Safe Haven CDS Premiums

Klingler, Sven; Lando, David

Document Version
Final published version

Published in:
Review of Financial Studies

DOI:
10.1093/rfs/hhy021

Publication date:
2018

Citation for published version (APA):
Klingler, S., & Lando, D. (2018). Safe Haven CDS Premiums. *Review of Financial Studies*, *31*(5), 1855-1895. https://doi.org/10.1093/rfs/hhy021

Safe Haven CDS Premiums

Sven Klingler
BI Norwegian Business School

David Lando
Copenhagen Business School, CEPR

Credit default swaps can be used to lower the capital requirements of dealer banks entering into uncollateralized derivatives positions with sovereigns. We show in a model that the regulatory incentive to obtain capital relief makes CDS contracts valuable to dealer banks and empirically that, consistent with the use of CDS for regulatory purposes, there is a disconnect between changes in bond yield spreads and in CDS premiums, especially for safe sovereigns. Additional empirical tests related to the volume of contracts outstanding, effects of regulatory proxies, and the corporate bond and CDS markets support that CDS contracts are used for capital relief. (*JEL* G12, G13, G15, G21, G28)

Received September 28, 2016; editorial decision January 26, 2018 by Editor Itay Goldstein. Authors have furnished an Internet Appendix, which is available on the Oxford University Press Web site next to the link to the final published paper online.

We argue in this paper that the level of sovereign CDS premiums and the notional amounts outstanding are significantly influenced by financial regulation. We focus mainly on sovereign CDS markets because the regulatory setting here is particularly well suited for our purpose. Derivatives-dealing banks engage in over-the-counter (OTC) derivatives, such as interest rate swaps, with sovereigns. Most sovereigns do not post collateral in these transactions and this leaves the dealer banks exposed to counterparty-credit risk. We explain how this risk—through a so-called "credit value adjustment (CVA)"—adds to the dealer banks' risk-weighted assets (RWAs) and hence to their capital requirements. This is true even when the sovereign is safe, because counterparty

---

We are grateful to the editor (Itay Goldstein) and two anonymous referees for their helpful feedback and suggestions. We also thank Patrick Augustin, Nicolae Gârleanu, Jesper Lund, Allan Mortensen, Martin Oehmke, Lasse Pedersen, Stephen Schaefer, Martin Scheicher, Suresh Sundaresan, Matti Suominen, Davide Tomio, and Guillaume Vuillemey and participants in Advanced Topics in Asset Pricing at Columbia University, Annual Meeting of the German Finance Association (2014), Arne Ryde Workshop, Aarhus Business School, Banco Portugal, Danmarks Nationalbank, EPFL, ESSEC, European Finance Association (2015), The Federal Reserve Bank of New York, Imperial College, and American Finance Association (2016) for helpful comments. Pia Mølgaard assisted us with the corporate bond and CDS data. Support from the Center for Financial Frictions (FRIC) [grant no. DNRF102] is gratefully acknowledged. David Lando is a member of the board of the Danish Financial Supervisory Authority and both authors have no conflicts of interest. Supplementary data can be found on *The Review of Financial Studies* Web site. Send correspondence to Sven Klingler, BI Norwegian Business School, Nydalsveien 37, 0442 Oslo, Norway; telephone +47 4641 0000. E-mail: sven.klingler@bi.no

doi:10.1093/rfs/hhy021 Advance Access publication March 2, 2018

risk for regulatory purposes is quantified using CDS premiums. As long as there is some credit risk and therefore a nonzero CDS premium, however small, dealer banks have an incentive to buy CDS protection to obtain capital relief. The value of capital relief may dominate the value of the default protection, and this effect is visible especially for safe sovereigns. The higher CDS premium is also needed to induce sellers to offer default protection, even on an almost risk-free entity, because the seller of the CDS must provide initial margin, and there is an opportunity cost of providing this margin. The end result is an equilibrium in which the CDS premium is significantly higher than what can be explained by credit risk alone.

We explain the mechanism in a simple one-period model with two agents: The first agent is a derivatives-dealing bank who holds a legacy position in an interest rate swap with a sovereign which adds to the bank's capital requirement. The dealer bank can buy CDS protection from the second agent who is an end user of derivatives with no previous exposure to the sovereign. The end user allocates his risky investment between the risky asset and selling CDS protection. Our model shows how CDS premiums depend on margin requirements for the seller and the buyer of CDS protection, capital requirements of the dealer bank and limits on leveraged investment in the risky asset. Guided by the model, we present a variety of empirical tests documenting that CDS contracts serve a regulatory purpose and that this is particularly visible for safe reference entities.

First, we investigate the link between derivatives positions of banks with sovereign counterparties and the net notional amounts of sovereign CDS outstanding. As a first reality check, we confirm that derivatives dealers are net buyers of sovereign CDS, and that the level and volatility of CDS premiums can justify purchasing protection on safe sovereigns for regulatory purposes. Our estimates of the CDS notional amount that can potentially be explained by the Basel III CVA capital charges can account for more than 50% of the total sovereign CDS volume outstanding, a number that is in line with estimates found in industry research letters. Passing these reality checks, we turn to information on bank derivative exposures toward sovereigns from EBA bank stress tests, which we use as a proxy for banks' so-called "expected exposure" (EE) toward sovereigns. In line with our hypothesis, we find a significant relationship between these exposures and CDS amounts outstanding.

Second, changes in bond yield spreads and changes in CDS premiums are almost unrelated for safe sovereigns. A central prediction of our model is that the regulatory component of CDS premiums is relatively larger for safe sovereigns than for less safe sovereigns. Figure 1 shows that regressing changes in bond yields on changes in the riskless rate (proxied by overnight swap rates) and changes in CDS premiums reveals a clear pattern in which the CDS premium explains a larger part of bond yields the riskier the sovereign becomes. For Germany, Japan, and the United States CDS premiums are not a significant explanatory variable for bond yields. For Great Britain the CDS premium is significant, but only at a 10% level. For the three risky European sovereigns

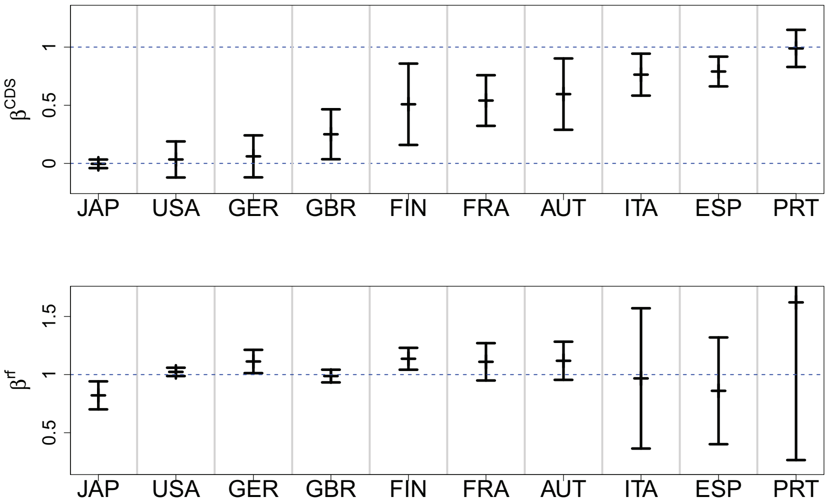


Figure 1
Explaining bond yields with risk-free rates and credit risk
The figure shows the parameter estimates and 95% confidence interval for β^{CDS} in panel A and for β^{rf} in panel B for ten different sovereigns, from the following regression:

$$\Delta Yield_t = \alpha + \beta^{CDS} \Delta CDS_t + \beta^{rf} \Delta rf_t + \varepsilon_t.$$

The ten countries are sorted by β^{CDS} from lowest to highest. $Yield_t$ denotes the 5-year bond yield; rf_t denotes the risk-free rate proxy; measured by swap rates based on overnight lending rates in the respective currency, and CDS_t is the 5-year CDS premium. The confidence intervals are computed based on heteroscedasticity-robust standard errors. All confidence intervals are symmetric around the estimate, allowing the reader to infer upper bounds. The Internet Appendix provides a table with more detailed regression results.

(Italy, Portugal, and Spain) in our core sample consisting of ten sovereigns, the regression coefficient on the CDS premium is close to one. We perform robustness checks to rule out other potential explanations for this disconnect such as the convenience benefits of safe assets and the cheapest-to-deliver option embedded in sovereign CDS. We also extend our core sample of ten sovereigns to a larger cross-section and show that our results hold for that extended cross-section as well.

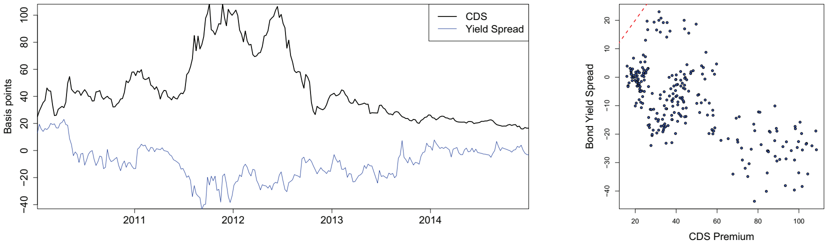
Third, we use a set of explanatory variables that proxy for the size of the bank's capital requirements arising from its derivatives exposure to sovereigns and the extent to which a bank is capital constrained. We label these variables "regulatory proxies" and find that for the safe haven sovereigns Germany, the United Kingdom, Japan, and the United States, these regulatory proxies can explain up to 29% of the variation in CDS premiums and are statistically significant. Even for the low-risk sovereigns Austria, Finland, and France, our regulatory capital proxies, have strong explanatory power for CDS premiums, but the effect of credit risk is also visible. For the risky sovereigns, Italy, Portugal, and Spain, CDS premiums are mainly driven by credit risk. In our extended sample, we find that increases in the volatilities of CDS premiums and Libor interest rates both increase the CDS premium, which follows from the fact that an increase in these volatilities leads to higher capital requirements.

Fourth and finally, evidence from corporate bonds suggests that the regulatory effects also carry over to safe corporate issuers. Using data for corporates offers two advantages over sovereigns. First, corporate CDS contracts have been actively traded prior to the financial crisis and we can use these pre-crisis data to test the effects of regulatory changes. Second, we document and exploit that nonfinancial firms, in contrast to financial firms, typically do not post collateral in their derivatives transactions with banks. For these issuers we therefore expect to see a similar pattern of falling correlation between CDS premiums and bond yield spreads as credit quality increases. For financial firms, which typically post collateral, we expect a stronger relationship between CDS premiums and bond yield spreads. Both predictions are confirmed in our data. We also find that the link between CDS premiums and bond yields for safe corporates breaks down after the financial crisis and more so for corporate issuers than for financial issuers.

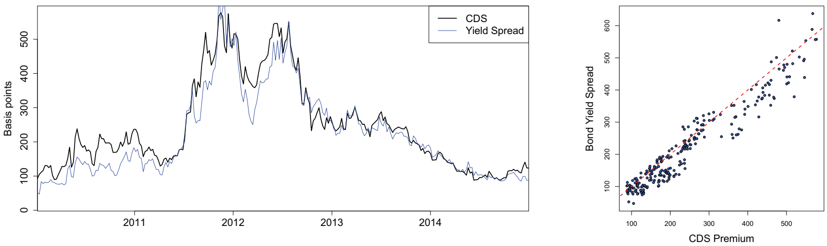
While we focus in this paper on the incentive to hedge that originates from regulation, our results have broader implications. When banks view equity issuance as costly, they have an incentive to hedge tradable financial risks (cf. Froot and Stein 1998). These hedges serve to avoid future fluctuations in accounting earnings that may force the bank to issue new equity to meet regulatory requirements or finance new investments. When banks enter into derivatives positions with sovereigns and corporate entities, fluctuations in counterparty credit risk affect earnings. Our findings suggest that hedging tradable credit risk may carry a cost that is different from the pricing of the risk in the underlying market.

1. Related Literature

Figure 2 illustrates the disconnect between CDS premiums and bond yield spreads for Germany and the much closer connection between the two variables for Italy. The observed patterns could not occur in a frictionless market where an increase in the CDS premium would also increase the corresponding bond yield. More precisely, the CDS premium and bond yield spread should be equal because of an arbitrage relationship. Hence, our work is related to the growing literature on the limits of arbitrage, as introduced by Shleifer and Vishny (1997) and studied by Gromb and Vayanos (2002) for the case in which arbitrageurs need to collateralize their positions. Gromb and Vayanos (2010) survey the literature on limits of arbitrage and summarize the basic idea in these models. An exogenous demand shock for a certain asset occurs to outside investors and arbitrageurs, who both are utility-maximizing and constrained, and take advantage of the shock by providing the asset. We contribute to this literature by providing a parsimonious model in the spirit of Gârleanu and Pedersen (2011),



A. CDS premium and bond yield for Germany



B. CDS premium and bond yield for Italy

Figure 2
The disconnect between CDS premiums and bond yield spreads
Panel A shows the time series of the German 5-year CDS premium and bond yield spread as well as a scatter plot of CDS premium and bond yield spreads. Panel B shows the time series of the Italian 5-year CDS premium and bond yield spread as well as a scatter plot of CDS premium and bond yield spreads. Yield spreads are computed as the difference between 5-year bond yields and the 5-year European Overnight swap rate (Eonia). All spreads are in basis points (bps).

who incorporate the supply-and-demand side, as well as the explicit financial frictions that drive the potential mispricing.

Yorulmazer (2013) is an early contribution arguing that capital relief is an important motive for banks to buy CDS protection. His main concern is how this may lead to increased systemic risk in the banking system. Gündüz (2016) uses CDS holding data and finds that banks purchase CDS contracts to reduce counterparty credit risk. We derive expressions for CDS premiums that incorporate the exact institutional features of CDS trading and capital relief, and we provide empirical support in several dimensions. Our evidence that banks hedge counterparty credit risk exposures is in contrast to Rampini et al. (2017), who focus on the use of derivatives for hedging interest rate and FX risk. They find that more financially constrained financial institutions hedge less because collateral requirements imply that hedging has an opportunity cost in terms of foregone lending. In our model and in the data, there is no such opportunity cost from hedging CVA risk. Hedging credit risk in fact frees up balance sheet capacity for the bank to invest more in the risky asset.

The difference between the CDS premium and the yield spread is commonly referred to as the CDS-bond basis, and a large strand of literature aims to explain this basis. Empirically, the CDS-bond basis has been studied for corporate issuers by Blanco et al. (2005), Longstaff et al. (2005), and Bai and Collin-Dufresne (2013), among others. O'Kane (2012), Gyntelberg et al. (2013), and Fontana and Scheicher (2016) analyze the CDS-bond basis for European sovereigns. Our empirical analysis complements this strand of literature by showing that for safe governments, changes in CDS premiums and yield spreads are virtually unrelated.

Gârleanu and Pedersen (2011) argue that the corporate CDS-bond basis is, to a large extent, driven by different margin requirements for bonds and CDS. Moreover, He et al. (2017) show a significant link between the returns of corporate CDS and dealer banks' balance sheet constraints. In line with these papers, we find that dealer banks' balance sheet constraints are relevant for sovereign CDS. We contribute to this literature by adding an explanation for the demand for CDS on safe sovereigns, which, according to our hypothesis, comes from regulatory frictions.

