CDS and Sovereign Bond Market Liquidity

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During the recent debt crisis in Europe, policy makers responded to the controversy surrounding CDS by implementing a series of policies that banned CDS trading. I use these bans as quasi-natural experiments to identify how derivative markets affect liquidity of the underlying cash market. I document that a temporary CDS ban increased bond market liquidity but a permanent ban instead decreased bond market liquidity. To explain these patterns, I build a dynamic search-theoretic model of over-the-counter bond and CDS markets that features an endogenous liquidity interaction between the two markets. My model shows that these opposing patterns are due to the fact that bond and CDS markets are substitute markets in the short run but are complementary markets in the long run. My results challenge existing theories of liquidity interaction among multiple markets and the common perception that the CDS market is a more liquid market than the bond market.

Are financial derivatives just redundant securities or do they affect the underlying asset, and in what ways? The recent crises in the US and in Europe and the policy debate surrounding these events illustrated our limited understanding of the recent financial innovations and derivatives such as credit derivatives and securitization. In this paper, I study both empirically and theoretically how derivatives affect price and liquidity of the underlying asset in a particular context: sovereign bond and credit default swap (CDS) markets.[1] The controversy surrounding CDS during the debt crisis in Europe culminated in a series of policies that banned "naked" purchases of CDS

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[1]A buyer of a CDS protection pays a periodic fee until either the contract matures or a default (or a similar event) occurs. In return, the protection seller transfers the purchased amount of insurance in the event of default. The contract specifies the reference entity, the contract maturity date, the insurance amount, and the events that constitute a credit event.

where investors buy CDS protection without actually owning the underlying government bonds. These policies serve as quasi-natural experiments that allow us to empirically identify the effect of naked CDS trading on the underlying bonds.

Using these bans and a diff-in-diff analysis, I document that permanent versus temporary CDS bans had completely opposite effects on bond market liquidity. When the EU voted in October 2011 to *permanently* ban naked CDS referencing EU countries, countries affected by the ban experienced a *decrease* in their bond market liquidity. When Germany *temporarily* banned naked CDS in May 2010, this pattern reversed: bond market liquidity temporarily *increased* instead.

To explain these opposing patterns and, consequently, shed light on how CDS markets affect the underlying bond market, I build a dynamic search-theoretic model of over-the-counter (OTC) bond and CDS markets. My model shows that, for traders who want a long exposure to credit risk, bond and CDS markets are substitute markets in the short run but are complementary markets in the long run. Depending on the nature of the ban, as a result, one effect dominates the other. When the CDS ban is temporary, long traders temporarily substitute out of the CDS into the bond market and bond market liquidity temporarily increases. When the ban is permanent, however, as traders are forced to exit the CDS market, they pull out from the bond market also and bond market liquidity decreases.

In the model, I capture the over-the-counter structure of bond and CDS markets using the search and bilateral bargaining mechanism of Duffie, Garleanu, and Pedersen (2005, 2007). A fraction of bond owners are hit by a liquidity shock that requires them to sell their bonds. Locating a buyer, however, involves search costs. When a seller finds a buyer, she takes into account the difficulty of locating a buyer again and resorts to selling her bond at a discounted price. Thus, as in the standard search framework, search costs create an illiquidity discount in bond prices.

I study how CDSs affect this illiquidity discount by modeling two novel features. The first is the presence of CDS markets. CDSs are derivative assets, while bonds are fixed supply assets, and trading CDS contracts also involves search costs. Traders cannot directly short bonds but can buy (naked) CDSs to short credit risk. This assumption captures the fundamental difference between bond and CDS markets: it is cheaper to short credit risk using the CDS market than the bond market. The second novel feature is endogenous entry: the investors' entry rate into the underlying bond market endogenously adjusts to the introduction (and the elimination) of the CDS market.

In this environment, the complementarity effect works as follows. For traders looking to acquire a long position, selling CDSs and buying bonds are two different ways to be exposed to credit risk and they can search for a counterparty simultaneously in both the CDS and the bond market. This ability to simultaneously search in both markets reduces the expected search time of acquiring a long position in either market: long traders now have twice as many potential counterparties and, hence, a higher probability of finding a counterparty in either market. A marginal long trader – who would have been deterred by the search cost when there was just the bond market – is now willing to enter both the CDS *and* the bond market. As a result, the CDS market is complementary to the bond market: the existence of naked CDS buyers increases bond market liquidity by changing the ex-ante incentive of a marginal trader to enter and search for a long position in either market. Permanently banning naked CDS trading reverses this complementarity effect and eliminates the positive externality on bond market liquidity: long traders are forced to exit the CDS market but, by exiting the CDS market, they pull out from the bond market also.

When the CDS ban is temporary, the benefit of adjusting entry and exit into the bond and CDS markets (at the extensive margin) does not outweigh the cost of doing so. As a result, the aggregate number of traders across bond and CDS markets remains unchanged and there is only a movement at the intensive margin between bond and CDS markets. Long traders – who would have otherwise sold CDSs to the naked buyers – temporarily resort to trading in the bond market by buying bonds and thereby increase liquidity in the bond market.

The model mechanism critically relies on both endogenous entry and search frictions in the CDS market. Without search frictions in the CDS market, the CDS market is redundant: the existence of naked CDS buyers does not affect bond market liquidity. Thus, trading frictions in the CDS market create an interaction between bond and CDS markets that helps rationalize the empirical patterns. Also, in the data transaction costs in sovereign CDS markets are non-trivial: CDS bid-ask spreads are, on average, ten times larger than bond bid-ask spreads. The importance of trading frictions in the CDS market both in the model and in the data challenges the common perception and a common assumption in recent papers that the CDS market is a more liquid market. My results show that this is not the case.

The fact that bond and CDS markets can be complementary markets is a novel result in light of existing theoretical studies of the liquidity interaction between multiple asset markets. These studies highlight the migration (or equivalently, the substitution) effect. In these models, the aggregate number of traders across markets is kept fixed and, consequently, introducing additional markets necessarily results in a fragmentation and migration of traders across multiple markets. I show that an important interaction between multiple markets arises out of endogenizing traders' entry decision at the extensive margin (consequently, the aggregate number of traders across markets is endogenous) and this channel helps rationalize the observed empirical patterns.

This paper contributes to the existing literature by providing the first theoretical framework of over-the-counter trading in both the underlying and derivative markets. The framework features an interdependent endogenous bond and CDS market liquidity and can be used to analyze topics of growing interest such as the CDS-bond basis and the relative price discovery and to study how relative liquidity in bond and CDS markets affect these mechanisms. Although I apply the model to sovereign bond and CDS markets, the model framework can applied to study a large class of assets and their derivatives that are traded over-the-counter: currency, commodities, asset-backed securities, real estate and other fixed-income assets (e.g. corporate bond, bank loans, and various interest rate securities).

The second main contribution of the paper is empirical. Empirically identifying how naked CDS trading affects the bond market is confounded by two issues. First, a direct measure of the amount of naked CDS purchases does not exist as we only observe the total amount of CDS purchased (the sum of naked and covered). The second issue is identifying causation as opposed to correlation. Using the CDS bans as quasi-natural experiments helps to circumvent these issues. My difference-in-difference analysis exploits the realization of these bans, the timing of these bans, and the fact that some countries were affected, while others were not. I also use daily data that I collected on over 3,200 individual bond issues across 66 government bond markets and CDS data for 66 countries including CDS spreads, liquidity, the amount of outstanding CDS, and the volume of CDS trade. Thus, the empirical analysis is to my knowledge the most comprehensive study of sovereign bond and CDS markets.

This paper highlights a novel mechanism in which naked CDS buyers directly affect liquidity of the underlying bond market. The most commonly posited effect of CDS on the bond market is the "covered" CDS story: the ability to insure one's bond portfolio by buying CDS is likely to attract traders into the bond market and increase bond market liquidity. As for the effect of naked CDS trading, a common hypothesis is that it increases liquidity of the CDS market itself and, consequently, *indirectly* increases bond market liquidity by making CDS a cheaper hedging tool. These effects, however, cannot explain why permanent versus temporary CDS bans would affect bond market liquidity differently. This paper instead proposes a theory that rationalizes the opposite effects within the same theoretical environment.

Another effect that my mechanism is distinct from is the basis trade. In a basis trade, investors trade on an arbitrage opportunity arising from how credit risk is priced in bond and CDS markets versus the theoretical arbitrage relationship between the two securities. For example, if the CDS price is too low relative to bond spreads, then a basis trading strategy would involve buying bonds and buying CDS. Thus, the existence of the CDS market, by creating a potential arbitrage opportunity, may increase the amount of trade and liquidity in the bond market. But basis trades necessarily involve a long position in one market (e.g. buying bonds as in the example) but a short position in the other market (e.g. buying CDS). In contrast, in my mechanism, there is an increase in the volume of trade and liquidity in the bond market due to traders seeking a long position in *both* markets.

Finally, an important policy implication of my results is that permanently banning naked CDS trading adversely affected bond market liquidity, depressed bond prices, and thereby increased sovereign's borrowing cost exactly when governments were trying to avert a liquidity dry-up and credit risk spiral. This result is particularly important in the context of a sovereign debt crisis.

Related Literature

This paper belongs to the search literature of financial assets beginning with the seminal papers Duffie, Garleanu, and Pedersen (2005, 2007). My framework is closely related to the extensions of their environment to multiple assets by Vayanos and Wang (2007), Weill (2008) and, in particular, it is a variant of Vayanos and Weill (2008)'s framework that sheds light on the on-the-run phenomenon of Treasury bonds. I contribute to this literature, first, by modeling over-the-counter trading in derivatives in addition to trading in the underlying asset and, second, by endogenizing the entry decisions of agents into the market for the underlying asset in response to the introduction of the derivative market.

A related paper is Afonso (2011) who endogenizes the entry decisions of traders but in a single market setting. My model differs by featuring both multiple markets and endogenous entry and therefore sheds light on the rate of entry into one market as a result of introducing another market and on the mechanism through which traders migrate between different markets.

A search theoretic paper applied specifically to CDS markets is Atkeson, Eisfeldt, and Weill (2012) who in a static setting study how banks' CDS exposure arises endogenously depending on their size and their exposure to aggregate risk. In contrast, my paper focuses on naked CDS and studies in a dynamic setting the feedback from the CDS market into the bond market by allowing trade in both the bond and the CDS market as opposed to just the CDS market. Oehmke and Zawadowski (2013a) explore how CDS affects bond prices in Amihud and Mendelson (1986) type framework with exogenous trading frictions. In contrast, my model features endogenous trading costs.

A related literature is equilibrium asset pricing models with exogenous trading frictions (see, for example, Amihud and Mendelson (1986), Acharya and Pedersen (2005)). My model features endogenous bond market liquidity and thereby allows for an endogenous interaction and a spillover between the underlying and the derivative markets.

A growing number of papers use reduced form approaches to price and quantify liquidity risk in bond and CDS markets. Longstaff, Mithal, and Neis (2005), Chen, Lesmond, and Wei (2007), Bao, Pan, and Wang (2011), for example, study liquidity of corporate bond markets and Beber, Brandt, and Kavajecz (2009) and Bai, Julliard, and Yuan (2012) of sovereign bond markets. Tang and Yan (2007), Chen, Fabozzi, and Sverdlove (2010), and Bongaerts, De Jong, and Driessen (2011) price liquidity risk in corporate CDS markets, and Beber, Brandt, and Kavajecz (2009), Bai, Julliard, and Yuan (2012) in sovereign CDS markets. These papers find a nontrivial magnitude of illiquidity in CDS markets. This paper complements this literature in two ways: first, it provides a theoretical framework to study bond and CDS liquidity, and, second, by using the CDS ban regulations, it documents novel empirical patterns in how bond and CDS market liquidity are interlinked.

Motivated by the theoretical arbitrage relation between how credit risk is priced through bond prices versus through CDS spreads, a growing number of papers study the joint dynamics of bond and CDS spreads, or equivalently the CDS-bond basis, as well as the relative price discovery mechanism in bond and CDS markets.[2] These papers' findings suggest that on average the arbitrage relation holds. But when it does not and the price of credit risk in these two markets deviate, where the price discovery takes place (determined by which of the two prices leads the other) is state dependent. In particular, one of the important determinants is the relative liquidity in these markets. I add to this literature by providing a tractable theoretical framework with endogenous liquidity interaction between the two markets and, hence, precise implications on liquidity and prices in both markets.

In empirically analyzing naked CDS bans, this paper is related to Boehmer, Jones, and Zhang (2013) and Beber and Pagano (2013) who document that short-selling bans on stocks during the financial crisis adversely affected stock market liquidity. In contrast to these papers, I study how regulations that restricted trade in one market affected another related market and, thereby, make inferences on the underlying interaction between the related asset markets.

My work is also related to the literature that studies how CDS affects the issuer of the debt security on which the CDS contracts are written. Empirical studies include Ashcraft and Santos (2009) and Subrahmanyam, Tang, and Wang (2011) who study the effect on firms' cost of borrowing and credit risk, respectively.[3] Also Das, Kalimipalli, and Nayak (2013) document that corporate bond market liquidity did not improve with the inception of the CDS market, while Massa and Zhang (2012) and Shim and Zhu (2010) document that CDS markets increased corporate bond market liquidity. In contrast, my paper identifies the effect of naked CDS trading (as opposed to the CDS market in general) on bond market liquidity and focuses on sovereign bond and CDS markets.

On the theoretical front, Arping (2013) and Bolton and Oehmke (2011) formalize the tradeoffs associated with the empty creditor problem in the context of corporate debt and Sambalaibat (2012) in the context of sovereign debt. Duffee and Zhou (2001) find that credit derivatives alleviate the lemons

[2]Studies of the relative price discovery in corporate bond and CDS include Blanco, Brennan, and Marsh (2005) and in sovereign bond and CDS: Fontana and Scheicher (2010), Arce, Mayordomo, and Peña (2012), Ammer and Cai (2011), Calice, Chen, and Williams (2011), Delatte, Gex, and López-Villavicencio (2011). More specifically on the CDS-bond basis, see, for example, Blanco, Brennan, and Marsh (2005) and Bai and Collin-Dufresne (2011). See Augustin (2014) for a survey of this literature.

[3]Ashcraft and Santos (2009) find that CDS has beneficial effects on firms' cost of borrowing for safer firms but adverse effects for riskier firms as banks may lose the incentive to monitor firms. Subrahmanyam, Tang, and Wang (2011) find CDS increases firms' credit risk which they attribute to protected creditors' reluctance to restructure. Berndt and Gupta (2009) find that borrowers, whose loans have been sold off, underperform.

problem associated with banks having private information on their loans.[4] Thompson (2007) and Parlour and Winton (2009) study the tradeoffs that banks face in selling off versus insuring loans on their balance sheets. Thus, these papers have focused on issues surrounding *covered* CDS buyers who are *directly* exposed to the issuer's default risk. This paper instead focuses on how *naked* CDS buyers affect the issuer's cost of borrowing through their effect on bond market liquidity and bond prices.[5]

This paper also contributes to the theoretical literature that studies the distribution of liquidity and trade across multiple markets. Examples that use information-based frameworks are Admati and Pfleiderer (1988), Pagano (1989), and Chowdhry and Nanda (1991), while search-theoretic ones are Vayanos and Wang (2007), Vayanos and Weill (2008), and Weill (2008). A typical result in these papers is that traders endogenously concentrate in one market and trade in the other market disappears. Multiple markets can co-exist under additional assumptions of heterogeneous agents and heterogenous markets so that there is a "clientele" effect.[6] The focus of these papers has been the endogenous cross-sectional distribution of liquidity and trade across markets and assets. This endogeneity is, consequently, on the intensive margin (i.e. the number of traders can vary in the cross-section but the aggregate number of traders is fixed), and the results of these papers are effectively partial equilibrium effects. In my model, if the aggregate number of traders is kept fixed, then (similar to these papers) with the introduction of the CDS market, traders migrate from the bond market to the CDS market and bond market liquidity decreases. However, my model also shows that if the aggregate number of traders is endogenous to the introduction of an additional security (i.e. the endogeneity is on the extensive margin), then the result is the opposite: the number of traders and liquidity in the market for the underlying asset increase.

More broadly, this paper belongs to the literature on the effect of derivatives such as options and futures on the market for the underlying assets. A majority of this literature is empirical.[7] Theoretical frameworks that study the effect of derivatives on liquidity of the underlying asset market include Subrahmanyam (1991), Gorton and Pennacchi (1993), and John, Koticha, Subrahmanyam, and Narayanan (2003) and they also get the "migration"

[4]Duffee and Zhou (2001) also show that that credit derivatives adversely affect the parallel loan sales market.

[5]Although I do not formally model the issuer's borrowing cost in the primary debt markets, He and Milbradt (2012) provide a formal treatment of the feedback loop between credit risk, the issuer's borrowing cost through the primary debt markets, and liquidity of the secondary bond markets.

[6]For example, Pagano (1989) shows that if markets differ in their fixed entry cost, then an equilibrium with multiple markets exists and has the following feature: the more liquid market has a larger fixed cost of entry and is also the market where only large traders (those needing a larger portfolio adjustment) are attracted to. This is because the larger market has a bigger absorbing capacity (i.e. minimal price impact) and the fixed entry cost can be spread over a large transaction size.

[7]See, for example, Chakravarty, Gulen, and Mayhew (2004) and the survey article, Mayhew (2000).

result as the above multiple market information-based models.[8] I add to the literature by endogenizing entry. Also, these papers are based on Kyle (1985) and Glosten and Milgrom (1985) type frameworks where illiquidity arises from asymmetric information. The stylized OTC search framework of my paper is better suited for sovereign bond markets for two reasons. First, trade in sovereign bond markets is fragmented across heterogenous bonds and, second, asymmetric information and insider trading are less severe with respect to governments than with respect to individual firms.

The paper is organized as follows. Section 1 presents the model environment, while Section 2 derives the main theoretical results. Section 3 describes the data and gives the institutional details on bond and CDS markets. Section 4 documents the empirical patterns that motivate the model. Section 5.1 discusses how the model implications rationalize the observed empirical patterns and Section 6 concludes. All proofs are in the Appendix.

1 Model

Agents are heterogenous in their valuation of asset cash flows. Their valuations change randomly and thus generate trade in equilibrium. But finding a counterparty involves search costs that endogenously depend on the relative number of buyers and sellers. As a result, asset owners resort to selling their asset at a discount, and search costs create an illiquidity wedge in asset prices relative to a frictionless price.

In particular, time is continuous and goes from zero to infinity. Agents are risk neutral, infinitely lived, and discount the future at the constant rate $r > 0$. There is a bond with supply S that pays a coupon flow δ_b. In addition, agents can trade CDS in which a buyer of a CDS contract pays a premium flow p_c and, in return, benefits from an expected insurance payment of δ_c. CDS allows both long and short positions to the underlying credit risk: a buyer of a CDS contract has a short exposure, while a seller has a long exposure. I assume that bonds allow only a long exposure and that agents cannot short bonds directly. The bond coupon flow can be interpreted as an expected coupon flow: with intensity η the bond defaults but otherwise pays a dollar of coupon. Hence, $\delta_b = (1-\eta)\$1$. Similarly, δ_c can be interpreted as an expected insurance payment: a CDS contract pays out a dollar if there is a default on the coupon payment, thus $\delta_c = \eta\$1$.

[8] Subrahmanyam (1991) and Gorton and Pennacchi (1993) using Kyle (1985) framework show that stock index futures market and security baskets, respectively, lower liquidity in the underlying stock market as some traders migrate to these derivative markets. John, Koticha, Subrahmanyam, and Narayanan (2003) also get similar results using Glosten and Milgrom (1985) framework to study the effect of options on stock market liquidity. Brennan and Cao (1996) and Cao (1999) using Hellwig (1980) environment show that options increase market depth of the underlying market. Other theoretical frameworks that study the effect of derivatives on aspects other than liquidity include Back (1993) and Biais and Hillion (1994). Back (1993) develops a framework based on Kyle (1985) to study the effect of options on price volatility. Biais and Hillion (1994) provide another information-based model of options and study their effect on price informativeness of the underlying asset.

Agents' utility valuations of assets switch randomly between high, average, and low types where each type values the bond and CDS payoffs as given in Table 1. Specifically, let $\theta = 1$ denote a long position (exposed to risk) through the bond or the CDS market, $\theta = 0$ no position, and $\theta = -1$ a short position (i.e. bought CDS). An agent with $\theta_b \in \{0, 1\}$ shares of the bond has a utility flow $\theta_b \left(\delta_b + x_t^b\right) - |\theta_b| y$. An agent with CDS position $\theta_c \in \{-1, 0, 1\}$ has a utility flow $-\theta_c \left(\delta_c + x_t^c\right) - |\theta_c| y$, where $x_t^b \in \{-x_b, 0, x_b\}$ and $x_t^c \in \{-x_{ch}, 0, x_{cl}\}$ are stochastic processes, and y is a cost of risk bearing that is positive for both long and short positions. I define an agent with $\{x_t^b = x_b, x_t^c = -x_{ch}\}$ as a high type, with $\{x_t^b = 0, x_t^c = 0\}$ as an average, and with $\{x_t^b = -x_b, x_t^c = x_{cl}\}$ as a low type.

The parameters x_b, x_{ch}, and x_{cl} can be interpreted as hedging benefits. High types may have an idiosyncratic endowment that is negatively correlated with the bond cash flow, while low types have an idiosyncratic endowment that is positively correlated with the bond. Thus, a low type agent would get an extra disutility of x_b from holding the bond ($\theta_b = 1$), while a high type would get an extra utility x_b. As a CDS seller ($\theta_c = 1$), a low type experiences a greater disutility paying out an insurance payment $(-(\delta_c + x_{cl}) - y)$ than a high type $(-(\delta_c - x_{ch}) - y)$. Conversely, as a CDS buyer ($\theta_c = -1$), a low type benefits more from an insurance payment $((\delta_c + x_{cl}) - y)$ than a high type $((\delta_c - x_{ch}) - y)$. Appendix A.1 gives a simple example of how the parameters x_b, x_{ch}, and x_{cl} can be functions of the default intensity of the bond. Appendix A.2 formally shows how, in an environment with risk averse agents, the hedging benefits are functions of the risk aversion parameter, the correlation between agents' idiosyncratic endowment and the bond cash flow, and the riskiness of the bond.

Table 1: Valuation of bond and CDS payments by high, average, and low type agents.

Agents are heterogenous in their valuation of bond and CDS cash flows. As shown in the "Bond Owner" column, high type agents derive a higher utility from a long exposure to the bond, while low type agents derive a disutility from a long exposure to the bond. Conversely, low type agents derive a higher utility from a short position (as shown in the "CDS Buyer" column), while high type agents derive a disutility from a short position. As a result, in equilibrium high type agents search for long positions, while low type agents short credit risk. Average type agents are in between.

Types	Bond Owner ($\theta_b = 1$)	CDS Buyer ($\theta_c = -1$)
High	$\delta_b + x_b - y$	$\delta_c - x_{ch} - y$
Average	$\delta_b - y$	$\delta_c - y$
Low	$\delta_b - x_b - y$	$\delta_c + x_{cl} - y$

Assumption 1. $x_{ch} + x_{cl} > 2y > x_{ch}$

Assumption 1 ensures that low valuation agents will want to short by buying CDS, while average types will not want to short. To see this, if a low type agent buys CDS from a high type, the buyer's flow surplus from the transaction is $(\delta_c + x_{cl}) - y - p_c$, while the seller's is $p_c - (\delta_c - x_{ch}) - y$. The total surplus is then $x_{ch} + x_{cl} - 2y$, which is positive from Assumption 1.

If, instead, an average type buys CDS from a high type, the total surplus is $x_{ch} - 2y$, which is negative from Assumption 1.

