

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 an 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.

There are a lot of reasons to think that frictions may arise from various institutional features of the CDS markets, such as margin requirements, capital constraints, and credit event determination. Such frictions could be responsible for a part of the observed premium. We do not disagree with such a view. Rather than giving a full explanation of the observed premium, our objective is in establishing a quantitative benchmark for the compensation based on default risk.

These initial arguments prompt us to make a first step towards developing a formal macro-based framework that allows to evaluate likelihood and risk premium 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 the 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 in response to the decline in output growth leads to inflationary environment. In our setup, expected output growth declines after the government raises taxes in response to an elevated debt burden. The central bank actions are inflationary 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.

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 quantitative framework that relies on standard building blocks.

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 (2016) 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 debt 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 ([Easterly and Rebelo, 1993](#); [Mendoza and Tesar, 1998](#), for example), 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 bond auctions to determine the payments by the long party. They take place within 30 days after a credit event. The

auctions allow delivery of any bond of a defaulted company from a pre-specified list leading to the cheapest-to-deliver option. The value of this option should be small for corporate names because their bonds tend to trade at approximately the same price after a credit event (Chernov, Gorbenko, and Makarov, 2013).

The protocols have also 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 (EUR). 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 US dollars (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 EUR payments with the ones in USD. While less liquid, the USD denominated contracts started trading in August 2010 to mitigate this issue.

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 the 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-à-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 the anxieties regarding the European credit crisis and the US fiscal uncertainty. So, clearly the contract is not the most liquid one, but nonetheless has a considerable 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 levels seen during the Lehman default 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.

The difference between the EUR and USD contracts in the overlapping period since August 2010 offers a sense how large the foreign exchange premium can be. It averages at 8 bps for the five-year contract with a standard deviation of 4 bps.

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.

Regulatory requirements embodied by the Basel III accord might be responsible for some of the movements in the CDS premium in the latter part of our sample. Dealers are allowed to buy protection against sovereign default to reduce a capital charge associated with their counterparty risk exposure. As pointed out by Klingler and Lando (2015), a sovereign protection seller would require a positive CDS premium even if the sovereign is riskless because of capital constraints. Anecdotally, some dealers started implementing the rule voluntarily in 2013. Klingler and Lando (2015) empirically attribute a fraction of CDS premiums to this effect in their sample from 2010 to 2014.

There could be non-credit-related risks that our model does not account for, but are potentially responsible for the US CDS premium. First, because “standard” contracts are denominated in EUR, 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. This risk may be ignored by explicit focus on modelling of

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

the USD denominated contracts. Second, the contracts may command liquidity premium because they are not the most actively traded ones. Third, the Basel III capital charge rule may impact the magnitude of the premium even if there is absolutely no credit risk. Fourth, 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 the bond auction with a cheapest-to-deliver option.

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.

As we pointed out earlier, 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 pricing kernel, which we derive from the global investor's preferences and her aggregate consumption process. Next, we describe the 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 the representative agent with recursive preferences:

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

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

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

Our economy is cashless and we use money as a unit of account only. Correspondingly, 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. 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 γ 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 perpetual 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 $1/\lambda$.

In the absence of default, the properties of debt and taxes are connected via the government budget constraint (GBC):

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

The GBC requires that government expenditures $G_t Y_t$ and due payments on long and short term debt (coupon payments and amortization) $(\gamma + \lambda)N_{t-1}^\ell/P_t + N_{t-1}^s/P_t$ 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 implies the tax rate:

$$\mathcal{T}_t = G_t - Q_t B_t + CF_t B_{t-1} \Pi_t^{-1} (Y_t/Y_{t-1})^{-1},$$

where $Q_t \equiv \omega Q_t^s + (1-\omega)Q_t^\ell$ is the market value of one unit of debt-to-GDP ratio, and $CF_t \equiv \omega + (1-\omega)(\gamma + \lambda + (1-\lambda)Q_t^\ell)$ is the promised cash flow per one unit of debt.

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; Schmitt-Grohe and Uribe, 2007). In particular, it is shown by Schmitt-Grohe and Uribe (2007) that, in a rich New Keynesian dynamic stochastic general equilibrium model, policy rules of this sort lead to welfare levels that are quantitatively indistinguishable from those stemming from optimal Ramsey policies, in which fiscal and monetary policies are designed to maximize welfare.

