A macrofinance view of US Sovereign CDS premiums[*]

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Abstract

Premiums on US sovereign CDS have risen to persistently elevated levels since the financial crisis. In this paper, we ask whether these premiums reflect the probability of a US *fiscal default*, namely a state in which budget balance can no longer be restored by further raising taxes or eroding the real value of debt by raising inflation. To that end, we develop a tractable equilibrium macrofinance model of the US economy, in which the fiscal and monetary policy stance jointly endogenously determine nominal debt, taxes, inflation and growth. While US CDS cannot be valued using standard replication arguments, we show how in our equilibrium model, CDS premiums reflect endogenous risk adjusted fiscal default probabilities. A calibrated version of the model is quantitatively consistent with high premiums on US sovereign CDS.

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https://sites.google.com/site/mbchernov/CSS_uscds_latest.pdf.

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1 Introduction

The credit crisis brought about a visible change in sovereign credit default swaps (CDS) of economically developed countries. Near zero trading volumes at near zero premiums in late 2007 have expanded to active trading at substantial premiums of hundreds of basis points. As the crisis has subsided, the sovereign CDS premiums remain elevated, nowhere close to the pre-crisis levels. The question that we address in this paper is which risks are so richly compensated in these markets.

At a first blush, the answer seems to be obvious. After all, CDS insure against default. But let's consider the USA as the most stark example: at the height of the crisis the cost of the five-year protection was 100 bps, and it traded around 20 bps since 2014. Is the US default so likely, or is the expected loss so severe to justify such premiums? According to basic reasoning the answer would be no. For instance, some observers believe that the USA is not going to default at all as it can either "inflate away" its debt obligations, or increase taxes, or both. Furthermore, by the standard replication argument, the CDS premium cannot be too different from the credit spread – the difference between a par yield of the credit name and that of a US Treasury – which, in the case of the USA, is mechanically zero at any maturity.

These initial arguments prompt us to make a first step towards developing a formal macro-based framework that allows to evaluate likelihood and severity of a sovereign default. The advantage of such an approach is that it allows to study the impact of monetary and fiscal policies, and does not require an ability to replicate an asset in order to value it.

Because it is a first step, we keep our setting as simple as possible. We specify an endowment economy and assume dynamics of many key variables such as aggregate output, consumption growth, and government expenditures. The secret glue that holds it all together and allows us to investigate the questions of interest is the government budget constraint (GBC). The government can tax the aggregate output and issue new nominal debt in order to finance its expenditures and repay its outstanding debt. Thus the GBC determines endogenously the relationship between the issued debt and taxes.

We specify monetary policy via a Taylor rule that determines behavior of inflation. In an endowment economy monetary policy usually does not have real effects. In contrast, in our setting with the GBC featuring nominal debt, inflation affects real quantities. Fiscal policy responds to the amount of outstanding debt and expected growth in the economy.

Our model endogenously allows for states of the economy in which budget balance can no longer be restored by raising taxes or by eroding the real value of debt by creating inflation. In such situations, the government will have no other choice other than defaulting on its debt. We will refer to such a scenario as a *fiscal default*. Episodes of fiscal stress arise in our model because we assume that an increase in the tax rate has a small, negative effect on future long-term output growth. Attempts to achieve budget balance by raising taxes thus may come with a slowdown in taxable income, which further exacerbates fiscal conditions. Fiscal default then arises when taxes cannot be raised further without reducing future tax revenues, in the spirit of a Laffer curve. This trade-off prompts our specification of a maximum amount of debt outstanding which is related to the expenditure and tax rates, and ultimately determines the timing of default.

We complement our setup with a global representative agent with Epstein and Zin (1989) preferences who is using her marginal rate of substitution to value assets. Consumption features time-varying conditional mean similar to Bansal and Yaron (2004). These assumptions allow to value nominal defaultable securities using inflation and timing of default derived from the GBC and policy rules.

Qualitatively, we find that the model provides significant insights into the macroeconomic determinants of CDS premiums on US Treasury debt. In the model, episodes of high government debt endogenously correspond to investors' high marginal utility states. When the government's expenditures rise, the likelihood that it finds itself close to a fiscal limit, a state in which further tax increases will reduce tax income, becomes more realistic. Default probabilities, and the likelihood of incurring losses on government debt thus go up in high marginal utility states. Writers of insurance against government debt thus face required payments in high marginal utility states. In order to be compensated for exposure to that risk, they earn high risk premia. In spite of potentially small average losses on government debt, and thus small average payments for insurers, they occur in the worst of all states. Within the context of the model, risk premiums thus make up a substantial part of CDS premiums beyond expected losses. On top of that, adhering to a Taylor rule requires the central bank to create inflation in response to the decline in output growth. In our setup, expected growth declines after the government raises taxes in response to an elevated debt burden. The central bank thus creates inflation in high debt episodes, consistent with the idea of inflating debt away.

Quantitatively, we find that our model can generate episodes of persistently elevated CDS premiums similar to the recent US experience. In simulations, our model produces CDS premiums of up to a 100 basis points on an annual basis. This is similar to peak values of US CDS premiums around the financial crisis in 2008. Perhaps more importantly, however, our model predicts episodes of persistently elevated CDS premiums even during calmer times. This is because in our setup with recursive preferences, investors will anticipate and dislike occasional shocks to default probabilities raising CDS premiums. The model is thus consistent with the notion that CDS premiums reflect investors' rational forecasts of the likelihood of US fiscal stress.

Organization. After discussing related literature, we collect some background about both sovereign and corporate CDS contracts in the next section. This highlights the particular challenges of calculating CDS premiums in the case of a sovereign in absence of a risk-free benchmark. In section 3 we describe the model and review its basic mechanics. In section 4, we outline our log linear solution technique, while deferring the details to the appendix. Section 5 discusses the calibration and the main quantitative implications for macroeconomic dynamics, and the pricing of risk-free and defaultable securities and CDS contracts. Section 6 offers a few concluding remarks.

Notation. We use capital letters to denote the levels of the variables. Lowercase letters are used for their logs. The changes in the variables are denoted by Δ.

Literature

Our work contributes to the growing literature on sovereign default and the pricing sovereign default risk, and adds a macrofinance perspective to it. While there is considerable interest in sovereign default both in macro and in finance, these literatures have evolved somewhat separately. Our paper is a first step towards synthesizing insights from macro and finance and distilling them into a tractable, quantitative framework.

The finance literature is mostly based on the contingent claims approach (CCA) that was originally developed to analyze defaultable corporate debt. This approach treats a bond as a (short put) option on the value of a firm's unlevered assets. Default is triggered by a combination of a firm's difficulty in servicing debt and provisions of a bankruptcy law. When applying CCA to sovereign debt, unlevered assets are replaced with present value of future output. The key difficulty is that there is no bankruptcy law at the sovereign level, so the cause and timing of default is not clear.

Strategic default takes place when penalties such as limited access to international debt markets, trade sanctions, etc. are outweighed by the debt burden. In the CCA framework, these considerations lead to default when present value of output under default exceeds the present value under continuation of debt service (Kulatilaka and Marcus, 1987). Gibson and Sundaresan (2005) endogenize the strategic default trigger and the resulting risk premiums (credit spreads) by embedding a bargaining game between the sovereign and the creditors. The issue with this approach is that there is inconclusive empirical evidence regarding the impact of sanctions on sovereign defaults. In our model the government defaults when it runs out of the available debt-servicing tools (issue new debt, inflate debt, tax more).

Affine models of sovereign default are focused on estimating a realistic model of a default probability and default risk premium in emerging economies using intensity-based approach. Duffie, Pedersen, and Singleton (2003) is focused on estimating a model of Russian credit spreads. Pan and Singleton (2008) estimate risk-adjusted default arrival rate and loss given default using sovereign CDS. Ang and Longstaff (2013) estimate a joint affine model of US CDS, US states and Eurozone sovereigns. Our model is able to provide economic underpinning of defaults and allows distinguishing between risk-adjusted and actual probabilities of default (recovery is fixed at a constant for simplicity, but this can be easily extended).