There is an infinite mass of average valuation agents. A fixed flow $2F_h$ of average types switch to a high type, and a flow F_l switch to a low type. A high type agent enters to trade in the bond and the CDS market only if the expected value of trading as a high type (denoted by V_{hn}) is at least greater than the value of her outside option. I assume that half of the agents that switch to a high type do not have an outside option and hence always enter, while the other half has a positive opportunity cost of entering denoted by O_h.[9] Among these agents, let ρ be the fraction that enter:

$$\rho = \begin{cases} 1 & V_{hn}(\rho) > O_h \\ [0,1] \text{ if } & V_{hn}(\rho) = O_h \\ 0 & V_{hn}(\rho) < O_h. \end{cases} \tag{1}$$

Thus, the total flow of high types actually entering is $(1+\rho)F_h$.[10] Conversely, high types switch to an average type with Poisson intensity γ_d, while low types switch to an average type with Poisson intensity γ_u. Thus, the steady state measure of high types is at least $\frac{F_h}{\gamma_d}$, while the steady state measure of low type agents is $\frac{F_l}{\gamma_u}$.

Assumption 2. $\frac{F_h}{\gamma_d} > S + \frac{F_l}{\gamma_u}$

Assumption 2 ensures that high types are the marginal investors in the bond.

1.1 The Bond and the CDS Market

Buyers and sellers in the bond market meet at a rate $\lambda_b \tau_{bb} \tau_{bs}$, where λ_b is the exogenous matching efficiency of the bond market, and τ_{bb} and τ_{bs} are the measures of bond buyers and sellers, respectively. Given the total meeting rate, buyers find a seller with intensity $q_{bs} \equiv \lambda_b \tau_{bs}$, and sellers find a buyer with intensity $q_{bb} \equiv \lambda_b \tau_{bb}$. Once matched, a buyer and a seller Nash-bargain over price so that the buyer gets a fraction ϕ of the total gains from trade and the seller gets the remaining surplus.

Analogously, in the CDS market, CDS buyers find a seller with intensity $q_{cs} \equiv \lambda_c \tau_{cs}$, and sellers find a buyer with intensity $q_{cb} \equiv \lambda_c \tau_{cb}$, where τ_{cb} and τ_{cs} are the measures of CDS buyers and sellers, respectively.

[9] Afonso (2011) provides a more general setup in which there is a continuous distribution of agents with different outside values. My setup would be a special case of this.

[10] The assumption that a portion of high types are always entering is for simplicity and is a way to scale up the measure of high types in the economy so that even if $\rho = 0$, the steady state measure of high types is greater than the steady state measure of low types and the bond supply. This simplifies the derivation of existence and uniqueness of the steady state equilibrium without affecting the main channels of the model.

1.2 Agent Types and Transitions

Table 2 shows the various types and their possible asset positions. The variable μ_τ denotes the measure of type $\tau \in \mathcal{T}$ agents, where $\mathcal{T} \equiv \{hn, ln, hob, aob, hoc, aoc, lsc\}$ is the set of agent types. Agent types hn and ln are high and low non-owners, hob and aob are high and average bond owners, hoc and aoc are high and average types that have sold CDS, and lsc are low types who have bought CDS.

Table 2: Agent Types

An agent type is composed of their valuation type (high "h", average "a", low "l") and their asset position (θ_b, θ_c). Their asset position can be either a non-owner "n": $(\theta_b, \theta_c) = (0, 0)$, a bond owner "$ob$": $(\theta_b, \theta_c) = (1, 0)$, a CDS seller "$oc$": $(\theta_b, \theta_c) = (0, 1)$, or a CDS buyer "$sc$": $(\theta_b, \theta_c) = (0, -1)$.

	(θ_b, θ_c)			
	$(0, 0)$	$(1, 0)$	$(0, 1)$	$(0, -1)$
High	μ_{hn}	μ_{hob}	μ_{hoc}	
Average	∞	μ_{aob}	μ_{aoc}	
Low	μ_{ln}			μ_{lsc}

Figure 1 shows the transitions between types. High types want an exposure to the underlying credit risk by either buying a bond or selling CDS. If they switch to an average type, they will try to liquidate their existing long position by selling the bond or will just exit the economy if they did not have any existing positions. Average types do not want neither a long nor a short exposure to risk so they just stay out of the markets. Low types want a short exposure, which is possible by buying CDS.

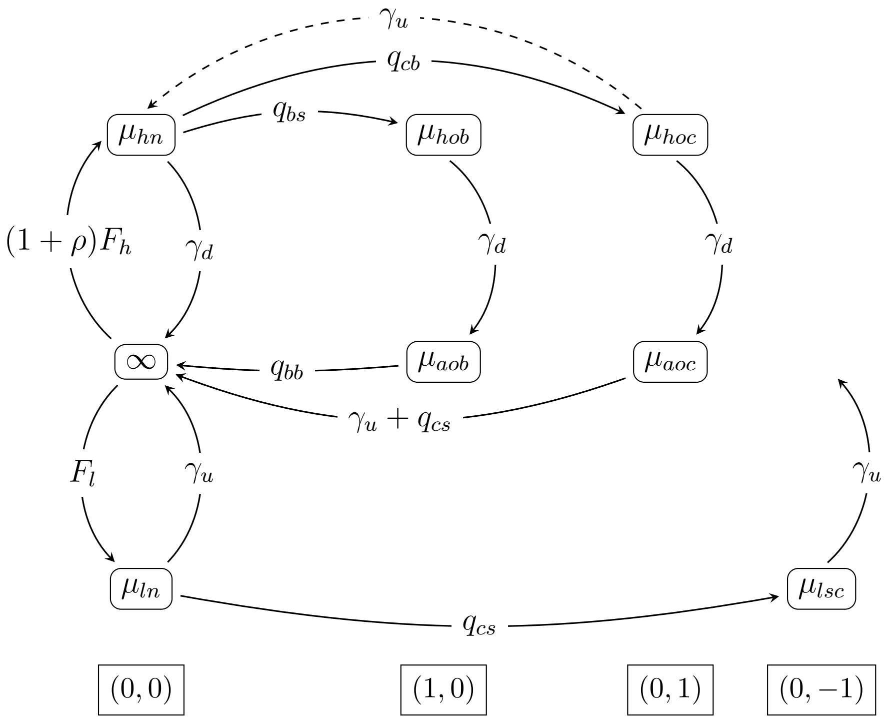
Since a high type non-owner (hn) wants a long exposure to credit risk, he will search to buy a bond or to sell CDS and will find counterparties with intensities q_{bs} and q_{cb}, respectively. Before he is even able to find a counterparty, he may switch to an average type and exit the economy. If he finds and trades with a bond-seller, he becomes a high type bond owner, hob. He is happy to hold that position until he is hit by a liquidity shock and becomes an average valuation, in which case he will become a bond seller (aob) in order to liquidate his bond position. Upon finding a bond buyer, he exits the market.

A high non-owner (hn) could also sell CDS (which occurs with intensity q_{cb}) and become a hoc type who has a long-exposure to credit risk. He is happy with this long exposure unless he switches to an average type and becomes one of aoc. As an average type, instead of remaining a CDS seller, he will try to unwind his position by searching for another CDS seller to take over his side of the trade at the original price. In practice, this is called *assignment* or *novation.*

Since a low non-owner (ln) wants to short credit risk, she searches to buy CDS, finds a counterparty with intensity q_{cs} and consequently becomes a CDS holder, lsc. If she switches to an average type, she terminates her contract, while her counterparty reverts back to an hn type and has to start over his search.

Figure 1: Transitions Between Agent Types

The figure shows the transitions between agent types. A flow of $(1+\rho)F_h$ agents enter the economy as high types and flow F_l as low types. High type agents are hit with a liquidity shock (and become an average valuation) with intensity γ_d. Conversely, low types switch to an average type with intensity γ_u. A trader seeking a long position (hn) finds a counterparty in the bond and the CDS market with probabilities q_{bs} and q_{cb}, respectively. A bond seller, aob, finds a buyer with probability q_{bb}. A trader seeking to establish a short position, ln, by buying CDS finds a counterparty with probability q_{cs}.



Given the search choices of agents, the measure of buyers and sellers in the bond and CDS markets are: $\tau_{bb} = \mu_{hn}$, $\tau_{bs} = \mu_{aob}$, $\tau_{cs} = \mu_{hn}$, $\tau_{cb} = \mu_{ln} + \mu_{aoc}$. Moreover, in the steady state, the measures of types are constant and the in-flow of agents has to equate the out-flow for each type as shown in Table 3.

Table 3: Flow-ins and outs

In the steady state equilibrium, the measure of agent types is constant: a flow of agents turning into a particular type (Flow-in) has to equal the flow of agents switching out of that type (Flow-out).

Type	Flow-in = Flow-out:
μ_{hn}	$(1+\rho)F_h + \gamma_u \mu_{hoc} = \gamma_d \mu_{hn} + (q_{bs} + q_{cb})\, \mu_{hn}$
μ_{ln}	$F_l = \gamma_u \mu_{ln} + q_{cs} \mu_{ln}$
μ_{hob}	$q_{bs} \mu_{hn} = \gamma_d \mu_{hob}$
μ_{aob}	$\gamma_d \mu_{hob} = q_{bb} \mu_{aob}$
μ_{hoc}	$q_{cb} \mu_{hn} = \gamma_d \mu_{hoc} + \gamma_u \mu_{hoc}$
μ_{aoc}	$\gamma_d \mu_{hoc} = \gamma_u \mu_{aoc} + q_{cs} \mu_{aoc}$
μ_{lsc}	$q_{cs} \mu_{ln} = \gamma_u \mu_{lsc}$

Bond market clearing imposes that the total measure of bond owners has to equal the bond supply:

$$\mu_{hob} + \mu_{aob} = S. \tag{2}$$

CDS market clearing requires that the total number of CDS contracts sold has to equal the number of CDS contracts purchased:

$$\mu_{hoc} + \mu_{aoc} = \mu_{lsc}. \tag{3}$$

1.3 Prices and Bargaining

Prices of bonds and CDS arise from bilateral bargaining between buyers and sellers. Let V_τ denote the expected utility of type $\tau \in \mathcal{T}$. A bond buyer's marginal benefit of buying a bond is the increase in his expected utility $V_{hob} - V_{hn}$, and his marginal cost is the bond price p_b. Thus, he is willing to buy as long as the marginal benefit is greater than the marginal cost: $V_{hob} - V_{hn} \geq p_b$, and the smaller the price is, the larger is his surplus. Analogously, for a seller, the marginal benefit of selling her bond is the bond price, p_b, and in return she is giving up the value of being a bond owner, V_{aob}, which is the marginal cost. Hence, she will sell as long as $p_b \geq V_{aob}$. Thus, the bond price has to lie in the interval: $V_{aob} \leq p_b \leq V_{hob} - V_{hn}$ and the length of this interval is the total surplus from trade. The buyer and the seller split the surplus proportional to their respective bargaining powers: ϕ and $1-\phi$. The greater the bargaining power of the buyer (i.e. higher ϕ), the lower the bond price:

$$p_b = \phi V_{aob} + (1-\phi)\left(V_{hob} - V_{hn}\right). \tag{4}$$

Analogously, a CDS seller and a CDS buyer Nash-bargain over price such that the seller and the buyer get ϕ and $1-\phi$ fractions of the total surplus, respectively. The buyer's surplus is $V_{lsc} - V_{ln}$ and the seller's is $V_{hoc} - V_{hn}$. Thus, the CDS price is implicitly defined by:

$$V_{hoc} - V_{hn} = \phi\left(V_{lsc} - V_{ln} + V_{hoc} - V_{hn}\right). \tag{5}$$

A CDS seller who switches to an average, *aoc*, will search for another CDS seller to take over his side of the trade (at the original price) and exit with zero utility if $0 - V_{aoc} > 0$.

1.4 Value Functions

To determine the expected utilities of types, consider, for example, an *hn* type. In a small time interval $[t+dt]$, he could (a) switch to an average valuation (with probability $\gamma_d dt$ and get utility 0), (b) become a bond owner (with probability $q_{bs}dt$ and get $V_{hob} - p_b$), (c) become a CDS seller (with probability $q_{cb}dt$ and get utility V_{hoc}), or (d) remain an hn type:

$$V_{hn} = (1 - rdt)\Big(\gamma_d dt(0) + q_{bs}dt(V_{hob} - p_b) + q_{cb}dtV_{hoc} \\ + (1 - \gamma_d dt - q_{bs}dt - q_{cb}dt)\,V_{hn}\Big).$$

After simplifying and taking the continuous time limit, we get:

$$rV_{hn} = \gamma_d(0 - V_{hn}) + q_{bs}(V_{hob} - p_b - V_{hn}) + q_{cb}(V_{hoc} - V_{hn}). \qquad (6)$$

The flow value equations for the other types are analogously derived and are shown in Appendix A.

1.5 Equilibrium

Definition 1. *A steady state equilibrium is given by types' measures $\{\mu_\tau\}_{\tau\in\mathcal{T}}$, prices $\{p_b, p_c\}$, entry decisions $\{\rho\}$, and value functions $\{V_\tau\}_{\tau\in\mathcal{T}}$ such that:*

1. *$\{\mu_\tau\}_{\tau\in\mathcal{T}}$ solve the steady state in-flow and out-flow equations in Table 3.*

2. *Market clearing conditions* (2) *and* (3) *hold.*

3. *Entry decisions, $\{\rho\}$, solve* (1).

4. *Bond and CDS prices, $\{p_b, p_c\}$, solve* (4) *and* (5).

5. *Agents' value functions, $\{V_\tau\}_{\tau\in\mathcal{T}}$, solve agents' optimization problem given by* (6), *and* (A.14) – (A.19).

The next proposition shows that a unique steady state equilibrium exists under the technical condition (7).

Proposition 1. *Suppose*

$$x_b - \frac{\left(x_{ch} + (x_{cl} - 2y)\left(\frac{q_{cs}+r+\gamma_u+\gamma_d}{q_{cs}+r+\gamma_u}\right)\right)}{\left(\frac{r+\gamma_d+\gamma_u+q_{cs}\phi_l+q_{cb}\phi_h}{q_{cb}\phi_h}\right)} > 0. \qquad (7)$$

Then, for small search frictions, there exists a unique equilibrium.

The proof is given in Appendix A. The proof of uniqueness involves the following steps. Given ρ, Appendix A shows that the set of equations that characterizes the dynamics of the population measures together with the market clearing conditions has a unique solution. Given this solution to the population measures, a linear system of equations characterizing the agents' value functions and prices uniquely determines $\{V_\tau\}_{\tau\in\mathcal{T}}$. Thus, for any $\rho \in [0, 1]$, V_{hn} is uniquely determined. The agent's entry decision can be either an interior solution or one of two corner solutions ($\rho = 0$, $\rho = 1$).

To show that the agents' entry decision has a unique solution, the Appendix shows that if (7) holds, V_{hn} is a strictly decreasing function of ρ.

Existence can be established only in the frictionless limit ($\lambda_b \to \infty$, and $\lambda_c \to \infty$) and involves verifying that all the conjectured optimal trading strategies are indeed optimal. In particular, I first show that the total surplus from trading the bond is positive: $\omega_b = V_{hob} - V_{hn} - V_{aob} > 0$. By construction, this will ensure that a high type agent will optimally choose to buy a bond, while an average type will not want to be a bondholder and, if she had previously purchased a bond, she will prefer to sell it. Second, Appendix A shows that the total surplus from trading CDS is positive $\omega_c = V_{hoc} - V_{hn} + V_{lsc} - V_{ln} > 0$. This will imply that high type agents will want to sell CDS, while low type agents will want to buy CDS. Third, I verify that average type agents will prefer to stay out of the markets completely instead of being a CDS buyer or a CDS seller: $0 - V_{aoc} > 0$. The latter ensures that an agent who was previously a high type and had sold CDS will prefer to find another seller to take over her side of the trade (at the original CDS price) and exit with zero utility.

2 Theoretical Results

To fix ideas, I will be interchangeably referring to buyers in the bond market (μ_{hn}) as liquidity providers. They also provide liquidity in the CDS market by selling CDS. Conversely, liquidity demanders in the bond market are the bond sellers (μ_{aob}) and in the CDS market are the CDS buyers ($\mu_{ln} + \mu_{aoc}$). Note that the measures of these liquidity demanders and providers arise endogenously depending on the endogenous entry decision ρ, the efficiency of the matching functions $\{\lambda_b, \lambda_c\}$, the parameters that determine flows into the economy $\{F_h, F_l\}$, and the transition intensities between different valuations, $\{\gamma_d, \gamma_u\}$.

Proposition 2. *If the bond market is frictionless ($\lambda_b \to \infty$), the bond price is given by*

$$p_b = \frac{\delta_b + x_b - y}{r} \tag{8}$$

and the CDS market does not affect the bond market.

Proposition (2) shows that, without search frictions in the bond market, the bond price is given by the present value of high types' valuation of the bond and that the CDS market does not affect the bond market. In the frictionless limit, a bond owner – who gets a liquidity shock and has a need to sell her bond – can do so instantaneously to another high type trader. As a result, bonds are only held by agents who derive a high utility from owning them and not by agents who have a lower valuation. Consequently, the bond price is given by the valuation of high type agents since from (4) the bond price is the weighted average of the marginal valuations of the two types of bond owners.

Proposition 3. *The bond price is given by:*

$$p_b = \frac{\delta_b + x_b - y}{r} - \underbrace{\left[\gamma_d \frac{x_b}{rk} + \phi\left(q_{bs} + r\right)\frac{x_b}{rk}\right]}_{\text{part of illiquidity discount}} - \underbrace{\frac{\left(q_{bb} + r\right)\left(1-\phi\right)}{rk} q_{cb}\Delta_{hoc}}_{\text{discount due to CDS}}, \quad (9)$$

where

$$\Delta_{hoc} \equiv \frac{\phi(-\phi q_{bs} x_b + k x_c)}{\left[r + \gamma_d + \gamma_u + q_{cs}(1-\phi) + \phi q_{cb}\right] k - \phi q_{cb} q_{bs} \phi},$$

$$k \equiv r + \gamma_d + q_{bs}\phi + q_{bb}(1-\phi).$$

Proposition (3) shows that with search frictions in the bond market the bond price is lower than the frictionless price in (8). The intuition is as follows. A bond owner – who gets a liquidity shock and has a need to sell her bond – faces a difficulty of locating a counterparty. Due to this wait, she is stuck with a bond that she gets a disutility from. When she does find a buyer, she takes into account the difficulty of locating a buyer again and resorts to selling at a discounted price. Conversely, a potential bond buyer takes into account this trading friction in case he has a liquidity need in the future and has to reverse his trade. Due to search costs, a potential buyer is only willing to buy at a low price, and a bond seller is also more willing to sell at a low price.

Thus, search costs create an illiquidity discount in the bond price given by the difference between (9) and the frictionless price: the sum of the second and the third terms in (9). In particular, the third term is an additional discount in the bond price due to bond buyers having an outside option of providing liquidity in the CDS market (by selling CDS).

Definition 2. *The illiquidity discount, d, in the bond price is defined by the difference between the frictionless bond price* (8) *and the bond price with search frictions present in the bond market* (9)*:*

$$d \equiv \gamma_d \frac{x_b}{rk} + \phi\left(q_{bs} + r\right)\frac{x_b}{rk} + \frac{\left(q_{bb} + r\right)\left(1-\phi\right)}{rk} q_{cb}\Delta_{hoc}.$$

2.1 The Effect of CDS on Bond Market Liquidity

The next proposition gives the main theoretical result of the paper by analyzing how the introduction of the CDS market affects the bond illiquidity discount. It shows that bond and CDS markets are complementary markets. In particular, the existence of naked CDS buyers increases bond market liquidity when entry is endogenous and CDS search frictions are not too severe ($\lambda_c > \bar{\lambda}_c$). Figure 2 illustrates the result.

Proposition 4 (The Complementarity Effect)**.** *In the equilibrium of Proposition* (1)*, there exists $\bar{\lambda}_c > 0$ such that for all $\lambda_c > \bar{\lambda}_c$,*

$$d\left(\lambda_c\right) \le d^{no\,cds}.$$

The proof is given in Appendix A and the mechanism consists of the following parts. First, for a given rate of entry, ρ, the introduction of the CDS market increases the value of entering the economy as a high type agent. This is illustrated in Figure 3 by a vertically upward shift in $V_{hn}(\rho)$ to the solid red line. For traders looking to acquire a long position (i.e. high type agents), selling CDSs and buying bonds are two different ways to be exposed to credit risk and they can search for a counterparty simultaneously in both the CDS and the bond market. This ability to simultaneously search in both markets reduces the expected search time of acquiring a long position in either market. In particular, long traders now have twice as many potential counterparties and, hence, a higher probability of finding a counterparty in at least one of the two markets than if there was just the bond market. A marginal long trader – who otherwise would have been deterred by the search cost when there was just the bond market – now has a greater incentive to enter and search in both the CDS *and* the bond market.

Second, each additional entrant increases competition and lowers the expected utility for every other high type agent. This is illustrated by the negative slope of $V_{hn}(\rho)$ in Figure 3. Long traders enter until the marginal entrant is again indifferent between entering or not (where V_{hn} crosses the outside option O_h). The above two mechanisms imply that the existence of the CDS market results in an increase in the equilibrium number of high type agents and the aggregate supply of liquidity (illustrated by the increase in the entry rate ρ from ρ^{nocds} to $\rho^{cds}_{\lambda_c<\infty}$ in Figure 3).

Third, the increase in the number of high type agents creates a positive externality in the bond market if the CDS market is subject to search frictions. With CDS search frictions ($\lambda_c < \infty$), the increase in the number of high type agents is strictly greater than the potential total demand for CDS ($\frac{F_l}{\gamma_u}$). Intuitively, due to search frictions in the CDS market, new entrants are held up searching for a long position instead of selling CDS *immediately* upon entry. This translates to an increased flow of traders actively searching for a long position in both markets and hence an increase in the number of bond buyers. Bond sellers, in turn, are able to find a buyer and sell more quickly, and thus bond market liquidity and the bond price increase due to CDS.

Figure 5 illustrates how the CDS market changes the bond market composition: there are more bond buyers and conversely fewer bond sellers. Figure 6 shows that the introduction of the CDS market also increases the volume of trade in the bond market.

2.1.1 The Importance of CDS Search Frictions

CDS has opposing complementary versus substitution effects on bond market liquidity. The substitution effect arises from bond buyers having an outside option of providing liquidity in the CDS market (by selling CDS). This effect lowers bond market liquidity by depressing the bond price (recall in (9) the additional discount in the bond price due to CDS). Thus, the increase in the number of high type agents due to CDS has to be large enough for the complementary effect to more than offset the substitution effect.

By how much the introduction of the CDS market increases the entry rate depends on the matching efficiency of the CDS market as illustrated in Figure 4. One extreme is a frictionless CDS market ($\lambda_c \to \infty$). In this case, the complementary and the substitution effects exactly offset one another. The increase in the equilibrium measure of all high type agents, $\left(\rho^{cds} - \rho^{nocds}\right) \frac{F_h}{\gamma_d}$, is exactly equal to the total demand for CDS (the measure of all low types, including those who have purchased CDS: $\frac{F_l}{\gamma_u} = \mu_{ln} + \mu_{lsc}$). Intuitively, upon entry, new liquidity providers sell CDS *immediately* to the flow of CDS buyers. As a result, introducing the CDS market increases the aggregate number of high type traders, but this increase does not translate to an increase in the number of bond buyers.

Figure 5 illustrates that when the CDS market becomes frictionless ($\lambda_c \to \infty$), the number of bond buyers and sellers (and hence the bond volume) converge back to the benchmark environment without CDS. The CDS market is therefore redundant and does not affect the bond market. The positive externality created by the CDS market only exists when there are trading frictions in the CDS market.

Proposition 5 formally shows that if the CDS market is frictionless, then it does not affect the illiquidity discount in the bond price.

Proposition 5. $\lim_{\lambda_c \to \infty} d(\lambda_c) = d^{\text{nocds}}$.