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 with fully flexible pricing mechanisms, 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 Fiscal default

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.

To capture this Laffer-curve intuition, we introduce two notions of expected surplus. One is the present value of tax receipts minus the expenditures:

$$S_t = E_t \sum_{j=1}^{\infty} M_{t,t+j} (\mathcal{T}_{t+j} - G_{t+j}) Y_{t+j} / Y_t. \quad (3.2)$$

Note that S_t coincides with the market value of debt, $Q_t B_t$, only if there is no default. The second one is expected sustainable surplus. It corresponds to the maximal tax rate, \mathcal{T}_t^* , that is feasible without lowering tax revenues:

$$S_t^* = E_t \sum_{j=1}^{\infty} M_{t,t+j} (\mathcal{T}_{t+j} \wedge \mathcal{T}_t^* - G_{t+j}) Y_{t+j}^* / Y_t^*,$$

and \mathcal{T}_t^* solves $S_t = S_t^*$. The notation Y_t^* highlights the different dynamics of output if the tax rate changes from the one prescribed by the GBC. If $\mathcal{T}_t > \mathcal{T}_t^*$ then the shrinking tax base would decrease the surplus.

These equations capture the idea that if \mathcal{T}_t becomes greater than \mathcal{T}_t^* then the current government policies will not be sustainable. So, the government should either adjust one of its policies, or default. We assume that the government is committed to its expenditures, monetary and debt management rules. Expenditures reflect, to a large extent, various entitlement programs that are hard to renegotiate. We do not allow changes in the policy rules intentionally so that we could highlight the default channel of CDS premiums. In practice, many changes may take place in an extreme fiscal situation, but our framework is too simple to account for all the contingencies.

Default can happen for two reasons. If the government raises \mathcal{T}_t above \mathcal{T}_t^* in order to satisfy the GBC, then, we assume, it will not be able to roll over its debt as investors will know

that the Laffer limit is violated. In this case, the GBC will feature only tax receipts and expenditures, and, in principle, the government could keep running like this until \mathcal{T}_t reaches 100%. To streamline the model, we assume that the government defaults in the period when it can no longer access the bond market. Alternatively, the government could apply \mathcal{T}_t^* as its tax rate, but then it would violate the GBC immediately. This would lead to a default again.

3.4 Defaultable securities

Denote default time by

$$t^D = \min\{t : \tau_t^* \leq \tau_t\},$$

and probability of default by P_t^D . So default will take place at time $t+1$ if $t^D = t+1$. Given the definition of the one-period ahead default probability, one can value the short-term bond:

$$Q_t^s = E_t \left(M_{t,t+1}^{\$} \left[(1 - \mathbf{1}_{\{t^D=t+1\}}) + (1 - L)\mathbf{1}_{\{t^D=t+1\}} \right] \right), \quad (3.3)$$

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:

$$Q_t^\ell = E_t \left(M_{t,t+1}^{\$} \left[(\gamma + \lambda + (1 - \lambda)Q_{t+1}^\ell)(1 - \mathbf{1}_{\{t^D=t+1\}}) + (1 - L)\mathbf{1}_{\{t^D=t+1\}} \right] \right).$$

CDS contract has two legs. The premium leg pays the CDS premium CDS_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 $CDS_t^T \times E_t(M_{t,t+j}^{\$} \mathbf{1}_{\{t+j < t^D\}})$. As a result the value of the premium leg is equal to

$$\text{Premium}_t^T = CDS_t^T \cdot \sum_{j=1}^T E_t M_{t,t+j}^{\$} \mathbf{1}_{\{t+j < t^D\}}.$$

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,

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

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

Importantly, CDS premiums depend on the joint behavior of the nominal pricing kernel and default probabilities. While we specify the process for the real pricing kernel 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.