The drivers of sovereign CDS premiums have been widely studied. Pan and Singleton (2008) and Longstaff et al. (2011) explain them by global investors' risk appetite; Ang and Longstaff (2013) suggest systemic risk as one potential driver; and Antón et al. (2015) suggest that buying pressure of CDS dealers plays a role. In addition, our theory helps explaining changes in the amounts of CDS outstanding, which have been studied by Oehmke and Zawadowski (2016) for corporate CDS and by Augustin et al. (2016) for sovereigns. Augustin et al. (2014) provide an extensive survey on sovereign CDS premiums.

Chernov et al. (2015) model default risk premiums of the U.S. government, and CDS premiums on U.S. government debt are also touched on in Brown and Pennacchi (2015), who argue that there may well be a credit risk element in U.S. Treasuries arising from underfunding of pension plans, and that U.S. CDS premiums reflect default risk. We agree that there may well be default risk premiums for safe sovereign CDS contracts, but we argue that the regulatory incentive to hold these contracts dominates in their pricing.

Illiquidity premiums in CDS have been studied in Bongaerts et al. (2011) and Junge and Trolle (2014), but these papers do not deal with sovereign CDS which, judging from volumes outstanding and trading activity, are by far the most liquid contracts.

2. Regulation and Sovereign CDS Demand

We first highlight the essential features of regulation of uncollateralized derivatives positions for banks that motivate our model and our empirical findings. A significant part of large dealer banks' exposure to sovereign entities comes from interest rate swaps and other OTC derivative positions. Unlike financial entities, most sovereigns do not post collateral in OTC derivatives positions and this leaves dealer banks exposed to counterparty credit risk. The current regulatory regime, referred to as Basel III (see Basel Committee on Banking Supervision, 2011), contains a charge related to this counterparty credit risk. While the risk of losses related to outright default of a derivatives counterparty had been dealt with in previous Basel accords, this new capital charge was motivated by the significant mark-to-market losses of derivatives positions that arose from deteriorating credit quality (but not outright default) of counterparties during the financial crisis.[1]

A bank will suffer mark-to-market losses if an OTC exposure has positive value to the bank and the credit quality of the counterparty deteriorates. In technical terms, a deteriorating credit quality will lead to an adjustment in the CVA of the bank's position. The CVA measures the difference between the value of the OTC exposure if held against a default-free counterparty versus a risky counterparty. When this difference increases, it implies a loss to the bank. Basel III imposes an addition to the bank's risk-weighted assets (RWAs), and therefore ultimately to its capital requirement, related to the risk of changes in the CVA. Importantly, the default risk of the counterparty that goes into the CVA calculation is measured using CDS premiums. This means that regardless of how safe the counterparty is, there is a capital charge as long as the CDS premium on the counterparty is strictly positive and not constant.

Basel III allows banks to avoid this addition to RWAs by purchasing CDS on the counterparty. Hence, this regulatory framework gives dealer banks an incentive to buy sovereign CDS instead of merely acting as net sellers of CDS contracts, which is common in most other markets. In line with this argument, Figure 3 shows that from 2010 on, after the announcement of Basel III, derivatives dealers are indeed net buyers of sovereign CDS. This is in contrast with the corporate CDS market, where dealer banks are typically short CDS contracts.[2] Even though derivatives dealers are typically long CDS positions in the corporate bond market, Figure 4 suggests that banks have a regulatory hedging motive for some corporates as well. The figure shows the fraction of uncollateralized derivative positions from the perspective of the largest six U.S. dealer banks, focusing on three different groups of counterparties: corporates, financials, and sovereigns. As we can see from the figure, sovereigns typically do not post collateral in their OTC derivatives transactions. Similarly, corporates leave most of their derivatives positions uncollateralized, whereas OTC derivatives positions with other financials are typically fully collateralized.

The notional amount of CDS that the bank needs to buy to obtain full capital relief is equal to EE arising from the OTC position. The EE captures that the bank will owe a defaulting counterparty the full value of the derivatives

[1] According to a Basel Committee 2011 press release, during the financial crisis, "roughly two-thirds of losses attributed to counterparty credit risk were due to CVA losses and only about one-third were due to actual defaults" (http://www.bis.org/press/p110601.htm).

[2] Unfortunately, no information for the buyers and the sellers of individual sovereigns is available. Hence, we cannot claim that the variation of the notional amount of sovereign CDS bought by dealers can be traced to financial regulation only. It is also possible that, especially during the European debt crisis, the end users' demand for CDS on risky sovereigns increased.

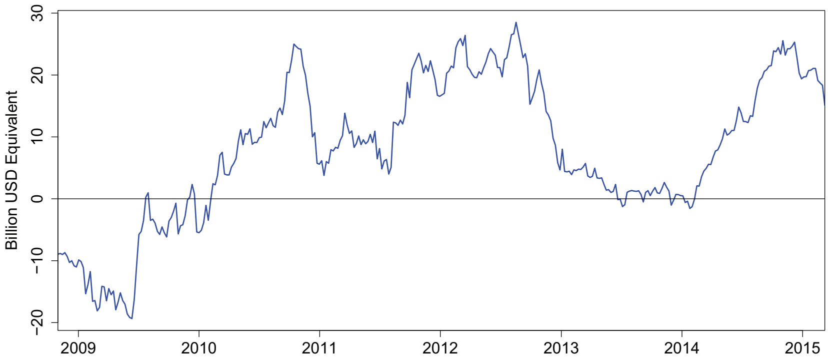


Figure 3
Derivatives dealers are net buyers of sovereign CDS
The figure shows the difference between the gross amount of sovereign-CDS contracts where derivatives dealers buy protection and the gross amount of sovereign CDS where derivatives dealers sell protection. The series is in billions of U.S. dollars and obtained from the Depository Trust & Clearing Corporation (DTCC).

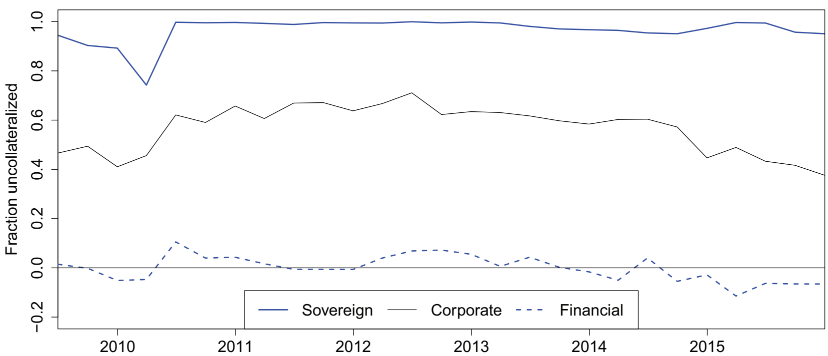


Figure 4
Fraction of bank's uncollateralized derivative positions
This figure shows the fraction of banks' uncollateralized derivatives exposures, split by counterparty. The data are from the call reports of the six U.S.-based G16 dealers (Bank of America, Citigroup, Goldman Sachs, JP Morgan, Morgan Stanley, and Wells Fargo). We obtain data on the "net current credit exposure" (Exposure) and the "total fair value of collateral" (Collateral) for OTC derivatives and construct the fraction of uncollateralized positions as the difference between exposure and collateral, divided by exposure. Financials include all banks and securities firms; sovereigns include all sovereign governments; and corporates include corporations and all other counterparties that are not classified as monolines or hedge funds. The uncollateralized exposures for monolines and hedge funds are not reported in this figure.

position if the position has a positive value to the counterparty, whereas the bank will only recover a fraction of the value of the position if it has a positive value to the bank. Hence, the EE consists of two parts: the net value of the outstanding derivatives position and the value of the counterparty's option to default. The second part can be viewed as a short position in a swaption, as we explain in more detail in Section 4.3. If the position is left unhedged, it will lead to an increase in RWAs that is proportional to EE and therefore a corresponding increase in the bank's capital requirement equal to a fraction of EE. The increase in RWAs depends on the credit risk of the underlying entity, which is measured through the level and volatility of the CDS premium. It is the trade-off between the cost of buying protection and the benefit of obtaining capital relief that is fundamental to our model in the next section.

3. The Model

We set up a simple one-period model that focuses on determining the CDS premium. In this model, a bank has an incentive to purchase CDS protection on an entity to obtain capital relief. An end user can earn the CDS premium by selling CDS to the bank, but needs trading capital to do so.

3.1 The assets

There are three different assets in the economy. First, there is a risky asset with price normalized to one, and normally-distributed time-1 payoff $\tilde{r} \sim \mathcal{N}(1+\mu,\sigma^2)$. We want to focus on the CDS premium and therefore take μ and σ^2 as exogenously given constants. The risky asset has a margin requirement m for both buying and short-selling the asset. Hence, one unit of wealth can at most support a long or short position of $1/m$ in the risky asset. From a regulatory perspective, the risky asset contributes to the risk-weighted assets of the bank. We choose for simplicity to let m also denote the contribution to the capital requirement for the bank associated with holding one unit of the risky asset. Second, a risk-free asset which pays off $1+r$ for each unit invested in it at time 0. We assume that the risk-free asset is in perfectly elastic supply and that r is an exogenously given constant. Third, a CDS contract on an entity that is not part of the model and can be thought of as a safe sovereign. The CDS premium s is the main focus of our model and will be determined in equilibrium. We denote by $\tilde{s}$ the random payoff on the CDS from the perspective of the protection buyer:

$$\tilde{s} := \begin{cases} -s, \text{ with probability } 1-p \\ \text{LGD, with probability } p, \end{cases}$$

and hence the expected payoff from the perspective of the protection buyer is

$$\bar{s} := p\text{LGD} - (1-p)s.$$

The initial margin for buying and selling the CDS is n^+ and n^- respectively. The notional amount of CDS outstanding is determined in equilibrium. The quantities s, n^+, and n^- are all per unit of insured notional, so the relevant dollar amounts were obtained by multiplying the numbers with the notional amount on the CDS contract. We refer to a long position in the CDS as representing a purchase of insurance. If, for example, $s = 45$ bps, a purchase of insurance of 1 dollars of notional, requires a payment of 0.0045 dollars at the end of the period if there is no default and leads to a positive cash flow equal to the loss given default (LGD) in the case of default.

3.2 The agents and their constraints

There are two different agents, a derivatives-dealing bank B and an end user of derivatives E. Agent i's wealth at time 1 is then given as

$$W_1^i = W_0^i(1+r)+g(\tilde{r}-r)+\bar{g}\tilde{s},$$

where $g \in \{b,e\}$ denotes the dollar amount of wealth invested in the risky asset for each agent type, and $\bar{g} \in \{\bar{b},\bar{e}\}$ denotes the notional amount insured by the CDS for each agent type. So, for example, $\bar{b}$ refers to the dollar amount on which the bank has bought protection (if $\bar{b}$ is positive) or sold protection (if $\bar{b}$ is negative). We assume that agents have mean-variance preferences and maximize the expected utility of their terminal wealth. To keep the model tractable, we make the following two simplifying assumptions. First, we assume that the return on the risky asset and the default event of the sovereign are uncorrelated. Second, we approximate the variance of the CDS payoff as $v(s) = (p-p^2)[\text{LGD}^2+2s\text{LGD}]$. The only difference between $v(s)$ and the variance of the CDS payoff is a term of the form $(p-p^2)s^2$, which, for the range of CDS premiums we consider, is at least an order of magnitude smaller than the dominating term. With that, the agents' optimization problem is given as

$$\max_{g,\bar{g}}\left[g(\mu-r)+\bar{g}\bar{s}-\frac{1}{2}(\sigma g)^2-\frac{1}{2}v(s)\bar{g}^2\right], \tag{1}$$

where we have chosen the risk-aversion parameter in front of the variance term for both agents to be equal to one. There will only be a supply of CDS from the end user when the expected return on buying CDS protection is negative, that is, $\bar{s}<0$, so the risk of selling protection is compensated, and this will be the case in equilibrium.

The agents' constraints involve capital requirements of the bank and funding requirements of the end user. Recall that the amount of wealth required to establish a position g in the risky asset is the same for long and short positions and given by $m|g|$. We refer to $m|g|$ as the margin requirement and to the wealth constraint due to margin requirements as the margin constraint. The margin requirement for establishing a long position $\bar{g}>0$ in the CDS (buying protection) is given by $n^+\bar{g}$ and by $n^-|\bar{g}|$ for establishing a short position $\bar{g}<0$ (selling protection). We think of the agent as having to deposit the amount of cash in a margin account where it earns the risk-free rate r.

The bank and the end user differ in their constraints. The end user's constraint is a margin constraint, and it is given as

$$me+n^-|\bar{e}| \leq W_0^E. \tag{2}$$

Equation (2) can be interpreted as follows. The end user can invest a maximum amount of $\frac{W_0^E}{m}$ in the risky asset. This would rule out taking a position in the

CDS contract because any nonzero position in the CDS contract reduces the degree to which the agent can make a levered investment in the risky asset. In equilibrium, the end user will only take long positions in the risky asset. Further, the end user will only consider selling the CDS in order to earn the CDS premium if it offers a positive expected return to do so.

The bank faces a different constraint arising from regulatory capital requirements. We assume that the bank has an interest rate swap with the reference entity of the CDS outstanding.[3] This position adds to the risk-weighted assets of the bank and reduces the bank's ability to lever its risky asset or take positions in the CDS market. As explained in Section 2, the contribution to risk-weighted assets is proportional to the EE of the interest rate swap. The bank can free up capital by purchasing CDS, and a CDS with a notional amount equal to EE removes the capital charge entirely. This frees up capital for investing in the risky asset, and this is the reason the bank is willing to enter into a CDS which has a negative expected excess return. The bank does not gain any capital relief from buying protection on a larger notional than EE. Rather than representing this as a kink in the margin constraint, we add the constraint $\bar{b} \leq EE$ to our optimization problem. Therefore, the bank's constraints can be written as

$$\begin{aligned} mb+n^{+}\bar{b}+\kappa(EE-\bar{b}) &\leq W_0^B, \\ \bar{b} &\leq EE. \end{aligned} \tag{3}$$

In equilibrium, the bank takes a long position in the risky asset and has a nonnegative position in the CDS. This is because the only other agent involved in the CDS market is the end user who, in equilibrium, sells CDS.

Recall that the bank's only reason for purchasing the CDS is the regulatory requirement described above. Without that regulation, the bank would have no incentive to purchase the CDS and the CDS premium would be determined by the credit risk of the underlying entity, the agent's risk aversion and margin requirements.

3.3 Equilibrium

In the market described above, equilibrium is defined by a premium s on the CDS contract and positions in the CDS contracts such that

(1) The end user and the bank maximize their mean-variance utility, as stated in Equation (1), subject to the constraints (2) and (3), respectively.