2.1.2 The Importance of Endogenous Entry

With exogenous entry, there is only the substitution effect. The introduction of the parallel CDS market shrinks the size of the bond market: some agents who would have otherwise bought bonds migrate to the CDS market and sell CDS instead. Existing bond sellers effectively compete with CDS buyers for the same set of traders that can provide liquidity in either market. Due to a fewer number of bond buyers, bond sellers face greater congestion externality and search costs. Thus, with exogenous entry, the effect of the CDS market is on the intensive margin only: the aggregate number of market participants is fixed, and there is only migration or substitution between the bond and the CDS market.

With endogenous entry, there is on the extensive margin a larger overall flow of traders into both bond and CDS markets. In particular, the increase in the entry rate more than offsets the substitution effect: it replaces the bond buyers that migrated to the CDS market and, due to search frictions in the CDS market, results in an even greater number of potential bond buyers.

2.1.3 Model Implication on a Permanent CDS Ban

The above results showed that bond and CDS markets are complementary markets: the existence of naked CDS buyers increases bond market liquidity. These results imply that permanently banning naked CDS buyers will reverse this positive effect and will lead to a decrease in bond market liquidity.

2.2 A Temporary Naked CDS Ban

So far, I have compared the steady-state bond prices and bond market liquidity in settings with and without CDS markets when the aggregate number of market entrants could adjust towards these steady states. This analysis can speak to the effect of a permanent CDS ban. In this section, I consider instead the immediate impact of a temporary CDS ban.

I model a temporary naked CDS ban as a one-time unexpected drop in the number of naked CDS buyers. To focus on the immediate impact of the shock, I assume that the flow of entrants remains fixed in the short run as the economy rebounds back to the steady state equilibrium. Time can be relabeled so that $t = 0$ corresponds to the time at which this shock occurs. As the shock hits, the distribution of the measure of types switches to $\{\mu_\tau(0)\}_{\tau\in\mathcal{T}} = \{\bar{\mu}_\tau\}_{\tau\in\mathcal{T}}$. I define $\{\bar{\mu}_\tau\}_{\tau\in\mathcal{T}}$ such that all its elements are equal to the steady state measure of types, except the measure of naked CDS buyers is zero: $\bar{\mu}_{ln} = 0$.

The time-varying equilibrium measure of hn type agents from this shock back to the steady state is given by the solution to the following ODE:

$$\dot{\mu}_{hn}(t) = (1+\rho)F_h + \gamma_u\mu_{hoc}(t) - \left[\gamma_d\mu_{hn}(t) + \left(q_{bs}(t) + q_{cb}(t)\right)\mu_{hn}(t)\right],$$

where the initial condition is given by $\{\mu_\tau(0)\}_{\tau\in\mathcal{T}} = \{\bar{\mu}_\tau\}_{\tau\in\mathcal{T}}$ and the entry rate ρ is kept fixed at the steady state level. The dynamics for the measures of other agents are analogously characterized in (A.45)–(A.51).

Agent hn's value function evolves according to:

$$\begin{aligned}\dot{V}_{hn}(t) = rV_{hn}(t) - [\gamma_d(0 - V_{hn}(t)) + q_{bs}(t)\left(V_{hob}(t) - V_{hn}(t) - p_b(t)\right) \\ + q_{cb}(t)(V_{hoc}(t) - V_{hn}(t))],\end{aligned}$$

where

$$p_b(t) = \phi V_{aob}(t) + (1-\phi)\left(V_{hob}(t) - V_{hn}(t)\right)$$

and

$$V_{hoc}(t) - V_{hn}(t) = \phi\left(V_{lsc}(t) - V_{ln}(t) + V_{hoc}(t) - V_{hn}(t)\right).$$

It is analogous for the other agents as shown in (A.52)–(A.58). Define $\Delta_{hob} \equiv V_{hob} - V_{hn}$, $\omega_b \equiv V_{hob} - V_{hn} - V_{aob}$, and $\omega_c \equiv V_{hoc} - V_{hn} + V_{lsc} - V_{ln}$. Then, we can rewrite all the ODEs for the value functions in terms of Δ_{hob}, ω_b and ω_c. For example,

$$\dot{V}_{hn}(t) = rV_{hn}(t) - \left[\gamma_d(0 - V_{hn}(t)) + q_{bs}(t)\phi\omega_b(t) + q_{cb}(t)\phi\omega_c(t)\right].$$

In turn, the solution for Δ_{hob}, ω_b and ω_c is given in Proposition 6.

Proposition 6. *Given the solution to the time-varying dynamics of agent* *measures, the dynamics for* Δ_{hob} *and* V_{aob} *are given by*:

$$\Delta_{hob} = \frac{\delta_b + x_b - y}{r} - \int_t^\infty e^{-r(s-t)} \left((\gamma_d + q_{bs}\phi)\, \omega_b + q_{cb}\phi\omega_c \right) ds,$$
$$V_{aob} = \frac{\delta_b - y}{r} + \int_t^\infty e^{-r(s-t)} q_{bb} (1-\phi)\, \omega_b ds,$$

where

$$\begin{bmatrix} \omega_b(t) \\ \omega_c(t) \end{bmatrix} = \int_t^\infty e^{-\int_t^s A(u)du} \begin{bmatrix} x_b \\ x_{cl} + x_{ch} - 2y \end{bmatrix} ds,$$

$$A(t) = \begin{bmatrix} r + \gamma_d + q_{bs}\phi + q_{bb}(1-\phi) & q_{cb}\phi \\ q_{bs}\phi & r + \gamma_d + \gamma_u + q_{cb}\phi + q_{cs}(1-\phi) \end{bmatrix}.$$

2.2.1 Model Implication on a Temporary CDS Ban

Figures 7 and 8 plot the transition dynamics of types' measures and of the bond illiquidity discount from the CDS ban at $t = 0$ back to the steady state. The sudden drop in the number of naked CDS buyers frees up long traders who would have otherwise sold them CDS. These long traders temporarily substitute trading in the CDS market with trading in the bond market as bond buyers. In turn, bonds sellers temporarily benefit from the ban as they now locate bond buyers more quickly and face lower search costs. The sudden temporary ban on naked CDS buyers, as a result, leads to a temporary increase in bond market liquidity. Thus, in the short term, bond and CDS markets are substitute markets. [11]

2.2.2 The Implicit Cost of Entry

The substitution effect arises because long traders resort to temporarily trading in the bond market instead of exiting entirely from both markets at the extensive margin. I arrive at this result by keeping the entry rate fixed, which is a reduced form way to capture a kind of adjustment cost of entry.

Although I do not explicitly incorporate such adjustment cost of entry, equation (10) illustrates one possible way of incorporating it. Now, in addition to comparing the value of entering $V_{hn}(\rho)$ with the outside investment opportunity O_h, high type agents have to take into account a cost of entry, $c(\rho)$, that varies with the entry rate:

$$\rho = \begin{cases} 1 & V_{hn}(\rho) - c(\rho) > O_h \\ [0,1] \text{ if } & V_{hn}(\rho) - c(\rho) = O_h \\ 0 & V_{hn}(\rho) - c(\rho) < O_h, \end{cases} \tag{10}$$

where $c'(\rho) \geq 0$, $c''(\rho) > 0$, $c(0) \geq 0$, and $c(1) < \infty$.

[11] As the ban is lifted, the number of traders searching to buy CDS increases until the fraction of CDS buyers who finds a CDS seller equals the flow of new low type agents entering the economy.

Figure 9 figuratively illustrates an example of such a cost function. The temporary CDS ban leads to a small decrease in the value of trading as a high type. When the scale of entry is already large and due to the convexity of $c(\rho)$, a tiny decrease in ρ results in a large decrease in the cost. As a result, the entry rate does not have to change much in response to a temporary ban. In contrast, with a permanent ban, the value of trading as a high type decreases by a lot. In addition, due to the convexity, as the entry rate ρ decreases, the resulting decrease in the cost of entry becomes less responsive. As a result, the entry rate has to decrease by a lot in response to a permanent ban. We can also back out how the short-run dynamics of the cost of entry has to look like from the dynamics of $V_{hn}(\rho^{ss})$ as shown in Figure 10.

3 Data and Market Descriptions

3.1 Background on Sovereign Bond Market

Government bonds trade in over-the-counter markets. A trader in the US, for example, shops for government bonds using phone calls, emails, messages and quotes through Bloomberg.[12] Locating a particular bond issue can be at times impossible.

In European government bond markets, MTS trading platforms have become an increasingly important trading venue since their inception in 1988. The MTS system is an inter-dealer trading platform that functions similar to an electronic limit order market and is not accessible to individual investors. However, despite its similarity to an equity market, trade is fragmented across heterogenous bonds and liquidity per bond is low.[13]

3.2 Bond Market Data

The bond price data comes from Thomson Reuters and consists of daily bid and ask price quotes for the period 2004-2012. Due to data access limitation, I use bonds that have not matured as of August 2012. To minimize differences across bonds, I use fixed coupon bonds. I exclude floating rate coupon bonds, perpetual bonds, index and inflation-linked bonds, and coupon strips. The final sample consists of 3,210 plain coupon bonds across 67 sovereigns. Thomson Reuters' bid and ask quotes are a composite of quotes collected from various sources including individual dealers, trade organizations such

[12]Trade in US Treasuries, however, is different than in other government bonds. See discussion in Vayanos and Weill (2008) and Fleming and Mizrach (2009) for institutional details specific to US Treasury markets.

[13]See Cheung, Rindi, and De Jong (2005) and Dufour and Skinner (2004) for more information on MTS trading platforms. Also, Pelizzon, Subrahmanyam, Tomio, and Uno (2013) analyze liquidity of Italian government bonds traded on MTS platforms. Although the Italian government bond market is one of the largest and the most liquid government bond markets, its liquidity, by daily trading volume and by the number of trades per bond, is comparable to the US municipal bond and the US corporate bond markets.

as the ICMA and IBoxx, and local market sources. Bond prices are quoted as a percent of the par (or face) value of the bond.[14]

As each sovereign will have multiple bond issues that vary by maturity, currency, and coupon, prices are aggregated by taking the average of all bond issues. For robustness, I consider other ways of aggregating across bond issues including the average weighted by the bond issue size, specific maturities, and maturity buckets.

Table 8 shows the overall descriptive statistics and Table 10 at the country level. The average bond bid-ask spread across all bonds and countries was 0.95% of the mid price (or 95 basis points). From the country-level Table 10, we see a lot of cross-country difference in the average bond bid-ask spread and that bid-ask spreads widen with credit risk: Greece has the highest average bid-ask spread of 3.51% (351 bps), while the U.S. has the lowest at 0.04% (4 bps).

3.3 Background on the CDS Market

As discussed before, credit default swaps are over-the-counter derivative contracts that resemble insurance protection against a default or a similar event (referred to as a "credit event") on bonds of a firm or a government (the "reference entity"). A buyer of a CDS protection pays a periodic fee (equivalently, the CDS price, premium, or spread) until either the contract matures or a credit event occurs. In return, the buyer gets paid by the seller the protection amount that was purchased (called "notional") in the event of default or a similar event on *any* one of the bonds covered by the contract of the reference entity. CDS contracts are therefore written on the level of firms and governments and not at an individual bond level.[15]

CDS contracts specify the reference entity, the contract maturity, the notional amount, the set of bonds of the reference entity that is covered by the contract, and the default events that constitute a credit event. The standard notional amounts are in the range of $10-20 million.[16] Prices of CDS contracts are paid quarterly and are quoted as annualized percentages of the contract notional.[17]

Whether a credit event has occurred or not is decided by the International Swaps and Derivatives Association (ISDA), which is the governing body of the CDS market.[18] The standard credit events for sovereign CDS are Failure

[14] For example, if the bond price is 95, the bond is trading at 95 cents on the dollar.

[15] This means, for example, if you are a holder of bond "A" of Greek government and Greece defaults on another bond "B" and both bonds are covered by the contract, you will be still be paid out even if your bond "A" has not been defaulted on.

[16] This is comparable to the most common transaction sizes of 5, 10, 25 million euros in, for example, the MTS Global Market (see Cheung, Rindi, and De Jong (2005)).

[17] For example, if the price of a CDS contract with $10 million notional is 200 basis points, the protection buyer pays $0.2 million annually in quarterly installments of $0.05 million. The price of a CDS contract can be thought of as, in its simplest form, the probability of default times one minus the recovery rate. For example, if a one year CDS contract is trading at 200 basis points, and the recovery rate was zero, then the implied probability of default is 2%.

[18] Credit events are decided by the "determination committee" of ISDA which consists

to Pay and Debt Restructuring.[19] Protection buyers get paid the difference between the notional and the recovery value (effectively, the price of defaulted bonds) that is determined through a special post-credit-event auction. For example, if an investor bought a CDS contract with a notional of $10 million and the recovery rate is 25%, she receives $7.5 million in cash. The ISDA finalizes the actual list of eligible bonds that can be submitted into the auction and oversees the auction. At the end of the auction, all bonds submitted into the auction are bought and sold at the same final bond price, and this final price is the price or the recovery rate that settles *all* CDS contracts on that reference entity. Although cash settlements have become standard now, CDS buyers also have the option of requesting a "physical settlement" of contracts by selling the bond during the auction.

3.4 CDS Data

CDS price data comprises of daily bid and ask price quotes from CMA for the five year maturity contracts over the period 2004-2012. Following market standards, they are reported in basis points. Table 8 summarizes the CMA CDS price data for all sovereigns and Table 10 at the country level.

CDS notional data comes from the Depository Trust and Clearing Corporation (DTCC) which provides a post-trade electronic confirmation service to CDS market participants. According to the DTCC, at least more than 90% of all worldwide trades in the CDS market gets recorded in their information warehouse. The DTCC provides historical data on both the volume of trade and the outstanding amount of protection. The volume data is the total notional of all trades on an average day per quarter for each sovereign over the period 2010 Q2 - 2012 Q2. The outstanding data consists of the outstanding gross notional, net notional, and the number of contracts for each sovereign over the period October 31, 2008 - July 28, 2012 at a weekly frequency. My analysis focuses on the outstanding CDS net notional as the amount of CDS purchased.[20]

Table 9 summarizes the DTCC data for all sovereigns and Table 11 at the country level.

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of 10 big dealer banks (e.g Bank of America, Barclays, BNP Paribas, Citibank, Credit Suisse, Deutsche Bank, Goldman Sachs, JPMorgan, Morgan Stanley, and UBS) and five buy side firms that tend to be hedge funds.

[19]For corporate CDS, bankruptcy is an additional standard credit event. There are three kinds of restructuring that vary by how restrictively they limit the set of eligible bonds: Modified Restructuring (MR), Modified Modified Restructuring (MMR), and Complete (or "old", "full") Restructuring (CR). MR is the most restrictive limiting eligible bonds to have maturity of up to 30 month after the declaration of a credit event, then MMR with 60 month maturity, and CR is the least restrictive with the standard 30-year maturity limit on bonds. CDS on North American reference entities usually feature MR (except CDS on high credit risk firms tend to completely exclude any debt restructuring as a credit event), while CDS on European firms feature the less restrictive MMR. Debt restructuring on CDS on sovereigns, on the other hand, most commonly specify CR.

[20]For a comprehensive analysis of the determinants of the amount of CDS purchased for firms, see Oehmke and Zawadowski (2013b).

4 Empirical Results

Empirically identifying how naked CDS trading affects bond market liquidity is confounded by two issues. First, a direct measure of the amount of naked CDS purchases does not exist as we only observe the total amount of CDS purchased (the sum of naked and covered). The second issue is identifying causation as opposed to correlation. But the naked CDS bans implemented in Europe serve as quasi-natural experiments and help to circumvent these issues.

In this section, I document that when the EU voted in October 2011 to *permanently* ban naked CDS on governments of the EU countries, countries affected by the ban experienced a decrease in their bond market liquidity. On May 18 2010, Germany temporarily banned naked buying of CDS on governments of the Eurozone, and the ban was effective overnight. Immediately following the ban, bond market liquidity increased for the countries affected by the ban. Thus, these two bans were associated with exactly opposite changes in bond market liquidity.

4.1 The Permanent CDS Ban

4.1.1 The Description of the Ban

Throughout 2011, market participants faced uncertainty over whether the EU would adopt measures to ban naked CDS. The uncertainty was finally resolved on October 18, 2011 when, after months of negotiations, the European Parliament and the EU states passed a law to permanently ban naked CDS.[21] The legislation applied to all CDS transactions referencing governments of the EU regardless of the geographic location of the transaction or the legal jurisdiction of the financial institution involved in the transaction.[22]

The final draft of the law was published March 2012 (Regulation EU No 236/2012).[23] Although the legislation was to be in effect beginning November 1, 2012, the March 2012 regulation stated that traders who enter new contracts after March 2012 would have to unwind them by November 2012. Contracts entered into before March 2012 could remain in place even beyond November 2012. Figure 11 compares the total CDS purchased referencing EU governments versus countries not affected by the ban. We see that the total amount of CDS purchased on EU sovereigns started to dramatically decrease starting around the time that the law was passed and has been declining ever since. This decrease did not occur for countries not affected

[21]For the draft of the law (number: 16338/11 EF 152 ECOFIN 739 CODEC 1873) that was agreed upon by the European Parliament and the Council of the European Union, see `http://register.consilium.europa.eu/pdf/en/11/st16/st16338.en11.pdf`.

[22]It also applied to CDS referencing three other European Economic Area countries: Iceland, Norway, Liechtenstein. But I will simply refer to the countries affected by the ban as the EU although I am including these other three in the analysis.

[23]Additional details emerged later with supplemental regulations EU No 826/2012 (29 June 2012), EU No 827/2012 (29 June 2012), and EU No 918/2012 (5 July 2012). For these drafts, see `http://ec.europa.eu/internal_market/securities/short_selling/index_en.htm`.

by the ban. Thus, anticipating the difficulty of renewing contracts beyond March 2012, traders started to decrease their activity already beginning fall of 2011.

A CDS purchase was considered covered if it was hedging a portfolio of assets that was correlated with government bonds of the reference entity.[24] In particular, the value of the portfolio had to have a historical correlation of at least 70% with the government bond price over a period of at least 12 months prior to the CDS purchase. If a CDS purchase could not satisfy this at the time of the purchase, it would be considered naked and hence prohibited. The correlation requirement would be automatically satisfied if the underlying position being hedged consisted of governments bonds (at all federal and local levels of the government), the liability of state enterprises, or the liability of enterprises that are guaranteed by the sovereign. The underlying portfolio could also consist of long positions in private entities within the reference entity country or even long positions through CDS itself. The legislation also exempted market making activities.

After the purchase, traders did not have to maintain the correlation throughout the CDS contract to allow for the fact that the price of the underlying assets can vary. But the size of the underlying positions had to remain "proportional" to the amount of CDS purchased. In other words, a trader could not buy bonds with the intent of selling them back once she purchases CDS.[25] In terms of how the regulation was enforced, upon request institutions were supposed to be able to provide such evidence of hedging.

4.1.2 Results

Now consider what happened to bond market liquidity. Figure 12 shows that following the ban bond market liquidity decreased for countries that were affected by the ban, while the same did not happen for countries not affected by the ban. I formally show this with a difference-in-difference analysis. I set the ban period, T_b, to be a four-month period starting the week after October 18th through the end February 2012. I explore the following panel

[24]Market participants were generally confused about how to actually interpret and satisfy the restrictions of the regulation.

[25]In addition, the regulation had various disclosure requirements of short positions through equity, sovereign bond and CDS markets. It also restricted short selling of equity and attempted to restrict naked short selling of governments bonds. Naked short selling is the sale of a security without having pre-borrowed. By definition, naked short selling is limited and temporary since the short seller has to borrow or buy the security to deliver it within the sale settlement period (usually 3 days or less). Otherwise, it results in a delivery failure. According to Comotto (2010), naked short selling of government bonds occurs rarely. When they do occur, it is intraday (for few hours and the short sell is covered), or occur because of operational errors. The regulation required that in order to short sell government bonds, a trader had to either have "located" the bond or have pre-borrowed it. The pre-borrowing arrangement prior to selling is the regular (covered) short selling and entails a contractual repo claim to a bond. But the locate requirement is a soft constraint and does not involve a contractual claim as it can be easily satisfied by email or phone. This regulation, as a result, did not affect short selling of government bonds but mainly targeted the CDS market.

regression using four-months of data before and after the ban of all countries:

$$d_{it} = c + \gamma_i + \lambda_t + X_{it}^{'}\beta + \delta D_{i\in EU,t\in T_b} + \epsilon_{it}, \tag{11}$$

where d_{it} is the bond bid-ask spread (% of the mid price) of country i at time t, c is a constant, γ_i and λ_t are the coefficients on country and time fixed effects, respectively, and X_{it} is a set of controls. $D_{i\in euro,t\in T_b}$ is a dummy variable that equals one for country-date observations for which the ban was in place. The control group is countries outside the EU (hence not affected by the ban) and the treatment group is the EU countries. The coefficient of interest is δ: it measures the effect of the CDS ban on liquidity of the European Union government bond markets.

Table 13 shows the regression results of (11) controlling for debt outstanding and CDS price as a measure of credit risk. The coefficient estimate of the *EU CDS Ban* (δ) in column 1 is positive and statistically significant (0.271, st. err: 0.105) and shows that the ban is associated with 27% increase in the proportional bid-ask spread.[26] The average bid-ask spread for the EU countries was about 1% of the mid price or $1 of round trip transaction cost for every $100 of transaction. Relative to this average, the round trip transaction cost increased 27% from $1 to $1.27. Columns 1 and 2 show that including CDS price as a measure of credit risk qualitatively does not change the results.

4.1.3 Alternative Specifications

To allow for the possibility that bond bid-ask spreads for different countries followed different trends, columns 3–6 allow for country specific trends. Column 7 includes instead a group specific trend: treated and control countries, as a group, followed different trends. We see that the observed decrease in bond market liquidity is robust to including country or group trends. As a robustness, column 5 excludes Greece as a potential outlier, and column 6 restricts the control group countries to just OECD countries. Both give qualitatively the same result.

We observe the total amount of CDS purchased and not covered and naked purchases separately. Since the ban targeted naked CDS trading in particular, the decrease in the total amount of CDS purchased during this period should capture more a decrease in naked rather than covered CDS purchases, and hence, should capture the amount of naked CDS positions outstanding prior to the ban.[27] Thus, if banning naked CDS positions caused bond market liquidity to decrease, a greater decrease in CDS net notional should be associated with a greater increase in the bond bid-ask spread. To check this hypothesis, column 4 adds an interaction term between the *EU CDS Ban* dummy variable with the change in net notional following the ban,

[26] See Footnote 33 for discussion on standard errors.

[27] The legislation applied to new CDS contracts and not existing positions. So the decrease in CDS net notional captures the maturation of CDS contracts that otherwise would have been renewed had there not been the ban.

EU CDS Ban$*\Delta Notl$. The positive and the statistically significant coefficient of the interaction term shows that among countries subject to the ban those that had potentially more naked CDS positions outstanding prior to the ban experienced even a greater widening of the bond bid-ask spread.

To check the hypothesis that the change in net notional following the ban is correlated with more naked CDS positions prior to the ban, Table 17 shows the correlation between the change in net notional during this period and the past level of CDS net notional controlling for debt outstanding and credit risk. We see a statistically significant positive correlation for the EU countries but not for the non-EU countries.

4.1.4 Possible Endogeneity of Regulations

Short selling bans are usually imposed during periods when regulators are concerned with stability and liquidity in financial markets. If the regulation was passed in anticipation of a decrease in liquidity, then the observed decrease in bond market liquidity following the ban may not be due to the ban (while the ban itself was ineffective in improving market conditions). However, this argument does not explain why liquidity increased following the temporary German ban.