3.5 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 four 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 GBC. Third, we describe the default condition that is based on the Laffer-curve argument. Finally, 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 four reflect a standard structure familiar from the literature on long-run risks following [Bansal and Yaron \(2004\)](#), our setup adds a specification of the government's and the central bank's policy instruments and default event. 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 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. Because our data on CDS spreads cover a relatively short and recent time period, we focus on a similar sample to construct the empirical counterparts for the macroeconomic moments. Specifically, we use the period from 2000 to 2014. 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 of substitution 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 autoregressive process to the GDP-government expenditures ratio 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. Intuitively, we would expect a raise in taxation to be bad news for trend growth. By setting $\varphi_y = -0.024$, 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 ([U.S., 2010](#)). 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 examine sensitivity with respect to this choice. 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. [Appendix A](#) outlines the procedure.

We start by discussing the macroeconomic implications of the model. Taking these as a benchmark, we 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 market value of debt to GDP ratio in the model is about 0.92, which is within one standard error of the one in the data. 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 debt limit is in the range of a 120-165 percent debt-to-GDP ratio. These numbers are well within the range of the CBO long-term debt projections ([CBO, 2016](#)). The corresponding tax limit is in the range of 70-97 percent. These are large numbers as compared to the average current tax rate. Yet the low bound is not far from that of

Trabandt and Uhlig (2011). Moreover, we would expect debt and tax limits to fall in downturns. We will confirm this intuition via correlations shortly.

The estimated distribution of tax limit determines fiscal default probabilities in the model. Our benchmark calibration yields a one-year ahead default probability in the range of 0 to 0.4%. As one external validation of this magnitudes, a Moody's report, Tempelman (2011), estimates this probability at 0.05%. We will later explore to what extent such a default probability can account for observed CDS premiums.

4.2.2 Inspecting the mechanism

To dissect the main economic mechanism underlying our quantitative results, we find it useful to inspect the response of our economy to a negative one-standard deviation shock to the long-run trend, x_t . In our model, innovations to variables other than policy shocks are perfectly correlated as is the case in a general equilibrium environment. Thus, behavior of the variables will be driven by the properties of the long-run trend. Figure 3 illustrates the comovement of all our variables. The same patterns are also reflected in the unconditional correlations reported in Table 3.

A negative shock to the long-run consumption trend triggers a raise in government expenditures. This is consistent with the countercyclicality of government expenditures. Naturally, these expenditures give rise to financing needs. Our fiscal policy rule then requires that they are partially financed by the government issuing debt. It is by the virtue of the fiscal rule that government debt is realistically countercyclical. However, the GBC requires budget balance, so that elevated expenditures also lead to a rise in the tax rates. Our specification of the fiscal block of the model thus is consistent with countercyclical fiscal policies.

Let us now examine how fiscal and monetary policy interact in our model. First, given our specification of the process governing output growth, a higher tax rate depresses expected output growth. As a result, an accommodative central bank tries to stimulate the economy in response by lowering the nominal short-rate, thereby creating inflation. This is because it adheres to the Taylor rule. As a result, inflation goes up in response to a negative shock, generating countercyclical inflation.

While inflation displays substantial short-run volatility, it also exhibits a small, persistent component. This reflects the central bank's response to long-lasting bad news about output growth induced by a persistent rise in taxes. This small persistent component is important for generating realistic nominal term structure in the model. This is because endogenous long-run inflation risk generates negative correlation between expected inflation and consumption growth implying a substantial inflation risk premium.

Since the tax base shrinks upon a rise in taxes, and government expenditures increase persistently, the fiscal limit (maximal sustainable tax rate) declines, and default probabilities

rise. Note that this rise in default probabilities coincides with an upward jump in the stochastic discount factor, or marginal utility. In other words, in our model episodes with high default probabilities and thus high potential losses endogenously coincide with high marginal utility times. To bear the risk of such losses, agents in our model thus require a credit risk premium to hold defaultable securities. It is this credit risk premium that allows our model to generate non-trivial CDS spreads.

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 model offers such an approach.

The pricing kernel 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 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 pricing kernel and accounting for a possibility of default similar to expression (3.3).

Table 4 summarizes three yield curves inferred from our calibrated model. First, we show the term structure of risk-free yields, corresponding to expectations of the equilibrium *real* pricing kernel 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* pricing kernel. 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 pricing kernel accounting for government default probabilities at various horizons, that is, the term structure of *default probabilities*.