Augustin and Tedongap (2014) value Eurozone CDS from the perspective of an Epstein-Zin agent as well. The key difference from our approach is that they also follow intensity-based approach, that is, they assume a function connecting a sovereign's default probability to expected consumption growth and macro volatility. In our model default probability is determined endogenously by interaction between fiscal policy and the GBC combined with monetary policy.

Strategic default is also at the core of the international macroeconomics literature on sovereign default in the spirit of Eaton and Gersovitz (1981). Recent work along these lines includes Arellano (2008); Arellano and Ramanarayanan (2012); Yue (2010). This important line of work solves general equilibrium, endowment models of small open economies in which governments default strategically in the best interest of households and analyzes the implications for sovereign credit spreads. Our paper differs from that work along several dimensions. From a quantitative viewpoint we operate in a risk-sensitive framework in which risk premia make up a sizeable component of spreads, and we focus on fiscal default as distinct from strategic default. Borri and Verdelhan (2012) use a risk-sensitive consumption-based model based on habit preferences to study emerging market sovereign default premia.

In the latter respect, our work is closer to recent work by Leeper (2013) on fiscal uncertainty and fiscal limits. Bi and Leeper (2013) and Bi and Traum (2012) analyze business cycle models that explicitly allow for fiscal limits and apply them to the recent episode in Greece. In contrast to our work, they do not focus on CDS premiums or spreads, and do not operate in a risk-sensitive framework. Moreover, our paper emphasizes a growth channel of fiscal policy via elevated tax rates depressing future growth prospects, that is absent in their work. While our channel is consistent with empirical evidence CITE, it emerges endogenously from recent work linking long-run risks and fiscal policy in models of endogenous growth (Croce, Kung, Nguyen, and Schmid, 2012; Croce, Nguyen, and Schmid, 2013).

2 A primer on USA Sovereign CDS

We start by providing basic background on corporate CDS. Subsequently, we use this information to motivate our interest in sovereign CDS and to explain important differences between the two types of contracts.

2.1 Corporate CDS

Prior to the introduction of the Big and Small Bang protocols in 2009, a long position in a corporate CDS contract required no payments upfront, quarterly premiums, and, in case of a credit event, delivery of allowed bonds of the corporate entity, or a cash payment with amount determined in a CDS auction in exchange for the full par (notional) paid in cash. The Big and Small Bang protocols have codified the use of auctions to determine the payments by the long party and established standardized CDS premiums (100 bps for investment grade and 500 bps for speculative grade entities). The standardized CDS premiums simplified netting and offsetting of positions but introduced the need to pay an upfront fee to ensure that present values of all the cash flows line up. The CDS contracts continue to be quoted on a par basis (zero payment upfront). For this reason, we ignore all these institutional details in the paper.

It is easy to obtain a back-of-the-envelope estimate of the quarterly premiums using the replication argument applied to par bonds. Par bonds have coupon payments such that the bond value is equal to par immediately after a coupon payment. Assuming that par bonds of matching maturity are available for both the entity and US Treasury, consider shorting the corporate bond, and buying the Treasury bond. Because these are par bonds, there are no payments upfront. The running payment is the difference between higher corporate and lower Treasury coupons, known as the credit spread. In case of a credit event, the Treasury bond can be sold at the par value, while the short position in the corporate bond requires the purchase of the bond in the market place and delivering it to the original owner.

In practice, par bonds may not be available, so it could be difficult to find matching maturity, or corporate bonds could be much more expensive to short due to their scarcity. All these complications introduce the non-zero difference between the CDS premium and a bond's credit spread, a.k.a. the CDS-bond basis (Blanco, Brennan, and Marsh, 2005; Longstaff, Mithal, and Neis, 2005). Typically the basis is positive reflecting the cost of shorting a corporate bond. Because these costs vary with a trading party, there is always "basis arbing" activity in the market place. As a result, with the exception of short-lived periods of stress, the basis is very close to zero.

To summarize, if one were to take a macro-fundamental view of the determinants of CDS premiums, there would be no new information relative to credit spreads obtained from bonds. All the differences in the two premiums come from differences in institutional features of CDS and bond markets, liquidity and lack of perfect match between the terms of the two types of instruments.

2.2 Sovereign CDS

The replication argument applied naively to a sovereign contract would imply zero premiums for the USA Sovereign CDS (US CDS for short) regardless of a contract's maturity. This stark implication clashes with the evidence and prompts us to focus specifically on US CDS as opposed to similar contracts for other developed economies. The failure of the replication argument could be caused by a number of factors that differentiate sovereign contracts from the corporate ones. We discuss these differences below. Additionally, the failure of the replication implies that one needs to use an equilibrium setting to determine the CDS premium. An equilibrium setup, to be discussed in the next section, will naturally bring out potential economic causes of a sovereign credit event.

There are three potential credit events that are covered by the US CDS: failure to pay, repudiation/moratorium, and restructuring. Failure to pay has received a lot of attention during the congressional debt ceiling debacles of 2011, 2013, and 2015. Debt ceiling is a direct and important channel that could trigger a payment on US CDS contracts and, therefore, its likelihood and expected severity must be reflected in CDS premiums. We find this avenue to be the least interesting economically because it is a hardwired outcome of a political decision making process (although the state of the economy may have an impact on a specific stance of politicians). Our primary interest is in how other avenues such as monetary and fiscal policies could trigger a credit event and how risks of these contingencies are priced.

In contrast to US corporate CDS, the US CDS are denominated in Euros. The rationale for such a feature is to separate the sovereign risk that the contract ensures from the payments made on this contract. Because US Treasuries are denominated in USD, the currency of all deliverable bonds is mismatched with the currency of a contract. This feature complicates the ability to replicate the US CDS using traded securities. Because the date of a credit event is uncertain one cannot use a currency forward or swap contracts to perfectly offset Euro payments with US dollars.

Additional difficulty in replicating a US CDS is that shorting of a Treasury bond would be implemented via a repo contract. Therefore, replication would be subject to rollover risk because even if one were to use term repos, the available maturities are much shorter than those of standard CDS contracts. The repo rate would increase with likelihood of a credit event rendering replication ineffective. This difficulty with replication manifests itself in sovereign basis trades. In contrast to their corporate counterparts, basis trade positions offset a CDS contract with exposure to the unhedged sovereign bond due to the lack of a risk-free or, more precisely, less risky instrument.

To summarize, lack of replication makes sovereign CDS non-redundant vis-a-vis their bond counterparts. This is the case even if one ignores the institutional differences between the two markets. Their combined premiums imply unobservable default-free rate. This point is particularly striking in the case of US securities because they typically serve as the least risky benchmarks for the rest of the world economy.

According to Augustin (2014), with gross notional amount of $3 trillion, sovereign CDS constitute about 11% of the overall credit derivatives market. Dealers have the largest market share of 70%. In particular, the average gross (net) notional amount of outstanding US CDS is $17 ($3.2) billion. To gain further insight into trading activity of the US CDS, we report our crude measure of liquidity in Figure 1. Because CDS contracts on Italian government are the most actively traded sovereign CDS, we report the ratio of weekly the net notional amount of US CDS to that of Italian CDS.[1] The average ratio is 18% and it ranges between 6.5% in the beginning of the sample and 33% in late 2011 at the peak of

[1] We are indebted to Patrick Augustin for sharing his data that was hand-collected from the Depository Trust and Clearing Corporation (DTCC).

the anxieties regarding the European credit crisis and the US fiscal uncertainty. So, clearly the contract is not the most liqiuid one, but nonetheless has a respectable trading activity.

Figure 2 displays recent history of the US CDS premiums for the most liquid contracts, which are the five-year ones. The premiums have rapidly increased from 0.2 bps in October 2007 to 20 bps during the Lehman crisis in September 2008. They continued marching up until they reached the peak of 100 bps in March 2009. As the first round of quantitative easing started expanding the premium came down and reached the Lehman levels by October 2009. From then on the premiums varied between 20 and 65 bps. The premiums started declining in the middle of 2012 and most recently settled at a level of about 20 bps, which is 100 times larger than the pre-crisis level.