Nevertheless, since the ban targeted particularly the naked CDS buyers, it still allows us to approximate the amount of naked CDS positions that had existed before the ban by using the decrease in the total CDS purchased following the ban. I check whether the cross-country variation in the drop has an explanatory power for the level of bond market liquidity *before* the ban for countries subject to the ban. Table 14 shows the estimates of the following regression:

$$\begin{aligned} d_{it-1} = c + \gamma_i + \lambda_{t-1} + X'_{it-1}\beta_1 + \beta_2 \Delta_{i(t-1,t)} Notl \\ + \delta D_{i \in EU, t \in T_b} * \Delta_{i(t-1,t)} Notl + \epsilon_{it-1}. \end{aligned} \tag{12}$$

We are interested in δ.[28] We see from the estimate of β_2 that normally future changes in CDS net notional are not correlated with the past level of bond market liquidity. But the decrease in net notional that countries subject to the ban experienced during the ban is associated with a higher level of bond market liquidity (tighter bid-ask spreads) prior to the ban. Thus, a potentially greater amount of naked CDS positions outstanding prior to the ban is correlated with a higher pre-ban level of bond market liquidity controlling for pre-ban levels of credit risk and debt outstanding.

[28]Since we are looking at the past level of bond market liquidity, the interpretation of $\Delta Notl$ in the current setup is different from the previous set-up.

4.2 The Temporary CDS Ban

4.2.1 The Description of the Ban

On Tuesday May 18th 2010, Germany prohibited naked purchases of CDS referencing Eurozone governments.[29] As recent as month prior to the ban Germany's rhetoric had been that there is no need to ban naked CDS trading. The regulation was unexpected by market participants and was implemented within the same day that the media first reported it. News about the ban first appeared around 1pm on Tuesday May 18, 2010 on Reuters. But the official details of the legislation did not emerge until late in the evening around 9:30pm. The regulation was effective from midnight the same day (within two and half hours from the release of the official statement) and was to be in effect through March 31, 2011. However, later on July 27, 2010 the regulation was made permanent.

The regulation also banned the naked short selling of 10 leading German financial stocks and the naked short selling of Eurozone governments bonds that were allowed to be listed on Germany's domestic stock exchange. The naked bond short selling restriction, as a result, applied to only a few German and Austrian bonds.

The May 18th 2010 regulation did not specify the territorial scope of the regulation. So it is not clear whether market participants interpreted the regulation to apply to all transactions regardless of the geographic location and the institution. However, According to Allen & Overy LLP and ISDA's conversations with BaFin (Germany's financial regulatory body), BaFin confirmed that the regulation applied to transactions where at least one of the counterparties is located in Germany. It would not, for example, apply to a transaction between the New York branch and the London branch of Deutsche Bank.

4.2.2 Results

In this section, I explore how this regulation affected bond market liquidity. Figure 13 plots the cross country average of the bond bid-ask spread. The dashed line shows the average for the EU countries that were not affected by the ban (i.e. naked CDS referencing these countries could still be purchased), while the solid line plots the average for the EU countries affected by the ban (i.e. the Eurozone countries). Two vertical lines are drawn for the week before the ban and the week of the ban. We see that for the countries affected by the ban, there was a large and sudden narrowing of the bond bid-ask spread, while this did not occur for the countries not affected by the ban. Figure 14 in the Appendix demonstrates the time series of CDS net notional around the ban.

To test this pattern formally, I carry out an exercise analogous to the EU ban. I set the initial period of the ban, denoted by T_b, to be a month long

[29] For the draft of the regulation, see http://www.bafin.de/SharedDocs/Aufsichtsrecht/EN/Verfuegung/vf_100518_kreditderivate_en.html.

period starting the week after the ban inception.[30] I explore the following regression using four months of data before and after the ban using the sample of EU countries:

$$d_{it} = c + \gamma_i + \lambda_t + X'_{it}\beta + \delta D_{i\in euro,t\in T_b} + \epsilon_{it}, \tag{13}$$

where d_{it} is the bond bid-ask spread (% of the mid), c is a constant, γ_i and λ_t are the coefficients on country and time fixed effects, respectively, and X_{it} is a set of controls. $D_{i\in euro,t\in T_b}$ is a dummy variable that equals one for country-date observations for which the ban was in place. The control group is the non-Eurozone countries within the EU (hence not affected by the ban), and the treatment group is the Eurozone countries. Thus, the difference δ is the effect of the CDS ban on liquidity of the Eurozone government bond markets.

Table 18 shows the regression results of (13). The coefficient estimate of the *CDS Ban* (δ), as shown in columns 1 and 2, is negative and statistically significant. During the initial period of the ban, countries subject to the CDS ban experienced a larger decrease in the bond bid-ask spread relative to the countries not subject to the ban. Comparing columns 1 and 2 shows that including CDS price does not make a difference. Columns 3 and 6 show that controlling for country or group specific trends, respectively, does not change the results. The observed decrease in the bid-ask spread is also robust to excluding Greece as a potential outlier (column 5).

Since the ban targeted naked CDS in particular, the decrease in CDS net notional following the ban should be associated more with the amount of naked CDS positions that had existed before the ban than the amount of covered CDS.[31] Thus, if banning naked CDS positions caused bond market liquidity to increase, a larger drop in CDS net notional should be associated with a larger decrease in the bond bid-ask spread. Column 4 checks this hypothesis as a further robustness. It includes an interaction of *CDS Ban* dummy with the change in net notional following the ban ($CDSBan{*}\Delta Notl$). The negative and statistically significant slope coefficient of the interaction term suggests that, among countries subject to the ban, those that had potentially more naked CDS positions prior to the ban experienced an even greater decrease in the bid-ask spread.

These results suggest that, first, naked CDS positions in particular have an effect on bond market liquidity, and second, the positive correlation between bond market liquidity and the amount of CDS positions that we saw in the previous section reversed during the initial period of the ban.

[30] Although the temporary ban was initially effective through March 2011, I restrict to a narrower ban period to capture the immediate impact of the ban. Given that the ban applied to institutions within Germany only, with more time, trades are likely to have shifted to other European countries outside Germany.

[31] Similar to the EU ban, the legislation banned new CDS contracts and would not have applied to existing CDS contracts. Thus, any decrease in net notional is capturing more the maturation of CDS contracts that would have otherwise been renewed had there not been the ban.

4.3 The Time-Series Pattern between CDS Trading Activity and Bond Market Liquidity

The observed decrease in bond market liquidity following the permanent CDS ban implies a positive correlation between the amount of naked CDS positions and bond market liquidity. In this section, I show that this positive correlation inferred from the ban is representative of the overall time-series pattern: a greater amount of CDS trading activity is associated with a more liquid bond market.

Although an empirical measure that captures the amount of naked CDS positions in isolation does not exist, we should be able to infer changes in the total CDS purchased that are due to changes in naked positions by controlling for "covered" positions. We can, in turn, control for covered positions by controlling for credit risk and debt outstanding. Therefore, I use CDS net notional outstanding as a measure proportional to the overall amount of naked positions after controlling for credit risk and debt outstanding.

4.3.1 Contemporaneous Regressions

In this section, I document that the amount of CDS net notional outstanding is positively and significantly correlated with bond market liquidity controlling for credit risk and debt outstanding. Figure 15 plots the time series pattern of CDS net notional and the proportional bond bid-ask spread for Italy over the period 2008-2012. Overall, a greater amount of CDS purchased is associated with narrower bond bid-ask spreads, i.e. greater liquidity. However, both bond market liquidity and the amount of CDS purchased are correlated with credit risk and the size of the bond market. Table 19 shows for the sample of European Union countries the results of regressing the bond bid-ask spread on CDS net notional while controlling for credit risk (proxied by CDS price) and the gross government debt outstanding. The coefficient estimate of CDS net notional (-0.261, se: 0.0396) says that if CDS net notional increases by one billion US dollar, the proportional bond bid-ask spread decreases by 0.261 (% of the mid price), or by about one fourth of the average proportional bid-ask spread.[32][33] An alternative specification of CDS net notional as the log of the ratio of CDS net notional to gross debt outstanding gives qualitatively the same result.

[32] The average was about 1.11% of the mid price as shown in Table 12 of descriptive statistics.

[33] Throughout, the panel regression analyses with time series data adjust for the fact that errors are correlated within country by including country fixed effects. In addition, I capture any non-fixed effect by modeling AR(1) correlation structure in disturbances to allow for the correlation between residuals to decay with time (as is the case with time series data). Standard errors also allow heteroskedasticity and correlation of disturbances across countries (e.g. Eurozone countries are more correlated with each other than with a non-Eurozone country).

4.3.2 Vector Autoregressions

As the regressions in Table 19 of contemporaneous variables do not necessarily imply causation, in this section I carry out vector autoregressions to explore the direction of causation. To summarize, below VAR and VECM results suggest that it is not just bond market liquidity driving CDS net notional and that CDS net notional also affects bond market liquidity.

First, I test whether there is a cointegration relationship between CDS price, CDS net notional, and the bond bid-ask spread. If there is no evidence of cointegration among the variables, I carry out the simpler VAR-in-differences. For 14 out of 23 European Union countries, there is no evidence of cointegration, while for the other 9 there is. For the former 14, Table 20 shows the results of the VAR-in-differences: it shows the p-values of the Granger-causality tests. For 5 out of these 14, CDS net notional Granger-causes bond bid-ask spreads, while for 2 out of 14, bond market liquidity Granger-causes CDS net notional. Thus, there is a stronger evidence that CDS net notional affects bond market liquidity.

For the other 9 countries for which the variables are cointegrated, I use vector error-correction models (VECM). The idea behind VECM is that a long term equilibrium relationship exists between cointegrated variables:

$$x_t - \alpha_0 - \alpha_1 \mu_t - \alpha_2 d_t = 0,$$

where x_t is a measure of credit risk, μ_t is CDS net notional, and d_t is the proportional bond bid-ask spread. Changes in the variables can be characterized as adjustments to deviations from this long-run equilibrium plus responses to the lagged changes:

$$\Delta x_t = \lambda_x \left(x_{t-1} - \alpha_0 - \alpha_1 \mu_{t-1} - \alpha_2 d_{t-1}\right) + \sum_{j=1}^{p-1} \beta_{1j} \Delta x_{t-j} + \sum_{j=1}^{p-1} \delta_{1j} \Delta \mu_{t-j} + \sum_{j=1}^{p-1} \gamma_{1j} \Delta d_{t-j},$$

$$\Delta \mu_t = \lambda_{notl} \left(x_{t-1} - \alpha_0 - \alpha_1 \mu_{t-1} - \alpha_2 d_{t-1}\right) + \sum_{j=1}^{p-1} \beta_{2j} \Delta x_{t-j} + \sum_{j=1}^{p-1} \delta_{2j} \Delta \mu_{t-j} + \sum_{j=1}^{p-1} \gamma_{2j} \Delta d_{t-j},$$

$$\Delta d_t = \lambda_{bond} \left(x_{t-1} - \alpha_0 - \alpha_1 \mu_{t-1} - \alpha_2 d_{t-1}\right) + \sum_{j=1}^{p-1} \beta_{3j} \Delta x_{t-j} + \sum_{j=1}^{p-1} \delta_{3j} \Delta \mu_{t-j} + \sum_{j=1}^{p-1} \gamma_{3j} \Delta d_{t-j}.$$

Gonzalo and Granger (1995) proposed a notion similar to Granger causality in the VECM framework. The variable that adjusts less to the deviation from the long term equilibrium would be considered to be the more important driver of the long-run equilibrium (i.e. it Granger-causes the other variables in the long run). Conversely, the variable that adjusts the most (indicated by a significant adjustment coefficient) has a more transitory as opposed to a permanent effect on the other variables. Table 21 shows the adjustment coefficients and t-statistics for CDS net notional and bond bid ask spreads. The t-statistics are generally bigger for the bond bid-ask spread than for CDS net notional. This suggests that CDS net notional affects bond market liquidity.

Next, I conjecture that changes in the amount of naked CDS positions affect CDS market liquidity and explore whether CDS liquidity Granger-causes bond market liquidity.[34] Table 22 reports the results of the Granger-causality tests. For 18 out 24 European Union countries, the CDS bid-ask spread Granger-causes the bond bid-ask spread, whereas for only 10 out of 24 countries the bond bid-ask spread Granger-causes CDS bid-ask spread.

The above VAR and VECM results suggest that it is not just bond market liquidity driving CDS trading activity and that naked CDS trading also affects bond market liquidity.

5 Discussion

5.1 Model Implications and the Empirical Patterns

I discuss now how the model mechanism rationalizes these contradictory empirical patterns. The model suggests that, in the long term, bond and CDS markets are complementary markets. Thus, when the CDS market is shut down permanently, it adversely affects liquidity of the bond market, which is consistent with the observed decrease in bond market liquidity after the permanent ban. Specifically, if the number of naked CDS buyers permanently decreases for an exogenous reason (as happened with the permanent EU ban), long traders – who would have been counterparties to naked CDS buyers – are forced to exit the CDS market. But by exiting the CDS market, they exit the bond market also. As a result, bond market liquidity and bond prices decrease. Importantly, bond and CDS markets are complementary markets only in the presence of search frictions in the CDS market. Hence, trading frictions in the CDS market create an interaction between bond and CDS markets that helps explain the empirical patterns.

In the short term, on the other hand, bond and CDS markets are substitute markets. As a result, when the CDS market is shut down temporarily, the immediate effect is an increase in bond market liquidity which is consistent with the observed increase in bond market liquidity following the temporary German ban. This is because the migration effect (specifically, its reverse) dominates: long traders do not exit at the extensive margin but instead resort to temporarily trading in the bond market. Bond sellers temporarily benefit from a greater number of bond buyers who would have otherwise sold CDS.

5.2 Search vs. Asymmetric Information

Another plausible effect of the CDS market is that as an instrument to trade on negative news, shorting credit risk through the CDS market may aggravate adverse selection problems in the bond market and may amplify a potential

[34] This set of regressions explores whether one market affects the other more and does not focus on the sign of the correlation. The sign of the correlation is sensitive to whether I use absolute CDS bid-ask spread or relative bid-ask spread (i.e. normalized by the mid price).

"run" on sovereign bond markets. This, in turn, may lead to a further liquidity dry-up in the bond market. Although plausible, this mechanism on its own cannot explain why different bans would affect bond market liquidity differently.

In the above scenario, potential bond investors as a group may have asymmetric information from what the sovereign knows about itself. It is also possible that illiquidity arises from asymmetric information amongst traders as in Kyle (1985) and Glosten and Milgrom (1985) type frameworks. The search framework is better suited for sovereign bond markets for two reasons. First, trade in sovereign bond markets are fragmented across heterogenous bonds. Second, asymmetric information and insider trading is less severe with respect to governments than with respect to individual firms.

6 Conclusion

This paper studies, both empirically and theoretically, the interaction between bond and CDS markets, and, in particular, how naked CDS trading affects liquidity of the underlying bond market. To identify how naked CDS trading affects bond market liquidity, I use two naked CDS bans implemented in Europe as quasi-natural experiments and analyze how they affected sovereign bond market liquidity. I document that the 2011 permanent EU ban adversely affected bond market liquidity but the 2010 temporary German instead increased bond market liquidity.

To reconcile these contradictory patterns, I build a search theoretic framework with interdependent bond and CDS markets liquidity. I show that, in the long term, bond and CDS markets are complementary markets. The introduction of the CDS market creates a positive externality in the bond market and increases bond market liquidity by attracting traders into both the CDS and the bond market. This result implies that permanently banning the CDS market will adversely affect bond market liquidity: by pulling out from the CDS market, traders pull out from the bond market also. But, in the short term, there is a substitutability between these two markets so that when the CDS market is banned only temporarily, instead of pulling out from both markets, traders temporarily migrate to the bond market.

My paper shows that different CDS bans can have different effects on liquidity of the underlying bond market. But the main policy implication of the paper is that permanently banning naked CDS trading will, in the long term, adversely affect bond market liquidity and hence increase sovereigns' cost of borrowing.

Key model ingredients that help reconcile the observed patterns are, first, search frictions in the CDS market. The complementariness of bond and CDS markets arises only in the presence of search frictions in the CDS market. The CDS market is otherwise redundant and does not affect bond market liquidity. The second key model ingredient is endogenous entry. The fact that bond and CDS markets can be complementary markets is a novel result in light of existing theoretical studies of the liquidity interaction between multiple asset markets. These studies highlight the migration (or equivalently, the substitution) effect. In these models, the aggregate number of traders across markets is kept fixed and, consequently, introducing additional markets necessarily results in a fragmentation and migration of traders across multiple markets. My results show that an important interaction between multiple markets arises out of endogenizing the aggregate number traders across markets by endogenizing traders' entry decision at the extensive margin.

A Appendix: Proofs

Agents' flow value equations are analogously derived to (6):

$$
\begin{aligned}
rV_{ln} &= \gamma_u(0 - V_{ln}) + q_{cs}(V_{lsc} - V_{ln}) && \text{(A.14)}\\
rV_{hob} &= \delta_b + x_b - y + \gamma_d(V_{aob} - V_{hob}) && \text{(A.15)}\\
rV_{aob} &= \delta_b - y + q_{bb}(0 - V_{aob} + p_b) && \text{(A.16)}\\
rV_{hoc} &= p_c - (\delta_c - x_{ch}) - y + \gamma_d(V_{aoc} - V_{hoc}) + \gamma_u(V_{hn} - V_{hoc}) && \text{(A.17)}\\
rV_{aoc} &= p_c - \delta_c - y + q_{cs}(0 - V_{aoc}) + \gamma_u(0 - V_{aoc}) && \text{(A.18)}\\
rV_{lsc} &= -p_c + (\delta_c + x_{cl}) - y + \gamma_u\,(0 - V_{lsc}) && \text{(A.19)}
\end{aligned}
$$

Proof of Proposition 1. The proof of uniqueness is shown in Lemma 1 and the proof of existence is shown in Lemma 2. □

Lemma 1. *Suppose* (7) *holds, then the steady state equilibrium is unique.*

Proof. First fix ρ, then using the in-flow out-flow equations and the market clearing conditions (2) (3), $\mu_{ln}, \mu_{hob}, \mu_{aob}, \mu_{hoc}, \mu_{aoc}, \mu_{lsc}$ can be solved as a function of μ_{hn}:

$$
\begin{aligned}
\mu_{ln} &= \frac{F_l}{\gamma_u + \lambda_c\mu_{hn}} && \text{(A.20)}\\
\mu_{hob} &= \frac{S\lambda_b\mu_{hn}}{\lambda_b\mu_{hn} + \gamma_d} && \text{(A.21)}\\
\mu_{aob} &= S - \frac{S\lambda_b\mu_{hn}}{\lambda_b\mu_{hn} + \gamma_d} && \text{(A.22)}\\
\mu_{hoc} &= \frac{\lambda_c F_l \mu_{hn}}{\gamma_u\left(\lambda_c\mu_{hn} + \gamma_d + \gamma_u\right)} && \text{(A.23)}\\
\mu_{aoc} &= \frac{\gamma_d F_l \lambda_c \mu_{hn}}{\gamma_u\left(\lambda_c\mu_{hn} + \gamma_u\right)\left(\lambda_c\mu_{hn} + \gamma_d + \gamma_u\right)} && \text{(A.24)}\\
\mu_{lsc} &= \frac{\lambda_c F_l \mu_{hn}}{\gamma_u\left(\lambda_c\mu_{hn} + \gamma_u\right)} && \text{(A.25)}
\end{aligned}
$$

And μ_{hn} itself is a solution to:

$$
(1+\rho)F_h - \gamma_d\mu_{hn}\left(\frac{S\lambda_b}{\lambda_b\mu_{hn} + \gamma_d} + \frac{\lambda_c F_l}{\gamma_u\left(\lambda_c\mu_{hn} + \gamma_d + \gamma_u\right)} + 1\right) = 0 \qquad \text{(A.26)}
$$

The LHS of (A.26) is positive at $\mu_{hn} = 0$, decreasing in μ_{hn}, and is negative for large μ_{hn}, hence (A.26) has a unique positive solution. Thus, (A.26) uniquely determines μ_{hn} and has a positive solution, while other μ's are uniquely determined by (A.20)-(A.24). Next, once μ's are solved, the value functions and prices are uniquely determined by a linear system of equations: (6),(A.14) -(A.19), and (4)-(5).

We are left with the endogenous entry decisions:

$$
\rho = \begin{cases} 1 & V_{hn}(\rho) > O_h \\ [0,1] \text{ if} & V_{hn}(\rho) = O_h \\ 0 & V_{hn}(\rho) < O_h \end{cases} \qquad \text{(A.27)}
$$

There are three cases: two corner solutions $\rho = 0$, and $\rho = 1$, and an interior solution. Next, I show that V_{hn} is strictly decreasing in ρ, which will imply that under each case the equilibrium is unique. The derivation in the proof of existence shows that:

$$
V_{hn} = \frac{q_{bs}x_b\phi + \Delta_{hoc}q_{cb}\left(r + \gamma_d + q_{bb}(1-\phi)\right)}{\left(r + \gamma_d\right)k},
$$

where

$$\Delta_{hoc} = \frac{x_{ch} + (q_{cs} + r + \gamma_u + \gamma_d)\frac{x_{cl} - 2y}{r + \gamma_u + q_{cs}} - \frac{1}{k} q_{bs}\phi x_b}{\frac{(1-\phi) q_{cs} + r + \gamma_u + \gamma_d}{\phi} + \frac{1}{k} q_{cb}\left(r + \gamma_d + (1-\phi)\, q_{bb}\right)}$$

None of the μ's other than μ_{hn} directly depend on ρ but depend only indirectly through μ_{hn}, thus we write:

$$\begin{aligned}
\frac{\partial V_{hn}(\rho)}{\partial \rho} &= \frac{\partial \mu_{hn}}{\partial \rho}\left(\frac{\partial V_{hn}}{\partial q_{bs}}\frac{\partial q_{bs}}{\partial \mu_{hn}} + \frac{\partial V_{hn}}{\partial q_{bb}}\frac{\partial q_{bb}}{\partial \mu_{hn}} + \frac{\partial V_{hn}}{\partial q_{cb}}\frac{\partial q_{cb}}{\partial \mu_{hn}} + \frac{\partial V_{hn}}{\partial q_{cs}}\frac{\partial q_{cs}}{\partial \mu_{hn}}\right) \\
&= \frac{\partial \mu_{hn}}{\partial \rho}\left(\frac{\partial V_{hn}}{\partial q_{bs}}\frac{\partial (\lambda_b \mu_{aob})}{\partial \mu_{hn}} + \frac{\partial V_{hn}}{\partial q_{bb}}\frac{\partial (\lambda_b \mu_{hn})}{\partial \mu_{hn}} + \frac{\partial V_{hn}}{\partial q_{cb}}\frac{\partial \lambda_c (\mu_{aoc} + \mu_{ln})}{\partial \mu_{hn}} + \frac{\partial V_{hn}}{\partial q_{cs}}\lambda_c\right) \\
&= \frac{\partial \mu_{hn}}{\partial \rho}\left(\frac{\partial V_{hn}}{\partial q_{bs}}\frac{\partial (\lambda_b \mu_{aob})}{\partial \mu_{hn}} + \frac{\partial V_{hn}}{\partial q_{bb}}\frac{\partial (\lambda_b \mu_{hn})}{\partial \mu_{hn}} + \frac{\partial V_{hn}}{\partial q_{cb}}\frac{\partial \lambda_c (\mu_{aoc} + \mu_{ln})}{\partial \mu_{hn}} + \frac{\partial V_{hn}}{\partial q_{cs}}\lambda_c\right)
\end{aligned} \tag{A.28}$$

Next, I derive $\frac{\partial V_{hn}}{\partial q_{bs}}$, $\frac{\partial V_{hn}}{\partial q_{bb}}$, $\frac{\partial V_{hn}}{\partial q_{cb}}$, and $\frac{\partial V_{hn}}{\partial q_{cs}}$.