The term structure of real risk-free yields is mildly downward sloping, which is consistent with the long-run risk paradigm. 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. Thus, 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. The first three columns report various versions of the data depending on the contract denomination (EUR in (1) and (2), and USD in (3)), and sample (2007-2016 in (1), and 2010-2016 in (2) and (3)). Main differences in averages are driven by the currency of the contract denomination rather than the sample.

The model-based averages are reported in column (4). Overall, we see that the model delivers an upward sloping term structure of CDS premiums with magnitudes that are consistent with the data. They are particularly close to the USD denominated numbers. This is natural as our model ignores currency risk. 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 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 (5) 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 (4) to the ones in column (5) reflects the magnitude of the aforementioned default premium. This ratio is approximately equal to 3 across all maturities. The default premium is so 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 a potential effect of such scenarios through the lens of our model. We 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 variation in the policies using counterfactual analysis. Table 6 reports results for the monetary policy. 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 rise. This happens because increase in mean inflation is accompanied by increase in its volatility. Larger shocks to inflation make the fiscal limit more

volatile, and therefore it can fall more relative to its mean as highlighted in Figure 3. This decrease in the fiscal limit is accompanied by an increase in default probability even though its mean declines. As result, the risk premium amplification mechanism that we highlighted in the previous section delivers larger risk premiums despite the decline in expected losses.

We obtain a similar result 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, again according to Figure 3, fiscal limit declines relative to its mean. As a result, the same mechanism is at play.

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. These 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 (QE), 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 λ , that is, the amortization rate of long-term debt in the government’s debt portfolio. Greenwood, Hanson, Rudolph, and Summers (2014) emphasize that the Fed’s QE activities were offset by the Treasury’s maturity extension program. As a result, maturity of the consolidated balance sheet of the two entities has experienced relatively small change. Our model is silent about the different roles of the two entities, so our experiments with varying effective maturity of debt apply to the joint implication of the Fed’s QE policy and the Treasury’s debt management.

Table 8 reports the results. Increasing λ effectively corresponds to a shortening of debt duration. We see that in our model such shifts come with elevated default probabilities, and hence CDS spreads. The last columns give a sense of the mechanism at work, in that shortening debt duration is accompanied with increases in the volatility of taxes and the volatility of market debt value. This is consistent with the notion of elevated rollover risk. When λ goes up, the fiscal rule dictates that the government has to refinance, or roll over, a larger fraction of debt in episodes with depressed long run growth prospects. Intuitively,

refinancing thus occurs when bond prices fall and expenditures are high, so that tax rates have to increase relatively more to restore budget balance. Clearly, more pronounced tax raises only exacerbate default probabilities, as reaching the tax limit is more likely.

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. Given 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-based finance is no longer available, justify the size of the observed premiums.

To that end, we develop an 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 the risk-free benchmark.

We find that our model quantitatively generates premiums on CDS contracts in line with the US experience since the financial crisis. Annualized CDS premiums peak at around 100 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 shocks to 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 a doubt 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, such movements would likely have welfare implications in a richer general equilibrium framework.

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A Computational Procedure

The model is summarized by a system of expectational difference equations. Solving for the endogenous variables in the system is complicated by (i) the nonlinearities induced by the pricing kernel and the possibility of default and (ii) the endogeneity of the default boundary τ^* , which depends on present values of endogenous variables. We deal with (i) by adopting a global, nonlinear solution method based on projection techniques, and with (ii) by implementing an iterative algorithm based on Monte Carlo methods.

Our solution strategy to deal with (i) is to approximate the endogenous variables π_t , q_t^s and q_t^l with flexible Chebyshev polynomials in the state variables $\varsigma_t = \{\tau_{t-1}, b_{t-1}, g_{t-1}, x_{t-1}, \varepsilon_t, \xi_t^b, \xi_t^q\}$. This amounts to solving for the coefficients of these polynomials that satisfy the model equations at specific points, namely the Chebyshev nodes. To find those, we choose bounds on the state variables and map those linearly into $[-1, 1]$, the domain of the Chebyshev polynomials. The bounds on the persistent stochastic variables x_t and g_t come from the [Tauchen \(1986\)](#) procedure to approximate an AR(1) process. Finding the coefficients of the Chebyshev polynomials at the relevant nodes thus translates into solving a nonlinear system of equations. To aid convergence, we start with lower order polynomials and successively increase the number of nodes.