(2) The CDS market clears

$$\bar{b}+\bar{e}=0. \tag{4}$$

[3] To keep the focus of our model on the equilibrium CDS premium, we abstract from modeling the interaction between the bank and the safe sovereign.

We show our main result using the following three parameter restrictions:

$$\frac{\mu - r}{\sigma^2} > \frac{1}{m} \max\left(W_0^E, W_0^B - n^+ EE\right), \tag{5}$$

$$\min\left(\frac{W_0^E}{n^-}, \frac{W_0^B}{\kappa}\right) > EE, \tag{6}$$

$$\kappa > n^+ \tag{7}$$

Inequality (5) ensures that both agents are constrained. In particular, the inequality ensures that their total amount of available risk capital is smaller than their unconstrained demand for the risky asset, which would be given as $\frac{\mu - r}{\sigma^2}$. Inequality (6) ensures that both the bank and the end user have a sufficient amount of wealth such that the bank's entire EE can be hedged. Finally, Inequality (7) ensures that purchasing the CDS has a net positive effect on the bank's investable capital. When these inequalities are satisfied, the following result holds:

Proposition 1. Assume that the inequalities (5), (6), and (7) are satisfied and define

$$s^b := \frac{1}{(1-p)(1+2R)} \left(\frac{\kappa - n^+}{m} \left(\mu - r - \frac{\sigma^2}{m} (W_0^B - EEn^+) \right) + p\text{LGD} \right) - \frac{R\text{LGD}}{1+2R}, \tag{8}$$

$$s_f^e := \frac{1}{(1-p)(1-2R)} \left(\frac{n^-}{m} \left(\mu - r - \frac{\sigma^2}{m} (W_0^E - n^- EE) \right) + p\text{LGD} \right) + \frac{R\text{LGD}}{1-2R}, \tag{9}$$

where $R := pEE\text{LGD}$.

If $s_f^e \leq s^b$, then s_f^e is the unique equilibrium CDS premium and in this equilibrium, the bank buys full protection on its entire expected exposure $\bar{b} = EE$ from the end user.

The proof of Proposition 1 can be found in Appendix B. We discuss the case in which the bank buys partial protection in the Internet Appendix.

3.3.1 Numerical example. In Figure 5 we illustrate the model by plotting, for a set of parameters, the supply $-\bar{e}$ and demand $\bar{b}$ for CDS as a function of the CDS premium. With our choice of parameters, described below, the end user starts selling CDS for $s > 84$ bps and would in fact be buying CDS for $s < 9$ bp. The bank is willing to buy CDS up to a value of the premium equal to 192 bp. The CDS market clears for a CDS premium of $s = 105$ bp.

Our choice of parameters is as follows: We set the expected excess return to $\mu - r = 0.055$. The standard deviation of the risky asset is given as $\sigma = 0.2$,

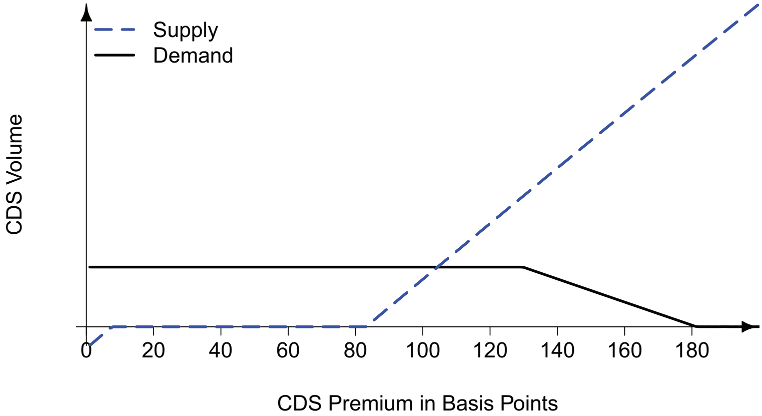


Figure 5
CDS supply and demand
The figure illustrates equilibrium in the market for CDS. The solid line indicates supply of CDS by the end user ($-\bar{e}$), and the dashed line indicates the demand for CDS by the bank ($\bar{b}$). The market clears for a CDS premium of 104.5 bps. The model parameters are $\mu - r = 0.055$, $\sigma = 0.2$, $m = 0.2$, $n^+ = n^- = 0.05$ $W_0^E = W_0^B = 0.2$, $p = 0.75\%$ LGD$=0.6$, $EE = 0.4$, and $\kappa = 0.15$.

which is approximately the long-term mean of the S&P 500 implied volatility index VIX. The initial wealth of bank and end user are set to $W_0^B = W_0^E = 0.2$ to satisfy inequality (5), which ensures binding constraints for both agents. Trading the risky asset requires an initial margin of $m = 0.2$ and this is also the addition to the capital requirement of the bank per unit of additional risky asset. We follow Gârleanu and Pedersen (2011) and assume a margin requirement of 5% for low-risk CDS entities. The bank either faces an addition to its risk-weighted assets of $\kappa EE = 0.06$ with $\kappa = 0.15$ and $EE = 0.4$ or buys CDS to free regulatory capital. Our choice of κ is based on the methods explained in Appendix C. EE is chosen as a large number relative to the bank's and end user's wealth for illustrative purposes. Finally, the default probability of the sovereign is $p = 0.75\%$ with LGD$=0.6$, which would correspond to a CDS premium of 45 bps in a risk-neutral world.

According to Moody's Investors Service (2011), the average recovery rates for sovereigns measured as trading price after 30 days divided by principal for defaults in the period is 31% (value-weighted) and 53% (issuer weighted). Still, one could argue that a LGD of 60% is too high for safe sovereigns, where a small technical default could be a likely outcome. Hence, we conclude this numerical example by investigating the impact of a lower LGD on the equilibrium CDS. We first note that the equilibrium condition is satisfied for $0 \leq \text{LGD} \leq 0.87$. Moreover, the CDS premium decreases to 74 bps (60 bps) if we decrease the LGD to 30% (15%). In the limiting case of an LGD equal to zero, the CDS premium is 48 bps and, in that simple case, the equilibrium condition is satisfied if $\kappa - n^+ < n^-$. An LGD of zero corresponds to having no default risk because there is no loss, and hence 48 bps can be viewed as the contribution to the CDS premium that comes from the regulatory frictions.

3.3.2 Model implications. Focusing on the case where the bank buys full protection, the equilibrium CDS premium is given in Equation (9) and our model has the following five testable predictions. First, for safe countries with low credit risk, a large fraction of the CDS premium is linked to regulatory proxies instead of credit risk. Second, the notional amount of CDS outstanding is higher for sovereigns with a larger amount of derivatives positions. Third, an increasing EE on the bank's swap position increases the CDS premium. Fourth, a capital-constrained bank is willing to pay an additional premium for CDS protection. When more banks become financially constrained, the regulatory hedging motive becomes stronger and the CDS premium increases. Finally, an increase in κ increases the regulatory hedging motive and therefore the CDS premium. In practice, κ depends on the risk that the credit quality of the counterparty deteriorates over the lifetime of the interest rate swap. This risk is measured through the level and the volatility of the CDS premium.

In addition to these five predictions, Equation (9) shows that a higher margin requirement for selling the CDS (i.e., a higher n^-), increases the CDS premium. We only test this prediction indirectly to the extent that margin requirements increase with CDS volatility. Equation (9) also shows that a higher excess return on the risky asset (i.e., a higher $\mu - r$) implies a higher CDS premium. This issue has been studied extensively by, among others, Longstaff et al. (2011), who document a strong link between global risk premiums and sovereign CDS premiums.

In line with our discussion on LGDs, our model shows that in the limit as the default probability of the underlying sovereign goes to zero, the CDS premium approaches a strictly positive level. Hence, in the limit as credit risk becomes small, only the regulatory incentive to buy CDS matters. In a world where the CDS premium and its volatility were zero, and banks had no exposures to hedge, a zero CDS premium would be an equilibrium too. But an infinitesimal disturbance away from zero brings us to the equilibrium CDS premium in Equation (9), which includes a regulatory premium. One could worry that once we are away from zero, a "doom loop" (as mentioned in Murphy (2012)) would be created in which a higher CDS premium leads to a higher regulatory demand for CDS which in turn increases CDS premiums, thus creating an upward spiral. Fortunately, our model shows that as long as the EE is fixed and the bank is constrained, a higher capital charge does not change the fact that the bank demands a notional equal to its EE, and therefore no "doom loop" occurs. However, the equilibrium CDS premium in our model is more sensitive to an increase in the default probability than the frictionless CDS premium with $EE = 0$.

4. Empirical Evidence

We now turn to our empirical analysis which falls into four broad categories: First, we investigate whether the regulatory relief per unit of CDS protection bought gives institutions an incentive to buy protection, and we investigate the volumes of CDS outstanding compared to the aggregate derivatives exposures of banks to sovereigns. Next, we investigate the covariation between CDS premiums and sovereign bond spreads. The regulatory incentive to buy CDS protection should lead to a smaller correlation between CDS premiums and bond yields for safe sovereigns, where the regulatory component can be large compared to the credit risk component. Third, we test whether different proxies for bank's incentives to hedge (capital constraints, increases in the size, and risk of EEs) have an effect on CDS premiums. Finally, we investigate whether the pattern of smaller correlation between CDS premiums and yield spreads for safe entities can also be found in U.S. corporate bond markets, whether the pattern is different for financial firms and nonfinancial firms, and whether it changes before and after the crisis.

4.1 Linking CDS volume to CVA hedging

According to several industry research notes, a large fraction of the outstanding sovereign CDS volume can be a consequence of financial regulation. For example, the fraction is estimated to be 25% in Carver (2011) and up to 50% in ICMA (2011). Appendix C provides more details about the computation of CVAs. In the Internet Appendix, we provide more anecdotal evidence to support our claim that derivatives dealers use sovereign CDS to hedge CVA risk. In this section, we focus on estimating a key model parameter κ and exploring the connection between the volume of bank derivatives positions with sovereign counterparties and the amount of CDS contracts outstanding.

To justify the use of sovereign CDS for CVA hedging, we need to make sure that the amount of capital relief per unit of CDS notional bought, $\kappa(s)$ as defined in Equation (C6) in Appendix C, is large enough to outweigh the margin costs associated with buying CDS contracts. Note that $\kappa(s)$ can be computed from historical CDS data which is why we make the dependence on s explicit here. We use CDS premiums for 10 different sovereigns, and our calculations of $\kappa(s)$ show that it is typically optimal for banks to hedge their entire CVA Value at Risk (VaR) using CDS contracts. We therefore proceed to check if this incentive shows in our data.

4.1.1 Data. We collect data on OTC derivatives outstanding for 28 different sovereigns from the 2013 EBA stress tests and 28 countries from the 2015 stress tests. The data refer to all OTC derivatives that a sovereign, or a government-sponsored entity, which was part of the EBA stress test,[4] has with

[4] Stress tests were conducted on banks in all European countries, including Great Britain. However, volumes for derivatives-dealing banks in Switzerland and the United States are not included in the notional amounts. Hence, all exposures are underestimated because some derivatives dealers are missing.

Table 1
CVA calculations based on EBA stress tests

	Mio USD			Basis points				
	Notional value	Fair value	CDS outst	CDS prem	$\sigma_1(s_t)$	$\sigma_3(s_t)$	$\frac{CS01}{EE}$	$\kappa(s)$
GER	402,855	34,072	13,118	42	19	24	0.26%	0.150
AUT	28,403	1,644	4,224	44	40	49	0.16%	0.271
FIN	95,414	5,073	2,189	30	14	18	0.13%	0.087
FRA	47,938	3,210	11,742	92	46	55	0.14%	0.234
ITA	106,959	19,136	16,916	284	118	133	0.32%	0.495
POR	9,423	564	3,684	430	214	290	0.09%	0.821
ESP	27,691	1,883	9,259	291	118	123	0.10%	0.401
GBR	7,920	19,255	5,842	42	12	30	3.08%	0.072
JAP	17,471	5,269	9,189	81	20	31	0.63%	0.091
USA	77,995	54,710	3,389	36	10	19	1.56%	0.052

OTC derivatives positions are provided by the European Banking Authority (EBA) in their stress tests from 2013 and converted to U.S. dollars using the 2013 year-end exchange rate. Notional value (fair value) is the total value (fair value) of OTC derivatives with positive fair value that European banks have outstanding with the respective sovereign. CDS outst is the net notional amount of sovereign CDS outstanding. CDS refers to the 5-year CDS premium as of year-end 2012. $\sigma_1(s_t)$ is the CDS volatility over the preceding year, and $\sigma_3(s_t)$ is the maximal annual volatility recorded over the preceding 3 years. $\frac{CS01}{EE}$ is computed using Equation (C4), and $\kappa(s)$ is calculated like in Equation (C6). EE is approximated using the fair value of all derivatives with positive fair value.

derivatives-dealing banks. The net notional of CDS outstanding is obtained from DTCC, CDS premiums were obtained from Markit, and the countries' debt outstanding is obtained from countryeconomy.com. We explain these data (as well as all other data in this paper) in more detail in Appendix A.

4.1.2 CVA and risk charges associated with derivatives. We initially focus on our core sample of ten sovereigns for which we are able to later run additional tests. In Columns 1 and 2 of Table 1, we report the notional value and the fair value of all derivatives for these ten sovereigns that have positive fair value for banks. The fair value of all derivatives with positive value gives an indication of how deep the derivatives are in-the-money. While netting of a banks' exposure with a sovereign might imply a smaller EE than the amount indicated by the fair value, there are other reasons the EE may be larger. First, the current fair value of a derivative nets out positive and negative values that the derivative may have in the future, whereas the calculation of EE is only based on values in future states in which the derivative has positive value. Second, the EBA data do not account for OTC exposures that non-European banks have with these sovereigns. Third, the fair value does not account for the option-like feature of EE discussed in Appendix C.

Because banks would need to buy CDS protection on a notional amount equal to the EE to hedge their OTC derivatives exposure toward sovereigns, the fair value of the outstanding derivatives with sovereign counterparties gives an indication of whether the order of magnitude of such positions is comparable to the amounts of CDS outstanding. Column 4 of Table 1 reports the amount of sovereign CDS outstanding for the respective countries. As we can see from the table, in all cases, except for the United States, the notional amounts of CDS outstanding are of the same order of magnitude as the fair value of derivatives positions with positive value. We test the relationship between CDS net notionals outstanding and sovereigns' derivatives positions on a larger cross-section of countries below.

Column 9 (furthest to the right) of Table 1 shows the amount of capital relief $\kappa(s)$ that one unit of sovereign CDS purchase will provide. Columns 5–8 provide the necessary input to calculate $\kappa(s)$. Appendix C explains the steps in detail. As we can see, the value ranges from lowest value of $\kappa(s)=0.052$ for the United States to the highest value of $\kappa(s)=0.821$ for Portugal. In Proposition 1, $\kappa(s)$ is written as κ, and we note that $\kappa > n^+$ is satisfied for all countries if we assume $n^+=0.05$. Note that it is likely that the margin requirement for buying CDS, especially on safe sovereigns, is in fact smaller than 0.05 because the margin would easily exceed the present value of the CDS contract even if the premium dropped to zero. Therefore, we can justify the purchase of a CDS as providing capital relief in all cases.