Figure 2 highlights some of the important events associated with the variations in the cost of protection. Many observers believe that an important reason for high US CDS premiums is the chance of default due to debt ceiling. Indeed, the premiums have increased from 40 to 60 bps during the first debt ceiling debacle of 2011. However, they have declined from 45 to 25 bps during the second debt ceiling crisis in 2013, and moved briefly between 15 and 25 bps during the 2015's debacle. Thus, even this technical reason to default cannot offer a full explanation of the magnitude of the protection premium.

There could be additional non-credit-related risks that our model does not account for, but are potentially responsible for the US CDS premium. First, because most contracts are denominated in Euros, there is exposure to currency risk that is difficult to hedge. The difficulty arises from the uncertain default dates, so a traditional currency swap would not match cash flows in default. Second, the contracts may command liquidity premium because they are not the most actively traded ones, as discussed earlier. Third, there is legal risk associated with the credit event determination by a committee comprised of 15 voting members: 10 from the sell side and five from the buy side. At present, there is poor understanding of the incentives of committee participants and how this may affect the decision whether a credit event took place or not. Last, but not least, there is a risk of uncertain recovery that is determined by an auction that takes place within 30 days after a credit event.

3 The model

We use a standard framework to link nominal debt, taxes, inflation and aggregate growth to fiscal and monetary policy through the government's budget constraint. The government can maintain the budget balance either by issuing new debt, or raising inflation or taxes. Fiscal default arises when the government can no longer service its debt. As a result, investors may want to buy protection against default events through sovereign CDS contracts.

We cannot use the standard replication argument to value CDS when Treasuries are themselves subject to credit risk. We therefore complement our setup with a global investor with Epstein and Zin (1989) preferences who is using her marginal rate of substitution to value assets. This allows us to value any financial security.

In this section we describe the details of this setup. We start with the stochastic discount factor, which we derive from the global investor's preferences and her aggregate consumption process. Next, we describe he dynamics of the aggregate economy and the government. Then we specify the interaction of the government's fiscal and monetary policy stance with the real economy. We conclude with the valuation of defaultable securities such as CDS.

3.1 Valuation of financial assets

We assume that there is a global representative agent with recursive preferences:

$$\begin{aligned} U_t &= \left[(1-\beta)C_t^{\rho} + \beta\mu_t(U_{t+1})^{\rho}\right]^{1/\rho} \\ \mu_t(U_{t+1}) &= E_t(U_{t+1}^{\alpha})^{1/\alpha}, \end{aligned}$$

where $\rho < 1$ captures time preferences (intertemporal elasticity of substitution is $1/(1-\rho)$), $\alpha < 1$ captures risk aversion (relative risk aversion is $1-\alpha$). Aggregate consumption is denoted by C_t.

With this utility function, the real pricing kernel is

$$M_{t+1} = \beta(C_{t+1}/C_t)^{\rho-1}(U_{t+1}/\mu_t(U_{t+1}))^{\alpha-\rho}.$$

Let P_t denote the price level. The agent is using the nominal pricing kernel $M_{t+1}^{\$} = M_{t+1}\Pi_{t+1}^{-1}$, where $\Pi_t = P_t/P_{t-1}$ is the inflation rate, to value nominal assets. We spell out the determinants of endogenous inflation below.

Consumption is assumed to have the following dynamics:

$$\begin{aligned} \Delta c_{t+1} &= \Delta c + x_t + \sigma_c \varepsilon_{t+1} \\ x_{t+1} &= \varphi_x x_t + \sigma_x \varepsilon_{t+1}, \end{aligned}$$

where the shock ε_{t+1} is $\mathcal{N}(0,1)$. This assumption is similar to Bansal and Yaron (2004), Model I, by allowing for a time-varying conditional mean in consumption growth. The shock to consumption growth and its expectation are perfectly correlated for simplicity.

3.2 The government and the economy

We assume that output Y_t evolves as follows:

$$\Delta y_{t+1} = \varphi_y(\tau_t - \tau) + \sigma_y \varepsilon_{t+1},$$

where $\tau_t = \log \mathcal{T}_t$ is the (log) tax rate at time t and τ is its unconditional mean. For simplicity, we assume the existence of one single tax rate and remain agnostic about its precise nature. This tax rate is time-varying and its dynamics arise endogenously through the fiscal authority's response to debt, as specified below. An identical shock to output and consumption serves as a modelling shortcut to the resource constraint that arises in general equilibrium models.

Importantly, we assume that deviations of the prevailing tax rate from the mean affect future growth prospects, through the parameter φ_y. Consistent with the evidence (Jaimovich and Rebelo, 2012; Croce, Kung, Nguyen, and Schmid, 2012), φ_y will be negative and small in our calibration, so that raising taxes will depress future growth prospects. While we assume this link directly, our specification is in the spirit of the literature on endogenous growth and taxation in which an elevated tax burden endogenously slows down growth through its effect on innovation (Rebelo, 1991; Croce, Nguyen, and Schmid, 2013).

Let G_t be the government expenditures as a fraction of output. Its log dynamics are given as follows:

$$g_{t+1} = (1 - \varphi_g)g + \varphi_g g_t - \sigma_g \varepsilon_{t+1}.$$

The negative sign in front of the volatility coefficient σ_g highlights perfect negative correlation between shocks to output and expenditures, so that a bad shock to the economy corresponds to the increase in expenditures.

In order to finance expenditures the government raises taxes and issues nominal debt. For simplicity, we assume that the government directly taxes output, so that the tax revenue in levels at time t is given by $\mathcal{T}_t Y_t$. We view this specification as a tractable way to capture the link between taxation and the aggregate economy. In a more elaborate setup, we could model labor and labor taxes, so that tax distortions would affect aggregate output through their impact on the labor-leisure decision (Croce, Nguyen, and Schmid, 2013). We assume that the government issues nominal debt with a face value N_t. The real face value of debt as a fraction of output is

$$B_t = (N_t/P_t)/Y_t.$$

The government finances its expenditures with two types of bonds, short-term with a price of Q_t^s, and long-term with a price of Q_t^ℓ per \$1 of face value. Short-term bonds mature in one period. We think of the short-term bond as the instrument of the monetary policy. We model long-term debt so as to allow for more realistic modeling of default and to be able to give an account of the quantitative easing episode within the context of our setup. For tractability, we assume that short-term and long-term bonds are issued in constant proportion: the nominal amounts are $N_t^s = \omega N_t$ and $N_t^\ell = (1-\omega)N_t$, respectively. Variation in ω can represent shifts in the overall maturity structure of government debt held by the public, such as those induced by the quantitative easing program of the Federal Reserve. We explore these variations in the sequel.

To retain a stationary environment with long-term debt, we model long-term via a sinking fund provision in the spirit of Leland (1994). A long-term bond specifies a coupon payment every period and requires a fraction λ of the debt to be repaid every period. This amounts to a constant amortization rate of the bond. Although this is console debt, it has an implicit maturity that is determined by the repayment rate λ. If $\lambda = 1$ this simplifies the bond to the one-period one, if $\lambda < 1$ then the implicit bond maturity is longer and proportional to $1/\lambda$.

The properties of debt and taxes are connected via the government budget constraint (GBC):

$$\begin{aligned} \mathcal{T}_t Y_t + Q_t^\ell (N_t^\ell - (1-\lambda) N_{t-1}^\ell)/P_t + Q_t^s N_t^s / P_t \\ = (c+\lambda) N_{t-1}^\ell / P_t + N_{t-1}^s / P_t + G_t Y_t. \end{aligned} \tag{3.1}$$

The GBC requires that government expenditures $G_t Y_t$ and due payments on long and short term debt (coupon payments and amorization) $(c+\lambda)N_{t-1}^l/P_t + N_{t-1}^s/P_t$ have to be covered either by tax income $\mathcal{T}_t Y_t$ or by issuing new long term or short term debt $Q_t^\ell(N_t^\ell - (1-\lambda)N_{t-1}^\ell)/P_t + Q_t^s N_t^s/P_t$. The GBC can be expressed as a fraction of output:

$$\begin{aligned} \mathcal{T}_t + [(1-\omega)Q_t^\ell + \omega Q_t^s] B_t - (1-\lambda)(1-\omega) Q_t^\ell B_{t-1} \Pi_t^{-1} (Y_t/Y_{t-1})^{-1} \\ = [(c+\lambda)(1-\omega) + \omega] B_{t-1} \Pi_t^{-1} (Y_t/Y_{t-1})^{-1} + G_t. \end{aligned}$$

We capture the monetary and fiscal policy stance by means of policy rules. In case of the monetary policy, this is achieved by a standard Taylor rule linking the nominal short term interest rate to macroeconomic variables. In line with the literature, we assume that the central bank responds to inflation and output growth, which we view as corresponding to the output gap in the New-Keynesian literature.