$$\frac{\partial V_{hn}}{\partial q_{bb}} = -\frac{q_{bs}\ \phi_h}{(r + \gamma_d)\, k^2}\phi_l B$$

$$\frac{\partial V_{hn}}{\partial q_{bs}} = \frac{\phi_h (r + \gamma_d + q_{bb}\phi_l)}{(r + \gamma_d)\, k^2} B$$

$$\frac{\partial V_{hn}}{\partial q_{cs}} = \frac{q_{cb}(r + \gamma_d + q_{bb}\phi_l)}{k (r + \gamma_d)\, C}\left(-\frac{\phi_l A}{\phi_h C} - \frac{(x_{\text{cl}} - 2y)\, \gamma_d}{(q_{cs} + r + \gamma_u)^2}\right)$$

$$\frac{\partial V_{hn}}{\partial q_{cb}} = \frac{A (r + \gamma_d + q_{bb}\phi_l)}{k (r + \gamma_d)\, C \phi_h}\left(\frac{r + \gamma_d + \gamma_u + q_{cs}\phi_l}{C}\right),$$

where

$$B \equiv x_b + \frac{q_{cb}}{C}\left(\frac{(r + \gamma_d + q_{bb}\phi_l)}{k} q_{cb}\frac{A}{C} - A - \frac{(r + \gamma_d + q_{bb}\phi_l)}{k} x_b\right)$$

$$A \equiv x_{\text{ch}} + \frac{(x_{\text{cl}} - 2y)(q_{cs} + r + \gamma_d + \gamma_u)}{q_{cs} + r + \gamma_u} - \frac{q_{bs} x_b \phi_h}{r + \gamma_d + q_{bs}\phi_h + q_{bb}\phi_l}$$

$$C \equiv \frac{r + \gamma_d + \gamma_u + q_{cs}\phi_l}{\phi_h} + \frac{q_{cb}(r + \gamma_d + q_{bb}\phi_l)}{k}$$

From here, $\frac{\partial V_{hn}}{\partial q_{cb}} > 0$ while $\frac{\partial(\lambda_c(\mu_{aoc} + \mu_{\text{ln}}))}{\partial \mu_{hn}} < 0$ implying that the third term in (A.28) is negative. Since $\frac{\partial V_{hn}}{\partial q_{cs}} < 0$, the fourth term (A.28) is also negative. But the sign of both $\frac{\partial V_{hn}}{\partial q_{bs}}$ and $\frac{\partial V_{hn}}{\partial q_{bb}}$ depend on the sign of B. Thus, consider B:

$$\begin{aligned}
B &= x_b + \frac{q_{cb}}{C}\frac{(r + \gamma_d + q_{bb}\phi_l)}{k} q_{cb}\frac{A}{C} - \frac{q_{cb}}{C} A - \frac{q_{cb}}{C}\frac{(r + \gamma_d + q_{bb}\phi_l)}{k} x_b \\
&= x_b\left(1 - \frac{q_{cb}}{C}\frac{(r + \gamma_d + q_{bb}\phi_l)}{k}\right) - \left(1 - \frac{q_{cb}}{C}\frac{(r + \gamma_d + q_{bb}\phi_l)}{k}\right)\frac{q_{cb}}{C} A \\
&= \left(1 - \frac{q_{cb}}{C}\frac{(r + \gamma_d + q_{bb}\phi_l)}{k}\right)\left(x_b - q_{cb}\frac{A}{C}\right)
\end{aligned}$$

First, $0 < \frac{q_{bb}\phi_l + \gamma_d + r}{k} < 1$ and $0 < \frac{q_{cb}}{C} < 1$. To see the latter, let $\phi_l = \phi_h$, then $C > q_{cs}$. From Assumption 2:

$$\mu_{hn} + \mu_{hoc} + \mu_{hoc} \geq \frac{F_h}{\gamma_d} > S + \frac{F_l}{\gamma_u}$$

But using the CDS market clearing condition, we have $\frac{F_l}{\gamma_u} = \mu_{\text{ln}} + \mu_{\text{lsc}} = \mu_{\text{ln}} + (\mu_{\text{hoc}} + \mu_{aoc})$. Thus,

$$\mu_{hn} + \mu_{\text{hoc}} + \mu_{\text{hob}} > S + \mu_{\text{ln}} + (\mu_{\text{hoc}} + \mu_{aoc})$$

Cancel μ_{hoc},

$$\mu_{hn} + \mu_{\text{hob}} > S + \mu_{\text{ln}} + \mu_{aoc}$$

$$\mu_{hn} > (S - \mu_{\text{hob}}) + \mu_{\text{ln}} + \mu_{aoc} > \mu_{\text{ln}} + \mu_{aoc}$$

Hence, $q_{cs} > q_{cb}$ and $C > q_{cs} > q_{cb}$. Thus, the term in the first bracket of B is positive. Now consider the term in the second bracket of B, $x_b - q_{cb}\frac{A}{C} = x_b - q_{cb}\Delta_{\text{hoc}}$:

$$\begin{aligned}
x_b - q_{cb}\Delta_{\text{hoc}} &= x_b - q_{cb}\frac{x_{\text{ch}} + \frac{(x_{\text{cl}}-2y)(q_{cs}+r+\gamma_d+\gamma_u)}{q_{cs}+r+\gamma_u} - \frac{q_{bs}\phi_h}{k}x_b}{\frac{r+\gamma_d+\gamma_u+q_{cs}\phi_l}{\phi_h} + \frac{q_{cb}(r+\gamma_d+q_{bb}\phi_l)}{k}} \\
&= x_b - \frac{x_{\text{ch}} + (x_{\text{cl}} - 2y)\left(1 + \frac{\gamma_d}{q_{cs}+r+\gamma_u}\right) - \frac{q_{bs}\phi_h}{k}x_b}{\frac{r+\gamma_d+\gamma_u+q_{cs}\phi_l}{q_{cb}\phi_h} + \frac{k-q_{bs}\phi_h}{k}} \\
&= \frac{\left(\frac{r+\gamma_d+\gamma_u+q_{cs}\phi_l+q_{cb}\phi_h}{q_{cb}\phi_h}\right)x_b - \left(x_{\text{ch}} + (x_{\text{cl}} - 2y)\left(\frac{q_{cs}+r+\gamma_u+\gamma_d}{q_{cs}+r+\gamma_u}\right)\right)}{\frac{r+\gamma_d+\gamma_u+q_{cs}\phi_l}{q_{cb}\phi_h} + \frac{k-q_{bs}\phi_h}{k}}
\end{aligned}$$

The sign of the expression depends on the numerator:

$$\left(\frac{r + \gamma_d + \gamma_u + q_{cs}\phi_l + q_{cb}\phi_h}{q_{cb}\phi_h}\right)x_b - \left(x_{\text{ch}} + (x_{\text{cl}} - 2y)\left(\frac{q_{cs} + r + \gamma_u + \gamma_d}{q_{cs} + r + \gamma_u}\right)\right)$$

This expression is positive from (7). Thus, $\frac{\partial V_{hn}}{\partial q_{bs}} > 0$ and together with $\frac{\partial \mu_{aob}}{\partial \mu_{hn}} < 0$ implies that the first term of (A.28) is negative. Also, since $\frac{\partial V_{hn}}{\partial q_{bb}} < 0$, the second term of (A.28) is also negative.

Finally from (A.26) and using the Implicit Function Theorem,

$$\frac{\partial \mu_{hn}}{\partial \rho} = \frac{F_h}{\gamma_d\left(\frac{s\lambda_b\gamma_d}{(\lambda_b\mu_{hn}+\gamma_d)^2} + \frac{\lambda_c f_l(\gamma_d+\gamma_u)}{\gamma_u(\lambda_c\mu_{hn}+\gamma_d+\gamma_u)^2} + 1\right)}$$

Thus, $\frac{\partial \mu_{hn}}{\partial \rho} > 0$, and, consequently, $\frac{\partial V_{hn}(\rho)}{\partial \rho} < 0$. □

Lemma 2. *Existence*

Proof. To show existence we verify that the conjectured optimal trading strategies are in fact optimal. In particular, first, we show that the total surplus from trading the bond is positive: $\omega_b = V_{hob} - V_{hn} - V_{aob} > 0$. By construction, this will ensure that individual surpluses to the buyer and the seller of the bond are positive: a high type agent optimally chooses to buy the bond, and an average type agent prefers to sell her bond. Second, we show that the total surplus from trading CDS is positive $\omega_c = V_{hoc} - V_{hn} + V_{lsc} - V_{ln} > 0$. This will imply that the high type agents will want to sell CDS, while low type agents will want to buy CDS. Third, we verify that the average type agents will prefer quit being a CDS seller: $0 - V_{aoc} > 0$. Thus, agents who have previously sold CDS when they were high types will prefer to find another seller to take over his side of the trade and exit the market with zero utility. I proceed by first deriving ω_b, ω_c, V_{aoc}.

Subtracting rV_{ln} (A.14) from rV_{lsc} (A.19) and defining $\Delta_{lsc} \equiv V_{lsc} - V_{ln}$, we get:

$$\Delta_{lsc} = \frac{\delta_c + x_{cl} - y - p_c}{r + \gamma_u + q_{cs}}$$

From (5):

$$\Delta_{hoc} = \frac{\phi}{1-\phi}\Delta_{lsc} = \frac{\phi}{1-\phi}\frac{\delta_c + x_{cl} - y - p_c}{r + \gamma_u + q_{cs}}$$

Also from the value function of V_{aoc},

$$V_{aoc} = \frac{p_c - (y + \delta_c)}{r + \gamma_u + q_{cds}} \tag{A.29}$$

Using (A.17) and substituting in the expression for V_{aoc}:

$$rV_{hoc} = p_c - (\delta_c - x_{ch}) - y + \gamma_d(\frac{p_c - (y + \delta_c)}{r + \gamma_u + q_{cds}} - V_{hoc}) - \gamma_u\Delta_{hoc}$$

Add $\gamma_d V_{hoc}$ to both sides:

$$(r + \gamma_d)V_{hoc} = p_c - (\delta_c - x_{ch}) - y + \frac{p_c - (y + \delta_c)}{r + \gamma_u + q_{cds}} - \gamma_u\Delta_{hoc}$$

Subtract $(r + \gamma_d)V_{hn}$ from both sides:

$$(r + \gamma_d + \gamma_u)\Delta_{hoc} = p_c - (\delta_c - x_{ch}) - y + \frac{p_c - (y + \delta_c)}{r + \gamma_u + q_{cds}} - (r + \gamma_d)V_{hn}$$

Thus, we have three equations and three unknowns, Δ_{hoc}, p_c, V_{hn}:

$$\Delta_{hoc} = \frac{\phi}{1-\phi}\frac{\delta_c + x_{cl} - y - p_c}{r + \gamma_u + q_{cs}}$$

$$(r + \gamma_d + \gamma_u)\Delta_{hoc} = p_c - (\delta_c - x_{ch}) - y + \frac{p_c - (y + \delta_c)}{r + \gamma_u + q_{cds}} - (r + \gamma_d)V_{hn}$$

$$V_{hn} = \frac{q_{bs}x_b\phi + \Delta_{hoc}q_{cb}\left(r + \gamma_d + q_{bb}(1-\phi)\right)}{(r + \gamma_d)\,k}, \tag{A.30}$$

where the latter comes from the solution to the equations for V_{hob}, V_{aob}, and V_{hn}. The solution for Δ_{hoc} is given by:

$$\Delta_{hoc} = \frac{x_{ch} + (q_{cs} + r + \gamma_u + \gamma_d)\,\frac{x_{cl} - 2y}{r + \gamma_u + q_{cs}} - \frac{1}{k}q_{bs}\phi x_b}{\frac{(1-\phi)q_{cs} + r + \gamma_u + \gamma_d}{\phi} + \frac{1}{k}q_{cb}\left(r + \gamma_d + (1-\phi)\,q_{bb}\right)} \tag{A.31}$$

From here:

$$p_c = \delta_c + x_{cl} - y - \frac{1-\phi}{\phi}(r + \gamma_u + q_{cs})\Delta_{hoc} \tag{A.32}$$

$$\omega_c = \frac{1}{\phi}\Delta_{hoc}$$

Using the solution to the equations for V_{hob}, V_{aob}, and V_{hn}:

$$\omega_b = \frac{x_b - q_{cb}\Delta_{hoc}}{r + \gamma_d + \phi q_{bs} + (1-\phi)q_{bb}} \tag{A.33}$$

To consider small search frictions, define $\epsilon \equiv \frac{1}{\lambda_b}$ and $n \equiv \frac{\lambda_c}{\lambda_b}$. We show existence for $\epsilon = 0$. Then by continuity, existence is established in the neighborhood of $\epsilon \equiv 0$ or for small search frictions. With the change of variables, (A.26) becomes:

$$(1+\rho)F_h - \gamma_d\mu_{hn}\left(\frac{S}{\mu_{hn} + \epsilon\gamma_d} + \frac{nF_l}{\gamma_u\left(n\mu_{hn} + \epsilon(\gamma_d + \gamma_u)\right)} + 1\right) = 0 \tag{A.34}$$

From (A.34), for any $\rho \in [0,1]$, μ_{hn} asymptotically converges to $\mu_{hn} = \frac{(1+\rho)F_h}{\gamma_d} - (S + \frac{F_l}{\gamma_u})$ therefore $0 < \lim_{\lambda_b,\lambda_c \to \infty} \mu_{hn} < \infty$ and $\lim_{\lambda_b,\lambda_c \to \infty} q_{bb} = \infty$. This also implies from (A.22) that $\lim_{\lambda_b,\lambda_c \to \infty} \mu_{aob} = 0$ and q_{bs} converges to a finite number. Analogously, $\lim_{\lambda_b,\lambda_c \to \infty} q_{cs} = \infty$ and from (A.20) and (A.24): $0 < \lim_{\lambda_b,\lambda_c \to \infty} q_{cb} < \infty$.

To show $\omega_c > 0$ using these limits, consider the numerator of Δ_{hoc}:

$$x_{ch} + (q_{cs} + r + \gamma_u + \gamma_d) \frac{x_{cl} - 2y}{r + \gamma_u + q_{cs}} - \frac{1}{k} q_{bs} \phi x_b$$

Using the above limits of q_{cs}, q_{bs}, and q_{bb}, it converges to $x_{\text{ch}} + x_{\text{cl}} - 2y$ which is positive by Assumption 1.

From (A.29), in order for $V_{aoc} < 0$, the CDS price has to be less than $p_c < \delta_c + y$. From (A.31) and (A.32):

$$p_c = (\delta_c + x_{\text{cl}}) - y - \frac{(1-\phi_h)(q_{cs} + r + \gamma_u)\left(\left(x_{\text{ch}} + \frac{(x_{\text{cl}} - 2y)(q_{cs} + \gamma_d + r + \gamma_u)}{q_{cs} + r + \gamma_u}\right) - \frac{x_b q_{bs} \phi_h}{k}\right)}{\phi_h \left(\frac{q_{cb}(q_{bb}\phi_l + \gamma_d + r)}{k} + \frac{(1-\phi) q_{cs} + \gamma_d + r + \gamma_u}{\phi_h}\right)}$$

This converges to $\delta_c + y - x_{ch}$, which is less than $\delta_c + y$. Thus, $V_{aoc} < 0$. Average types will not want to buy CDS because the flow utility would be $\delta_c - y - p_c$. Given that $p_c \to \delta_c + y - x_{ch}$, this converges to $x_{ch} - 2y$ which is negative by Assumption (1). To show $\omega_b > 0$, consider the numerator of (A.33): $x_b - q_{cb}\Delta_{hoc}$. Since $0 < \lim q_{cb} < \infty$ and Δ_{hoc} converges to zero, $x_b - q_{cb}\Delta_{hoc}$ converges to $x_b > 0$. The above results show existence for $\epsilon = 0$. By continuity, existence is also established near $\epsilon = 0$.

□

Proof of Proposition 2. The bond price is $p_b = \phi(V_{hob} - V_{hn}) + (1-\phi)V_{aob}$. Solving V_{hob} and V_{aob}:

$$V_{hob} = \frac{\delta_b + x_b - y}{r} - \frac{\gamma_d (x_b + q_{bb}(1-\phi)V_{hn})}{r(r + \gamma_d + q_{bb}(1-\phi))} \tag{A.35}$$

$$V_{aob} = \frac{\delta_b + x_b - y}{r} - \frac{(r + \gamma_d)(x_b + q_{bb}(1-\phi)V_{hn})}{r(r + \gamma_d + q_{bb}(1-\phi))} \tag{A.36}$$

where from the earlier derivation:

$$V_{hn} = \frac{q_{bs} x_b \phi + \Delta_{hoc} q_{cb} (r + \gamma_d + q_{bb}(1-\phi))}{(r + \gamma_d) k} \tag{A.37}$$

Thus, we derive the limits of q's, and Δ_{hoc} as $\lambda_b \to \infty$ for an arbitrary λ_c. With the change of variable, $\epsilon \equiv \frac{1}{\lambda_b}$, (A.26) becomes:

$$(1+\rho)F_h - \gamma_d \mu_{hn} \left(\frac{S}{\mu_{hn} + \epsilon\gamma_d} + \frac{\lambda_c F_l}{\gamma_u (\lambda_c \mu_{hn} + \gamma_d + \gamma_u)} + 1\right) = 0$$

For $\epsilon = 0$,

$$\frac{(1+\rho)F_h}{\gamma_d} - S - \mu_{hn} \left(\frac{\lambda_c F_l}{\gamma_u (\lambda_c \mu_{hn} + \gamma_d + \gamma_u)} + 1\right) = 0 \tag{A.38}$$

For any $\rho \in [0,1]$, the LHS of (A.38) is positive at $\mu_{hn} = 0$, decreasing in μ_{hn}, and is negative for large μ_{hn}, Hence, (A.38) has a positive finite solution, $0 < \lim_{\lambda_b \to \infty} \mu_{hn} < \infty$, and this implies $\lim_{\lambda_b \to \infty} q_{bb} = \infty$, and $k \to \infty$. This also implies from (A.22) that $\lim_{\lambda_b \to \infty} \mu_{aob} = 0$ and q_{bs} converges to a finite number. Analogously, $\lim_{\lambda_b \to \infty} q_{cs} = \infty$ and from (A.20) and (A.24):

$0 < \lim_{\lambda_b \to \infty} q_{cb} < \infty$.

Then as discussed above, the numerator of Δ_{hoc} converges to a finite number, while the denominator converges to ∞, thus, $\Delta_{hoc} \to 0$. So $V_{hn} \to 0$, hence $V_{hob} \to \frac{\delta_b + x_b - y}{r}$, $V_{aob} \to \frac{\delta_b + x_b - y}{r}$ and $p_b \to \frac{\delta_b + x_b - y}{r}$. □

Note that since $V_{hn} \to 0$, $\rho \to 0$. This is why the assumption that there is some proportion of high types who do not have an outside opportunity and always enter simplifies some of the proofs. Otherwise, as high types enter at a smaller and smaller rate, the steady state measure of high types can become smaller than $S + \frac{F_l}{\gamma_u}$. As a result, the marginal investor of the bond is not necessarily the high type and the frictionless price is not given by the valuation of the high types.

Proof of Proposition 3. Combining (A.35)-(A.37) we get the bond price. □

Proof of Proposition 4. Consider the interior solution $V_{hn}(\rho^{cds}) = O_h$. Since the bond price is $p_b = \phi(V_{hob} - V_{hn}) + (1-\phi)V_{aob}$, for an interior solution ($V_{hn}^{nocds} = V_{hn}^{cds} = O_h$) it is sufficient to show that $V_{hob}(q_{bb}^{cds}) > V_{hob}(q_{bb}^{nocds})$ and $V_{aob}(q_{bb}^{cds}) > V_{aob}(q_{bb}^{nocds})$. From (A.35) and (A.36), the derivative with respect to q_{bb}:

$$\frac{\partial V_{hob}}{\partial q_{bb}} = -\frac{\gamma_d \left(\left(r+\gamma_d\right) V_{hn} - x_b\right)(1-\phi)}{r\left(r+\gamma_d+q_{bb}(1-\phi)\right)^2}$$

$$\frac{\partial V_{aob}}{\partial q_{bb}} = -\frac{\left(r+\gamma_d\right)\left(\left(r+\gamma_d\right) V_{hn} - x_b\right)(1-\phi)}{r\left(r+\gamma_d+q_{bb}(1-\phi)\right)^2}$$

Thus, the condition for both V_{hob} and V_{aob} to be increasing in q_{bb} at $q_{bb} = q_{bb}^{nocds}$ is: $(r+\gamma_d)V_{hn} - x_b < 0$ evaluated at $q_{bb} = q_{bb}^{nocds}$.

Without CDS, the solution for V_{hn} is

$$V_{hn}^{nocds} = \frac{q_{bs} x_b \phi}{(r+\gamma_d)(r+\gamma_d+q_{bs}\phi+q_{bb}(1-\phi)} \tag{A.39}$$

Rearranging we get:

$$\left(r+\gamma_d\right) V_{hn} = \frac{q_{bs}\phi}{(r+\gamma_d+q_{bs}\phi+q_{bb}(1-\phi)} x_b < x_b$$

Next, we show that $q_{bb} = \lambda_b \mu_{hn}$ increases with CDS. Consider the solution for V_{hn}:

$$V_{hn}^{cds} = \frac{x_b q_{bs}^{cds} \phi_h}{k^{cds}\left(\gamma_d+r\right)} + \frac{q_{cb}\Delta_{\text{hoc}}\left(q_{bb}\phi_l+\gamma_d+r\right)}{k^{cds}\left(\gamma_d+r\right)} \tag{A.40}$$

Compare this with (A.39). The fact that $V_{hn}^{nocds} = V_{hn}^{cds} = O_h$ and that the second term of (A.40) is asymptotically positive implies that:

$$\frac{x_b q_{bs}^{cds} \phi_h}{k^{cds}\left(\gamma_d+r\right)} < \frac{x_b q_{bs} \phi_h}{k\left(\gamma_d+r\right)}$$

The term $\frac{x_b q_{bs}\phi_h}{k(\gamma_d+r)}$ is strictly decreasing in μ_{hn}. Thus, it has to be the case that $\mu_{hn}^{cds} > \mu_{hn}^{nocds}$.

Now consider the corner solution $\rho = 1$. This will be the case when $V_{hn}(\rho = 1) > O_h$. Keeping ρ fixed, when CDS matching efficiency λ_c decreases, V_{hn} increases. Thus, as λ_c decreases, V_{hn} keeps increasing and even when $\rho = 1$, it increases beyond O_h. Now, keeping ρ fixed, μ_{hn} is lower for some positive λ_c compared to the environment without CDS because high types end up selling CDS instead of buying bonds. When it was an interior solution, there was always enough entry so that the entry effect more than offset this congestion channel. However, as λ_c decreases further, the value of providing liquidity in the CDS market increases (V_{hn} increases) but at the boundary

$\rho = 1$ everyone who could have entered has entered. So if λ_c is too small (CDS search frictions too high), then the partial equilibrium effect dominates. As a result, bond market liquidity and bond price is lower with CDS. □

Proof of Proposition 5. Consider what (A.26) limits to for an arbitrary λ_b as $\lambda_c \to \infty$:

$$\frac{(1+\rho)F_h}{\gamma_d} - \left(\frac{S\lambda_b\mu_{hn}}{\lambda_b\mu_{hn} + \gamma_d} + \frac{F_l}{\gamma_u} + \mu_{hn}\right) = 0 \tag{A.41}$$

The LHS of (A.41) is positive at $\mu_{hn} = 0$, decreasing in μ_{hn}, and is negative for large μ_{hn}. Thus, for any ρ, μ_{hn} is finite as $\lambda_c \to \infty$. As a result, μ_{aob}, q_{bs} and q_{bb} are finite. Since $\mu_{ln} + \mu_{aoc} \to 0$, q_{cb} is also finite. But $q_{cs} = \lambda_c\mu_{hn} \to \infty$ Thus, $\Delta_{hoc} \to 0$.

