revenue responds to the state of the economy (the smaller $\phi_{T,y}$), and the more responsive the sovereign risk premium to the deficit (the larger ξ).*

Proof.

1. If $\xi = 0$, $a^* = \mu > 0$. As a result, case 1 of Proposition 2 is the relevant one. First note that condition a) will always be satisfied. What remains to be checked is condition b). For the statement in the proposition, it suffices to observe that if $\xi = 0$ the left-hand side of condition b) is independent of φ, and the right-hand side is strictly increasing in φ.

2. In order for the range of fundamental parameters for which determinacy holds to be bigger with $\varphi \in (0,1)$ under the stated conditions than with $\varphi = 0$, we have to have $a^* < a$, and
$$(1 - \beta\mu)(a - a^*) > \mu\bar{\sigma}^*\kappa_y^* - \mu\bar{\sigma}\kappa_y.$$

$a^* < a$ boils down to $\frac{\phi_{T,y}-\varphi}{1-\varphi} < \phi_{T,y}$, which is true for $0 < \varphi < 1$.
The second condition reduces to

$$(1 - \beta\mu)\xi(1 - \phi_{T,y})\frac{\varphi}{1 - \varphi} > \kappa\nu\frac{\varphi}{1 - \varphi}.$$

For $\varphi \in (0,1)$ this yields $\phi_{T,y} < 1 - \frac{\kappa\nu}{(1-\beta\mu)\xi}$, the condition in the corollary.

■

D.2   Statement and proof of Corollary 5

Corollary 5 *Under the conditions of Propositions 1 and 3:*

1. *The government spending multiplier, ϑ_g, is positive if and only if*

$$(1 - \mu) - \frac{\mu\bar{\sigma}\kappa_g}{1 - \beta\mu} > \mu\xi\bar{\sigma}. \tag{45}$$

Note, conversely, that the spending multiplier can be negative if the risk premium has a sufficiently detrimental effect on the economy, that is, if ξ is large enough.

2. *Government spending at the lower bound is self-financing if $\vartheta_g > 1/\phi_{T,y}$. This is the case if*

$$\phi_{T,y} > \frac{(1-\beta\mu)(1-\mu) - \mu\bar{\sigma}\kappa_y}{(1-\beta\mu)(1-\mu) - \mu\bar{\sigma}\kappa_g}.$$

This cutoff is independent of ξ.

3. *If $\xi = 0$, provided that the conditions for determinacy in Proposition 1 are satisfied, the government spending multiplier is strictly larger than one. This case corresponds to the analysis by Christiano et al. (2011) and Woodford (2011).*

4. *If $\xi > 0$, the government spending multiplier is unambiguously larger than 1 if $\phi_{T,y} > 1 - \frac{\kappa\nu}{\xi(1-\beta\mu)}$, that is, if tax revenue is sufficiently responsive to output.*

Proof.

1. Under the restrictions for determinacy provided by Proposition 1, the denominator of ϑ_g is unambiguously positive. $\vartheta_g > 0$ thus requires $(1-\beta\mu)(1-b) - \mu\bar{\sigma}\kappa_g > 0$, which solves to the expression in equation (45).

2. The deficit (in deviation from the steady state) is given by $g_L - \phi_{T,y}y_L$. Government spending will thus be self-financing if $1 - \phi_{T,y}\vartheta_g < 0$. Insert the multiplier from equation (41), observe that the denominator is positive by the assumption of determinacy. Substitute for a and b using the expressions given in the proposition. Simplifying yields the desired inequality for $\phi_{T,y}$.

3. The conditions for determinacy require that $(1-\beta\mu)(1-a) - \mu\bar{\sigma}\kappa_y > 0$, so the denominator of ϑ_g is positive. $\vartheta_g > 1$ then boils down to

$$(1-\beta\mu)(1-b) - \mu\bar{\sigma}\kappa_g > (1-\beta\mu)(1-a) - \mu\bar{\sigma}\kappa_y.$$

Now, if $\xi = 0$ then $a = b$. $\vartheta_g > 1$ therefore requires $-\mu\bar{\sigma}\kappa_g > -\mu\bar{\sigma}\kappa_y$, or $\kappa_g < \kappa_y$, which is true.

4. For $\xi > 0$, $\vartheta_g > 1$ is equivalent, after substituting $\kappa_y - \kappa_y = \kappa\nu$, to $\phi_{T,y} > 1 - \frac{\kappa\nu}{\xi(1-\beta\mu)}$.

∎

E Delayed fiscal retrenchment

The analytical results presented in Section 3 pertain to fiscal retrenchment while monetary policy is constrained by the ZLB. For completeness, we also consider in this appendix a retrenchment that is designed to take effect only once monetary policy has exited from the ZLB. As discussed in Corsetti et al. (2010), fiscal consolidation generally reduces aggregate

demand and inflation when it occurs. However, the *expectation of future* fiscal consolidation may unfold a positive upfront effect on output. Indeed, if spending cuts are implemented when the central bank is no longer constrained, the policy rate will fall in both nominal and real terms (recall, $\phi_\pi > 1$). In anticipation of the lower future path of short-term interest rates, long-term interest rates decline immediately, boosting consumption and output.