4.1.3 Testing the link between CDS volumes and CVA risk. After having established that our estimate of CVA hedging need is of the same order of magnitude as the sovereign CDS market for our sample of ten sovereigns, we next conduct a formal test of whether there is a link between outstanding CDS volumes and sovereigns' derivatives exposures to banks on a larger sample. To that end, we expand the sample to include all sovereigns that have derivatives positions with a positive fair value for European and U.K. banks. We also add the results from the December 2013 and 2015 stress tests. Panel A of Figure 6 shows a scatter plot of CDS volumes outstanding (measured as the net notional outstanding) against the fair value of all derivatives with positive value for reporting banks (both on a logarithmic scale). As we can see from the figure, there is a strong positive relationship between the two numbers. In line with our hypothesis that financial regulation drives the demand for sovereign CDS, we find more CDS outstanding on sovereigns with more derivatives contracts outstanding. The only large outlier is China, where the CDS net notional outstanding is significantly larger than the fair value of banks' derivatives positions.

To test the significance of the relationship between sovereign CDS outstanding and banks' derivatives exposures, we next run cross-sectional regressions of the following form:

$$\log(CDS_{i,t})=\alpha_0+\alpha_1\mathbb{1}_{\{2015\}}(t)+(\beta_0^{FV}+\beta_1^{FV}\mathbb{1}_{\{2015\}}(t))\log(FV_{i,t})$$
$$+(\beta_0^{Debt}+\beta_1^{Debt}\mathbb{1}_{\{2015\}}(t))\log(Debt_{i,t})+\varepsilon_{i,t}, \quad (10)$$

where $FV_{i,t}$ is the sum of positive fair values of derivatives that banks have entered into with country i in year t. Table 2 shows the results of testing the full specification and submodels. In panel A, we run regression (10) without the

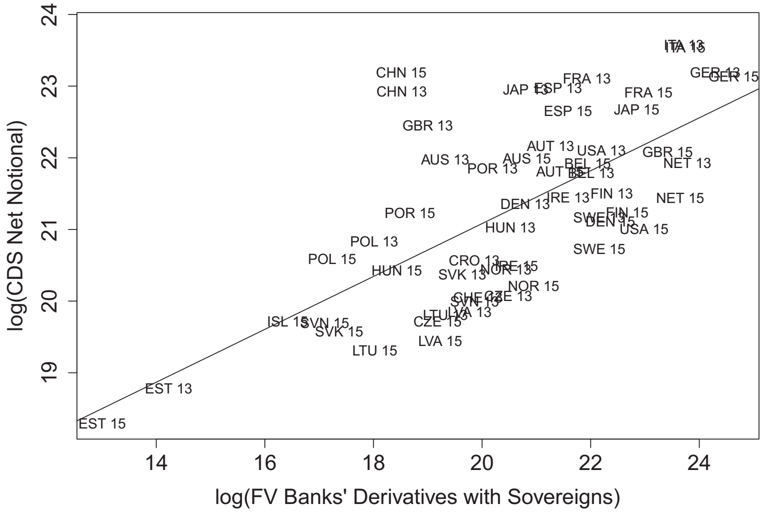


Figure 6
Banks' derivatives exposures and CDS volumes outstanding
This figure illustrates the relationship between the net notional amount of CDS outstanding on a sovereign (y-axis) and the fair value of all derivatives positions that European banks and banks in the United Kingdom have toward the same sovereign (x-axis). The fair value is the value of all derivatives positions with positive fair value that banks have toward the respective sovereign. Data on the fair value of the derivatives positions were obtained from the EBA stress tests in December 2013 and in December 2015. The Internet Appendix reports the countries comprising the tests. The net notional CDS amounts outstanding are year-end and obtained from the DTCC database.

dummies using only FV as the regressor. We add dummy variables for the level and the slope coefficient in panel B. Each dummy variable is equal to one if the data are from the 2015 stress test and zero otherwise. As we can see from the table, the fair value of all derivatives outstanding is a significant explanatory variable for the total amount of CDS outstanding. Overall, 45% of the cross-sectional variation in CDS net notional outstanding can be explained by derivatives outstanding. Moreover, neither the level nor the slope significantly change from 2013 to 2015.

To rule out that the link between sovereign CDS outstanding and dealer banks' sovereign derivatives positions is purely driven by the amount of sovereign debt outstanding, we add the total debt outstanding for each of the sovereigns as a control variable to our regression in panel C of Table 2. As we can see from the table, controlling for sovereign debt outstanding lowers the statistical and economic significance of our variable. However, even after controlling for the sovereigns' debt outstanding, the fair value of banks' derivatives positions with sovereigns is still statistically significant at a 1% level. Moreover, adding a dummy variable for the level and the two slope coefficients shows that the effect of debt outstanding does not change significantly from 2013 to 2015.

Table 2
Banks' derivatives exposures and CDS volumes outstanding

	(1)	(2)	(3)	(4)
Intercept	13.70***	13.73***	6.96***	6.58***
	(0.89)	(1.65)	(1.41)	(1.59)
Intercept $\times \mathbb{1}_{\{2015\}}$		−0.05		0.81
		(1.95)		(2.96)
$\log(FV)$	0.37***	0.37***	0.10***	0.11**
	(0.04)	(0.08)	(0.04)	(0.05)
$\log(FV) \times \mathbb{1}_{\{2015\}}$		−0.01		0.00
		(0.09)		(0.09)
$\log(Debt)$			0.46***	0.48***
			(0.07)	(0.07)
$\log(Debt) \times \mathbb{1}_{\{2015\}}$				−0.04
				(0.16)
Observations	55	55	55	55
Adjusted R^2	0.45	0.44	0.77	0.76

This table shows the results of regressing the logarithm of the sovereign CDS net notional outstanding on the indicated variables, including all countries that are listed in the DTCC database and the EBA stress tests. $\log(FV)$ is the fair value of all derivatives positions with positive fair value, that European banks and banks in the United Kingdom have toward a sovereign. $\log(Debt)$ is the total sovereign debt outstanding for the respective country. Data on the fair value of the derivatives positions were obtained from the EBA stress tests in December 2013 and December 2015. The net notional CDS amounts outstanding are year-end obtained from the DTCC database. Amounts of debt outstanding were obtained from `countryeconomics.com`. Heteroscedasticity robust standard errors are reported in parentheses. *** indicates significance at a 1% level, and ** indicates significance at a 5% level.

4.2 Sovereign CDS premiums and bond yields

Figure 2 suggests a larger disconnect between bond yield spreads and CDS premiums for safer countries. Hence, we now run a regression analysis to investigate whether this pattern is borne out in the data. The disconnect would be consistent with the model's prediction that the regulatory contribution to the CDS premiums is of fixed size and therefore likely to play a more significant role for safer sovereigns. We proceed in four steps. First, we describe the data used in this subsection. Second, we run a regression analysis of bond yields on CDS premiums and risk-free rates for our main sample of ten sovereigns. Third, we test the robustness of our finding to alternative explanations. Finally, we run additional tests utilizing a larger cross-section of sovereigns.

4.2.1 Data. We study the relationship between CDS premiums and bond yield spreads for 10 different sovereigns, using 5-year data based on weekly observations sampled every Wednesday. We focus our analysis on the period from January 2010 to December 2014 and have both a core sample and an extended sample. The core sample consists of ten sovereigns: Japan, the United Kingdom, the United States, and the seven Eurozone countries with the most frequent quotes for both CDS premium and yield spread.[5] In addition, we

[5] We focus on the four major safe haven currencies because of data availability. For instance, CDS contracts on Switzerland and Singapore are typically not among the top 1,000 DTCC most actively traded contracts and quotes exist only infrequently.

use a larger cross-section of sovereigns with available 10-year bond yields and Libor swap rates in their currency. Our analysis of sovereigns starts in 2010 because the regulatory requirements were first announced in 2010. In contrast to corporate CDS premiums, sovereign CDS premiums experienced virtually no variation before the financial crisis (see, e.g., Acharya et al. 2014). Hence, it is impossible to obtain an informative time series before the change in regulation.

The sovereign CDS data were obtained from Markit. The CDS premium for the United States is denominated in Euro, all other CDS premiums are denominated in U.S. dollars. We use the Bloomberg system to obtain 5-year bond yields and corresponding risk-free rate proxies. Bloomberg uses the most recent issue of the 5-year benchmark bond to compute the yield. If there is no benchmark bond with matching maturity available, no yield is reported. As a proxy for the risk-free rate, we use 5-year swap rates based on overnight lending. In these contracts one party pays a periodic floating rate based on the overnight lending rate and in return receives a fixed rate, denoted the swap rate. For the extended cross-section, we use 10-year bond yields and swap rates based on Libor rates (both are more readily available for smaller countries).

4.2.2 Credit risk in bond yields. To test whether the credit risk in government bonds is reflected by CDS premiums we run regressions of the following type:

$$\Delta Yield_t = \alpha + \beta^{CDS} \Delta CDS_t + \beta^{rf} \Delta rf_t + \varepsilon_t, \tag{11}$$

where $\Delta Yield_{i,t}$, $\Delta CDS_{i,t}$, and $\Delta rf_{i,t}$ denote changes in the bond yield, CDS premium, and risk-free rate for each country. If CDS premiums were a clean measure of credit risk, we would expect that an increase of one basis point in the CDS premium increases the corresponding bond yield by one basis point. If β^{CDS} is significantly different from 1 and possibly even close to 0 it supports our theory that CDS premiums are driven by factors other than credit risk. Using this specification instead of directly comparing yield spreads and CDS premiums has the advantage that we can also check whether our proxy for the risk-free rate is reasonable and reflected in the bond yield.

To get an overview of the results, we first sort the ten sovereigns by their estimate for β^{CDS} from small to large. We then plot the parameter estimates and the 95% confidence intervals for the estimates (corresponding to 1.96 standard deviations) in Figure 1. Panel A shows the estimates for β^{CDS} for the ten sovereigns. As we can see from the figure, the sorting according to β^{CDS} also corresponds to our model prediction. The relationship between bond yields and CDS premiums for the safe haven sovereigns Japan, the United States, Germany, and the United Kingdom is lowest. In particular, none of the parameter estimates is significantly different from zero at a 5% confidence level. Then, β^{CDS} for Finland, France, and Austria, which we refer to as "low-risk" sovereigns, is significantly different from zero but still well below one and below the estimate for the risky sovereigns, Italy, Spain, and Portugal. On the other hand, the estimates for β^{rf}, reported in panel B, are all significantly different from zero (at a 5% confidence level) and are close to one. Notably, with the exception of Japan, Germany, and Finland, none of the estimates is significantly different from one at the 95% confidence level. Overall, Figure 1 illustrates a large disconnect between CDS premiums and bond yield spreads for safe sovereigns. Additional details such as the adjusted R^2 values and the exact parameter estimates can be found in the Internet Appendix.

4.2.3 Robustness to other explanations. There could be other explanations for why β^{CDS} is insignificant for safe sovereigns. First, safe haven bonds typically carry a "convenience yield" or "liquidity premium," meaning that investors are willing to accept a lower yield on very safe and liquid assets (see, e.g., Krishnamurthy and Vissing-Jorgensen 2012). Second, a so-called "cheapest-to-deliver" (CtD) option is embedded in sovereign CDS. The CtD option can increase the CDS premium because it allows the protection buyer to deliver the cheapest bond, out of a basket of deliverable bonds, in case of a debt restructuring. Third, CDS contracts also can be used for proxy hedging, which induces a demand for sovereign CDS as a proxy for country-specific risks.

We start by discussing the convenience yield argument for the case of German government bonds. On the one hand, because of implicit and explicit guarantees for German banks during the financial crisis and its responsibilities in the Eurozone, it is conceivable that German government bonds are not entirely free of credit risk. On the other hand, German government bonds are arguably the safest and most liquid Euro-denominated assets. Hence, investors might accept a lower bond yield for the convenience of holding such a safe and liquid asset. We use a variety of different proxies for the convenience yield of government bonds. Our main proxy is the difference between the 3-month overnight swap rate and the 3-month sovereign bond yield. We use this as a proxy for convenience yield because the credit risk for a bond issuer with high credit quality is smallest for short maturities. Hence, the 3-month German benchmark bond can be viewed as almost free of credit risk and the difference to the 3-month Eonia swap rate can be attributed to the convenience yield.[6]

In addition to this proxy, we add the spread between bonds issued by the Kreditanstalt für Wiederaufbau (KfW) and the German government bond yields as a proxy for convenience yield for Germany. The argument here is that KfW bonds are guaranteed by the German government and, hence, have the same credit risk as German government bonds but a different liquidity. Therefore, the spread between KfW bonds and German government bonds can reflect the liquidity premium in German government bonds.

[6] We note that this proxy for convenience yield might be problematic for the United States, where debates about the debt ceiling lead to elevated CDS premiums on the United States for short-term contracts (see Brown and Pennacchi 2015). We therefore add several additional proxies for convenience yield for the United States.

The difference between the 3-month overnight swap rate and the 3-month sovereign bond yield is also available for Japan, the United Kingdom, and the United States, so we use this to proxy a convenience yield for those countries as well. For the United States, we also consider the spread between on-the-run and off-the-run bonds as an additional proxy. An increase in this spread points to a situation where there is an elevated demand for the more liquid on-the-run treasury bonds which indicates more demand for highly liquid assets. Finally, we add the weekly government bond turnover as another proxy for flight to liquidity. This variable is available on a weekly basis for the United Kingdom and the United States. [7]

To control for the CtD option, embedded in sovereign CDS, we obtain, for each sovereign in our sample, mid-market bond prices with 1 to 10 years to maturity. We restrict our sample to bullet bonds with a fixed maturity, exclude inflation-linked bonds, and only use bonds in a country's own currency. To ensure that the CtD proxy is not driven by small bonds, we require a minimum issuance equivalent to 1 billion U.S. dollars for countries with large bond markets (Germany, Japan, the United States, the United Kingdom, and Italy) and a minimum issuance equivalent to 250 million U.S. dollars for the remaining countries. For each country i, we then approximate the CtD option as

$$CtD_{i,t} = 100 - \min_j(Price_j).$$

Table 3 exhibits the results of this analysis. As we can see from the table, adding the convenience yield proxies and the CtD proxy to the regression does not change our inference about β^{CDS}. Out of the four sovereigns, β^{CDS} is only significant for the United Kingdom and only at a 10% level. Moreover, in line with capturing a benefit of holding safe and liquid bonds, increases in our convenience yield proxy, measured as the difference between 3-month overnight swap rates and 3-month bond yields, correspond to decreasing bond yields. However, this proxy for convenience yield is only significant for Germany. In addition, the KfW spread is significant at a 1% level for Germany, and increases in that spread also correspond to decreases in German bond yields. For the United States, the on-the-run off-the-run spread is significant at a 10% level and increases in that spread correspond to lower bond yields. Changes in bond turnover are insignificant for the United States and significant at a 10% level for the United Kingdom Finally, we note that the R^2 values for Germany, the United Kingdom, and the United States are all above 0.8 which mitigates omitted variable concerns because we are capable of explaining most of the variation in bond yields with our explanatory variables. We note that the proxy for the CtD is significant with a positive sign for three out of the

[7] For Japan, turnovers are available on a monthly basis. We exclude turnovers for Japan in Table 3 to keep the number of observations comparable across countries. However, adding turnover for Japan leaves our inference about β^{CDS} unchanged. Turnovers are only available for Germany on a semiannual basis.