In case of the fiscal policy, we assume that the government sets the amount of new debt issued in response to the amount of debt outstanding and expected economic conditions x_t. Mechanically, then, the prevailing tax rate has to be such as to establish budget balance in the GBC. Our specification is related to policy rules examined in the recent literature on monetary-fiscal interactions (Bianchi and Ilut, 2014; Leeper, 1991, 2013).

Summarizing, the government controls the real debt and nominal interest rate through the fiscal and monetary policies, respectively

$$\begin{aligned} b_t &= \rho_0 + \rho_b b_{t-1} + \rho_x x_t + \xi_t^b, && \text{(Fiscal policy)} \\ -q_t^s &= \delta_0 + \delta_\pi \pi_t + \delta_y \Delta y_t + \xi_t^q, && \text{(Monetary policy)} \end{aligned}$$

where $\pi_t = \log \Pi_t$ is the (log) inflation rate. Intuitively, the parameter ρ_b determines how fast the government intends to pay back outstanding debt. Similarly, we allow for the possibility that the government increases public debt in bad times by responding to x_t. The parameter $\rho_x < 0$ determines the intensity of this interaction. Innovations $\xi_t^b \sim \mathcal{N}(0, \sigma_b^2)$

and $\xi_t^q \sim \mathcal{N}(0, \sigma_q^2)$ capture the uncertainty about future indebtedness of the government and monetary policy, respectively. As is well-known, obtaining determinacy imposes restrictions on the parameters of both the fiscal and the monetary policy rules (see Leeper, 1991, 2013), which we will discuss in the calibration section.

Given the real pricing kernel, the Taylor rule implies the dynamics of inflation as in Gallmeyer, Hollifield, Palomino, and Zin (2007). This reflects the fact that the nominal short rate implied by the nominal pricing kernel and that implied by the Taylor rule must be consistent. In this line of work, which evolves around endowment economies, monetary policy has no scope of affecting real variables. In our setting, the GBC is the channel through which monetary policy influences real quantities because it affects the real value of outstanding debt, which in turn feeds into the tax rate and output growth.

3.3 Defaultable securities

We think of government default in the model in the sense of fiscal default, namely scenarios in which budget balance can no longer be restored by further raising taxes or inflating debt away, as opposed to mere technical defaults resulting from the political decision making process or strategic considerations.

Limits to raising taxes arise frequently in macroeconomic models with distortionary taxes in the context of Laffer curves. Laffer curves relate the government's tax revenue to the prevailing tax rate. While they typically start out increasing for low tax rates, they often reach the 'slippery slope' (Trabandt and Uhlig, 2011) where further raising tax rates actually lowers tax revenues, so that tax policy becomes an ineffective tool to balance the budget. This is because distortionary taxation tends to negatively affect the tax base such as in the case of labor taxes, where excessive taxation reduces the incentives to work.

Our model captures the negative effect of taxes on the tax base by means of the output growth equation (3.1). Large debt-financed budget deficit leads to higher debt level through the fiscal policy rule and, as a result, to higher taxes via the GBC implying shrinking tax base. The negative effect of taxes on the tax base limits the future stream of surplus the government can generate in any state, and thus the maximal amount of debt it can repay.

We thus define the fiscal limit B_t^* as the maximum sustainable amount of debt outstanding, which is given by the expected future stream of surplus:

$$B_t^* = E_t \sum_{j=1}^{\infty} M_{t,t+j}(\mathcal{T}_{t+j} - G_{t+j}). \tag{3.2}$$

Note that the fiscal limit is conditional on the current state of the economy. Default must then occur whenever government debt exceeds the fiscal limit, or, equivalently, whenever $b_{t+1} \geq b_{t+1}^*$. Denote default time by

$$\tau^d = \min\{t : b_t \geq b_t^*\}.$$

So default will take place at time $t+1$ if $\tau^d = t+1$.

Given the definition of the one-period ahead default probability, one can value the short-term bond:

$$Q_t^s \;=\; E_t\left(M^{\$}_{t,t+1}\left[(1-\mathbf{1}_{\{\tau^d=t+1\}}) + (1-L)\mathbf{1}_{\{\tau^d=t+1\}}\right]\right), \tag{3.3}$$

where L is the the loss given default. We can also value the long-term bond by relying on one-period ahead default probabilities via the following recursive representation:

$$Q_t^\ell \;=\; E_t\left(M^{\$}_{t,t+1}\left[(c+\lambda+(1-\lambda)Q^\ell_{t+1})(1-\mathbf{1}_{\{\tau^d=t+1\}}) + (1-L)\mathbf{1}_{\{\tau^d=t+1\}}\right]\right)$$

where c is a coupon as fraction of real value of the debt notional amount, and λ is the repayment rate that effectively controls duration of this debt.

CDS contract has two legs. The premium leg pays the CDS premium c_t^T every quarter until a default takes place. It pays nothing after default. The protection leg pays a fraction of the face value of debt that is lost in default and nothing if there is no default before maturity. Accordingly, the value of the fixed payment to be made at time $t+j$ is $c_t^T \times E_t(M^{\$}_{t,t+j}\mathbf{1}_{\{t+j<\tau^d\}})$. As a result the value of the premium leg is equal to

$$\text{Premium}_t^T = c_t^T \cdot \sum_{j=1}^{T} E_t M^{\$}_{t,t+j}\mathbf{1}_{\{t+j<\tau^d\}}.$$

The protection leg can be represented as a portfolio of securities, each of them maturing on one of the days of the premium payment, $t+j$, and paying L if default took place between $t+j-1$ and $t+j$, and nothing otherwise. Thus,

$$\text{Protection}_t^T \;=\; L \cdot \sum_{j=1}^{T} E_t(M^{\$}_{t,t+j}\mathbf{1}_{\{t+j-1<\tau^d\leq t+j\}})$$

The CDS premium c_t^T is determined by equalizing the values of the two legs.

Importantly, CDS premiums depend on the joint behavior of the stochastic discount factor and default probabilities. While we specify the process for the stochastic discount factor exogenously, default probabilities reflect the endogenous responses of our economy to shocks. To the extent that the endogenous dynamics of our economy predict high government indebtedness in times of low consumption growth prospects, the global representative agent in our model will require compensation for potential default losses during such episodes. In other words, prices of default-sensitive securities will reflect a risk premium beyond expected losses.

3.4 Discussion

We have presented a simple model of the US economy which endogenously allows for scenarios triggering the government's default on its debt. Before we proceed to describe the model solution, let us briefly review its ingredients.

There are three building blocks. The first block describes the dynamics of the aggregate economy as given by (3.1). Second, there is a government or policy block including the fiscal and monetary rules, and the government budget constraint. Third, there is a pricing block that derives a risk-sensitive pricing kernel from recursive preferences given a process for consumption growth. While blocks one and three are a standard structure familiar from the literature on long-run risks following Bansal and Yaron (2004), our setup adds a rich specification of the government's and the central bank's policy instruments. While we do not complete the model in general equilibrium, we link all these blocks through the government budget constraint.

Inflation arises endogenously as the nominal interest rate implied by the Taylor rule has to coincide with that implied by the nominal pricing kernel. Inflation thus has real effects in our model, because it determines the real value of debt and thus the prevailing tax rate, which in turn impacts expected growth. Growing debt-financed deficits can lead to episodes of elevated tax rates which may trigger default.