When the solution is interior,

$$V_{hn}^{cds} = V_{hn}^{nocds} = O_h \tag{A.42}$$

Then, using $\Delta_{hoc} \to 0$ and (A.30):

$$\frac{x_b q_{bs}^{cds}\phi_h}{k^{cds}\left(\gamma_d + r\right)} = \frac{x_b q_{bs}^{nocds}\phi_h}{k^{nocds}\left(\gamma_d + r\right)} \tag{A.43}$$

Since this expression is uniquely determined by μ_{hn}, it has to be that:

$$\mu_{hn}^{cds} = \mu_{hn}^{nocds} \tag{A.44}$$

Thus, $q_{bb} = \lambda_b\mu_{hn}$ is the same as without CDS. Consequently, from (A.35)-(A.36) and (A.42), V_{hob} and V_{aob} are the same with or without CDS. Thus, when $\lambda_c \to \infty$, the bond price is the same as in the benchmark environment without CDS. For (A.44) to hold, from (A.41), the entry rate (hence the measure of high types) increases enough to exactly offset the total measure of low types $\frac{F_l}{\gamma_u}$: $\frac{(\rho^{cds} - \rho^{nocds})F_h}{\gamma_d} = \frac{F_l}{\gamma_u}$.

If entry is exogenous, $\lim_{\lambda_c \to \infty} p_b(\lambda_c) < p_b^{\text{no cds}}$ because the measure of high types (hence the measure of bond buyers) decreases due the existence of low types. □

Proof of Proposition 6. The population measures evolve according to:

$$\dot{\mu}_{hn}(t) = (1+\rho)F_h + \gamma_u\mu_{hoc}(t) - \left[\gamma_d\mu_{hn}(t) + \left(q_{bs}(t) + q_{cb}(t)\right)\mu_{hn}(t)\right] \tag{A.45}$$

$$\dot{\mu}_{ln}(t) = F_l - \left[\gamma_u\mu_{ln}(t) + q_{cs}\mu_{ln}(t)\right] \tag{A.46}$$

$$\dot{\mu}_{hob}(t) = q_{bs}\mu_{hn}(t) - \gamma_d\mu_{hob}(t) \tag{A.47}$$

$$\dot{\mu}_{aob}(t) = \gamma_d\mu_{hob}(t) - q_{bb}\mu_{aob}(t) \tag{A.48}$$

$$\dot{\mu}_{hoc}(t) = q_{cb}\mu_{hn}(t) - \left[\gamma_d\mu_{hoc}(t) + \gamma_u\mu_{hoc}(t)\right] \tag{A.49}$$

$$\dot{\mu}_{aoc}(t) = \gamma_d\mu_{hoc}(t) - \left[\gamma_u\mu_{aoc}(t) + q_{cs}\mu_{aoc}(t)\right] \tag{A.50}$$

$$\dot{\mu}_{lsc}(t) = q_{cs}\mu_{ln}(t) - \gamma_u\mu_{lsc}(t) \tag{A.51}$$

Value functions evolve according to:

$$\dot{V}_{hn}(t) = rV_{hn}(t) - [\gamma_d(0 - V_{hn}(t)) + q_{bs}(t)\phi\omega_b(t) + q_{cb}(t)(V_{hoc}(t) - V_{hn}(t))] \tag{A.52}$$

$$\dot{V}_{ln}(t) = rV_{ln}(t) - [\gamma_u(0 - V_{ln}(t)) + q_{cs}(t)(V_{lsc}(t) - V_{ln}(t))] \tag{A.53}$$

$$\dot{V}_{hob}(t) = rV_{hob}(t) - [\delta_b + x_b - y + \gamma_d(V_{aob}(t) - V_{hob}(t))] \tag{A.54}$$

$$\dot{V}_{aob}(t) = rV_{aob}(t) - [\delta_b - y + q_{bb}(t)\,(1-\phi)\,\omega_b(t)] \tag{A.55}$$

$$\dot{V}_{hoc}(t) = rV_{hoc}(t) - [p_c(t) - (\delta_c - x_{cl}) - y + \gamma_d(V_{aoc}(t) - V_{hoc}(t)) + \gamma_u(V_{hn}(t) - V_{hoc}(t))] \tag{A.56}$$

$$\dot{V}_{aoc}(t) = rV_{aoc}(t) - [p_c(t) - \delta_c - y + q_{cs}(t)(0 - V_{aoc}(t)) + \gamma_u(0 - V_{aoc}(t))] \tag{A.57}$$

$$\dot{V}_{lsc}(t) = rV_{lsc}(t) - [-p_c(t) + (\delta_c + x_{ch}) - y + \gamma_u\,(0 - V_{lsc}(t))] \tag{A.58}$$

Using the ODE for V_{hob} and V_{hn}:

$$\dot{\Delta}_{hob} = r\Delta_{hob} - [\delta_b + x_b - y - (\gamma_d + q_{bs}\phi)\,\omega_b - q_{cb}\phi\omega_c]$$

Together with the ODE for V_{aob}:

$$\dot{\omega}_b = -x_b + (r + \gamma_d + q_{bs}\phi + q_{bb}\,(1-\phi))\,\omega_b + q_{cb}\phi\omega_c \tag{A.59}$$

Analogously, we get the ODE for ω_c,

$$\dot{\omega}_c = -x_{cl} + q_{bs}\phi\omega_b + (r + \gamma_d + \gamma_u + q_{cb}\phi + q_{cs}(1-\phi))\,\omega_c \tag{A.60}$$

To solve for ω_b and ω_c, we write (A.59) and (A.60) in this form:

$$\begin{bmatrix} \dot{\omega}_b(t) \\ \dot{\omega}_c(t) \end{bmatrix} = -\begin{bmatrix} x_b \\ x_{cl} + x_{ch} - 2y \end{bmatrix} + A(t)\begin{bmatrix} \omega_b(t) \\ \omega_c(t) \end{bmatrix},$$

where

$$A(t) = \begin{bmatrix} r + \gamma_d + q_{bs}\phi + q_{bb}\,(1-\phi) & q_{cb}\phi \\ q_{bs}\phi & r + \gamma_d + \gamma_u + q_{cb}\phi + q_{cs}(1-\phi) \end{bmatrix}$$

Thus, the solution is:

$$\begin{bmatrix} \omega_b(t) \\ \omega_c(t) \end{bmatrix} = \int_t^\infty e^{-\int_t^s A(u)du} \begin{bmatrix} x_b \\ x_{cl} + x_{ch} - 2y \end{bmatrix} ds$$

From here, the solutions to the ODE for Δ_{hob} and V_{aob} are given by:

$$\Delta_{hob} = \frac{\delta_b + x_b - y}{r} - \int_t^\infty e^{-r(s-t)}\left((\gamma_d + q_{bs}\phi)\,\omega_b + q_{cb}\phi\omega_c\right) ds$$
$$V_{aob} = \frac{\delta_b - y}{r} + \int_t^\infty e^{-r(s-t)} q_{bb}\,(1-\phi)\,\omega_b ds$$

□

A.1 A Simple Example of Hedging Benefits

Let $\theta = 1$ denote a long position (exposed to risk) through the bond or CDS market, $\theta = 0$ no position, and $\theta = -1$ a short position (i.e. bought CDS). An agent with $\theta_b \in \{0, 1\}$ shares of the bond has a utility flow:[35]

$$\theta_b \left(\delta_b + x_t^b\right)$$

and an agent with CDS position $\theta_c \in \{-1, 0, 1\}$ has a utility flow:

$$-\theta_c \left(\delta_c + x_t^c\right), \tag{A.61}$$

where $x_t^b \in \{-x_b, 0, x_b\}$ and $x_t^c \in \{-x_{ch}, 0, x_{cl}\}$ are stochastic processes. I define an agent with $\{x_t^b = x_b, x_t^c = -x_{ch}\}$ as a high type, with $\{x_t^b = 0, x_t^c = 0\}$ as an average, and with $\{x_t^b = -x_b, x_t^c = x_{cl}\}$ as a low type.

The bond coupon flow, δ_b, can be interpreted as an expected coupon flow: with intensity η the bond defaults but otherwise pays \$1 of coupon. Hence, $\delta_b = (1-\eta)\$1$. Similarly, δ_c can be interpreted as an expected insurance payment. A CDS contract pays out if there is default on the coupon payment: with intensity η CDS pays \$1 thus, $\delta_c = \eta\$1$. According to (A.61), a high type values this as $\delta_c - x_{ch}$, while a low type values this as $\delta_c + x_{ch}$. Thus, as a CDS seller ($\theta_c = 1$), a low type experiences a greater disutility *paying out* the insurance payment $-(\delta_c + x_{cl})$ than a high type $-(\delta_c - x_{ch})$. Conversely, as a CDS buyer ($\theta_c = -1$), a low type benefits more *receiving* the insurance payment $(\delta_c + x_{cl})$ than a high type $(\delta_c - x_{ch})$. Tables below show a simple example of how x_b, x_{ch}, and x_{cl} can depend on cash flow of the bond and CDS, and the default intensity of the bond. A more formal derivation in Section A.2 shows how, in an environment with risk averse agents, just two types of agents, and just the bond market, the hedging benefits are a function of the risk aversion parameter, the correlation between agents' idiosyncratic endowment and the bond, and riskiness of the bond.

Table 4: The Expected Valuation of the Bond Payoff

Consider an example where with intensity, η, the bond defaults and pays no coupon, otherwise pays \$1 of coupon. Hence, the expected coupon is $\delta_b = (1-\eta)\$1$. The table shows valuations of the bond cash flow by high, average, and low types.

		Utility Valuation		
	Bond Payoff	High	Ave	Low
$1-\eta$	\$1	1	1	1
η	\$0	ϵ_h	0	$-\epsilon_l$
Expected Valuation:		$\overbrace{(1-\eta)\,1}^{\delta_b} + \overbrace{\eta\epsilon_h}^{x_{bh}}$	$\overbrace{(1-\eta)}^{\delta_b}$	$\overbrace{(1-\eta)}^{\delta_b} - \overbrace{\eta\epsilon_l}^{x_{bl}}$

Table 5: The Expected Valuation of the CDS Payoff as a CDS Buyer

With intensity η the bond defaults and CDS pays \$1 and zero otherwise. Hence, the expected insurance payment is $\delta_c = \eta\$1$. The table shows a simple example of utility valuations of the cash flow as a CDS buyer by different types. In the default state, low types get an extra utility for extra \$1 than high types. Thus, in expectation, as a CDS buyer a low type benefits more *receiving* the insurance payment $(\delta_c + x_{cl})$ than a high type $(\delta_c - x_{ch})$.

	Cash Flow of CDS Buyer	Utility Valuations		
		High	Ave	Low
$1-\eta$	\$0	0	0	0
η	\$1	$1-\epsilon_h$	1	$1+\epsilon_l$
Expected Valuation:		$\overbrace{\eta}^{\delta_c} - \overbrace{\eta\epsilon_h}^{x_{ch}}$	$\overbrace{\eta}^{\delta_c}$	$\overbrace{\eta}^{\delta_c} + \overbrace{\eta\epsilon_l}^{x_{cl}}$

[35] For an expositional purpose, let us ignore y that is in section 1.

Table 6: The Expected Valuation of the CDS Payoff as a CDS Seller

With intensity η the bond defaults and CDS seller has to pay $1. The table shows a simple example of utility valuations of the cash flow as a CDS seller by different types. In the default state, low types get an extra disutility for paying out the insurance than high types. Thus, in expectation, as a CDS seller a low type experiences a greater disutility *paying out* the insurance payment $-(\delta_c + x_{cl})$ than a high type $-(\delta_c - x_{ch})$.

	Cash Flow of CDS Seller	Utility Valuations		
		High	Ave	Low
$1-\eta$	$0	0	0	0
η	−$1	$-(1-\epsilon_h)$	-1	$-(1+\epsilon_l)$
Expected Valuation		$-(\overbrace{\eta}^{\delta_c} - \overbrace{\eta\epsilon_h}^{x_{ch}})$	$-\overbrace{\eta}^{\delta_c}$	$-(\overbrace{\eta}^{\delta_c} + \overbrace{\eta\epsilon_l}^{x_{cl}})$

A.2 A Formal Derivation of Hedging Benefits

In this section, I illustrate in a simpler environment a micro foundation for the liquidity shock x_b when the asset is risky and agents are risk averse. This derivation follows Vayanos and Weill (2008) and Duffie, Gârleanu, and Pedersen (2007). I simplify the baseline model in the paper by considering just two types (high and low) instead of three types (high, average, low), and no CDS markets. I simplify the notation by denoting continuous time dependence $y(t)$ as y_t.

Agents have CARA utility preferences with risk aversion parameter α and time preference rate of β. The risky asset has cumulative dividend process, D_t, of:

$$dD_t = \delta dt + \sigma_D dB_t, \tag{A.62}$$

where B_t is a standard Brownian motion. Agents also have an idiosyncratic cumulative endowment process:[36]

$$de_t = \sigma_e \left[\rho_t dB_t + \sqrt{1-\rho_t^2} dZ_t\right],$$

where Z_t is another standard Brownian motion independent of B_t. The high and low types come in with the variable $\rho_t \in \{\rho_l, \rho_h\}$ that is a two-state Markov chain with $\rho_l > \rho_h$. If $\rho_t = \rho_l$, the agent is currently a low type agent which means her endowment process is highly correlated with the asset's dividend process, D_t, but if her type switches to a high type, $\rho_{t+\Delta t} = \rho_h$, her endowment process will be less correlated with D_t.[37] Analogous to the baseline model, a low type agent switches to high type with intensity γ_u, and high type to low type with intensity γ_u. We restrict the agent's asset position to $\theta_t \in \{\theta_n, \theta_o\}$, where $0 < \theta_n < \theta_o$. As there are two correlation types and two possible asset positions, there are total of four agent types: $\mathcal{T} = \{hn, ln, hob, lob\}$. hn and ln are high and low types, respectively, who both hold θ_n shares of the asset, while hob and lob are high and low types, respectively, who both hold θ_o shares of the asset. Table 7 illustrates the switching probabilities from $\tau_t \in \{hn, ln, hob, lob\}$ to $\tau_{t+\Delta t} \in \{hn, ln, hob, lob\}$.

[36] The endowment process can have a trend component: $de_t = \mu_e dt + \sigma_e \left[\rho_t dB_t + \sqrt{1-\rho_t^2} dZ_t\right]$

[37] With three types, we could have a three-state Markov chain with, for example, $\rho_t \in \{-\rho, 0, \rho\}$ for some $\rho > 0$, where if $\rho_t = \rho$, an agent is low type, if $\rho_t = 0$, an agent's endowment has no correlation, and if $\rho_t = -\rho$ an agent is high type as her endowment is negatively correlated with the risky asset (and she would be willing to be exposed to the risky asset *relative* to the low type agent).

		$\tau_{t+\Delta t}$			
		hn	ln	hob	lob
τ_t	hn	$(1-\gamma_d dt - q_{bs}dt)$	$\gamma_d dt$	$q_{bs}dt$	$0dt$
	ln	$\gamma_u dt$	$(1-\gamma_u dt)$	0	0
	hob	0	0	$(1-\gamma_d dt)$	$\gamma_d dt$
	lob	0	$q_{bb}dt$	$\gamma_u dt$	$(1-\gamma_u dt - q_{bb}dt)$

Table 7: Switching probabilities from τ_t to $\tau_{t+\Delta t} \in \{hn, ln, hob, lob\}$

An agent's optimization problem is:

$$J(W_0, \tau_0) = \max_{\{c_t\}} \mathbb{E} \int_0^\infty e^{-\beta t} u(c_t) dt \tag{A.63}$$

subject to:[38]

$$dW_t = (rW_t - c_t + \delta\theta_t)\, dt + (\sigma_D \theta_t + \rho_t \sigma_e)\, dB_t + \sigma_\eta \sqrt{1-\rho_t^2} dZ_t - p_b d\theta_t, \tag{A.64}$$

where W_t is the agent's wealth process, W_0 is given, p_b is the asset price. $J(W_0, \tau_0)$ is the maximized value of the objective function as a function of two state variables, the wealth process and the agent type $\tau \in \mathcal{T}$.

Equation (A.63) can be written recursively as:[39]

$$J(W_t, \tau_t) = \max_{c_0} u(c_t)\Delta t + (1-\beta\Delta t)\, \mathbb{E} J(W_{t+\Delta t}, \tau_{t+\Delta t}) \tag{A.65}$$

Deriving the Hamilton-Jacobi-Bellman (HJB) Equation

Next, we derive the Hamilton-Jacobi-Bellman (HJB) equation from (A.65). Subtract $(1-\beta\Delta t)\, J(W_t, \tau_t)$ from both sides and divide by Δt:

$$\beta J(W_t, \tau_t) = \max_{c_t} u(c_t) + (1-\beta\Delta t)\, \mathbb{E}\left[\frac{J(W_{t+\Delta t}, \tau_{t+\Delta t}) - J(W_t, \tau_t)}{\Delta t}\right]$$

In the limit as $\Delta t \to 0$

$$\beta J(W_t, \tau_t) = \max_{c_t} u(c_t) + \mathbb{E}\left[\frac{dJ(W_t, \tau_t)}{dt}\right]$$

The next step is deriving the expectation of the total differential of $J(W_t, \tau_t)$. We approximate the total differential $dJ(W_t, \tau_t)$ by a Taylor expansion:

$$dJ(W_t, \tau_t) = J_W(W_t, \tau_t) dW_t + \frac{1}{2} J_{WW}(W_t, \tau_t) dW_t^2 + J_\tau(W_t, \tau_t) d\tau_t + \frac{1}{2} J_{\tau\tau}(W_t, \tau_t) d\tau_t^2,$$

[38](A.64) comes from $dW_t = (rW_t - c_t)\, dt + dD_t\theta_t + de_t - p_b d\theta_t$.

[39]This comes from observing that over a small time interval $[0, \Delta t]$, (A.63) can be written as:

$$J(W_0, \tau_0) = \mathbb{E} \int_0^\infty e^{-\beta t} u(c_t^*) dt = u(c_0^*)\Delta t + e^{-\beta \Delta t} \mathbb{E}\left[\int_{\Delta t}^\infty e^{-\beta(t-\Delta t)} u(c_t^*) dt\right],$$

where $\{c_t^*\}$ is the optimal consumption path. The term inside the expectations operation is $J(W_{\Delta t}, \tau_{\Delta t})$, thus $J(W_0, \tau_0) = \max_{c_0} u(c_0)\Delta t + e^{-\beta\Delta t} \mathbb{E} J\left(W_{\Delta t}, \tau_{\Delta t}\right)$. Similarly if we start at $\{W_t, \tau_t\}$ and approximate $e^{-\beta\Delta t} \approx 1 - \beta\Delta t$, we get (A.65).

where dW_t is given by A.64. Thus,

$$\mathbb{E}dW_t = (rW_t - c_t + \mu_D\theta_t + \mu_\eta)\, dt - Pd\theta_t$$

$$\mathbb{E}dW_t^2 = (\sigma_D\theta_t + \sigma_\eta\rho_t)^2\, dt + \sigma_\eta^2\left(1-\rho_t^2\right) dt = \left((\sigma_D\theta_t)^2 + 2\sigma_D\theta_t\sigma_\eta\rho_t + \sigma_\eta^2\right) dt$$

$$\mathbb{E}J_\tau(W_t,\tau_t)d\tau_t = \begin{cases} \gamma_d dt\,(J(W_t,ln) - J(W_t,hn)) + q_{bs}dt\,(J(W_t - P(\theta_o-\theta_n), hob) - J(W_t,hn)) & \text{if } \tau_t = hn \\ \gamma_u dt\,(J(W_t,hn) - J(W_t,ln)) & \text{if } \tau_t = ln \\ \gamma_d dt\,(J(W_t,lob) - J(W_t,hob)) & \text{if } \tau_t = hob \\ \gamma_u dt\,(J(W_t,hob) - J(W_t,lob)) + q_{bb}dt\,(J(W_t + P(\theta_o-\theta_n), ln) - J(W_t,lob)) & \text{if } \tau_t = lob \end{cases}$$

As all the $d\tau_t$ terms involve dt term, $\mathbb{E}\frac{1}{2}J_{\tau\tau}(W_t,\tau_t)d\tau_t^2 = 0$.

When $\tau_t = lob$,

$$\begin{aligned} \mathbb{E}dJ(W_t,lob) &= J_W(W_t,lob)\,(rW_t - c_t + \delta\theta_o)\,dt + \frac{1}{2}J_{WW}(W_t,lob)\left((\sigma_D\theta_o)^2 + 2\sigma_D\theta_o\sigma_e\rho_t + \sigma_e^2\right) dt \\ &+ \gamma_u dt\,(J(W_t,hob) - J(W_t,lob)) + q_{bb}dt\,(J(W_t + P(\theta_o-\theta_n), ln) - J(W_t,lob)) \end{aligned}$$

Thus, the Hamilton-Jacobi-Bellman (HJB) equation when $\tau_t = lob$:

$$\begin{aligned} \beta J(W_t,lob) &= \max_{c_t} \quad u(c_t) + J_W(W_t,lob)\,(rW_t - c_t + \delta\theta_o) && \text{(A.66)} \\ &+\frac{1}{2}J_{WW}(W_t,lob)\left((\sigma_D\theta_o)^2 + 2\sigma_D\theta_o\sigma_e\rho_t + \sigma_e^2\right) \\ &+\gamma_u\,(J(W_t,hob) - J(W_t,lob)) + q_{bb}\,(J(W_t + P(\theta_o-\theta_n), ln) - J(W_t,lob)) && \text{(A.67)} \end{aligned}$$

The HJB equations for the other types are derived analogously.

Proposition 7. *Solutions for $J(W_t,\tau_t)$ are of the form:*

$$J(W_t,\tau_t) = -e^{-r\alpha(W_t+V_\tau+a)}$$

where V_τ $\tau \in \mathcal{T} = \{hn, ln, hob, lob\}$ are given by:

$$\begin{aligned} rV_{lob} &= (k(\theta_0) - \theta_0 x_b) + \gamma_u\frac{1-e^{-r\alpha(V_{hob}-V_{lob})}}{r\alpha} + q_{bb}\frac{1-e^{-r\alpha(P(\theta_o-\theta_n)+V_{ln}-V_{lob})}}{r\alpha} \\ rV_{ln} &= (k(\theta_n) - \theta_n x_b) + \gamma_u\frac{1-e^{-r\alpha(V_{hn}-V_{ln})}}{r\alpha} \\ rV_{hob} &= k(\theta_0) + \gamma_d\frac{1-e^{-r\alpha(V_{lob}-V_{hob})}}{r\alpha} \\ rV_{hn} &= k(\theta_n) + \gamma_d\frac{1-e^{-r\alpha(V_{ln}-V_{hn})}}{r\alpha} + q_{bs}\frac{1-e^{-r\alpha(-P(\theta_o-\theta_n)+V_{ho}-V_{hn})}}{r\alpha} \end{aligned}$$

and $k(\theta) = \delta\theta - \frac{1}{2}r\alpha\left(\sigma_D^2\theta^2 + 2\sigma_D\theta\sigma_e\rho_h\right)$, $x_b = r\alpha\,(\rho_l - \rho_h)\,\sigma_D\sigma_e$ *and* $\bar{a} = \frac{1}{r}\left(\frac{log(r)}{\alpha} - \frac{r-\beta}{r\alpha} - \frac{1}{2}r\alpha\sigma_e^2\right)$.