By the nature of this transmission mechanism, the exact timing of consolidation is crucial. When firms anticipate the future drop in demand, they start, because of nominal rigidities, to reduce prices somewhat before the government cuts actually take place. In other words, inflation eases in advance of the actual fiscal retrenchment. If much of the retrenchment is set to occur too soon after the period in which monetary policy exits from the ZLB, the effect on the real rate of interest can be perverse, that is, real rates may rise while monetary policy is still constrained, hampering the recovery. In order to assess the effects on economic activity more formally, we state the following proposition and corollary.

Proposition 6 *In the economy specified in Proposition 1, let $\tilde{g}_t$ take on a value of 0 whenever the interest rate is constrained to 0. In the first period in which this constraint on monetary policy ceases to bind let $\tilde{g}_t = g_a < 0$, marking an episode of fiscal austerity. In each subsequent period, let government spending remain at that austerity value with probability $\varrho \in [0,1)$ and otherwise return to $\tilde{g}_t = 0$ forever. Assume that the conditions for determinacy are satisfied. Then, while interest rates are constrained to zero, output is given by*

$$
\begin{aligned}
y_L \;=\; \tfrac{1}{d}\big[\;\; &\bar{\sigma}(1-\beta\mu)[\log(1+i^d)-\Gamma] + (1-\mu)(1-\beta\mu)(1+\bar{\sigma}\xi\phi_{T,y})(y_a-g_a) + \bar{\sigma}(1-\mu)\pi_a \\
&- (1-\mu)(1-\beta\mu)\bar{\sigma}\xi(1-\phi_{T,y})g_a \;\;\big],
\end{aligned}
$$
(46)

where $d = (1-\beta\mu)[1-a]-\bar{\sigma}\mu\kappa_y$, $a := \mu+\mu\xi\phi_{T,y}\bar{\sigma}$ as in Proposition 1, and y_a and π_a denote, respectively, output and inflation in the austerity period, equal to

$$
y_a = \frac{(1-\varrho)(1-\beta\varrho)+\bar{\sigma}(\phi_\pi-\varrho)\kappa_g}{(1-\varrho)(1-\beta\varrho)+\bar{\sigma}(\phi_\pi-\varrho)\kappa_y}g_a,
$$
(47)

and

$$
\pi_a = \frac{(1-\varrho)(\kappa_y-\kappa_g)}{(1-\varrho)(1-\beta\varrho)+\bar{\sigma}(\phi_\pi-\varrho)\kappa_y}g_a.
$$
(48)

Proof. For the austerity phase the IS equation is given by

$$
(y_a-g_a)(1-\varrho) = -\bar{\sigma}\left[\phi_\pi\pi_a - \varrho\pi_a\right],
$$

and the Phillips curve reads as

$$
\pi_a = \beta\varrho\pi_a + \kappa_y y_a - \kappa_g g_a.
$$

These two equations solve to expressions (47) and (48).

At the ZLB, in turn, the IS equation is given by

$$
\begin{aligned}
y_L(1-\mu) \;=\; & (1-\mu)(y_a - g_a) \\
& -\bar{\sigma}\left[-\log(1+i^d) + \Gamma + \xi[(1-\mu)g_a - \phi_{T,y}(1-\mu)y_a - \phi_{T,y}\mu y_L] - \mu\pi_L - (1-\mu)\pi_a\right],
\end{aligned}
$$

and the Phillips curve reads as

$$
\pi_L = \beta\mu\pi_L + \beta(1-\mu)\pi_a + \kappa y_L.
$$

Solving the latter two equations leads to the equation for output, y_L, equation (46) in the proposition. ∎

Corollary 7 *Under the conditions in Proposition 6,*

1. *if $\xi = 0$, retrenchment after monetary policy ceases to be constrained boosts economic activity in the zero-interest rate phase unless too much of the retrenchment is expected to occur too soon after the exit from the ZLB phase. More precisely, there exists a value of $\varrho \in [0,1)$ such that $y_L > 0$ if $g_a < 0$. This is the case for any $\varrho > \frac{1+\phi_\pi(\beta\mu-1)}{\beta\mu}$.*

2. *Suppose that $\phi_{T,y} > 0$ and that for the values of ξ considered here the equilibrium is determinate. Suppose the fundamental parameters are such that the effect of future austerity on y_L would be positive without the sovereign risk channel ($\xi = 0$). Then the magnitude of the effect of future retrenchment on y_L will be larger still if the economy is subject to the sovereign risk channel. Indeed, the effect will be larger, the larger ξ.*

3. *For some parameterization the effect of future austerity is positive if $\xi > 0$, while it is negative if $\xi = 0$.*

Proof.

1. For the case $\xi = 0$, abstracting from constants, we have that $y_L = 1/d[(1-\mu)(1-\beta\mu)(y_a - g_a) + \bar{\sigma}(1-\mu)\pi_a]$.