Default probabilities are reflected in the pricing of defaultable bonds. Treasury bonds and thus the central bank's policy instrument are themselves subject to credit risk. Even the value of a hypothetical nominal bond that has no cash flow risk depends on the default probability because inflation does. This is because the combination of fiscal and monetary policies and the GBC imply that inflation depends on the risky government debt.

4 Quantitative Analysis

In this section, we evaluate to what extent the possibility of a US fiscal default can quantitatively account for CDS premiums observed since the onset of the financial crisis. We calibrate our model in a way that is quantitatively consistent with salient features of the recent US monetary and fiscal experience. We check our if the calibrated model implies CDS premiums that are consistent with the ones in the data. Moreover, our risk-sensitive specification allows for a decomposition of CDS premiums into a default probability and a default risk premium. Finally, we can use our calibrated model as a laboratory for a set of counterfactual experiments that highlights the different channels that affect valuation of the sovereign default risk.

We start by describing our calibration approach, and then proceed to illustrate the main mechanisms driving the quantitative results and counterfactuals.

4.1 Calibration

We report our baseline parameter choices in table 1. We calibrate the model at a quarterly frequency, consistent with the availability of macroeconomic data. We need to calibrate parameters from four different groups. First, we follow the literature on long-run risks to select our preference parameters. Second, we pick parameters governing the exogenous stochastic processes in our model, such as output growth, consumption growth and, critically, government expenditures. We do so by matching time series moments of their empirical counterparts. Third, we choose parameters controlling maturity and payment structure of government debt. Finally, we specify the fiscal and monetary policy rules to match the recent US policy experience in a high debt environment.

Our choice of preference parameters follows Bansal and Yaron (2004). As is well-known, the combination of relatively high risk aversion and an intertemporal elasticity above one allows to rationalize sizeable risk premia in many markets. In a similar vein, the calibration of the consumption growth process reflects long-run risks, and the parameter choices follows Bansal and Yaron (2004). To calibrate G_t, we fit an autogressive process to the GDP-government expenditures ratio in the US postwar sample which pins down its mean, autocorrelation and volatility. Turning to the output dynamics, a critical parameter is φ_y which is the elasticity of output growth with the respect to taxes. Intuitvely, we would expect a raise in taxation to be bad news for trend growth. By setting $\varphi_y = -0.015$, based on the empirical estimate obtained in Croce, Kung, Nguyen, and Schmid (2012), our parameter choice is consistent with that notion. We choose σ_y to match the relative volatility of consumption and output growth observed in the data.

The weighted average maturity of US Treasury bonds is 59 months on average, but it has been rising consistently over the past few years, reaching about 69 months by the end of 2015 (US Treasury). In addition, debt of maturity that is less than one year represents about 20%-30% of all outstanding debt. These numbers allow us to select the ω - λ combination. We pick ω to be 0.2 to match the latter fact. In order to match the long-term average maturity, we select $\lambda = 0.04$. In counterfactuals, we provide extensive sensitivity with respect to these choices. Finally, there is little guidance about the recovery rate in a potential default of the US government. Perhaps erring on the conservative side, we assume a recovery rate of 80 percent ($L = 0.2$) in our benchmark calibration. This is quite a bit higher than in the US corporate bond market, where recovery rates around 50 percent are a good starting point, as reported for example in Chen (2010).

Our calibration of the parameters in the policy rules is quite standard. We choose the parameters of the Taylor rule following the parameterization in Gallmeyer, Hollifield, Palomino, and Zin (2007). This choice implies an average inflation rate in line with the data. In order to pin down the parameters in the fiscal rule, we run a regression of the debt to GDP ratio on its lagged value, and a proxy for expected consumption growth. We compute an estimate of x_t from data on consumption growth using the Kalman filter and the assumed model parameters.

4.2 Quantitative Results

Possibility of default induces strong nonlinearities in both payoffs and the discount factor. Therefore, we use a global, nonlinear solution method. Endogenous variables are approximated using Chebychev polynomials and solved for using projection methods.

We start by discussing the macroeconomic implications of the model. Taking these as a benchmark, we will then proceed to examine the quantitative implications for CDS premiums.

4.2.1 Matching Quantities

Table 2 summarizes the main implications for macroeconomic quantities. The average debt-to-GDP ratio in the model is about 0.96, which is within two standard errors of the one in the data. The government expenditures correspond to slightly more than a third of output, while it is about a quarter in the data. The expenditures are partially financed by taxes. Identifying and pinning down one single relevant aggregate tax rate is complicated by the tax code. We use the estimates from McGrattan and Prescott (2005) as our sample statistics. Our model matches these numbers quite closely. Average inflation is matched as well.

While matching basic macroeconomic moments is important to discipline our analysis, our main interest concerns possibilities of fiscal defaults. Table 2 also gives a first sense of the possibility of such events in our model. The model suggests that the unconditional mean of the fiscal limit is in the range of a 110-150 percent debt-to-GDP ratio. These numbers are will within the range of the CBO long-term debt projections. We would expect fiscal limits to fall in downturns. We will confirm this intuition via correlations shortly. The estimated distribution of fiscal limits determine fiscal default probabilities in the model. Our benchmark calibration yields an average one-year ahead default probability of about 20 basis points. We will later explore to what extent such a default probability can account for observed CDS premiums.

4.2.2 Inspecting the mechanism

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Table 3 gives a sense of how the likelihood of default varies with macroeconomic conditions by reporting the cross-correlations between the main variables in the model. Naturally, debt-to-GDP and taxes are negatively correlated with G_t. A rise in government expenditures creates financing needs, which can either come through debt or taxes, or both. Given our fiscal rule, the government issues debt in response to adverse economic conditions.

The government then raises taxes in order to satisfy its budget constraint. Increases in government expenditures and a higher debt burden lower the expected future surplus the government can generate, and thus the fiscal limit. Accordingly, the probability of a fiscal default raises with tax rates and the debt burden. Higher government expenditures also come with elevated expected inflation, as the central bank attempts to accommodate the associated decline in output, by means of the Taylor rule. Importantly, episodes of a high debt burden and an elevated probability of a fiscal default coincide with times of low consumption growth, making such times high-marginal utility states.

The implication that high debt and therefore high default probability states are bad states in a marginal utility sense is important for the pricing of default insurance, that is, CDS. If default insurance insures against bad marginal utility states, it makes it more valuable for risk averse agents, so that sellers of insurance, or CDS writers, earn the corresponding risk premia. Our model allows to identify the size of such a risk premium. Indeed, the evidence from other credit markets such as corporate bond markets suggests that risk premia accounting for the fact that default losses tend to occur in bad marginal utility states are substantial. Intuitively, we would expect that component to be large for US sovereign CDS as well, as a US default must correspond to a very bad state for the global economy. Our model can account for that intuition and allows to quantify it.

Figure 4 distills the main dynamic mechanisms in our model by means of impulse responses. It shows responses to a one-standard deviation negative innovation to government expenditures. Higher government expenditures raise financing needs in order to balance the budget. The government budget constraint requires that this happens through an increase in debt or higher taxes, or both. In the model, on impact, debt financing needs to adjust. Rising debt requires future funding needs to restore long-run budget balance, so that the government raises taxes by virtue of the interaction between the fiscal policy rule and the GBC. Higher taxes translate into bad news for future output growth by means of our output growth specification, equation (3.1), which is bad news for future growth prospects. This raises the the default probability. Simultaneously, a higher debt burden comes with a raise in expected inflation, as our monetary authority engages in loosening monetary policy so as to erode part of the debt burden.

4.2.3 Term Structures of Risk-free and Defaultable Securities

As discussed previously in the paper, the standard replication approach for corporate CDS contracts does not apply in the context of US sovereign CDS premiums due to lacking risk-free benchmark. While US Treasury bonds are often conveniently interpreted as such a benchmark, the very notion of observed non-zero CDS premiums on US government debt invalidates this view. When US government debt is subject to credit risk itself, approaches other than replication are called for determination of CDS premiums. Our equilibrium approach offers such an approach.