To find the default boundary, we proceed as follows. For some initial default boundary $\tau_t^{*(0)} \equiv \tau^{*(0)}(\varsigma_t)$, we obtain the corresponding bond prices and inflation $q_t^{s,(0)}$, $q_t^{l,(0)}$ and $\pi_t^{(0)}$ using the Chebyshev collocation method described above. With these solutions at hand, we evaluate the expected sustainable (log) surplus s_t^* in any state ς_t via Monte Carlo simulations. Starting from any state ς_t , we simulate the model forward for T periods to obtain s_t^* and an updated $\tau_t^{*(1)}$ for that state. Note that this $\tau^{*(1)}(\varsigma_t)$ depends on the endogenous variables $q_t^{s,(0)}$, $q_t^{l,(0)}$ and $\pi_t^{(0)}$, which were obtained as functions of the initial default boundary $\tau_t^{*(0)}$. We choose T sufficiently large to accommodate the persistence of the underlying processes.

Our algorithm then iterates back and forth between the projection step and the simulation step. More precisely, starting from any $\tau_t^{*(j)}$, we obtain an updated default boundary $\tau_t^{*(j+0.5)}$ by solving the model with projection and simulating it forward. Our aim is to iterate that procedure to convergence, so that $\max_{\varsigma_t} \|\tau^{*(j)}(\varsigma_t) - \tau^{*(j+0.5)}(\varsigma_t)\| < \bar{\varepsilon}$. To facilitate convergence, we implement a relaxation scheme by introducing $\tau^{*(j+1)}(\varsigma_t) = (1 - \zeta)\tau^{*(j)}(\varsigma_t) + \zeta\tau^{*(j+0.5)}(\varsigma_t)$, where ζ is a relaxation parameter. The convergence criterion becomes $\max_{\varsigma_t} \|\tau^{*(j)}(\varsigma_t) - \tau^{*(j+1)}(\varsigma_t)\| < \bar{\varepsilon}$. We also check that bond prices and inflation stabilize in the iterative process.

With the default boundary τ_t^* at hand, it is straightforward to evaluate the CDS premiums CDS_t^T on the grids. Our model statistics are computed from 100 simulations of 15 years of data, to be consistent with our empirical targets.

Table 1
Calibration

Parameter	Description	Value
<i>1. Preferences</i>		
β	Subjective discount factor	0.997
ρ	IES= $(1 - \rho)^{-1}$	1/3
α	RRA= $(1 - \alpha)$	-9
<i>2. Exogenous processes</i>		
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	-0.024
σ_g	Volatility of G	0.075
φ_g	Autocorrelation of G	0.990
<i>3. Different Maturities and Default</i>		
ω	Share of short term debt	0.200
λ	Repayment rate	0.040
γ	Coupon payment	0.050
L	Losses in the default event	0.200
<i>4. Policy parameters</i>		
δ_π	Inflation loading coefficient	1.500
δ_y	Output growth coefficients	0.500
σ_q	Monetary policy shock	0.003
ρ_b	Debt loading coefficient	0.960
ρ_x	Expected growth coefficient	-0.220
σ_b	Fiscal rule shock	0.008

Notes. Section 4.1 describes the calibration.

Table 2
Macroeconomic Moments

	Data		Model	
	Mean	Std	Mean	Std
Market value of debt ($Q_t B_t$)	0.916	0.086	0.903	0.112
Taxes (\mathcal{T}_t)	0.326	0.031	0.354	0.124
Annual gross inflation (Π_t)	1.011	0.012	1.012	0.027
Debt limit (S_t^*)			1.414	0.119
Tax limit (\mathcal{T}_t^*)			0.829	0.068
Default probability (P_t^D)			0.002	0.001

Notes. This table reports basic macro moments. The empirical moments come from the BEA quarterly data and cover the sample period 2000 Q1 to 2016 Q2. All moments are annualized. To compute theoretical moments we simulate the data at quarterly frequency 100 times for 15 years and average across simulations.