Table 3
Explaining bond yields with credit risk, risk-free rates, and convenience yield

	Japan	U.S.	Germany	U.K.
Intercept	−0.19*	0.04	−0.21	0.10
	(0.11)	(0.13)	(0.26)	(0.35)
ΔCDS_t	−0.01	−0.00	0.08	0.20*
	(0.02)	(0.07)	(0.09)	(0.12)
Δrf_t	0.82***	0.89***	0.87***	0.75***
	(0.06)	(0.05)	(0.06)	(0.06)
ΔCY_t	−0.07	0.03	−0.07	−0.15
	(0.11)	(0.11)	(0.06)	(0.11)
$\Delta OnOff_t$		−0.33**		
		(0.15)		
$\Delta Turnover_t$		0.99		0.62
		(0.67)		(0.73)
ΔKfW_t			−0.23***	
			(0.06)	
ΔCtD_t	0.17	1.99***	3.72***	4.25***
	(0.13)	(0.60)	(0.83)	(0.74)
Observations	240	253	252	170
Adjusted R^2	0.73	0.96	0.84	0.86

This table shows the results of a regression of the following form:

$$\Delta Yield_t = \alpha + \beta^{CDS} \Delta CDS_t + \beta^{rf} \Delta rf_t + \beta^{CY} \Delta CY_t + Controls_t + \varepsilon_t.$$

$Yield_t$ is the 5-year bond yield of the most recently issued government bond, CDS_t is the 5-year CDS premium, rf_t denotes the risk-free rate proxy measured by 5-year overnight swap rates, CY_t is a proxy for the convenience yield, measured as the difference between the 3-month overnight swap rate and the 3-month bond yield for the respective sovereign. $Controls_t$ include changes in the turnover of Treasury bonds with 3 to 6 years to maturity or Gilts with any maturity, changes in the 10-year on-the-run off-the-run spread, changes in the spread between KfW bond yields and German government bond yields, and changes in our proxy for the CtD option, embedded in sovereign CDS. Heteroscedasticity-robust standard errors are reported in parentheses. * indicates significance at 10% level, ** at 5% level, and *** at 1% level.

four sovereigns. While CtD is an important potential omitted variable in this regression, it is difficult to interpret the sign and size of the estimate here. We therefore investigate the role of CtD further in Section 4.3.

An alternative potential reason for banks to purchase sovereign CDS is "proxy hedging." For example, a bank may choose to use sovereign CDS to hedge exposures that are strongly correlated with the risk of the sovereign, such as public companies on which no CDS is traded, or diversified loan portfolios in that country. We cannot distinguish whether a bank has purchased CDS protection because of a derivatives exposure or as part of a proxy hedging strategy, but the implications are the same: a bank concerned with managing its regulatory capital and its earnings volatility is willing to pay for this through CDS contracts. In both cases this hedging demand may cause a disconnect between the CDS premium and bond yield spreads that is most pronounced for low-risk sovereigns.

4.2.4 Additional cross-sectional evidence. Next, we use a larger cross-section of 23 sovereigns to investigate whether the pattern of breakdown between CDS premiums and bond yields is robust to using a larger cross-section of sovereigns and a different sampling frequency. The larger cross-section comprises the countries from the analysis of EBA stress tests in Table 2 for which 10-year bond yields are available on Bloomberg. In addition, we utilize this larger cross-section of monthly observations to test an additional model implication: According to our theory, derivatives-dealing banks purchase CDS to obtain capital relief, and this purchase can be driven by factors unrelated to the credit risk of the underlying sovereign if, for example, the notional amount of derivatives increases. Hence, when dealer banks increase their sovereign CDS holdings they might affect the CDS premium at times when there is no change in bond yields, and this leads to a stronger disconnect between CDS premiums and bond yields. For our larger sample of sovereigns, we collect bond yields for 10-year bonds (which are available for a larger cross-section of countries) and Libor swap rates in their respective currency for 23 of the countries that we analyzed in Section 4.1.3. We use Libor swap rates in the respective currencies instead of overnight swap rates because Libor rates are available for a larger cross-section of countries. As indicated by the high β^{rf}, this proxy works fine as well. We classify countries into three riskiness categories, based on their average CDS premium throughout the sample period. A country is classified as "safe" if its average CDS premium is below the 33% percentile of the averages in the entire sample. Similarly, a country is classified as "low-risk" or "risky" if its average CDS premium is between the 33% and 66% percentile or above the 66% percentile respectively.

Panel A of Table 4 confirms our main finding from the previous section: For safe sovereigns, CDS premium and bond yields are virtually unrelated. Moreover, the link between CDS premium and bond yield is also weak for low-risk sovereigns and highest for high-risk sovereigns.

In addition, we add an interaction term between changes in CDS premiums and months in which the change in sovereign CDS positions held by derivatives-dealing banks is above the 80% percentile (relative to the entire time series). The amount of sovereign CDS bought by derivatives-dealing banks is a good proxy for their CVA hedging activities because of the link between banks' derivatives exposures with sovereigns and the notional amount of CDS outstanding that we document in Section 4.1.3. As we can see from panel A of Table 4, β^{CDS} remains almost unchanged for safe sovereigns in times when dealer banks increase their sovereign CDS positions, and hence β^{CDS} remains indistinguishable from zero for safe sovereigns. More importantly, for low-risk and risky sovereigns, the link between CDS premium and bond yield drops sharply in times of increasing dealer-bank sovereign CDS holdings and β^{CDS} drops from 0.44 to 0.16 and from 0.74 to 0.43 for low-risk and risky sovereigns, respectively. Overall, panel A of Table 4 reveals that the breakdown between CDS premium and bond yield is more severe when the amount of sovereign CDS bought by derivatives-dealing banks increases significantly.[8]

[8] We have constructed an alternative measure of dealer banks' CDS demand by aggregating the "net current credit exposure" from the call reports of the six U.S.-based G16 dealers. Similar to the results in panel A of Table 4, we

Table 4
Cross-sectional tests

	safe	low risk	risky
A. Dependent variable is $\Delta Yield_{i,t}$			
Intercept	0.06	-1.03	-1.99
	(0.35)	(0.81)	(1.76)
$\Delta CDS_{i,t}$	-0.13*	0.44***	0.74***
	(0.07)	(0.07)	(0.05)
$\Delta CDS_{i,t} \times \mathbb{1}_{\{\Delta DB_t \geq q(80\%)\}}$	-0.00	-0.28**	-0.31**
	(0.12)	(0.11)	(0.14)
$\Delta rf_{i,t}$	1.03***	0.77***	0.73***
	(0.02)	(0.07)	(0.09)
Observations	478	390	391
Adjusted R^2	0.88	0.49	0.57
B. Dependent variable is $\Delta CDS_{i,t}$			
Intercept	-0.09	0.25	0.59
	(0.38)	(0.84)	(1.86)
$\Delta YS_{i,t}$	-0.16**	0.35***	0.73***
	(0.07)	(0.08)	(0.08)
$\Delta IR_{i,t}^{Vol}$	0.03***	0.02	0.09***
	(0.01)	(0.01)	(0.03)
$\Delta CDS_{i,t}^{Vol}$	0.16***	0.18***	0.11***
	(0.06)	(0.04)	(0.04)
Observations	478	390	391
Adjusted R^2	0.11	0.25	0.59
Credit ratio	0.23	0.71	0.91

This table shows the results of two different panel regressions, using month-end data on 23 different sovereigns. The maturities of all instruments are 10 years. Panel A shows the results of a regression of changes in bond yields ($\Delta Yield_{i,t}$) on changes in CDS premiums ($\Delta CDS_{i,t}$) and changes in the risk-free rate proxy, measured by the 10-year Libor swap rate. $\mathbb{1}_{\{\Delta DB_t \geq q(80\%)\}}$ is an indicator variable that is equal to one if the change in CDS positions held by derivatives dealers is above its 80% quantile and zero otherwise. The quantile is computed over the entire sample period. Panel B shows the results of a regression of changes in premiums ($\Delta CDS_{i,t}$) on changes in yield spreads ($YS_{i,t}$), measured as the difference between bond yield and risk-free rate proxy as well as changes in interest rate volatility $\Delta IR_{i,t}^{Vol}$ and changes in CDS volatility $\Delta CDS_{i,t}^{Vol}$. The countries in the sample are classified as "safe," "low risk," and "risky," based on their average CDS premiums over the entire sample period. The sample of safe countries consists of Denmark, Finland, Germany, Netherlands, Norway, Sweden, the United Kingdom, and the United States. The sample of low-risk countries consists of Austria, Belgium, China, Czech Republic, France, Japan, and Slovakia. The sample of risky countries consists of Ireland, Italy, Poland, Portugal, Spain, Bulgaria, Slovenia, and Romania. Heteroscedasticity-robust standard errors are reported in parentheses. * indicates significance at 10% level, ** at 5% level, and *** at 1% level. The sample period is from January 2010 to December 2014.

4.3 Regulatory constraints as drivers of CDS premiums

In our model, dealer banks have an incentive to use CDS for hedging when their capital constraints are binding, and the demand for CDS should increase if the EE of their derivatives positions with sovereigns increase. In this section we test whether proxies for dealer capital constraints and EE are significant in explaining CDS premiums. We focus on various market-based measures

find a larger disconnect between bond yields and CDS premiums for risky sovereigns in quarters with significant increases in dealer banks sovereign exposures. However, given that this measure captures only six of the sixteen major dealer banks and is only available on a quarterly basis, we have relegated these results to the Internet Appendix.

because, as noted, for example, by Flannery (2014), accounting-based values are notoriously bad predictors of bank distress.

4.3.1 Data. Next, we describe two proxies that can capture regulatory hedging motives. First, the expected default frequency (EDF), which is an estimate of a firm's default risk, is computed by Moody's Analytics. The estimate builds on a two-step procedure. In the first step, information on a firms' market value of equity and its liability structure is used to infer the firm's asset value and asset volatility, and from this a "distance-to-default" is computed which measures the distance, scaled by volatility, of a firm's assets to a default boundary. In the second step, the distance-to default is converted into a default probability, the EDF, using the result of a nonparametric regression which links distance-to-default to default probabilities using a large historical sample. When a bank has a large EDF, it indicates that the stock market views the bank as having a small equity buffer compared to the riskiness of its assets, and we therefore use it as a proxy for the degree to which the bank is capital constrained. We denote by EDF_t the average of the Moody's Expected Default Frequency (EDF) for the sixteen largest derivatives-dealing banks (G16 banks).[9] Because there is a strong connection between sovereign credit risk and bank credit risk (see, for instance, Kallestrup et al. 2016), we first regress the average EDF on the yield spread of the respective sovereign and use the residual of this regression as EDF_t.[10]

Second, $Swptn_t$ which is the (basis point) premium on an option to enter a 5-year swap position, as fixed payer or fixed receiver, in the respective currency, over the next 5 years. This variable captures the option-like feature of banks' EE from interest rate swaps toward sovereigns, and we therefore use it as a proxy for EE. The relationship between the EE and the value of a swaption is used for example in Sorensen and Bollier (1994), and the basic idea is as follows: let $S(c,r_t,t,T)$ denote the value at date t of a swap contract for the party receiving the fixed payment c per period until maturity T. For simplicity, we assume it to be a function of the short rate r_t at date t. Let s_t denote the at-market swap rate at date t, that is, the rate satisfying $S(s_t,r_t,t,T)=0$. The value at date t of an at-market swap that was entered at date 0 is then $S(s_0,r_t,t,T)$, and this value is positive precisely when $s_t < s_0$. We write the exposure of the fixed receiver at date t as $\max(S(s_0,r_t,t,T),0)$. This is precisely the value at date t of the option to enter into a swap as a fixed receiver at the rate s_0. In essence, the swaption

[9] These sixteen banks are Morgan Stanley, JP Morgan, Bank of America, Wells Fargo, Citigroup, Goldman Sachs, Deutsche Bank, Nomura, Societe Generale, Barclays, HSBC, Credit Agricole, BNP Paribas, Credit Suisse, Royal Bank of Scotland, and UBS.

[10] Our results are robust to several modifications of this specification. First, directly using the average EDF instead of the residual gives results similar to those for the statistical and economic significance of the regulatory proxies. Second, we modify the average EDF by dropping the EDFs of banks located in the respective country of the average EDF measure. For instance, if we ran a regression for Germany, we computed the average EDF without using the Deutsche Bank. Again, we obtain similar results.

value is related to EE, because only states in which the swap has positive value to the bank expose the bank to counterparty credit risk.

4.3.2 Regression analysis for the core sample. For each country, we now run the following regression:

$$\Delta CDS_t = \alpha + \beta^{YS} \Delta YS_t + \beta^{CtD} \Delta CtD_t + \beta^{Swptn} \Delta Swptn_t + \beta^{EDF} \Delta EDF_t + \varepsilon_t. \tag{12}$$

YS_t is the difference between 5-year bond yield and 5-year overnight swap rate in the respective currency. We include this variable as a proxy for credit risk because, as explained earlier, there could be a small credit risk component in 5-year bond yields, even for safe sovereigns. CtD_t is the CtD proxy for each of the sovereigns. The remaining two variables are independent of the sovereign's credit risk and we refer to them as regulatory proxies in the following.

The results of this analysis are exhibited in Table 5. Examining the results for the four safe haven sovereigns in our sample, we find that the regulatory proxies are both statistically and economically significant. The R^2 of the regression ranges from 6% for the United States to 35% for Germany. To confirm that the explanatory power comes from the regulatory proxies we run a separate regression of the CDS premium on the bond yield spread and the CtD proxy and report the ratio of the adjusted R^2 from this regression over the adjusted R^2 of the entire regression under "credit ratio." The credit ratio ranges from 0.11 for Japan, over 0.17 for the United States and Germany, to 0.43 for the United Kingdom, indicating that most of the explanatory power in these regressions comes from the two regulatory variables. Turning to the statistical significance, we can see that for Germany and Japan both regulatory proxies are statistically significant. For the United Kingdom and the United States, ΔEDF_t is the only significant regulatory proxy. For the United Kingdom, the yield spread is statistically significant at a 1% level. As mentioned before, the United Kingdom started posting collateral in its OTC derivatives transactions in late 2012. The posting of collateral mitigates counterparty-credit risk and, therefore, lowers the CVA capital charge and the dealer banks' incentive to buy CDS protection. Hence, it is in line with our theory that regulatory proxies are less significant for the United Kingdom [11] Interestingly, the CtD has a negative sign for all four sovereigns. A perceived low risk of a triggering event for the CDS is consistent with a coefficient close to zero, and it is reassuring that it is not significantly positive. But there is no clear reason that we can think of for the negative coefficient.