The stochastic discount factor in our model implies an equilibrium term-structure of real risk-free yields. The term structure of US Treasury yields cannot serve as an empirical empirical counterpart to these yields. There are two sources of discrepancies. First, the term structure of Treasury yields refers to nominal bonds. Second, and more importantly, these bonds are not insulated from credit risk as highlighted above. Nonetheless, one can infer a theoretical counterpart to US Treasury yields from our model by using the nominal stochastic discount factor and accounting for a possibility of default similar to expression (3.3).

Table 4 reports three yield curves obtained in our calibration. First, the term structure of risk free yields, corresponding to expectations of the equilibrium *real* stochastic discount factor at various horizons. Second, we report what we call the term structure of pseudo-risk free nominal yields. This curve corresponds to expectations of the equilibrium *nominal* stochastic discount factor. We label them pseudo-risk free, as endogenous inflation in our model reflects the risk of a government default, while the real discount factor does not. Lastly, we report the yield curve of nominal, defaultable bonds, corresponding to expectations of the nominal stochastic discount factor accounting for government default probabilities at various horizons, that is, the term structure of *default probabilities*.

A few observations are in order. First, in our calibration, the term structure of real risk-free yields is, consistent with the long-run risk paradigm, mildly downward sloping. In the context of our model, this is an implication of a high intertemporal elasticity of substitution. Empirically, no clear consensus about the average slope of the real term structure has yet emerged. Various researchers have interpreted the data on inflation-protected bonds (TIPS) in the US as pointing to an upward sloping real yield curve, while others point to the short data sample and conflicting evidence from a longer data sample on inflation-indexed bonds in the UK. Neither line of argument provides guidance for our purposes, as even an upward sloping term structure of real yields does not allow disentangling the effects of inflation and default risk, which is at the core of our setup.

Given the real risk free term structure, our model generates nominal pseudo risk free yield curves that are on average upward sloping. Because the real term structure is mildly downward sloping, our model predicts a realistically upward sloping term structure of inflation expectations and, importantly, inflation risk premia. As described earlier, inflation is endogenously countercyclical in the model. Indeed, adhering to the Taylor rule requires the central bank to raise inflation in response to elevated government indebtedness, in order to restore budget balance by eroding the real debt burden. This is because high debt leads the government to raise taxes, depressing long-term growth prospects, and lowering the output growth, which the central bank reacts to. Inflation thus erodes away the payoff to holding debt precisely in high marginal utility states so that bond holders will require an inflation risk premium to hold government bonds.

Lastly, the term structure of nominal defaultable yields - the model counterpart of US Treasury yield curves - is upward sloping as well. This curve reflects inflation expectations and an inflation risk premium adjustment, and, in addition, it accounts for the term structure of default expectations and a *default risk premium*. The default risk premium accounts for the fact that the model naturally predicts potential government defaults to occur in high debt episodes, which we showed to endogenously coincide with high marginal utility states in the model. Notably, the defaultable term structure is steeper than the nominal pseudo risk-free curve, implying that default risk cannot be avoided by inflating away debt. Such default premia thus reflect market expectations about limits to the ability of the central bank to restore budget balance by means of inflation. This is consistent with the recent empirical evidence in Hilscher, Raviv, and Reis (2014) on the limited ability of inflation to balance the government budget. We explore this further in the subsequent counterfactual analysis.

4.2.4 Fiscal Defaults and CDS Premiums

We now examine the pricing of CDS contracts and the link between CDS premiums and the probability of a US fiscal default. Table 5 provides the results. We report average CDS premiums from the data and from the model, in basis points. Overall, we see that the model delivers an upward sloping term structure of CDS premiums with magnitudes that are consistent with the data. There are some quantitative discrepancies, but, as highlighted in section 2.2, our model does not account for the risks associated with various institutional features of the contract. On balance, the results suggests that accounting for default risk only goes a long way in explaining the magnitudes of CDS premiums.

Traditionally, credit models fit premiums at the longer end better than at the short end of the curve. This is a standard implication of structural models of the defaultable term structure, especially consumption-based ones. We get magnitudes that are consistent with the data because our default boundary is moving over time and time is discrete so there is no perfect anticipation of default in the next instant.

These CDS premiums are substantial despite modest default probabilities in the model. As in all models of defaultable securities, default spreads can be decomposed into two components, namely expected losses, and default risk premia. In our model, losses given default are known so default risk premium reflects the compensation sellers of protection require in order to bear the risk of experiencing the default event in high marginal utility states. The calibrated loss is relatively small. It is conservative because the burden of fitting CDS premiums rests on the ability of our model to generate high default risk premium.

Indeed, column (3) of Table 5 confirms that risk premiums are substantial. The column displays the size of CDS premiums if investors were risk-neutral. The ratio of the numbers in column (2) to the ones in column (3) reflects the magnitude of the aforementioned default premium.

Within the context of the model, the default premium is large because fiscal default endogenously is more likely to happen in high marginal utility states, so that selling default insurance earns a high covariance risk premium, akin to default risk premia in other debt markets, such as corporate bond markets. The model is thus consistent with high CDS premiums reflecting investors' rational forecasts of the likelihood of US fiscal stress.

4.2.5 Inflating and taxing away debt

A common view is that a US default is unlikely as the government can always resort to higher taxation or creating inflation to restore budget balance. We now examine this link through the lens of our model. Within this context, we will represent an attempt to inflate away the debt burden with a shift towards a looser monetary policy stance. This is captured by a shift towards lower values of δ_π in the Taylor rule. Similarly, we can represent a shift towards a fiscal policy with more aggressive taxation by lowering ρ_b. This means that new debt is issued in smaller amount, which would imply higher taxes via the GBC.

We now quantitatively evaluate some of the associated policies using counterfactual analysis. Table 6 reports results for the monetary policy. It reports moments associated with a reduction of δ_π relative to the benchmark case. First, such loosening of the monetary policy stance has the desired effect of increasing the average inflation rate. Similarly, as expected, the average debt is reduced, which comes with a reduction in default probabilities.

Remarkably, CDS premiums, rather than falling, in the light of the reduction of default probabilities, rise. A loosening monetary policy stance does not just raise average inflation, but also its volatility and its correlation with the stochastic discount factor. This is because a lesser concern about inflation leads the central bank to lower short-term interest rates more in response to lower output growth. This increases the volatility of inflation, and its correlation with output growth, and therefore with the real stochastic discount factor. In our calibration, this raises the volatility of the nominal pricing kernel. Accordingly, while average default probabilities fall, CDS risk premia increase, and the net effect is a slight increase in CDS premiums.

A similar result obtains in the case of an attempt to tax away debt. As Table 7 shows, using taxes more aggressively to respond to economic conditions does lead to a fall in the average debt burden and default probabilities, while the average tax rate goes up. The volatility of taxes also goes up, and so does their correlation with consumption growth. This is because the government will need to use taxation more aggressively in bad times to restore budget balance. We observe a similar effect as in the inflating away debt scenario, in that CDS premiums increase despite the decline in default probabilities. This is because risk premium moves in the opposite direction.

These experiments illustrate some pitfalls associated with the notion of inflating or taxing away the government debt obligations. While these policies tend to have the desired effects for the first moments of debt, taxes and inflation, they come with endogenous movements in second moments. The movements are priced in our risk-sensitive framework and push CDS risk premiums in the opposite direction.

4.2.6 Shifting debt duration

In our baseline model, we represent monetary policy through a standard Taylor rule linking the short-term interest rate to inflation and output growth. In response to the financial crisis, the Federal Reserve has increasingly relied on non-standard monetary policy instruments. Under the label of quantitative easing, these measures effectively shift the average duration of outstanding Treasuries. Arguably, the use of these instruments has critically shaped Treasury markets in our sample. We now discuss our analysis of how shifts in debt duration affect default probabilities and CDS premiums, through the lens of our model.

In our quantitative experiments, we capture shifts in debt duration by variations in ω, that is, the weight on short versus long-term debt in the government's debt portfolio. To isolate duration shifts relative to changes in overall indebtedness, we adjust the coupon c on long-term bonds accordingly so as to keep overall debt $Q_t B_t$ constant. Table 8 reports the results.

Overall, we see that varying ω produces modest changes in average default probabilities and 5-year CDS premiums.