Table 3
Correlations

	$\log(Q_t B_t)$	τ_t	g_t	s_t^*	τ_t^*	$\log P_t^D$	$\log E_t(\Pi_{t+1})$
Δc_t	-0.305	-0.680	-0.509	0.493	0.627	-0.904	-0.478

Notes. This table reports correlations between main variables in our model. We simulate the data at quarterly frequency 100 times for 15 years and average across simulations.

Table 4
Term Structure

Maturity, years	Model			Data
	Real yields	Pseudo risk-free yields	Yields	Yields
1	0.52	1.90	2.09	2.01
3	0.46	2.27	2.48	2.53
5	0.38	2.59	2.83	3.03
10	0.21	3.41	3.68	3.76

Notes. This table reports annualized mean yields across horizons of various fixed income instruments in the model and the data. The empirical moments correspond to US nominal treasury bonds in the sample between 2000 Q1 and 2016 Q2. We simulate the data at quarterly frequency 100 times for 15 years and average across simulations.

Table 5
CDS Spreads

Maturity, years	Data € (1)	Data € (2)	Data \$ (3)	Model (4)	$L\cdot\text{Mean}(P_t^D)$ (5)
1	16.13	15.61	13.29	11.42	3.97
3	22.18	21.66	17.32	15.94	5.62
5	29.34	31.29	23.11	20.72	7.30
10	40.79	46.86	34.92	33.91	12.16

Notes. This table reports annualized mean CDS premiums across maturities in the data and the model. Column (1) displays EUR denominated contracts from 2007 Q2 to 2016 Q2. Column (3) displays USD denominated contracts from 2010 Q3 to 2106 Q2. Column (2) shows EUR denominated contracts for the same sample as the USD denominated ones. Column (4) shows the theoretical premiums. The table also reports theoretical expected losses on the government debt portfolio in column (5). We simulate the data at quarterly frequency 100 times for 15 years and average across simulations.

Table 6
Monetary Policy and CDS Premiums

δ_π	$Q_t B_t$	Mean		Π_t	Std
		P_t^D	CDS_5		Π_t
1.50	0.9034	0.0024	21	1.0123	0.0274
1.35	0.8829	0.0022	23	1.0181	0.0315
1.20	0.8538	0.0019	24	1.0236	0.0382

Notes. This table reports theoretical moments corresponding to various magnitudes of monetary policy response to inflation, δ_π . Means and standard deviations are annualized. We simulate the data at quarterly frequency 100 times for 15 years and average across simulations.

Table 7
Fiscal Policy and CDS Premiums

ρ_b	$Q_t B_t$	Mean		\mathcal{T}_t	Std
		P_t^D	$CDS_t(5)$		\mathcal{T}_t
0.96	0.9034	0.0024	21	0.3540	0.1237
0.94	0.8729	0.0021	23	0.3817	0.1365
0.92	0.8515	0.0019	25	0.4022	0.1443