Proof. Using the guessed functional form, $J(W_t,\tau_t) = -e^{-r\alpha(W_t+V_\tau+a)}$, and the first order condition of (A.66), we can solve for the optimal consumption rate for agent τ:[40]

$$c_\tau = -\frac{log\,(r)}{\alpha} + r\,(W + V_\tau + a)$$

[40]FOC with respect to c_t is: $0 = \alpha e^{-\alpha c} - J_W(W_t,\tau_t)$. Using $J_W = r\alpha e^{-r\alpha(W+V_\tau+a)}$, $re^{-r\alpha(W+V_\tau+a)} = e^{-\alpha c}$. Rewrite it as: $e^{log(r)}e^{-r\alpha(W+V_\tau+a)} = e^{-\alpha c}$

Inserting the optimal consumption back into the HJB equation A.66 and using $J_W = r\alpha e^{-r\alpha(W+V_\tau+a)}$ and $J_{WW} = -r^2\alpha^2 e^{-r\alpha(W+V_\tau+a)}$:

$$
\begin{aligned}
-\beta e^{-r\alpha(W+V_{lob}+a)} &= -e^{log(r)-r\alpha(W+V_{lob}+a)} + r\alpha e^{-r\alpha(W+V_{lob}+a)}\left(\frac{log\,(r)}{\alpha} - r\,(V_{lob}+a) + \delta\theta_o\right) \\
&-\frac{1}{2}r^2\alpha^2 e^{-r\alpha(W+V_{lob}+a)}\left((\sigma_D\theta_o)^2 + 2\sigma_D\theta_o\sigma_e\rho_t + \sigma_e^2\right) + \gamma_u\left(-e^{-r\alpha(W+V_{hob}+a)} + e^{-r\alpha(W+V_{lob}+a)}\right) \\
&+q_{bb}\left(-e^{-r\alpha(W+P(\theta_o-\theta_n)+V_{ln}+a)} + e^{-r\alpha(W+V_{lob}+a)}\right)
\end{aligned}
$$

Cancel $e^{-ra(W+a)}$ and divide everything by $e^{-r\alpha V_{lob}}$:

$$
\begin{aligned}
-\beta &= -r + r\alpha\left(\frac{log\,(r)}{\alpha} - r\,(V_{lob}+a) + \delta\theta_o\right) - \frac{1}{2}r^2\alpha^2\left((\sigma_D\theta_o)^2 + 2\sigma_D\theta_o\sigma_e\rho_t + \sigma_e^2\right) \\
&+\gamma_u\left(-e^{-r\alpha(V_{hob}-V_{lob})} + 1\right) + q_{bb}\left(-e^{-r\alpha(P(\theta_o-\theta_n)+(V_{ln}-V_{lob}))} + 1\right)
\end{aligned}
$$

Divide by $-r\alpha$:

$$
\begin{aligned}
\beta\ \frac{1}{r\alpha} &= rV_{lob} + \gamma_u\frac{e^{-r\alpha(V_{hob}-V_{lob})} - 1}{r\alpha} + q_{bb}\frac{e^{-r\alpha(P(\theta_o-\theta_n)+(V_{ln}-V_{lob}))} - 1}{r\alpha} \\
&-\frac{log\,(r)}{\alpha} + ra + \frac{1}{\alpha} - \left(\delta\theta_o - \frac{1}{2}r\alpha\left(\sigma_D^2\theta_o^2 + 2\sigma_D\theta_o\sigma_e\rho_t + \sigma_e^2\right)\right)
\end{aligned}
$$

Rearranging, we find the expression for $\bar{a}$:

$$
\begin{aligned}
0 = &\ rV_{lob} + \gamma_u\frac{e^{-r\alpha(V_{hob}-V_{lob})} - 1}{r\alpha} + q_{bb}\frac{e^{-r\alpha(P(\theta_o-\theta_n)+(V_{ln}-V_{lob}))} - 1}{r\alpha} \\
&+r\bar{a} - r\frac{1}{r}\left(\frac{log\,(r)}{\alpha} - \frac{r-\beta}{r\alpha} - \frac{1}{2}r\alpha\sigma_e^2\right) - \left(\delta\theta_o - \frac{1}{2}r\alpha\left(\sigma_D^2\theta_o^2 + 2\sigma_D\theta_o\sigma_e\rho_t\right)\right)
\end{aligned}
$$

Thus, defining $\bar{a} \equiv \frac{1}{r}\left(\frac{log(r)}{\alpha} - \frac{r-\beta}{r\alpha} - \frac{1}{2}r\alpha\sigma_e^2\right)$, we get:

$$
0 = \ rV_{lob} + \gamma_u\frac{e^{-r\alpha(V_{hob}-V_{lob})} - 1}{r\alpha} + q_{bb}\frac{e^{-r\alpha(P(\theta_o-\theta_n)+V_{ln}-V_{lob})} - 1}{r\alpha} - \left(\delta\theta_o - \frac{1}{2}r\alpha\left(\sigma_D^2\theta_o^2 + 2\sigma_D\theta_o\sigma_e\rho_t\right)\right)
$$

Add and subtract $\frac{1}{2}r\alpha 2\sigma_D\theta_o\sigma_e\rho_h$:

$$
\begin{aligned}
0 = &\ rV_{lob} + \gamma_u\frac{e^{-r\alpha(V_{hob}-V_{lob})} - 1}{r\alpha} + q_{bb}\frac{e^{-r\alpha(P(\theta_o-\theta_n)+V_{ln}-V_{lob})} - 1}{r\alpha} \\
&-\left(\delta\theta_o - \frac{1}{2}r\alpha\left(\sigma_D^2\theta_o^2 + 2\sigma_D\theta_o\sigma_e\rho_h\right)\right) + \theta_0 r\alpha\,(\rho_l - \rho_h)\,\sigma_D\sigma_e
\end{aligned}
$$

Define: $k(\theta) \equiv \delta\theta - \frac{1}{2}r\alpha\left(\sigma_D^2\theta^2 + 2\sigma_D\theta\sigma_e\rho_h\right)$ and $x_b \equiv r\alpha\,(\rho_l - \rho_h)\,\sigma_D\sigma_e$

$$
0 = rV_{lob} + \gamma_u\frac{e^{-r\alpha(V_{hob}-V_{lob})} - 1}{r\alpha} + q_{bb}\frac{e^{-r\alpha(P(\theta_o-\theta_n)+V_{ln}-V_{lob})} - 1}{r\alpha} - (k(\theta_0) - \theta_0 x_b)
$$

Rearranging:

$$
rV_{lob} = (k(\theta_0) - \theta_0 x_b) + \gamma_u\frac{1 - e^{-r\alpha(V_{hob}-V_{lob})}}{r\alpha} + q_{bb}\frac{1 - e^{-r\alpha(P(\theta_o-\theta_n)+V_{ln}-V_{lob})}}{r\alpha} \tag{A.68}
$$

It's similar to the other agent types. □

Comparison to the Baseline Model

In the limit as $\alpha \to 0$, the general value function (A.68) satisfies the value functions with risk-neutral agents of the baseline model of in the text of the paper. To see this, linearizing (A.68) (using $e^z - 1 \approx z$) for small α, we get:

$$rV_{lob} = (k(\theta_0) - \theta_0 x_b) + \gamma_u (V_{hob} - V_{lob}) + q_{bb} (V_{ln} - V_{lob} + p_b (\theta_o - \theta_n)) \tag{A.69}$$

(A.69) is analogous to the value functions of the baseline model with risk-neutral agents. Thus, the baseline model is a reduced form approximation of the more general specification with risk averse agents and risky assets.

The illiquidity shock or cost, $x_b = r\alpha (\rho_l - \rho_h) \sigma_D \sigma_e$, captures the risk aversion of agents (α), the riskiness of the asset (σ_D) and the endowment (σ_e), and the difference in the correlation of low and high types ($\rho_l - \rho_h$). The larger is any of these parameters, the larger is the illiquidity cost.

B Appendix: Model Figures

Figure 2: The Bond Illiquidity Discount

This figure illustrates the main result of the paper. It shows the difference in the bond illiquidity discount with and without CDS as a function of the CDS market efficiency (λ_c). With the existence of naked CDS buyers, the bond illiquidity discount (the solid blue line) is lower than the benchmark without CDS (dashed red line). If the CDS market is frictionless ($\lambda_c \to \infty$), the CDS market is redundant and does not affect bond market liquidity.

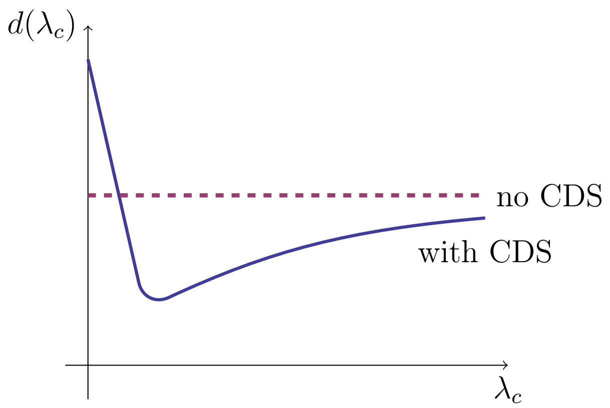


Figure 3: The Value of Trading as a High Type

The figure plots the value of trading as a long trader, V_{hn}, as a function of the entry rate (ρ). The value increases with the introduction of the CDS market (the curve shifts up) and is higher with search frictions present in the CDS market ($\lambda_c < \infty$) than without search frictions in the CDS market ($\lambda_c = \infty$). The equilibrium entry rate is determined by the intersection of V_{hn} and their outside option (the horizontal line at O_h).

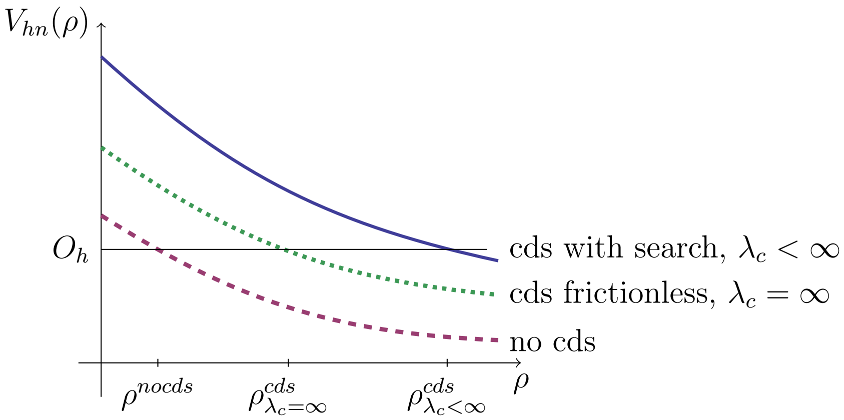


Figure 4: The Rate of Entry

The diagram illustrates how the introduction of the CDS market affects the entry rate, ρ, of long traders. By how much the entry rate increases depends on the total potential demand for CDS (i.e. the steady state measure of low types, $\frac{F_l}{\gamma_u}$, who in equilibrium want to short credit risk) and the CDS market matching efficiency, λ_c. The dashed line is the additional number of long traders in the economy due to the existence of naked CDS buyers. As the CDS market is frictionless, $\lambda_c \to \infty$, the increase in the measure of long traders exactly equals the demand for CDS (the horizontal line).

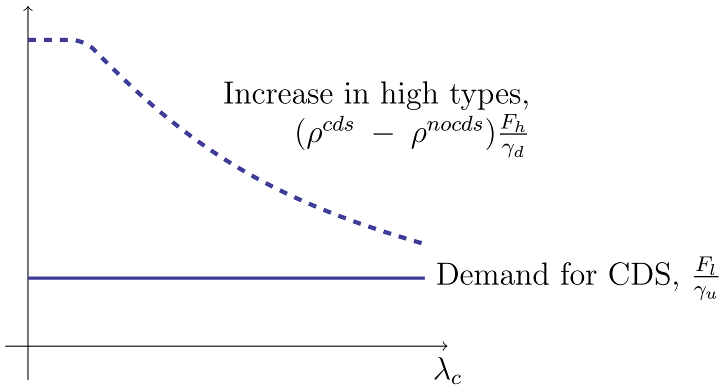


Figure 5: The Effect of CDS on Bond Market Composition

The figure compares the relative composition of buyers and sellers in the bond market with (solid line) and without CDS (dashed line) as a function of the CDS market efficiency (λ_c). The introduction of the CDS market increases the number of bond buyers (left panel) and decreases the number of bond sellers (right panel). If the CDS market is frictionless ($\lambda_c \to \infty$), the CDS market is redundant and does not affect the bond market composition.

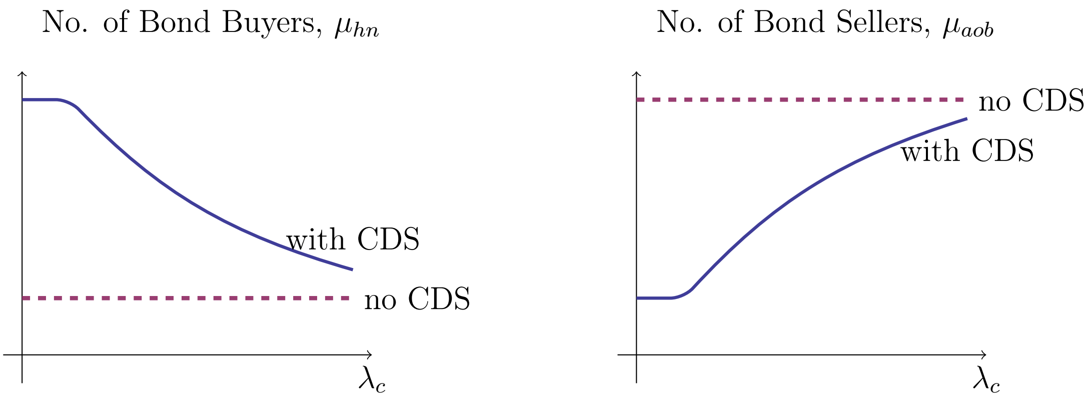


Figure 6: The Effect of CDS on Bond Volume

The figure compares the volume of trade in the bond market with (solid line) and without CDS (dashed line) as a function of the CDS market efficiency (λ_c). The introduction of the CDS market increases bond market volume. If the CDS market is frictionless ($\lambda_c \to \infty$), the CDS market is redundant and does not affect bond market volume.

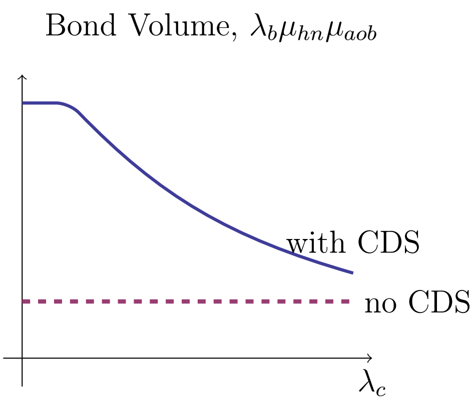


Figure 7: The Transition Dynamics of Types' Measures After a Temporary CDS Ban

A temporary naked CDS ban is modeled as a shock to the steady at time $t = 0$ that sets the number of naked CDS buyers to zero (as can be seen in the left panel). The figure plots the time varying equilibrium path back to the steady state number of CDS buyers (the left panel), bond buyers (the middle panel), and bond sellers (the right panel).

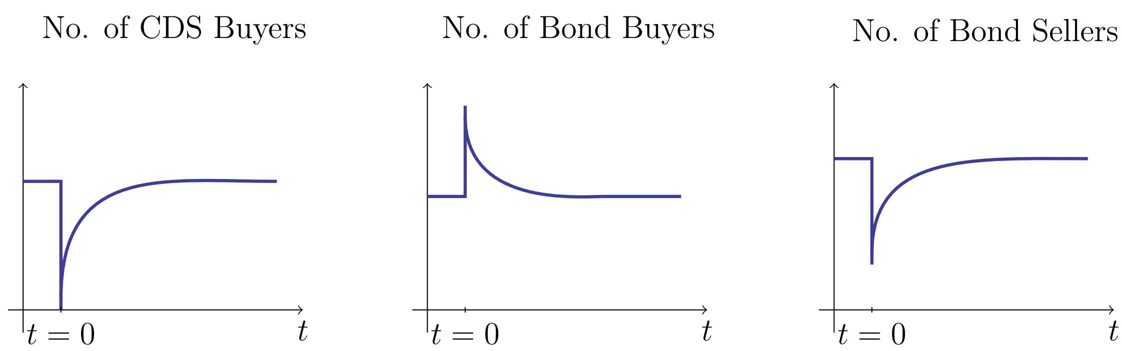


Figure 8: The Transition Dynamics of Bond Illiquidity

A temporary naked CDS ban is modeled as a shock to the steady at time $t = 0$ that sets the number of naked CDS buyers to zero. The figure plots the short run dynamics of the bond illiquidity discount. With a temporary naked CDS ban, the illiquidity discount temporarily decreases (i.e. liquidity increases).

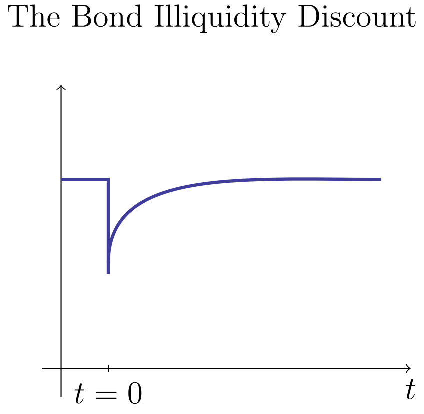


Figure 9: Cost of Entry

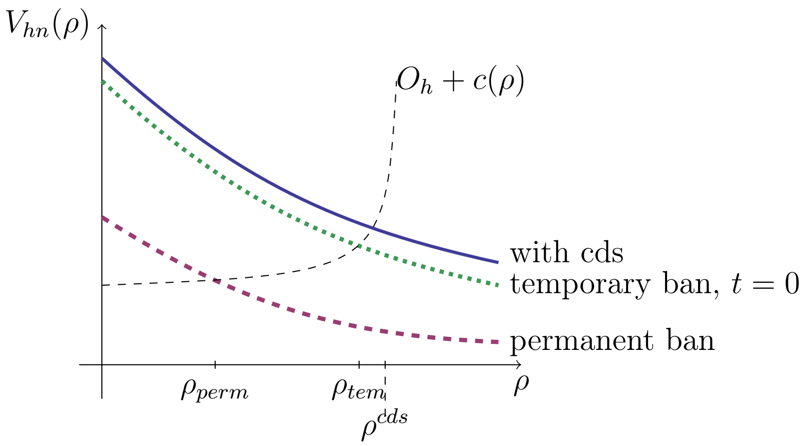
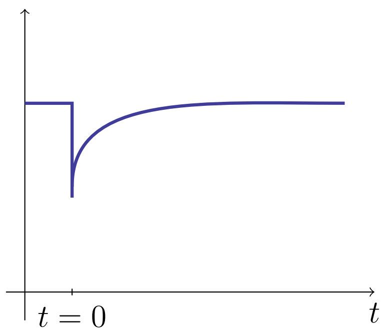


Figure 10: The Implicit Short-run Dynamics of the Cost of Entry $c(\rho(t))$



C Appendix: Data Tables

Table 8: Descriptive Statistics: Prices and Bid-Ask Spreads in Bond and CDS Markets

This table shows the descriptive statistics for the bond and CDS data for the period 2004Q1-2012Q1 across 65 sovereigns. Bond prices are quoted as a percent of the par (or face) value of the bond; for example, if the bond price is 95, the bond is trading at 95 cents on the dollar. "Bond Mid Price" is the average of the bid and the ask prices, and "Bond Price Bid-Ask (% of Par)" is the absolute bid-ask spread (the ask price minus the bid price). For example, if the ask and bid prices are 100.92 (% of par) and 100.00 (% of par), respectively, then "Bond Price Bid-Ask (% of Par)" would be 0.92 (% of par). "Bond Price Bid-Ask (% of Mid)" is the bid-ask spread as a percent of the mid price. Bond prices were also converted to yield-to-maturity. "Bond Mid Yield (%)" is the average of the bid and ask yields. Prices of CDS contracts are quoted in annualized percentages of the contract notional. Following market standards, they are reported in basis points. "CDS Mid (b.p.)" is the average of the bid and ask CDS prices (in basis points), "CDS Bid-Ask (b.p.)" is the absolute bid-ask spread in basis points, while "CDS Bid-Ask (% of Mid)" is the bid-ask spread as a percent of the mid price.

	Mean	St. Dev.	Min	Max	No obs.
(1) Bond Mid Price (% of Par)	106.56	13.75	27.94	166.67	1478
(2) Bond Price Bid-Ask (% of Par)	0.92	1.01	0.02	17.08	1478
(3) Bond Price Bid-Ask (% of Mid)	0.95	1.46	0.02	33.02	1478
(4) Bond Mid Yield (%)	5.37	2.93	-7.14	33.12	1478
(5) CDS Mid (b.p.)	205.20	438.87	1.73	10433.54	1478
(6) CDS Bid-Ask (b.p.)	15.11	43.73	1.00	1158.71	1478
(7) CDS Bid-Ask (% of Mid)	13.67	16.41	0.89	102.68	1478

Table 9: Descriptive Statistics: DTCC CDS Transactions Data

This table shows the descriptive statistics for the volume of trade in the CDS market (for an average day per quarter over 2009-2012) and the outstanding amount of CDS contracts and their total notional (gross and net) over 2008-2012. "Average Daily Number of Trades" is the daily total number of CDS trades; "Average Daily Notional" is the total notional of all trades per day in million $, this is effectively the daily volume of trade in the CDS market; "Daily Not'l (annual'd), % of Gross" is the daily CDS notional (annualized: daily CDS notional times 250 trading days) as percent of the outstanding gross notional, this is effectively CDS turnover. "Gross Government Debt" is the general government gross debt outstanding in million USD from World Bank Quarterly External Debt Statistics, and "Gross Not'l as % of Gross Debt" is the outstanding gross notional as percent of the outstanding gross government debt. Other variables are self explanatory. All CDS related data in this table comes from DTCC.

	Mean	St. Dev.	Min	Max	No obs.
(1) Average Daily Number of Trades	12.37	16.01	0.00	116.00	418
(2) Average Daily Notional (mln $)	162.66	240.02	2.50	1600.00	421
(3) Outstanding Gross Notional (mln $)	40007.57	47584.39	1659.32	310852.44	726
(4) Outstanding Net Notional (mln $)	3889.49	4789.88	251.42	27828.78	726
(5) Daily Not'l (annual'd), % of Gross	77.16	48.58	8.53	358.12	421
(6) Outstanding Number of Contracts	2829.47	2751.65	92.44	13324.67	726
(7) Gross Government Debt (bln $)	859.58	2511.51	5.75	16777.28	726
(8) Gross Not'l as % of Gross Debt	27.93	36.77	0.04	254.07	726

Table 10: Descriptive Statistics at the Country Level: Bond and CDS Price Data

This table shows for each country the average of the variables in Table 8. See Table 8 for the description and units. The column numbers correspond to the row numbers of Table 8.