Turning to the results for the three low-risk sovereigns in our sample we find that our regulatory proxies have some economic and statistical significance.

[11] It is unlikely that the effect is dramatic, because legacy positions remain uncollateralized. Hence, the date at which the United Kingdom started posting collateral on their OTC derivatives positions is not a clean cutoff.

Table 5
Sovereign CDS premiums, credit risk, and regulatory proxies

	Interc	β^{YS}	β^{CtD}	β^{Swptn}	β^{EDF}	Adj. R^2	Credit ratio	# Obs
JAP	0.01	0.14	−0.95	0.04*	0.13*	0.09	0.11	256
	[0.02]	[0.40]	[−0.73]	[1.78]	[1.68]			
USA	−0.08	0.04	−0.15	0.00	0.05***	0.06	0.17	251
	[−0.49]	[0.36]	[−0.72]	[0.18]	[4.76]			
GER	−0.04	0.06	−1.30**	0.04***	0.16***	0.35	0.17	256
	[−0.18]	[0.91]	[−2.43]	[2.7]	[4.93]			
GBR	−0.24	0.18***	−0.54*	0.02	0.10***	0.21	0.43	256
	[−1.11]	[3.12]	[−1.88]	[1.06]	[4.76]			
FIN	0.00	0.11***	−0.20	0.01	0.14***	0.43	0.16	242
	[−0.02]	[3.32]	[−1.32]	[1.21]	[6.12]			
FRA	0.07	0.53***	0.91	0.05**	0.40***	0.57	0.51	256
	[0.16]	[7.38]	[1.41]	[1.98]	[6.65]			
AUT	−0.12	0.40***	0.67	0.03	0.27***	0.42	0.57	256
	[−0.29]	[4.43]	[1.06]	[1.2]	[4.17]			
ITA	0.04	0.51***	2.73	0.13**	0.74***	0.64	0.75	256
	[0.04]	[5.60]	[1.33]	[2.28]	[6.43]			
ESP	−0.09	0.65***	2.49*	0.08	0.40***	0.66	0.94	256
	[−0.10]	[8.11]	[1.68]	[1.23]	[4.03]			
POR	0.30	0.53***	2.24	0.15	1.09***	0.66	0.86	255
	[0.15]	[6.64]	[0.93]	[0.90]	[3.96]			

The table reports parameter estimates and heteroscedasticity-robust t-statistics for regressions of the following form:

$$\Delta CDS_t = \alpha + \beta^{YS}\Delta YS_t + \beta^{CtD}\Delta CtD_t + \beta^{Swptn}\Delta Swptn_t + \beta^{EDF}\Delta EDF_t + \varepsilon_t .$$

YS_t is the difference between 5-year bond yield and 5-year overnight swap rate in the respective currency. ΔCtD_t is the change in our estimate of the CtD option, embedded in the sovereign CDS. $Swptn_t$ is the (basis point) premium on an option to enter a 5-year swap position, as fixed payer or fixed receiver, in the respective currency, over the next 5 years. ΔEDF_t is the residual of changes in the average of the Moody's expected default frequency (EDF) for the sixteen largest derivatives-dealing banks, regressed on changes in the yield spreads of the respective sovereign. Credit ratio denotes the ratio of the adjusted R^2 from a regression of ΔCDS_t on ΔYS_t and ΔCtD_t to the adjusted R^2 from the full regression specified above. The sample period is January 2010 to December 2014, using weekly observations sampled each Wednesday. The numbers in square brackets are heteroscedasticity robust t-statistics. * indicates significance at 10% level, ** at 5% level, and *** at the 1% level.

EDFs are significant for all three countries, but $\Delta Swptn_t$ is only significant for France. The main difference between this group and the group of safe haven sovereigns is that bond yield spreads are statistically significant at a 1% level for all three countries and contribute to the explanatory power of our regression with a Credit Ratio ranging from 0.16 for Finland to 0.57 for Austria. Overall, the results for low-risk sovereigns confirm our model implications from Section 3 that both credit risk and regulatory proxies help explaining the variation in CDS premiums. The finding is also in line with an industry research note (Carver, 2011) that attributes the disconnect between CDS premiums and yield spreads for France in 2011 to CVA hedging.[12] An increased demand for sovereign CDS aimed at obtaining capital relief, combined with a lack of natural sellers for these

12 Carver (2011) quotes an official of the French debt management office: "On the demand side [for sovereign CDS] we see mostly two types of players: hedge funds and CVA desks, as they move into line with Basel III. It's possible that some of the dislocation with the cash market is due to legitimate CVA hedging." We provide additional anecdotal evidence on CVA hedging in the Internet Appendix.

contracts can cause the CDS premium to increase, even if the fundamental credit risk remains constant. Our proxy for the CtD has the correct sign for the riskier sovereigns France and Austria, but it is statistically insignificant.

For the three risky sovereigns in our sample, Italy, Portugal, and Spain, we first observe that yield spreads on bonds are clearly the major driver for CDS premiums. The parameter estimate for the yield spread is statistically significant at a 1% level and the credit ratio ranges from 0.75 for Italy to 0.94 for Spain. Interestingly, both regulatory proxies are statistically significant for Italy. This observation as well as the relatively low credit ratio for Italy can be explained by the fact that Italy is arguably the least risky of the three risky sovereigns and has a large notional amount of interest rate swaps outstanding (see, for instance, Totaro and Salzano 2013). Therefore, it supports our theory that regulatory proxies help explaining the variation in Italian CDS premiums. The coefficient for the CtD is positive for all three risky sovereigns and significant at a 10% level for Spain. This is in line with an effect we would expect: The value of the CtD option should increase as the probability of a restructuring event increases, and be negligible if a restructuring event is seen as highly unlikely.

4.3.3 Regression analysis for the extended cross-section. Finally, we return to the extended cross-section of 23 countries and run additional tests using two new regulatory proxies. For each of the three risk categories (safe, low risk, and risky), we run the following panel regression for all countries in that risk category:

$$\Delta CDS_{i,t} = \alpha + \beta^{YS} \Delta YS_{i,t} + \beta^{IR} \Delta IR_{i,t}^{Vol} + \beta^{CDS} \Delta CDS_{i,t}^{Vol} + \varepsilon_t, \tag{13}$$

where $\Delta YS_{i,t}$ is the change in yield spreads, measured as the difference between bond yield and Libor rate, $\Delta IR_{i,t}^{Vol}$ is the change in interest rate volatility, measured as the standard deviation of daily Libor rates in month t, and $\Delta CDS_{i,t}^{Vol}$ is the change in CDS volatility from month $t-1$ to month t. Note that the regressions are run monthly so that we can include measures of volatility estimated from daily data over nonoverlapping 1-month periods.

The first new regulatory proxy in this regression is the change in the realized volatility of the 10-year Libor swap rate. We use this variable instead of swaption premiums because swaption premiums are not available for smaller countries, such as Denmark and Poland. As explained above, the EE of a swap contract can be viewed as the value of a swaption. Therefore, an increase in interest-rate volatility increases the swaption value, which in turn increases the EE and hence the capital charge. The second regulatory proxy is the volatility of changes in CDS premiums. We use the standard deviation of changes (as opposed to standard deviations of levels) because this is the measure used in the regulatory prescription. As explained in Section 3, a higher CDS volatility increases κ, which increases the regulatory hedging motive and therefore the CDS demand and the CDS premium.

Panel B of Table 4 exhibits the results of these regressions. As we can see from the table, both regulatory proxies are highly significant for all risk categories. The coefficient β^{IR} ranges from 0.02 for low-risk sovereigns to 0.09 for risky sovereigns, suggesting that a one basis point increase in the annual interest rate volatility increases the CDS premium by up to 0.09 bps. Moreover, β^{CDS} ranges from 0.11 for risky sovereigns to 0.18 for low-risk sovereigns, indicating that a one basis point increase in the annual volatility of CDS premium changes increases the CDS premium by up to 0.18 bps. Most strikingly, the credit ratio is 0.23 for safe countries, meaning that the majority of explanatory power comes from the two regulatory variables. As for our core sample of 10 countries, the credit ratio increases in the riskiness of the countries and reaches 0.91 for risky countries, indicating that the majority of explanatory power comes from changes in yield spreads.

4.4 Evidence from corporate bond markets

Figure 1 illustrates the breakdown between CDS premium and bond yield for safe sovereigns. We argue that this breakdown is likely caused by regulatory incentives to buy CDS protection on sovereigns. Apart from collateralized derivatives positions with sovereigns, banks also engage in uncollateralized derivatives positions with corporates, and they are also required to compute and report CVA for these positions. To the extent that banks hedge this CVA risk either for regulatory reasons or for accounting reasons (seeking to minimize earnings volatility arising from CVA volatility), we would expect to see a similar pattern of smaller correlation between CDS premiums and yield spreads for safe corporate bonds.

Using data for corporates offers two advantages over sovereigns. First, corporate CDS contracts have been actively traded prior to the financial crisis.[13] Second, we can distinguish between financial firms and nonfinancial firms. As highlighted in Figure 4, nonfinancial firms tend to not post collateral in their derivatives transactions and we would therefore expect to see a similar pattern of falling correlation between CDS premiums and bond yield spreads as credit quality increases. In contrast to that, financial firms are more likely to collateralize their derivatives positions and we would therefore expect a stronger relationship between CDS premiums and bond yield spreads for these issuers.

4.4.1 Data. We obtain corporate bond yields from TRACE and focus our analysis on rated bonds with maturities between 3 and 10 years for which matching CDS premiums with no restructuring (docclause XR) are available

[13] In contrast to corporate CDS premiums, sovereign CDS premiums experienced virtually no variation before the financial crisis. For example, in the sample period from January 2001 to June 2007, the standard deviation of CDS premiums in our sample of ten sovereigns ranged from 0.22 bps for the United States to 2.59 bp for Germany, with Japan being the only country with some moderate standard deviation (of 8.49 bps).

on Markit. We use the last traded yield on each trading day and use a maturity-matched CDS premium, interpolated between the two CDS premiums with nearest maturity available. Similarly, we use a maturity-matched proxy for the risk-free rate, which are swap rates based on Libor (like in Bai and Collin-Dufresne 2013).[14] We clean the data set for obvious outliers, that is, we remove firms where the average CDS-bond basis is above 1.000 bps and individual observations where the CDS-bond basis is above 1.000 bps. Next, we split the sample into five categories: Aaa-Aa-rated corporate bonds, A-rated corporate bonds, Baa-rated corporate bonds, and Ba-C-rated corporate bonds. As a control group, we also include Aaa-Aa-rated financials, which are more likely to post collateral than nonfinancials. We focus our analysis on individual bonds, that is, one firm could issue multiple bonds and we include all bonds that fulfill our criteria in the analysis.

Using these filtering criteria leads to an average time to maturity of approximately 5 years for all subcategories and a number of available bonds that ranges from 87 for Aaa-Aa corporates to 304 for Aaa-Aa financials.[15]

4.4.2 Regression results. In this section, we investigate the relationship between bond yields and CDS premiums for our sample of corporate bonds. Table 6 shows the results of regressing changes in corporate bond yields on changes in CDS premiums, controlling for changes in the risk-free rate, utilizing data from the entire sample period. As we can see from the table, β^{CDS} is 0.42 for Aaa-Aa corporates and significantly different from 1. For A and Baa corporates, β^{CDS} is close to one and not significantly different from one. Hence, for corporate bonds with low credit risk, the CDS premium seems to be driven by other factors than credit risk. Table 6 also shows that for non-investment-grade corporates, β^{CDS} is also significantly different from one. In addition, β^{rf} is insignificant and close to zero for these bonds. One possible explanation for this observation could be a large illiquidity component in these bond yields (see, for instance, Longstaff et al. 2005).

Next, we investigate the breakdown of the relationship between bond yield and CDS premium for Aaa-Aa-rated corporate bonds further. To that end, we split the overall time series into three subperiods: (1) July 2002 to June 2007, (2) July 2007 to December 2009, and (3) January 2010 to December 2014. The idea behind this split is that, according to our theory, there should be no breakdown between CDS premium and bond yield before the financial crisis because the new regulation was only announced afterward. During the financial crisis, the CDS-bond basis became massive (see, for instance, Duffie 2010; Gârleanu and Pedersen 2011; Bai and Collin-Dufresne 2013, among many

[14] The advantage of using Libor swap rates instead of overnight swap rates is that they are readily available for every tenor throughout the sample period.

[15] Additional summary statistics for the data set are available in the Internet Appendix.

Table 6
Link between corporate bond yields and CDS premiums

	Aaa - Aa	A	Baa	Ba-C
Intercept	−0.00	−0.00	−0.00	−0.00
	(0.00)	(0.00)	(0.00)	(0.00)
ΔCDS_t	0.42***	1.02***	0.93***	0.52***
	(0.04)	(0.11)	(0.05)	(0.05)
Δrf_t	0.92***	0.89***	0.68***	0.02
	(0.02)	(0.02)	(0.04)	(0.10)
Observations	19,629	20,249	20,414	29,562
Adjusted R^2	0.42	0.34	0.35	0.30

The table shows the results of a regression of the following form:

$$\Delta Yield_{i,t} = \alpha + \beta^{CDS} \Delta CDS_{i,t} + \beta^{rf} \Delta rf_{i,t} + \varepsilon_{i,t}.$$

$Yield_{i,t}$ is the bond yield of corporate bond i, $CDS_{i,t}$ is the maturity-matched CDS premium for bond i, $rf_{i,t}$ is the maturity-matched proxy for the risk-free rate (measured as Libor rate). The sample period is July 2002 to December 2014. Heteroscedasticity-robust standard errors, clustered on bond level are reported in parentheses. ***, **, and * indicate significance at a 1%, 5%, and 10% level, respectively.

Table 7
Link between bond yields and CDS premiums in different episodes

	Pre	Crisis	Post
Intercept	−0.00	0.00	0.00*
	(0.00)	(0.00)	(0.00)
ΔCDS_t	0.98***	0.48***	0.50***
	(0.09)	(0.11)	(0.07)
$\Delta CDS_t \times \mathbb{1}_{\{Corporate\}}$	−0.20	−0.10	−0.25**
	(0.27)	(0.12)	(0.11)
Δrf_t	0.90***	0.73***	0.96***
	(0.02)	(0.05)	(0.02)
Observations	36,153	12,842	19,823
Adjusted R^2	0.43	0.22	0.57

The table shows the results of a regression of the following form:

$$\Delta Yield_{i,t} = \alpha + \beta^{CDS} \Delta CDS_{i,t} + \beta^{Corp} \Delta CDS_{i,t} \times \mathbb{1}_{\{Corporate\}}(t) + \beta^{rf} \Delta rf_{i,t} + \varepsilon_{i,t}.$$

$Yield_{i,t}$ is the bond yield of bond i, $CDS_{i,t}$ is the maturity-matched CDS premium for bond i, $\mathbb{1}_{\{Corporate\}}$ is a dummy variable that equals one if the underlying is a corporate bond issuer and zero if the underlying is a financial, $rf_{i,t}$ is the maturity-matched proxy for the risk-free rate (measured as LIBOR rate). Nonfinancials include bonds of nonfinancial corporations with an Aaa or an Aa rating. Financials include bonds of financial corporations with Aaa or Aa rating. Under Pre, the results for the July 2002 to June 2007 subperiod are reported. Under Crisis, the results for the July 2007 to December 2009 subperiod are reported. Under Post, the results for the January 2010–December 2014 subperiod are reported. Heteroscedasticity-robust standard errors, clustered on bond level are reported in parentheses. ***, **, and * indicate significance at a 1%, 5%, and 10% level, respectively.

others) and therefore a breakdown of the relationship between CDS premium and bond yield is possible for other reasons than CVA hedging. Only in the third subperiod does our argument apply. We also analyze a sample of Aaa-Aa-rated financial bonds, where we expect a stronger link between CDS premiums and bond yields.