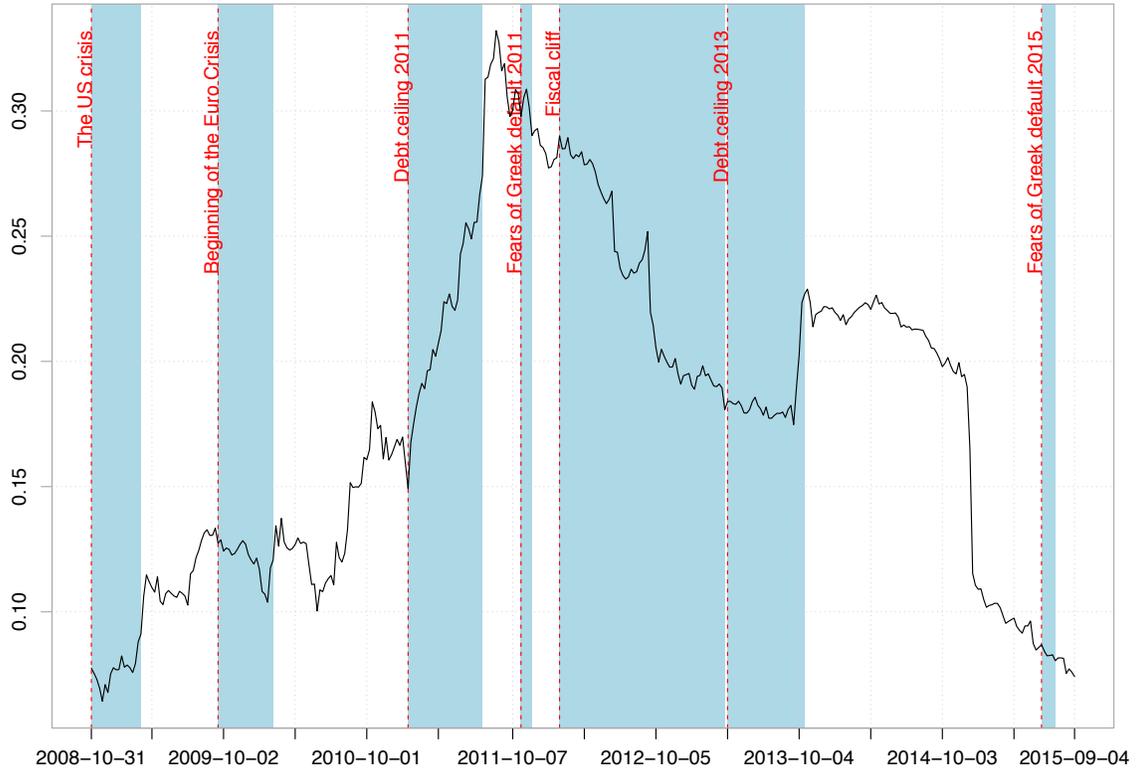
Notes. This table reports theoretical moments corresponding to various magnitudes of fiscal policy response to debt, ρ_b . Means and standard deviations are annualized. We simulate the data at quarterly frequency 100 times for 15 years and average across simulations.

Table 8
Debt Duration and CDS Premiums

λ	Mean		Std	
	P_t^D	$CDS_t(5)$	\mathcal{T}_t	$Q_t B_t$
0.01	0.0021	18	0.1190	0.1081
0.04	0.0024	21	0.1237	0.1124
0.16	0.0032	27	0.1436	0.1317

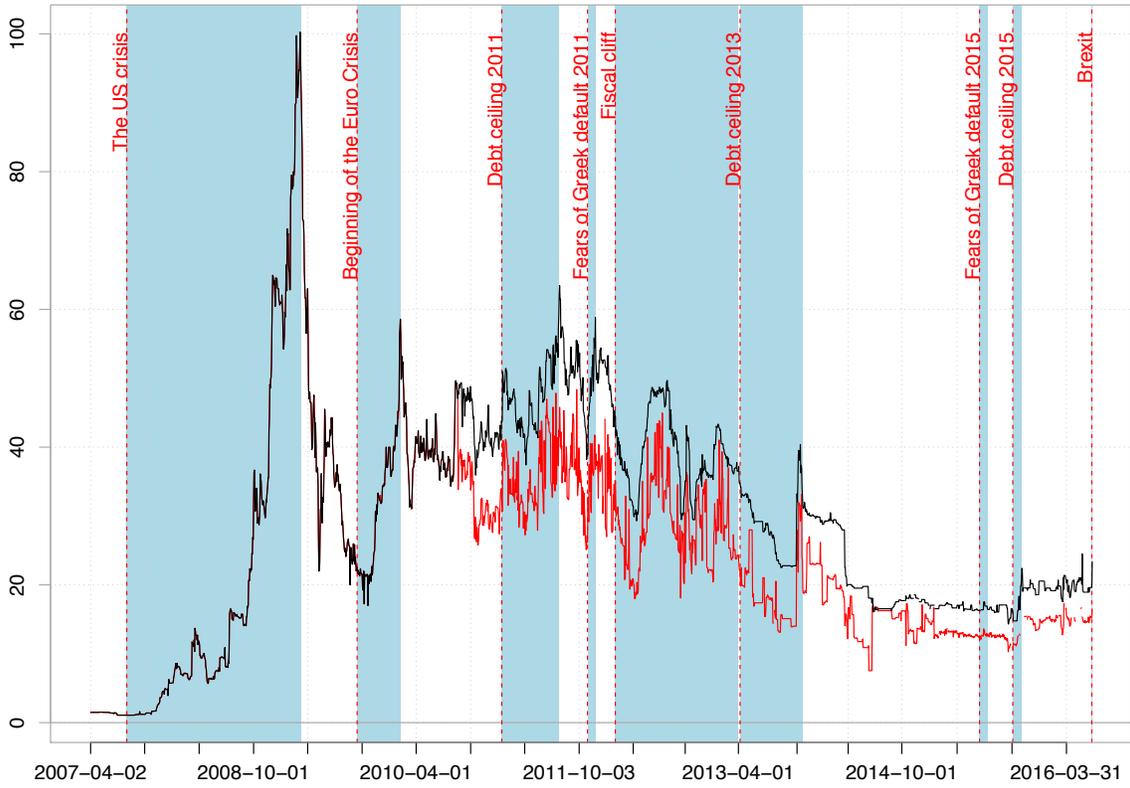
Notes. This table reports theoretical moments corresponding to various magnitudes of the amortization rate of long-term debt, λ . Means and standard deviations are annualized. We simulate the data at quarterly frequency 100 times for 15 years and average across simulations.