   Note that $d = (1-\mu)(1-\beta\mu) - \bar{\sigma}\mu\kappa_y > 0$ since Proposition 6 assumes determinacy of the equilibrium; cp. condition b) in Proposition 1. $y_L > 0$ (meaning that future austerity increases output at the ZLB relative to the case of no action) thus requires

   $$
   (1-\mu)(1-\beta\mu)(y_a - g_a) + \bar{\sigma}(1-\mu)\pi_a > 0. \tag{49}
   $$

   Substitute for y_a and π_a using equations (47) and (48). Further note that the denominator in the expressions for π_a and y_a is positive (we have assumed determinacy in Proposition 6, so $\phi_\pi > 1$, and therefore especially $\phi_\pi - \varrho > 0$). Furthermore, observe that $\kappa_y - \kappa_g > 0$, and that $g_a < 0$. Using these observations, inequality (49) resolves to $\varrho > \frac{1+\phi_\pi(\beta\mu-1)}{\beta\mu}$.

2. Let superscript ^{w} denote outcomes at the ZLB with the sovereign risk channel in operation ($\xi > 0$); y_L^w, for example, denotes output. With a superscript ^{o}, denote the terms in the absence of the sovereign risk channel ($\xi = 0$). Note, first, that y_a, g_a, π_a are independent of the interest spread. Note, second, that with $\xi > 0$ and $\phi_{T,y} > 0$, we have $d^w = (1 - \beta\mu)(1 - \mu - \mu\xi\phi_{T,y}\bar{\sigma}) - \bar{\sigma}\mu\kappa_y < d^o$. Note, third, that $d^w > 0$ by the assumption of determinacy made in Proposition 6. Thus $[\frac{d^o}{d^w} - 1] > 0$.

   We have to check

   $$\partial y_L^w / (-\partial g_a) > \partial y_L^o / (-\partial g_a) > 0. \tag{50}$$

   The first inequality, after substituting for y_a and π_a in (46), is equivalent to

   $$
   \begin{aligned}
   &\left[\tfrac{d^o}{d^w} - 1\right]\bar{\sigma}(1 - \mu)(\kappa_g - \kappa_y)\left[(1 - \beta\mu)(\phi_\pi - \varrho) - 1 + \varrho\right] \\
   &+ \tfrac{d^o}{d^w}\bar{\sigma}(\phi_\pi - \varrho)(\kappa_g - \kappa_y)\bar{\sigma}\xi\phi_{T,y}(1 - \mu)(1 - \beta\mu) \\
   &+ \tfrac{d^o}{d^w}(1 - \mu)(1 - \beta\mu)\left[(1 - \varrho)(1 - \beta\varrho) + \bar{\sigma}(\phi_\pi - \varrho)\kappa_y\right]\bar{\sigma}\xi(\phi_{T,y} - 1) < 0.
   \end{aligned}
   $$

   The second row is strictly negative because $\phi_\pi > 1 > \varrho$ and $\kappa_g < \kappa_y$. The third row is strictly negative since $\phi_{T,y} \in (0,1)$. As for the first row, since $\kappa_g - \kappa_y < 0$ it will be strictly negative if $(1 - \beta\mu)(\phi_\pi - \varrho) - 1 + \varrho > 0$. This condition is equivalent to the condition for a positive effect of future retrenchment with $\xi = 0$ stated in item 1 of the corollary, namely $\varrho > \frac{1 + \phi_\pi(\beta\mu - 1)}{\beta\mu}$. Therefore, whenever the second inequality in (50) holds, so does the first.

3. It suffices to show one such parameterization. In particular, let $\phi_{T,y} = 0$. In that case, the sovereign risk channel does not affect the determinacy condition, nor does it affect the denominator defined as d above. The condition that ensures that a retrenchment after the ZLB has a positive effect on output at the ZLB is

   $$\frac{1}{d}[(1 - \mu)(1 - \beta\mu)(y_a - g_a) + \bar{\sigma}(1 - \mu)\pi_a - (1 - \mu)(1 - \beta\mu)\bar{\sigma}\xi g_a] > 0$$

   Now, y_a, π_a do not depend on ξ. In addition, under the conditions provided in the proposition, $(1 - \mu)(1 - \beta\mu)\bar{\sigma}\xi$ is unambiguously positive if $\xi > 0$, while g_a is negative. As a result, for any persistence of the retrenchment ϱ (and so in particular also for those that violate the inequality provided in item 1 of the corollary), there exist values of $\xi > 0$ that make the above condition hold.

■

Here we are primarily interested in the output effects during the period in which monetary policy is constrained. Corollary 7 provides a detailed characterization. In the absence of a sovereign risk channel, the corollary shows that future spending cuts that take effect after the end of the ZLB phase raise output in the early periods unless too much of the retrenchment is expected to occur soon after the exit from the ZLB, i.e., future retrenchment efforts need to be sufficiently persistent; compare Corsetti et al. (2010) and Woodford (2011). The corollary

also highlights that the sovereign risk channel would enhance any crowding-in of output while at the ZLB; see Item 2 of Corollary 7. In addition, for certain parameterizations, future retrenchment, even if not particularly persistent, may stimulate output at the ZLB if the fiscal situation is fragile ($\xi > 0$), whereas such a retrenchment would have negative effects in the absence of the sovereign risk channel, that is, for $\xi = 0$ (Item 3).