Table 7 shows the results of regressing changes in bond yields on changes in CDS premiums and risk-free rates, allowing for a different slope coefficient for corporate CDS, using Aaa-Aa-rated bonds from financial and nonfinancial issuers over the three different time intervals. As we can see from the table, both nonfinancials and financials have a β^{CDS} that is not significantly different from one before the financial crisis. Moreover, there is no significant difference between β^{CDS} for financial and nonfinancial firms. During the financial crisis, β^{CDS} drops sharply and is significantly different from one for both samples. However, β^{CDS} is, again, not significantly different for financials than for nonfinancials. Only for the January 2010 to December 2014 subperiod do we observe a significant difference between β^{CDS} in the two samples. The β^{CDS} coefficient is only 0.50 for financials and 0.25 lower for corporates, indicating a massive disconnect between CDS premium and bond yield for nonfinancial firms after the financial crisis. In line with our hypothesis, this disconnect is less pronounced for financial firms.

5. Conclusion

In its motivation for including CVA charges in bank capital regulation, the Basel Committee argued that roughly two-thirds of losses attributed to counterparty credit risk during the financial crisis came from losses associated with mark-to-market losses due to deteriorating credit quality as opposed to outright defaults. Hence, CVA plays an important role for earnings and capital requirements of derivatives-dealing banks. That CDS contracts can serve to lower capital requirements and earnings volatility arising from CVA provides an interesting laboratory for studying the extent to which banks are willing to pay for regulatory capital relief.

We provide theoretical and empirical evidence that the use of CDS contracts for capital relief purposes affects both CDS premiums and notional amounts outstanding, and that the impact is particularly pronounced for safe haven CDS premiums. Our empirical evidence has four main components. First, derivatives-dealing banks are long CDS, and notional amounts of CDS are related to the amount of derivatives that banks have entered into with sovereign counterparties. Second, changes in bond yield spreads and in CDS premiums are almost unrelated for safe sovereigns. Third, proxies for incentives to use sovereign CDS for capital relief are significant in explaining CDS premiums for most safe sovereigns. Fourth and finally, evidence from corporate bonds suggests that the disconnect also carries over to safe corporate issuers. In this market, we have reliable price data both pre-crisis and post crisis, and we can exploit different collateralization practices for financial and nonfinancial counterparties.

For safe haven sovereigns it may seem particularly puzzling that banks pay CDS premiums to hedge such risk exposure. If entering an interest rate swap with a safe sovereign has positive net present value for the dealer bank, then why not simply accept this risk on the asset side and issue the relevant amount of equity to meet capital requirements? If Modigliani-Miller irrelevance holds, then this should be costless. Our findings suggest, that in line with Froot and Stein (1998), banks view equity issuance as costly, and they therefore optimally choose to hedge tradeable financial risks. CDS contracts on safe sovereigns make CVA risk – which impacts both earnings and capital – tradeable.

Furthermore, a trading desk in a bank operates under given risk limits and tries to optimize return on equity capital given a certain line of regulatory capital. This creates an incentive to utilize the allocated capital optimally as seen from the trading desk. The optimal allocation may involve buying derivatives that reduce the capital requirement. In this sense, our findings complement the results in Andersen et al. (2017), who show that the use of so-called "funding value adjustments" in the pricing of interest rate swaps serve the purpose of aligning incentives between a swap desk and bank shareholders.

Appendix A. Data Descriptions

This appendix provides additional details about the data used for our analysis.

1. **Sovereign CDS premiums.** We obtain CDS premiums with a 5-year maturity on ten sovereigns from Markit, who provides daily mid-market quotes. We use weekly mid-market quotes in our analysis sampled every Wednesday. In line with previous research (e.g., Fontana and Scheicher 2016), we use the CDS premium of contracts with "CR" as restructuring clause. We also obtain CDS premiums with a 10-year maturity for our extended sample of 23 sovereigns, following the same procedure as described for the 5-year CDS.
2. **Sovereign bond yields.** Sovereign bond yields for 5-year bonds for our sample of ten countries were obtained from the Bloomberg system. Bloomberg uses the latest 5-year benchmark bond to compute the yield. Yields are computed for bonds with semiannual (Italy, Great Britain, Japan, and the United States) and annual (Spain, Austria, Finland, France, and Germany) coupon payments. The day-count convention is Actual/Actual. We also obtain bond yields with a 10-year maturity for our extended sample from the Bloomberg system.
3. **Corporate bond yields.** We obtain the last traded yield on a trading day for each corporate bond that fulfills our filtering criteria from TRACE. Our filtering criteria are that we only use rated bonds with 3 to 10 years to maturity and a matching CDS with XR restructuring clause.
4. **Corporate CDS premiums.** We obtain CDS premiums with the same maturity on the same day as the corporate bond yields from Markit. We only use contracts with "XR" (no restructuring) as restructuring clause.
5. **Risk-free rate proxies.** For the main sample of ten sovereigns, we use swap rates based on overnight lending rates with the same 5-year maturity and the same currency as the bond yield. For European sovereigns, we use Eonia swap rates; for Great Britain, we use Sonia swap rates; for Japan, we use Tibor swap rates; and for the United States, we use OIS rates.

   For U.S. corporates, we use LIBOR swap rates with matching maturity as the underlying bonds as the risk-free rate proxy.

   For our extended sample of sovereigns, we use Libor rates in the respective currency where possible. For Bulgaria, Romania, Slovakia, and Slovenia, we approximate their risk-free rates using Euribor swap rates. All rates were obtained from Bloomberg.

The day-count convention for these swap rates is 360/Actual, but we do not correct for this difference in day-count conventions when computing yield spreads.

6. **CDS amounts outstanding.** Data on amounts of CDS outstanding were obtained from the Depository Trust Clearing Corporation (DTCC), who collects information on outstanding CDS amounts. We use net notional amounts outstanding in our analysis.
7. **Sovereign debt outstanding.** We obtain data on public debt outstanding from contryeconomy.com, which provides annual numbers on countries' public debt outstanding.
8. **Sovereign CDS bought by derivatives dealers.** This number is computed as the difference between gross notional of all sovereign CDS bought by derivatives dealers and gross notional of all sovereign CDS sold by derivatives dealers. The figures were obtained from the DTCC, who publishes weekly information on the gross amount of sovereign CDS bought and sold by derivatives dealers and by end users.
9. **Swaption data.** The swaption quotes are basis point prices of swaption straddles in the respective currencies. A swaption straddle is a portfolio of a long position in a receiver swaption (which gives its owner the right, but not the obligation, to enter into a swap contract as a fixed receiver) and a long position in a payer swaption (which gives its owner the right, but not the obligation, to enter into a swap contract as a fixed payer). Because at-the-money swaptions refer to swap contracts with zero value, an application of the put-call parity shows that payer and receiver swaption have the same price. The data were obtained from Bloomberg.
10. **CDS volatility.** To compute this variable, we use the same formula used in the new Basel capital requirements. That is, at date t, we compute the standard deviation of the changes in the CDS premium. We use monthly standard deviations for our regression analysis and a sample period over the past 252 (756) trading days for the VaR (stressed VaR) calculation.
11. **Interest rate volatility.** We compute the monthly interest rate volatility as the standard deviation of daily Libor swap rates in the respective currency within that month.
12. **G16 EDF.** We obtain 1-year expected default frequencies (EDFs) for the sixteen largest derivatives-dealing banks, commonly referred to as G16 banks, from Moody's Analytics. We then take the average of the sixteen EDFs and orthogonalize the resultant time series for the respective yield spread of the sovereign we analyze.
13. **On-the-run/off-the-run spread.** The spread is computed for bonds with 10 years to maturity, because estimates for this maturity are less noisy than at the 5-year maturity. The 10-year on-the-run yield is obtained from the FED H.15 Web site, and the 10-year off-the-run yield is constructed as explained by Gürkaynak et al. (2007). Data were obtained from http://www.federalreserve.gov/pubs/feds/2006.
14. **KfW spread.** We collect mid-market prices of all euro-denominated bullet bonds with an issuance volume above 1 billion issued by the KfW and the German government. We follow Schuster and Uhrig-Homburg (2015) and fit a Nelson and Siegel (1987) model to the KfW bond prices and the German government bond prices by minimizing the sum of squared duration-weighted differences between observed and model-implied bond prices. We then use these model parameters to extract a 5-year zero-coupon yield for both time series. The KfW spread is then given as the difference between 5-year KfW zero-coupon yield and 5-year German government zero-coupon yield. All bond data were obtained from Bloomberg.
15. **Government bond turnover.** We collect data on weekly Treasury and Gilt turnover from the Federal Reserve's and the Bank of England's website, respectively. For Gilts, because of a lack of finer measure, we use the aggregate turnover of all Gilts. For the United States, we use the turnover of all bonds with 3 to 6 years to maturity.

16. **Cheapest-to-deliver proxy.** To approximate the cheapest-to-deliver (CtD) option, embedded in sovereign CDS, we obtain mid-market bond prices with 1 to 10 years to maturity for each sovereign from the Bloomberg system. We only use bullet bonds with a fixed maturity that are issued in a country's own currency, and we exclude inflation-linked bonds. To ensure that our CtD proxy is not driven by small bonds, we require a minimum issuance volume equivalent to 1 billion U.S. dollars for countries with large bond markets, that is, Japan, the United States, the United Kingdom, Germany, and Italy, and a minimum issuance volume equivalent to 250 million U.S. dollars for the remaining countries. We then construct our CtD proxy as follows:

$$CtD_{i,t} = 100 - \min_j (Price_{j,t}),$$

using the time t prices of all available bonds that satisfy our filters.

Appendix B. Proof of Proposition 1

To prove Proposition 1, we proceed in four steps. First, we derive the end user's optimal asset holdings using the Kuhn-Tucker (KT) theorem, by first assuming that the KT conditions are satisfied. Second, we proceed in a similar way to obtain the bank's optimal asset holdings.[16] Third, we solve for equilibrium and derive the equilibrium condition stated in the proposition. Finally, we verify that the solutions obtained are indeed nonnegative.

We start by deriving the end user's optimal asset holdings. To conform with the convention that the variables over which we optimize are nonnegative, we let $\bar{e}$ denote the number of CDS contracts *sold* by the end user. The end user's Lagrangian is then given as

$$\mathcal{L}(e,\bar{e},\lambda) = \Big(e(\mu - r) - \bar{s}\bar{e} - 1/2(\sigma e)^2 - 1/2\bar{e}^2 v(s)\Big) - \lambda\big(me + n^- \bar{e} - W_0^E\big), \qquad \text{(B1)}$$

where $v(s) := (p-p^2)(\text{LGD}^2 + 2s\text{LGD})$. This is an approximation of the variance of $\tilde{s}$, which is given as $(p-p^2)(s^2 + \text{LGD}^2 + 2s\text{LGD})$, where we ignore the quadratic term s^2.

Therefore, the KT conditions for the end user's problem are

$$\mu - r - \sigma^2 e - \lambda m \le 0 \qquad (=0 \text{ if } e > 0) \qquad \text{(B2)}$$

$$-\bar{s} - \bar{e}v(s) - \lambda n^- \le 0 \qquad (=0 \text{ if } \bar{e} > 0) \qquad \text{(B3)}$$

$$W_0^E - me - n^- \bar{e} \ge 0 \qquad (=0 \text{ if } \lambda > 0) \qquad \text{(B4)}$$

$$e, \bar{e} \ge 0.$$

First, assuming $\lambda = 0$, which corresponds to the case in which the end user is not bound by the margin constraints, the optimal investments in the risky asset and the CDS are given as

$$e = \frac{\mu - r}{\sigma^2} \equiv e^U$$

$$\bar{e} = -\frac{\bar{s}}{v(s)} \equiv \bar{e}^U.$$

Note that $\bar{e}^U$ is strictly positive if $\bar{s} < 0$ or, equivalently, $s > \frac{p}{1-p}\text{LGD}$.

[16] The KT theorem can be applied because the objective function is concave and the constraints are linear and therefore concave as well. Hence, a stationary point satisfying the KT conditions is a maximum.

Next, for $\lambda > 0$, which corresponds to the constrained case, Equations (B2)–(B4) imply

$$e = \frac{\mu - r - \lambda m}{\sigma^2} = e^U - \lambda \frac{m}{\sigma^2} \tag{B5}$$

$$\bar{e} = -\frac{\bar{s} + \lambda n^-}{v(s)} = \bar{e}^U - \lambda \frac{n^-}{v(s)} \tag{B6}$$

$$\lambda = \frac{me^U + n^- \bar{e}^U - W_0^E}{C^E(s)}, \tag{B7}$$

where $C^E(s) = \frac{m^2}{\sigma^2} + \frac{(n^-)^2}{v(s)}$. Note that Inequality (5) ensures that $\lambda > 0$. and that the end user starts supplying CDS contracts if

$$s > s_0 := s = \frac{1}{1-p}\left[\frac{n^-}{m}\left(\mu - r - \frac{\sigma^2}{m} W_0^E\right) + p\text{LGD}\right]. \tag{B8}$$

We will verify that $e > 0$ and $\bar{e} > 0$ in equilibrium in our final step.