5 Conclusion

Premiums on US sovereign CDS rose to unprecedented levels during the financial crisis, and have remained elevated even after the crisis has subsided. Give the apparent size of these premiums, commentators have widely speculated whether they indeed reflect financial market expectations about an impending US default. After all, casual inspection suggests that the US government can always balance the budget by raising taxes or else, by inflating away the real value of debt. In this paper, we ask whether the likelihood of a fiscal default, namely a state when tax or inflation finance is no longer available, justify the size of the observed premiums.

To that end, we develop a tractable equilibrium model of the US economy with a representative agent featuring recursive preferences, in which monetary and fiscal policy jointly endogenously determine the dynamics of growth, debt, taxes and inflation. Fiscal default obtains when the economy approaches the slippery slope of the Laffer curve, where a further increase of the tax rate reduces tax revenue. Our equilibrium approach allows us to value CDS contracts reflecting risk-adjusted probabilities of fiscal default, thereby overcoming the challenge that standard replication arguments for CDS pricing fail in absence of an obvious risk-free benchmark.

We find that our model quantitatively generates premiums on 10-years CDS contracts in line with the US experience since the financial crisis. Annualized CDS premiums peak at around 150 basis points in the model. This is because high debt and default probability episodes endogenously correspond to high marginal utility states in the model, so that selling default insurance earns high risk premia. Importantly, CDS premiums raise persistently even in response to small blips in the likelihood of fiscal default, as investors with recursive preferences anticipate and dislike such states. Our model is thus consistent with the view that high CDS premiums reflect investors' rational forecasts of the likelihood of US fiscal stress.

Our results also cast some doubts on the notion that the government can restore budget balance by simply inflating or taxing away debt. In the context of our model, elevated mean inflation and taxes do come with a reduction of average debt, and default probabilities, but similarly they bring about endogenous movements in the second moments of these variables, both in volatilities and correlations. While our partial equilibrium model merely suggests that such policies can also lead to a raise in risk premia, in a richer general equilibrium framework, such movements would likely have welfare implications.

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Table 1
Calibration

Parameter	Description	Value
1. Preferences		
β	Subjective discount factor	0.985
ρ	IES=$(1-\rho)^{-1}$	1/3
α	RRA=$(1-\alpha)$	-9
2. Exogenous processes		
σ_c	Volatility of shocks to Δc	0.014
σ_x	Volatility of LLR process	$\sigma_c \times 0.044$
φ_x	Autocorrelation of LLR	0.936
σ_y	Volatility of shocks to Δy	0.022
φ_y	Elasticity output growth - taxes	-0.015
σ_g	Volatility of G	0.006
φ_g	Autocorrelation of G	0.980
3. Different Maturities and Default		
ω	Share of short term debt	0.2
λ	Repayment rate	0.04
c	Coupon payment	0.05
L	Losses in the default event	0.2
4. Policy parameters		
δ_0	Taylor rule intercept	0.01
δ_π	Inflation loading coefficient	2
δ_y	Output growth coefficients	0.35
σ_q	Monetary policy shock	0.01
ρ_0	Fiscal rule intercept	0.9
ρ_b	Debt loading coeffcient	0.96
ρ_x	Expected growth coeffcient	-0.21
σ_b	Fiscal rule shock	0.025

Table 2
Macroeconomic Moments

	Mean (data)	Std (data)	Mean (model)	Std (model)
Debt ($Q_t B_t$)	0.916	0.018	0.963	0.026
Expenditures (G_t)	0.239	0.027	0.354	0.032
Taxes ($\mathcal{T}_t$)	0.326	0.031	0.348	0.097
Annual Gross Inflation (Π_t)	1.022	0.023	1.027	0.041
Fiscal Limit (B_t^*)			1.320	0.096
P_t(default)			0.002	0.001

Notes. Explain the data sources

Table 3
Correlations

	$Q_t B_t$	$\mathcal{T}_t$	G_t	B_t^*	P_t(default)	$E_t(\Pi_{t+1})$	Δc_t
B_t	1						
$\mathcal{T}_t$	0.679	1					
G_t	0.789	0.928	1				
$Q_t B_t^*$	−0.913	−0.911	−0.944	1			
P_t(default)	0.934	0.942	0.952	−0.988	1		
$E_t(\Pi_{t+1})$	0.866	0.912	0.884	−0.402	0.940	1	
Δc_t	−0.253	−0.698	−0.472	0.326	−0.892	−0.492	1

Table 4
Term Structure

	Mean (real yields)	Mean (pseudo risk free)	Mean (yields)
1 year	1.34	3.82	4.01
2 years	1.31	3.98	4.17
3 years	1.28	4.27	4.52
4 years	1.25	4.53	4.77
5 years	1.21	4.69	5.06

Notes. Should we add yields in the data? Fix sample period for all empirical targets? 1, 3, 5, 10

Table 5
CDS Spreads

CDS	Mean (data) (1)	Mean (model) (2)	$L\cdot$Mean(P_t(default)) (3)
1 year	16.89	12.11	4.28
2 years	19.83	14.32	5.09
3 years	23.29	16.61	5.88
4 years	28.07	19.04	6.75
5 years	30.59	21.25	7.53
10 years	41.75	39.17	14.04

Notes. 1,3,5,10

Table 6
Monetary Policy and CDS Premiums

δ_π	Mean(Q_tB_t)	Mean$(P_t(\text{default}))$	Mean(CDS_5)	Mean(Π_t)	Std(Π_t)	Corr$(\pi_t, \Delta c_t)$
2	0.9634	0.0022	21	1.0268	0.0407	-0.152
1.75	0.8845	0.0018	24	1.0420	0.0492	-0.196
1.5	0.8142	0.0012	27	1.0611	0.0575	-0.228

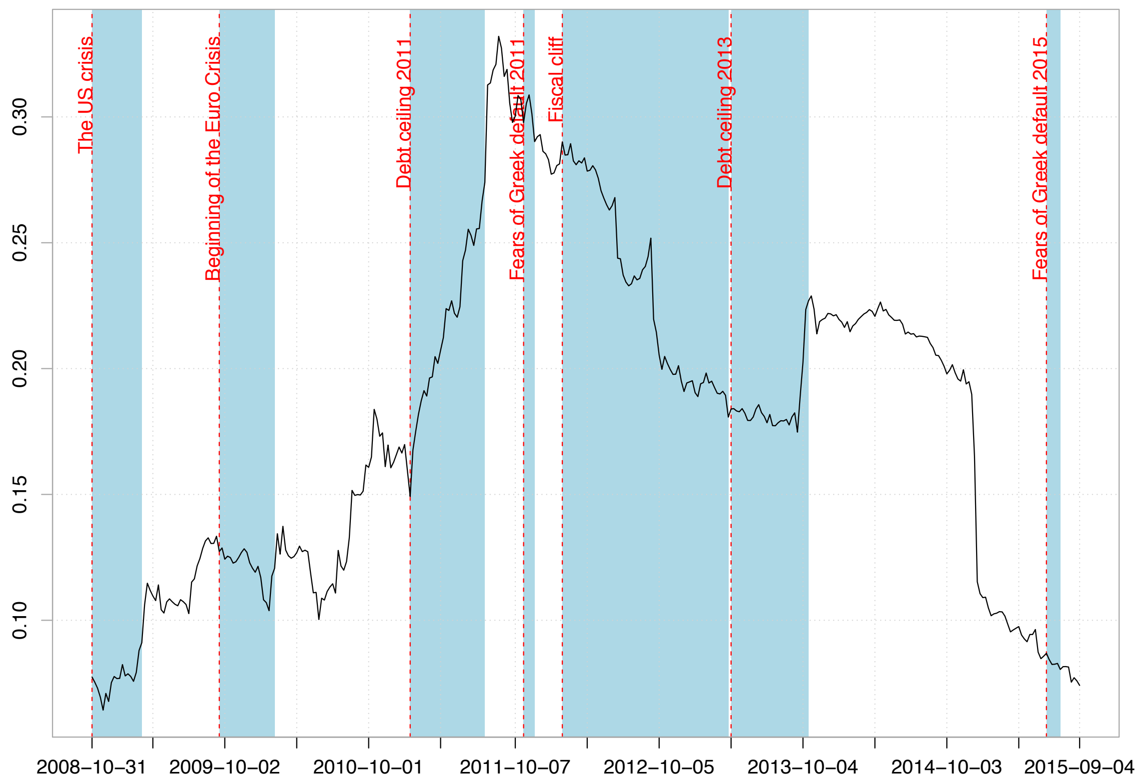
Table 7
Fiscal Policy and CDS Premiums

ρ_b	Mean (Q_tB_t)	Mean $(P_t(\text{default}))$	Mean (CDS_5)	Mean$(\mathcal{T}_t)$	Std$(\mathcal{T}_t)$	Corr$(\tau_t, \Delta c_t)$
0.96	0.9634	0.0022	21	0.3482	0.0970	-0.8044
0.94	0.9302	0.0019	23	0.3762	0.1292	-0.8517
0.92	0.8986	0.0015	26	0.4048	0.1631	-0.9128