Figure 1
Liquidity of US CDS



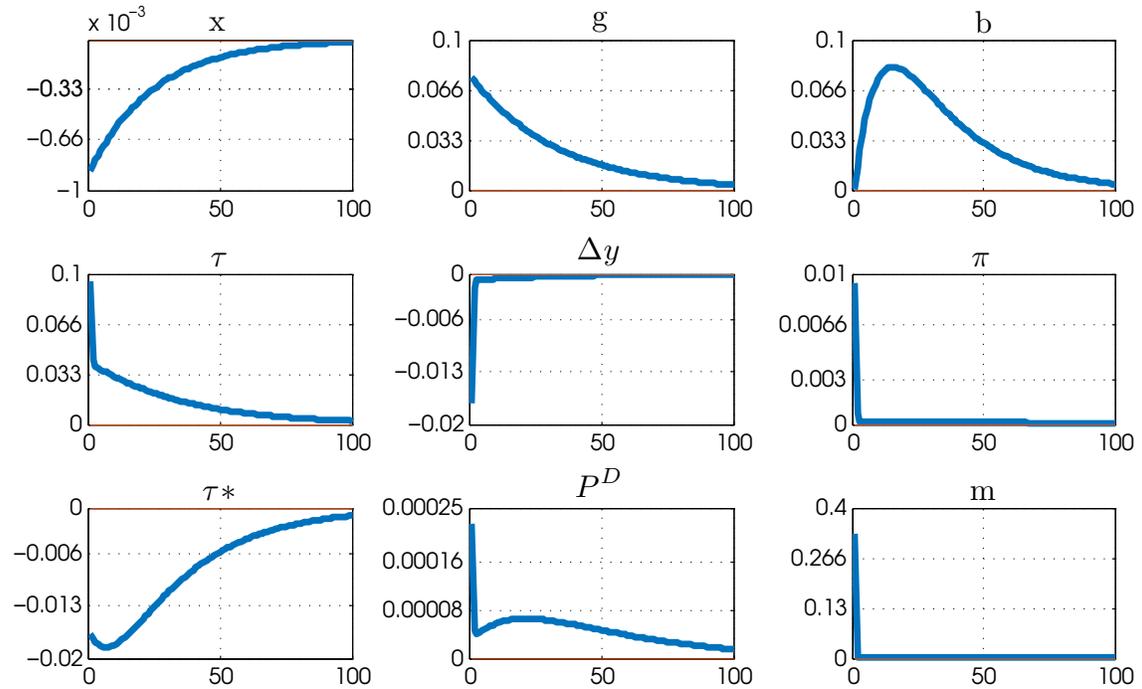
Notes. We plot the time-series of liquidity of the US CDS market. CDS contracts on Italian government are the most actively traded sovereign contracts. For this reason, our liquidity measure is equal to the ratio of the weekly net notional amount of US CDS to that of Italian CDS. The time series is complemented 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. The dark line represents quotes in EUR from April 2007 to June 2016, and the light one is in USD from August 2010 to June 2016. The time series are 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



Notes. We plot the responses of model variables to a one standard deviation negative innovation ε_t to the long-run consumption trend, over 100 quarters. The responses are reported in decimal deviations from the variables means.