Our second step is to derive the bank's optimal asset holdings. We follow the same procedure as for the end user, writing up the Lagrangian and the KT conditions for the bank's optimization problem:

$$\mathcal{L}(b, \bar{b}, \lambda_1, \lambda_2) = \left(b(\mu - r) + \bar{s}\bar{b} - 1/2(\sigma b)^2 - \frac{1}{2}\bar{b}^2 v(s)\right) -$$
$$-\lambda_1\left(mb + n^+\bar{b} + \kappa(EE - \bar{b}) - W_0^B\right) - \lambda_2\left(\bar{b} - EE\right).$$

From this we get the KT conditions:

$$\mu - r - \sigma^2 b - \lambda_1 m \le 0 \qquad (=0 \text{ if } b > 0) \tag{B9}$$

$$\bar{s} - \bar{b}v(s) - \lambda_1(n^+ - \kappa) - \lambda_2 \le 0 \qquad (=0 \text{ if } \bar{b} > 0) \tag{B10}$$

$$W_0^B - \kappa EE - mb - \bar{b}(n^+ - \kappa) \ge 0 \qquad (=0 \text{ if } \lambda_1 > 0) \tag{B11}$$

$$EE - \bar{b} \ge 0 \qquad (=0 \text{ if } \lambda_2 > 0) \tag{B12}$$

$$b, \bar{b} \ge 0.$$

Again, we first look at the unconstrained case, where $\lambda_1 = \lambda_2 = 0$ and obtain

$$b = \frac{\mu - r}{\sigma^2} \equiv b^U$$

$$\bar{b} = \frac{\bar{s}}{v(s)} \equiv \bar{b}^U$$

Next, we look for a stationary point such that all conditions are satisfied with equality. This corresponds to a situation in which the bank buys full protection ($\bar{b} = EE$) and invests $b > 0$ in the risky asset. We find

$$\bar{b} = EE \tag{B13}$$

$$b = b^U - \lambda_1 \frac{m}{\sigma^2} \tag{B14}$$

$$\lambda_1 = \frac{\sigma^2}{m^2}\left(mb^U + n^+ EE - W_0^B\right) \tag{B15}$$

$$\lambda_2 = -EEv(s) + \bar{s} - \frac{\sigma^2}{m^2}\left(mb^U + n^+ EE - W_0^B\right)(n^+ - \kappa), \tag{B16}$$

where the first equality holds by construction. Note that inequality (5) ensures that the bank's margin constraint binds and $\lambda_1 > 0$ is fulfilled. For $\lambda_2 > 0$ to hold, the CDS premium must satisfy the following inequality:

$$s < s_b := \frac{1}{(1-p)(1+2R)}\left[\frac{\kappa - n^+}{m}\left(\mu - r - \frac{\sigma^2}{m}(W_0^B - EEn^+)\right) + p\text{LGD}\right] - \frac{R\text{LGD}}{(1+2R)}. \quad \text{(B17)}$$

Hence, the bank demands full protection as long as the CDS premium satisfies inequalities (B17) and (5).

The third step of our proof is to compute the equilibrium CDS premium. The expression depends on whether the supply curve rises quickly enough to meet demand in the range of CDS premiums where demand is flat (i.e., the full protection case) or the supply curve crosses in the range where the demand curve has begun its descent against 0. We focus on the rate at which the end user is willing to supply EE contracts. If the rate at which this occurs is below the rate at which the bank starts decreasing its demand away from full protection, the equilibrium CDS premium, which equates EE and the end user's supply (given by Equation (B6), is given as:

$$s = s_f^e := \frac{1}{(1-p)(1-2R)}\left(\frac{n^-}{m}\left(\mu - r - \frac{\sigma^2}{m}(W_0^E - n^- EE)\right) + pLGD\right) + \frac{R\text{LGD}}{1-2R}.$$

Finally, in equilibrium, $\bar{b} > 0$ and $\bar{e} > 0$ are fulfilled. Inequalities (7) and (6) ensure that $e > 0$ and $b > 0$, which completes the proof of the proposition. ■

Appendix C. CVA and Capital

We outline in this appendix some background on regulation that helps us understand the size of the capital requirement for a bank with a derivatives exposure to a sovereign. The CVA of a bank's derivatives position with a risky counterparty measures the difference between the value of the position with a risk-free counterparty and the same derivative with the credit-risky counterparty. It is defined by the Basel Committee (see Basel Committee on Banking Supervision 2011) as

$$\text{CVA} = \text{LGD}\sum_{i=1}^{T}\mathbb{Q}(\tau \in (t_{i-1}, t_i))\text{EE}(t_{i-1}, t_i), \quad \text{(C1)}$$

where τ is the default time of the counterparty. LGD is the loss given default, $\mathbb{Q}$ is the risk-neutral default probability of the counterparty in the time interval $[t_{i-1}, t_i]$, and $\text{EE}(t_{i-1}, t_i)$ is the average EE for the same interval. Since default of the counterparty is only costly in states in which the derivative has positive value for the bank, the exposure is calculated as an expectation over values in these states.

Importantly, the probability of default is computed using CDS premiums. It is defined in Basel Committee on Banking Supervision (2011) as

$$\mathbb{Q}(\tau \in (t_{i-1}, t_i)) = \max\left[0, \left(\exp\left(-\frac{s_{i-1}t_{i-1}}{\text{LGD}}\right) - \exp\left(-\frac{s_i t_i}{\text{LGD}}\right)\right)\right],$$

where s_i is the CDS premium on the counterparty for a CDS with maturity date i. The maximum operator ensures nonnegative default probabilities, which is irrelevant for our computations because we use a constant CDS premium based on the 5-year rate.

Capital requirements are computed based on a VaR measure for the CVA, which depends on potential fluctuations in the CVA due to changes in counterparty credit risk. Because counterparty risk is measured through CDS premiums, CVA VaR is a function of the volatility of CDS premiums and the sensitivity of CVA to changes in the CDS premium. Two CVA VaR measures enter into the computation: one based on CDS volatility over the last year and a stressed VaR based on the largest volatility realized over the past 3 years. The simple (nonstressed) CVA VaR has the form:[17]

$$\text{CVA\_VaR} = 3 \times \text{WorstCase} \times \text{CS01}. \tag{C2}$$

WorstCase is given as

$$\textit{annual CDS volatility} \times \sqrt{\frac{10}{252}} \times \Phi^{-1}(0.99). \tag{C3}$$

The factor 3 is a supervisory multiplier, see Gregory (2012). The "credit delta" CS01 expresses the sensitivity of CVA toward a 1-bps change in the CDS premium. To simplify calculations, we assume throughout the paper that the CDS term structure is flat and that CS01 measures the risk of a parallel shift. With this assumption, and using a constant EE, CS01 is given as on page 33 of Basel Committee on Banking Supervision (2011):

$$\text{CS01} = EE \times 10^{-4} \times \sum_{i=1}^{T} \left(t_i \exp\left(-\frac{st_i}{\text{LGD}}\right) - t_{i-1} \exp\left(-\frac{st_{i-1}}{\text{LGD}}\right)\right) \frac{D_{i-1} + D_i}{2}. \tag{C4}$$

Thus, WorstCase $\times$ CS01 represents a linear approximation of a move in CVA that is not surpassed with a probability of 99% over a 10-trading day period (assuming normally distributed movements of the CDS premium).

The same type of formula is used to compute a so-called "stressed" CVA VaR in which the maximum annual volatility observed over the last 3 years is plugged into the WorstCase part instead of the annual volatility computed over the last year. Having computed the CVA in both a normal version and a stressed version, the addition to risk-weighted asset, RWA, is conservatively set to be the *sum* of the two VaR measures:

$$RWA = 12.5 \times (CVA\ VaR + CVA\ Stressed\ VaR), \tag{C5}$$

where the multiplication with 12.5 ensures that the added capital requirement is equal to the sum of $CVA\ VaR$ and $CVA\ Stressed\ VaR$ under an 8% capital rule.

We assume in our calculations that the capital requirement is $0.1 \cdot RWA$, but it might be set even higher, because the dealer banks that we are looking at have extra capital buffers related to their status as systemically important banks and their desire to stay on the safe side of binding capital requirements.

In our model, the bank has the choice between accepting a capital requirement of $\kappa(s)EE$ or buying CDS protection on a notional amount equal to EE. From our calculations above, it follows that

$$\kappa(s) = 0.1 \cdot 12.5 \cdot c \cdot \frac{CS01}{EE} (\sigma_1(s_t) + \sigma_3(s_t)), \tag{C6}$$

where $\sigma_1(s_t)$, $\sigma_3(s_t)$, and c are, respectively, the CDS volatility over the last year, the maximal level of the annual volatility over the last 3 years, and a constant collecting constants from Equations (C2) and (C3). This expression for $\kappa(s)$ only depends on the level and the volatility of CDS premiums. We are therefore able to compute values of $\kappa(s)$ and see if historical data confirm a potential for capital relief.

[17] We follow Gregory (2012) (p. 390) with this formula. Different banks might use different approaches to compute VaR. A more common way among banks with more than one counterparty is to use historical simulation to compute the CVA VaR.

References

Acharya, V., I. Drechsler, and P. Schnabl. 2014. A pyrrhic victory? Bank bailouts and sovereign credit risk. *Journal of Finance* 69:2689–2739.

Andersen, L., D. Duffie, and Y. Song. 2017. Funding value adjustments. Working Paper, Stanford University.

Ang, A., and F. A. Longstaff. 2013. Systemic sovereign credit risk: Lessons from the U.S. and Europe. *Journal of Monetary Economics* 60:493–510.

Antón, M., S. Mayordomo, and M. Rodriguez-Moreno. 2015. Dealing with dealers: Sovereign CDS comovements in Europe. Working Paper.

Augustin, P., V. Sokolovski, M. Subrahmanyam, and D. Tomio. 2016. Why do investors buy sovereign default insurance. Working Paper, New York University.

Augustin, P., M. Subrahmanyam, D. Tang, and S. Wang. 2014. Credit default swaps: A survey. *Foundations and Trends in Finance* 9:1–196.

Bai, J., and P. Collin-Dufresne. 2013. The CDS-bond basis. Working Paper, Georgetown University and EPFL.

Basel Committee on Banking Supervision. 2011. Basel III: A global regulatory framework for more resilient banks and banking systems. Bank for International Settlements.

Blanco, R., S. Brennan, and I. W. Marsh. 2005. An empirical analysis of the dynamic relation between investment-grade bonds and credit default swaps. *Journal of Finance* 60:2255–81.

Bongaerts, D., F. C. J. M. de Jong, and J. Driessen. 2011. Derivative pricing with liquidity risk: Theory and evidence from the credit default swap market. *Journal of Finance* 66:203–40.

Brown, J. R., and G. G. Pennacchi. 2015. Discounting pension liabilities: Funding versus value. Working Paper, National Bureau of Economic Research.

Carver, L. 2011. Dealers predict CVA-CDS loop will create sovereign volatility. *Risk Magazine*, November 2. https://www.risk.net/regulation/basel-committee/2120808/dealers-predict-cva-cds-loop-will-create-sovereign-volatility.

———. 2013. Capital or P&L? Deutsche bank losses highlight CVA trade-off. *Risk Magazine*, October 13. https://www.risk.net/regulation/basel-committee/2295553/capital-or-pl-deutsche-bank-losses-highlight-cva-trade.

Chernov, M., L. Schmid, and A. Schneider. 2015. A macrofinance view of US sovereign CDS premiums. Working Paper, UCLA and Duke University.

Duffie, D. 2010. Presidential address: Asset price dynamics with slow-moving capital. *Journal of Finance* 65:1237–67.

Duffie, D., M. Scheicher, and G. Vuillemey. 2015. Central clearing and collateral demand. *Journal of Financial Economics* 116:237–52.

Flannery, M. J. 2014. Maintaining adequate bank capital. *Journal of Money, Credit and Banking* 46:157–80.

Fontana, A., and M. Scheicher. 2016. An analysis of euro area sovereign CDS and their relation with government bonds. *Journal of Banking & Finance* 62:126–40.

Froot, K. A., and J. C. Stein. 1998. Risk management, capital budgeting, and capital structure policy for financial institutions: An integrated approach. *Journal of Financial Economics* 47:55–82.

Gârleanu, N., and L. H. Pedersen. 2011. Margin-based asset pricing and deviations from the law of one price. *Review of Financial Studies* 24:1980–2022.

Gregory, J. 2012. *Counterparty credit risk and credit value adjustment: A continuing challenge for global financial markets*. New York: Wiley.

Gromb, D., and D. Vayanos. 2002. Equilibrium and welfare in markets with financially constrained arbitrageurs. *Journal of Financial Economics* 66:361–407.

———. 2010. Limits of arbitrage. *Annual Review of Financial Economics* 2:251–75.

Gündüz, Y. 2016. Mitigating counterparty risk. Working Paper, Deutsche Bundesbank.

Gürkaynak, R. S., B. Sack, and J. H. Wright. 2007. The US Treasury yield curve: 1961 to the present. *Journal of Monetary Economics* 54:2291–304.

Gyntelberg, J., P. Hördahl, K. Ters, and J. Urban. 2013. Intraday dynamics of euro area sovereign CDS and bonds. Working Paper, Bank for International Settlements.

He, Z., B. Kelly, and A. Manela. 2017. Intermediary asset pricing: New evidence from many asset classes. *Journal of Financial Economics* 126:1–35.

ICMA. 2011. The impact of derivative collateral policies of european sovereigns and resulting Basel III capital issues. Research Report, ICMA Group.

Junge, B., and A. B. Trolle. 2014. Liquidity risk in credit default swap markets. Research Paper, Swiss Finance Institute.

Kallestrup, R., D. Lando, and A. Murgoci. 2016. Financial sector linkages and the dynamics of bank and sovereign credit spreads. *Journal of Empirical Finance* 38:374–93.

Krishnamurthy, A., and A. Vissing-Jorgensen. 2012. The aggregate demand for treasury debt. *Journal of Political Economy* 120:233–67.

Longstaff, F., S. Mithal, and E. Neis. 2005. Corporate yield spreads: Default risk or liquidity? New evidence from the credit default swap market. *Journal of Finance* 60:2213–53.

———. J. Pan, L. H. Pedersen, and K. J. Singleton. 2011. How sovereign is sovereign credit risk? *American Economic Journal: Macroeconomics* 3:75–103.

Moody's Investors Service. 2011. Sovereign default and recovery rates, 1983-2010. Special Comment. Moody's Investors Service.

Murphy, D. 2012. The doom loop in sovereign exposure. *FT Alphaville*, April 12. https://ftalphaville.ft.com/2012/04/12/946181/the-doom-loop-in-sovereign-exposures/

Nelson, C. R., and A. F. Siegel. 1987. Parsimonious modeling of yield curves. *Journal of Business* 60:473–89.

Oehmke, M., and A. Zawadowski. 2016. The anatomy of the CDS market. *Review of Financial Studies* 30:80–119.

O'Kane, D. 2012. The link between eurozone sovereign debt and CDS prices. Working Paper, EDHEC-Risk Institute.

Pan, J., and K. Singleton. 2008. Default and recovery implicit in the term structure of sovereign CDS spreads. *Journal of Finance* 63:2345–84.

Rampini, A. A., S. Viswanathan, and G. Vuillemey. 2017. Risk management in financial institutions. Working Paper, Duke University.

Schuster, P., and M. Uhrig-Homburg. 2015. Limits to arbitrage and the term structure of bond illiquidity premiums. *Journal of Banking & Finance* 57:143–59.

Shleifer, A., and R. W. Vishny. 1997. The limits of arbitrage. *Journal of Finance* 52:35–55.

Sorensen, E. H., and T. F. Bollier. 1994. Pricing swap default risk. *Financial Analysts Journal* 50:23–33.

Totaro, L., and G. Salzano. 2013. Italy is euro area's biggest swap loser after deals backfired. *Bloomberg*, April 23. https://www.bloomberg.com/news/articles/2015-04-23/italy-is-euro-area-s-biggest-swap-loser-after-deals-backfired.

Yorulmazer, T. 2013. Has financial innovation made the world riskier? CDS, regulatory arbitrage and systemic risk. Working Paper, Federal Reserve Bank of New York.