Table 8
Debt Duration and CDS Premiums

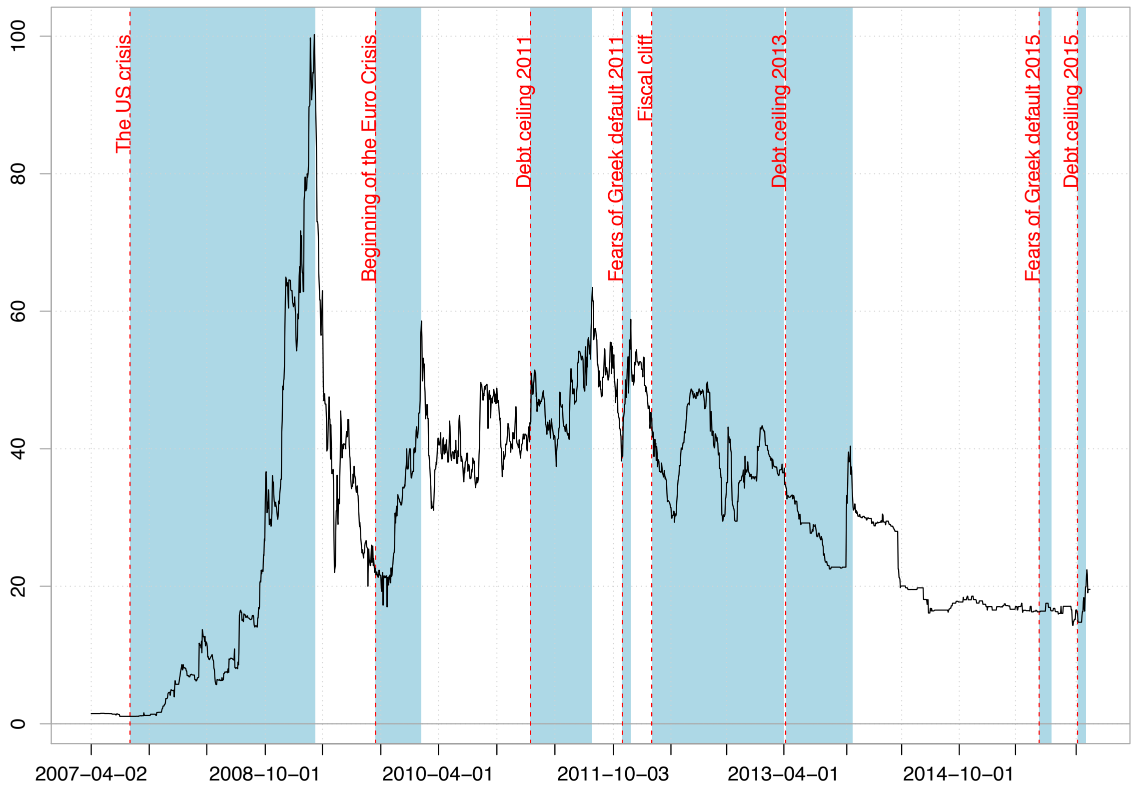
ω	Mean $(P_t(\text{default}))$	Mean (CDS_5)	Mean (B^*)	Std (B^*)
0.2	0.0026	27	1.2935	0.0922
0.4	0.0018	116	1.3368	0.0907
0.6	0.0022	21	1.3204	0.0963
0.8	0.0027	30	1.3082	0.0989

Figure 1
Liquidity of US CDS



Notes. We plot the time-series of liquidity of the US CDS market. CDS contracts on Italian government are the most actively traded sovereign contracts. For this reason, our liquidity measure is equal to the ratio of the weekly net notional amount of US CDS to that of Italian CDS. The time series is complemented by the highlights of major economic and political events.

Figure 2
History of US CDS premiums



Notes. We plot the time-series of premiums on five-year contracts from April 2007 to November 2015. The time series is complemented by the highlights of major economic and political events during that period. The premiums are expressed in basis points per year.

Figure 3
Impulse Responses I

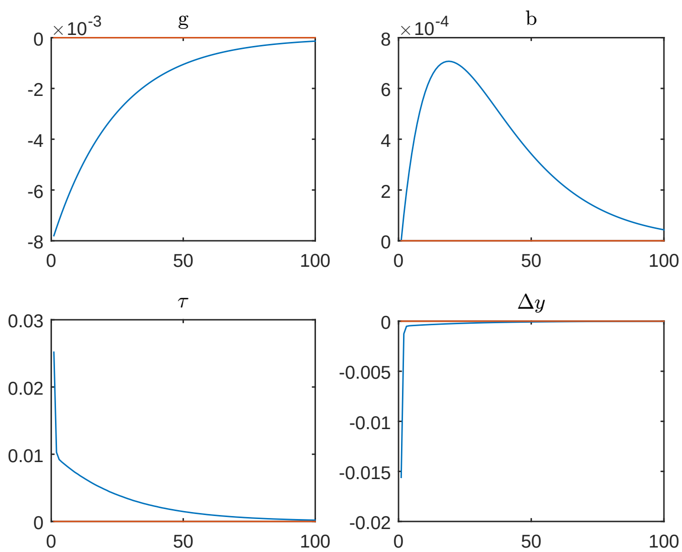
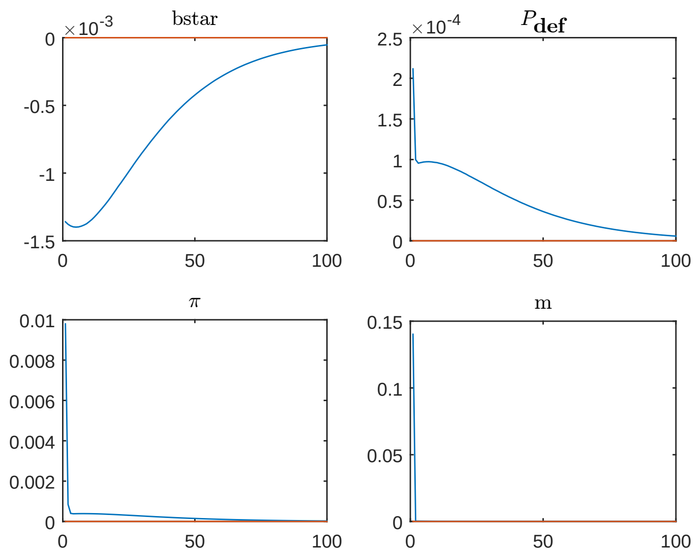

g
×10-3
0
-2
-4
-6
-8
0
50
100
b
×10-4
8
6
4
2
0
0
50
100
τ
0.03
0.02
0.01
0
0
50
100
Δy
0
-0.005
-0.01
-0.015
-0.02
0
50
100

Figure 4
Impulse Responses II


bstar
×10^-3
0
-0.5
-1
-1.5
0
50
100
$P_{\mathbf{def}}$
×10^-4
2.5
2
1.5
1
0.5
0
0
50
100
π
0.01
0.008
0.006
0.004
0.002
0
0
50
100
m
0.15
0.1
0.05
0
0
50
100