	Bond Price			Bond Yield	CDS Price		
	(1) mid	(2) ba	(3) ba/mid	(4) mid	(5) mid	(6) ba	(7) ba/mid
Argentina	72.43	1.62	2.72	13.72	1239.13	38.14	2.42
Australia	104.05	0.31	0.28	4.93	60.69	6.07	10.87
Austria	104.74	0.42	0.39	3.83	46.33	3.55	41.33
Bahrain	98.54	0.75	0.76	5.73	249.16	19.50	8.25
Belgium	109.22	0.66	0.62	3.89	59.83	4.11	38.01
Brazil	119.65	0.92	0.77	6.92	213.88	6.88	2.88
Bulgaria	114.46	0.64	0.58	4.80	167.74	12.05	11.20
Chile	103.42	0.66	0.63	4.66	65.00	9.40	22.62
China	101.98	0.67	0.65	4.22	62.00	4.88	10.95
Colombia	115.95	1.59	1.39	7.10	211.30	9.34	4.33
Costa Rica	119.45	4.12	3.47	3.89	197.59	30.20	15.57
Croatia	101.19	0.59	0.59	5.16	166.80	13.85	13.42
Czech Republic	102.34	0.61	0.60	3.94	58.23	6.54	28.49
Denmark	108.94	0.39	0.35	2.89	57.49	5.49	11.66
Dominican Republic	110.47	2.70	2.48	6.76	300.21	69.52	23.75
Egypt	102.97	1.54	1.60	4.77	314.71	18.94	6.59
El Salvador	105.87	2.06	1.98	7.18	274.42	39.01	14.79
Finland	106.38	0.43	0.40	2.91	37.49	4.54	14.10
France	110.24	0.18	0.16	3.44	45.51	2.93	32.14
Germany	109.84	0.13	0.11	3.22	27.43	2.56	35.64
Greece	104.98	2.40	3.51	6.39	818.63	42.67	11.78
Guatemala	118.69	2.01	1.66	5.10	177.20	39.00	23.87
Hong Kong	103.67	0.57	0.55	3.55	41.00	6.39	25.31
Hungary	96.63	0.74	0.79	5.88	174.75	6.48	10.14
Iceland	93.33	1.23	1.39	7.96	217.21	26.14	29.66
Indonesia	108.68	0.86	0.82	7.61	233.24	14.31	5.46
Iraq	85.98	1.27	1.50	7.28	394.34	57.35	14.42
Ireland	95.69	0.97	1.06	5.81	357.07	14.03	5.29
Israel	105.57	0.94	0.88	4.09	87.65	10.58	16.24
Italy	109.38	0.50	0.46	4.08	93.76	3.82	12.89
Japan	104.00	0.17	0.17	1.11	73.68	4.70	8.44
Korea	107.47	0.19	0.20	1.82	91.72	5.15	7.86
Latvia	93.66	1.65	1.87	6.16	429.42	30.63	6.34
Lebanon	106.20	1.68	1.63	6.23	382.96	33.16	8.26
Lithuania	98.00	1.26	1.43	6.00	316.98	24.72	7.15
Malaysia	104.82	0.30	0.29	3.63	99.32	4.90	4.99
Mexico	114.38	0.82	0.71	5.63	121.50	4.63	4.50
Morocco	97.19	1.77	1.87	5.55	185.87	29.48	14.71
Netherlands	107.87	0.23	0.21	3.02	53.04	5.06	11.70
New Zealand	110.79	0.39	0.32	4.40	76.08	7.42	9.68
Norway	107.97	0.39	0.36	2.95	25.49	3.78	15.79
Pakistan	82.80	1.91	2.64	10.90	799.65	143.97	15.33
Panama	117.79	1.83	1.56	6.38	168.40	11.67	6.91
Peru	113.10	1.12	1.03	6.30	180.66	11.20	5.86
Philippines	113.87	0.85	0.75	7.15	252.18	10.60	3.81
Poland	100.51	0.70	0.75	4.68	89.43	5.89	15.13
Portugal	98.19	0.98	1.25	5.50	236.77	9.40	13.58
Qatar	134.87	1.11	0.83	5.49	74.20	10.98	22.23
Romania	96.85	1.18	1.30	6.66	333.36	18.21	5.00
Russia	141.36	1.08	0.89	6.31	176.96	5.48	3.39
Slovak Republic	102.15	0.83	0.81	4.05	61.13	7.68	27.72
Slovenia	101.36	0.64	0.65	4.17	125.56	11.55	9.90
South Africa	105.26	0.75	0.73	5.86	129.57	7.86	7.68
Spain	101.41	0.44	0.44	4.01	178.11	5.69	4.45
Sweden	112.51	0.51	0.43	3.29	48.22	4.96	12.27
Switzerland	115.25	0.88	0.75	1.37	46.37	8.18	17.34
Thailand	99.14	0.17	0.17	3.27	125.07	6.25	5.00
Tunisia	112.98	0.33	0.29	6.08	164.16	17.77	11.10
Turkey	109.08	0.83	0.80	6.47	245.00	6.95	2.49
Ukraine	93.94	1.09	1.46	8.38	623.08	40.56	5.71
United Kingdom	110.11	0.11	0.11	3.55	69.20	4.46	7.59
United States	112.41	0.04	0.04	1.12	44.22	5.53	12.95
Uruguay	114.84	1.55	1.41	4.53	165.57	58.68	36.77
Venezuela	94.68	1.52	1.82	10.20	762.27	25.27	3.53
Vietnam	102.48	0.95	0.94	6.46	240.06	16.83	7.91
Total	106.56	0.92	0.95	5.37	205.20	15.11	13.67

Table 11: Descriptive Statistics at the Country Level: DTCC CDS Transactions Data

This table shows for each country the average of the variables in Table 9. See Table 9 for the description and units. The column numbers correspond to the row numbers of Table 9.

	(1) Trades	(2) D Notl	(3) Gross Notl	(4) Net Notl	(5) Vol/Notl	(6) Contracts	(7) Debt	(8) Notl/Debt
Argentina	14.12	127.04	51128.71	2005.88	58.24	5402.24	188.84	27.08
Australia	10.25	124.96	12737.10	2340.57	175.90	1223.64	281.64	3.96
Austria	9.50	178.57	41462.82	6926.69	88.43	1788.86	280.22	14.66
Belgium	17.25	227.83	34689.50	5587.55	123.53	1692.91	468.85	7.30
Brazil	38.75	527.42	149945.74	13773.91	78.98	10976.56	1357.57	11.11
Bulgaria	4.25	34.95	17604.31	1174.65	46.10	1792.73	7.79	226.22
Chile	1.00	9.28	4103.50	542.42	48.62	433.87	19.01	24.20
China	22.14	207.20	36183.67	4467.73	107.63	3738.12	1544.44	2.43
Colombia	4.75	59.82	29955.13	2067.81	47.40	3100.72	99.13	30.58
Croatia	2.25	20.31	6957.01	645.65	63.36	940.07	25.55	27.00
Czech Republic	1.62	17.69	9335.36	997.29	40.09	780.84	75.92	12.18
Denmark	6.12	69.65	11402.03	2294.45	110.66	753.61	136.85	8.24
Egypt	4.62	22.66	3301.37	703.38	161.85	739.48	173.73	1.87
Finland	2.00	49.24	11795.68	2080.52	80.33	466.75	115.71	9.88
France	48.00	751.06	70524.73	13530.02	183.61	3107.82	2185.89	3.14
Germany	20.75	442.33	74806.12	14204.94	114.96	2273.48	2689.71	2.74
Greece	20.50	207.10	66021.98	6544.82	66.61	3331.57	443.55	14.76
Hong Kong	.	.	1705.10	586.40	.	125.00	77.59	2.20
Hungary	18.00	171.53	55362.56	3580.07	67.98	4734.15	105.87	52.29
Iceland	1.12	6.85	8041.10	899.64	22.67	1112.89	12.11	67.58
Indonesia	12.88	103.98	34771.02	2347.58	69.79	4404.34	185.00	18.89
Ireland	15.88	183.73	34660.07	4495.52	109.56	1844.76	189.18	18.09
Israel	.	.	7972.05	867.66	.	883.76	167.06	4.71
Italy	54.12	905.55	239173.95	22927.95	84.49	6439.61	2508.14	9.50
Japan	23.62	235.73	32841.52	5118.98	123.33	3094.66	11924.96	0.26
Korea	23.12	191.78	58609.57	4194.89	78.47	6289.65	333.95	17.75
Latvia	1.38	11.14	8331.06	714.38	30.89	1029.60	9.35	89.78
Lebanon	0.88	4.71	2005.05	455.91	56.65	320.46	53.27	3.76
Lithuania	1.12	8.31	5260.09	701.13	35.15	614.79	13.48	39.43
Malaysia	4.62	44.52	18993.22	1173.03	58.22	2380.99	135.32	14.29
Mexico	22.62	279.96	105715.77	6966.41	59.23	8762.12	453.09	23.27
Netherlands	4.38	72.67	16643.36	2796.76	84.04	790.74	509.03	3.24
New Zealand	0.62	5.51	2717.42	523.38	48.08	295.47	51.96	5.24
Norway	1.12	24.57	6416.15	979.87	79.21	285.46	218.75	2.87
Panama	1.38	10.58	6971.72	697.17	35.68	972.53	10.91	63.88
Peru	7.50	72.46	22014.63	1820.25	71.59	2264.87	36.77	59.83
Philippines	11.00	109.23	62354.69	2678.16	46.00	7256.49	85.65	74.09
Poland	9.88	109.15	29995.43	2105.51	76.54	2724.02	255.38	11.63
Portugal	22.12	281.60	56096.89	6853.02	104.09	2621.39	220.90	25.05
Qatar	3.00	27.77	6131.54	531.59	93.73	784.09	44.61	15.15
Romania	3.75	34.62	15876.14	1235.60	49.70	1662.19	49.92	32.64
Russia	24.38	250.19	104350.07	4944.82	59.21	7566.12	177.79	60.91
Slovak Republic	1.00	10.21	8968.89	926.96	25.48	699.42	35.92	24.92
Slovenia	0.75	7.79	4180.75	797.17	40.03	352.02	20.06	20.62
South Africa	10.25	103.94	38728.05	2199.24	62.20	4264.44	124.45	32.33
Spain	62.12	909.26	116133.54	14820.21	156.35	4801.36	893.63	12.71
Sweden	3.75	64.69	15142.33	2889.23	86.27	819.05	187.70	7.99
Thailand	4.75	41.41	18196.95	1146.42	57.15	2513.53	138.68	13.24
Tunisia	0.25	3.12	1998.25	285.63	36.28	306.24	19.27	10.36
Turkey	25.12	311.98	152490.26	5697.12	53.85	10097.13	298.35	51.23
Ukraine	7.50	78.70	45877.98	1636.15	44.92	3781.47	51.81	92.49
United Kingdom	18.00	248.77	43986.36	8077.81	103.85	2830.08	1733.67	2.43
United States	4.50	101.24	16403.97	3143.99	121.84	663.41	14319.44	0.11
Venezuela	13.62	135.78	50593.94	2003.41	60.89	5017.19	126.20	40.71
Vietnam	3.25	29.03	7980.77	613.96	79.06	1166.30	55.00	14.46
Total	12.37	162.66	40007.57	3889.49	77.16	2829.47	859.58	27.93

Table 12: Descriptive Statistics: the EU

The table shows the descriptive statistics for the weekly observations of the bond bid-ask spread (% of the mid price), CDS price (% of notional), CDS net notional (in billion USD) over the period October 2008 - March 2012 for the sample of European Union countries.

	Mean	St. Dev.	Min	Max	No obs.
Bond Bid-Ask (% of mid)	1.16	2.22	0.04	35.64	3913
CDS Price (% of Notl)	2.45	6.00	0.17	208.58	3932
CDS Net Notional (bln $)	5.40	5.98	0.45	29.46	3932

Table 13: The Effect of the Permanent EU Ban on Contemporaneous Bond Illiquidity

This set of regressions explores the effect of the permanent EU-wide ban on naked CDS trading on bond market liquidity. The table shows coefficient estimates from generalized least squares regressions with both country and time fixed effects. The dependent variable is the bond market bid-ask spread (% of the mid price). The main variable of interest is *EU CDS Ban* dummy variable that equals one for country-date observations for which the CDS ban was in place. Control variables are CDS price as % of notional as a measure of credit risk, *CDS Price,* and gross debt outstanding in trillion USD, *Gross Debt*. Columns 1 and 2 compare whether including CDS price makes a difference. Columns 3–6 have country specific trends, while Column 7 allows for a group specific trend instead. Column 4 allows for a "treatment" intensity by incorporating an interaction between the ban dummy and the decrease in net notional between the ban period and before the ban period, $\Delta Notl$ (in billion USD). Column 5 excludes Greece as a potential outlier. Column 6 restricts the sample to OECD countries only. Standard errors are given in parentheses and allow disturbances to have heteroskedasticity, contemporaneous correlation across countries, and AR(1) serial correlation within countries.

	Dependent Variable: Bond Bid-Ask						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gross Debt	-0.288***	-0.418***	-0.505***	-0.466**	-0.113***	-0.726***	-0.654***
	(0.104)	(0.0798)	(0.0818)	(0.232)	(0.0378)	(0.232)	(0.0860)
EU CDS Ban	0.271***	0.786***	0.652***	0.419*	0.314***	0.780**	0.959**
	(0.105)	(0.241)	(0.196)	(0.218)	(0.0482)	(0.335)	(0.442)
CDS Price		0.123***	0.0391	0.0401	0.328***	0.0384	0.122***
		(0.00423)	(0.0447)	(0.0360)	(0.0690)	(0.0359)	(0.00502)
EU CDS Ban∗ΔNotl				0.647**			
				(0.316)			
Week FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Trends	No	No	Yes	Yes	Yes	Yes	No
Group Trends	No	No	No	No	No	No	Yes
No. obs	2457	1802	1802	1560	1772	900	1802
No. countries	63	62	62	52	61	30	62
R2	0.57	0.87	0.90	0.90	0.89	0.90	0.88

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 14: The Effect of the Permanent EU Ban on Past Bond Illiquidity

This set of regressions explores the effect of the permanent EU-wide ban on naked CDS trading on bond market liquidity *before* the ban. The table shows coefficient estimates from generalized least squares regressions with both country and time fixed effects. The dependent variable is lagged bond market bid-ask spread (% of the mid price). The main variable of interest is *EU CDS Ban*$*\Delta$*Notl* that is an interaction of the decrease in net notional and a dummy variable that equals one for country-date observations for which the CDS ban was in place. Control variables are lagged CDS price as % of notional as a measure of credit risk, *CDS Price,* and lagged gross debt outstanding in trillion USD, *Gross Debt.* Column 3 excludes Greece as an outlier. Standard errors are given in parentheses and allow disturbances to have heteroskedasticity, contemporaneous correlation across countries.

	Dependent Variable: Lagged Bond Bid-Ask		
	(1)	(2)	(3)
L4.CDS Price	0.203***	0.204***	0.633***
	(0.0516)	(0.0511)	(0.0267)
L4.Gross Debt	6.055**	5.982**	-11.54***
	(2.932)	(2.909)	(1.449)
ΔNotl	0.0166	0.0566	0.0144
	(0.0858)	(0.0635)	(0.0664)
EU CDS Ban∗ΔNotl		-0.334***	-0.279**
		(0.0613)	(0.115)
Week FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
No. obs	156	156	153
No. countries	52	52	51
R2	0.99	0.99	0.98

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 15: The Permanent EU Ban and Bond Illiquidity: Excluding Greece

This set of regressions repeats the main exercise in the paper by restricting the sample to OECD countries. It explores the effect of the permanent EU wide ban of naked CDS trading on bond market liquidity. The table shows coefficient estimates from generalized least squares regressions with both country and time fixed effects. The dependent variable is the bond market bid-ask spread (% of the mid price). The main variable of interest is *EU CDS Ban* dummy variable that equals one for country date observations for which CDS ban was in place. Control variables are CDS price as % of notional as a measure of credit risk, *CDS Price,* and gross debt outstanding in trillion USD, *Gross Debt.* Columns 1 and 2 compare whether including CDS price makes a difference. Columns 1–3 have country specific trends, while column 4 has group specific trend. Column 3 allows for "treatment" intensity by incorporating interaction between the ban dummy and the decrease in net notional between the ban period and before the ban period, $\Delta Notl$ (in billion USD). Standard errors are given in parentheses and allow disturbances to have heteroskedasticity, contemporaneous correlation across countries, and AR(1) serial correlation within countries.

	Dependent Variable: Bond Bid-Ask			
	(1)	(2)	(3)	(4)
Gross Debt	-0.0908	-0.113***	-0.109*	-0.103***
	(0.0608)	(0.0378)	(0.0630)	(0.0239)
EU CDS Ban	0.190**	0.314***	0.253**	0.436***
	(0.0953)	(0.0482)	(0.124)	(0.0853)
CDS Price		0.328***	0.434***	0.408***
		(0.0690)	(0.0761)	(0.0361)
EU CDS Ban$*\Delta$Notl			0.239***	
			(0.0803)	
Week FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Country Trends	Yes	Yes	Yes	No
Group Trends	No	No	No	Yes
No. obs	2418	1772	1530	1772
No. countries	62	61	51	61
R2	0.84	0.89	0.89	0.82

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 16: The Permanent EU Ban and Bond Illiquidity: OECD Sample

This set of regressions repeats the main exercise in the paper by excluding Greece as a potential outlier. It explores the effect of the permanent EU wide ban of naked CDS trading on bond market liquidity. The table shows coefficient estimates from generalized least squares regressions with both country and time fixed effects. The dependent variable is the bond market bid-ask spread (% of the mid price). The main variable of interest is *EU CDS Ban* dummy variable that equals one for country date observations for which CDS ban was in place. Control variables are CDS price as % of notional as a measure of credit risk*, CDS Price,* and gross debt outstanding in trillion USD, *Gross Debt.* Columns 1–2 have country specific trends, while column 3 has a group specific trend. Column 2 allows for "treatment" intensity by incorporating the interaction between the ban dummy and the decrease in net notional between the ban period and before the ban period, $\Delta Notl$ (in billion USD). Standard errors are given in parentheses and allow disturbances to have heteroskedasticity, contemporaneous correlation across countries, and AR(1) serial correlation within countries.

	Dependent Variable: Bond Bid-Ask		
	(1)	(2)	(3)
CDS Price	0.0384	0.0387	0.121***
	(0.0359)	(0.0358)	(0.0339)
Gross Debt	-0.726***	-0.759***	-0.754***
	(0.232)	(0.240)	(0.188)
EU CDS Ban	0.780**	0.606**	0.966**
	(0.335)	(0.247)	(0.393)
EU CDS Ban$*\Delta$Notl		0.582*	
		(0.300)	
Week FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
Country Trends	Yes	Yes	No
Group Trends	No	No	Yes
No. obs	900	870	900
No. countries	30	29	30
R2	0.90	0.91	0.89

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 17: Correlation between the Change in Notional during the Ban with the Level of Notional Before the Ban

This table checks the cross-country correlation between the decrease in CDS net notional during the ban and the level of net notional before the ban, *Notl(t-1)*. The change in net notional is constructed as the level of net notional averaged over the ban period minus the level of net notional averaged over the pre-ban period. The correlation controls for the pre-ban levels of debt outstanding, *Gross Debt(t-1)*, and credit risk measured by CDS price, *CDS Price(t-1)*. *EU* is a dummy variable that equals 1 for the EU countries. For the EU countries, the correlation is significant, while for the non-EU countries there is no significant correlation.

	Dependent Variable: Change in Net Notional (1)
Notl(t-1)	-0.0312 (0.0361)
EU	-0.144 (0.238)
EU∗ Notl(t-1)	0.0838** (0.0394)
Gross Debt(t-1)	-0.0142 (0.0356)
CDS Price(t-1)	0.0346* (0.0201)
Constant	0.0673 (0.178)
No. obs	54
R2	0.24

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 18: The Effect of the Temporary German Ban on Bond Illiquidity

This set of regressions explores the effect of May 2010 German ban on naked CDS trading on bond market liquidity. The table shows coefficient estimates from generalized least squares regressions with both country and time fixed effects. The dependent variable is the bond market bid-ask spread (% of the mid price). The main variable of interest is *CDS Ban* dummy variable that equals one for country-date observations for which the CDS ban was in place. Control variables are CDS price as % of notional as a measure of credit risk, *CDS Price,* and gross debt outstanding in trillion USD, *Gross Debt.* $\Delta Notl$ is the decrease in net notional between the ban period and before the ban period and captures "treatment" intensity. Columns 1 and 2 compare whether including CDS price makes a difference. Columns 3–5 have country specific trends, while column 6 allows for a group specific trend instead. Column 4 allows for a "treatment" intensity by incorporating an interaction between the ban dummy and the decrease in net notional between the ban period and before the ban period, $\Delta Notl$ (in billion USD). Column 5 excludes Greece as a potential outlier. Standard errors are given in parentheses and allow disturbances to have heteroskedasticity, contemporaneous correlation across countries, and AR(1) serial correlation within countries.

	Dependent Variable: Bond Bid-Ask					
	(1)	(2)	(3)	(4)	(5)	(6)
Gross Debt	2.033***	1.453***	0.425*	0.570	0.473	-0.0634
	(0.120)	(0.309)	(0.237)	(0.562)	(0.310)	(0.0488)
CDS Ban	-0.216***	-0.217***	-0.233***	-0.143***	-0.0757**	-0.219***
	(0.0572)	(0.0589)	(0.0584)	(0.0482)	(0.0382)	(0.0575)
CDS Price		0.235*	0.110	0.114	0.151**	0.229*
		(0.124)	(0.148)	(0.139)	(0.0666)	(0.125)
CDS Ban$*\Delta$Notl				-0.304**		
				(0.119)		
Week FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Country Trends	No	No	Yes	Yes	Yes	No
Group Trends	No	No	No	No	No	Yes
No. obs	816	740	740	740	706	740
No. countries	24	24	24	24	23	24
R2	0.74	0.81	0.85	0.85	0.93	0.81

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 19: The Bond Bid-Ask Spread and CDS Net Notional: the EU

The table reports the coefficient estimates from generalized least squares regressions with both country and time fixed effects for the sample of EU countries. The dependent variable is the bond market bid-ask price spread (% of the mid price). The main variable of interest is CDS net notional outstanding (*CDS Notional*) in billions of USD. Control variables are CDS price (% of notional) as a measure of credit risk, *CDS Price,* and gross government debt outstanding in billion USD, *Gross Debt.* Column (3) shows an alternative specification of CDS net notional (*CDS Notional/Debt*) as the log of the ratio of CDS net notional to gross debt outstanding. Standard errors are given in parentheses and allow disturbances to have heteroskedasticity, contemporaneous correlation across countries, and AR(1) serial correlation within countries.

	Dependent Variable: Bond Bid-Ask		
	(1)	(2)	(3)
CDS price	0.106***	0.105***	0.106***
	(0.0129)	(0.0127)	(0.0130)
CDS Notional	-0.111***	-0.261***	
	(0.0174)	(0.0396)	
Gross Debt		0.00296***	
		(0.000461)	
CDS Notional/Debt			-0.357***
			(0.0492)
Week FE	Yes	Yes	Yes
Country FE	Yes	Yes	Yes
No. obs	3913	3913	3913
No. countries	24	24	24
R2	0.59	0.60	0.58

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 20: Granger Causality: CDS Net Notional and Bond Bid-Ask Spreads

The table reports Granger causality test results from the underlying vector autoregressive regressions:

$$\Delta y_t = \beta_0 + \sum_{j=1}^{p-1} \Delta y_{t-j} + \Delta\epsilon_t$$

where y_t is a vector of three variables: 1) CDS price, 2) the absolute CDS bid-ask spread, and 3) the bond bid-ask (% of mid). The reported results are for the set of countries for which Johansen trace statistics cannot reject the null that there is no cointegration among the variables. The lag order, p, is selected to optimize Akaike information criterion for each country. The table reports p-values of the Wald test statistics of the null hypotheses that, in column 1, H0: the bond market bid-ask spread does not Granger-cause the CDS net notional, and in column 2, H0: CDS net notional does not Granger-cause the bond bid-ask spread. We see that for 5 out of 14, CDS net notional Granger-causes bond bid-ask spreads, while for only 2 out of 14, bond market liquidity Granger-causes CDS net notional.

	Bond Causes CDS	CDS Causes Bond
Austria	0.04	0.20
Belgium	0.33	0.07
Croatia	0.19	0.03
Finland	0.61	0.07
Greece	0.95	0.90
Hungary	0.91	0.04
Ireland	0.67	0.19
Italy	0.54	0.04
Latvia	0.97	0.17
Lithuania	0.00	0.19
Poland	0.44	0.30
Slovak_Republic	0.65	0.84
Slovenia	0.42	0.66
Spain	0.74	0.46

Table 21: VECM: CDS Net Notional and Bond Bid-Ask Spreads

The table reports adjustment coefficients (λ_{CDS} and λ_{bond}) for the underlying VECM specification:

$$\Delta x_t = \lambda_x \left(x_{t-1} - \alpha_0 - \alpha_1 \mu_{t-1} - \alpha_2 d_{t-1}\right) + \sum_{j=1}^{p-1} \beta_{1j} \Delta x_{t-j} + \sum_{j=1}^{p-1} \delta_{1j} \Delta \mu_{t-j} + \sum_{j=1}^{p-1} \gamma_{1j} \Delta d_{t-j}$$

$$\Delta \mu_t = \lambda_{CDS} \left(x_{t-1} - \alpha_0 - \alpha_1 \mu_{t-1} - \alpha_2 d_{t-1}\right) + \sum_{j=1}^{p-1} \beta_{2j} \Delta x_{t-j} + \sum_{j=1}^{p-1} \delta_{2j} \Delta \mu_{t-j} + \sum_{j=1}^{p-1} \gamma_{2j} \Delta d_{t-j}$$

$$\Delta d_t = \lambda_{bond} \left(x_{t-1} - \alpha_0 - \alpha_1 \mu_{t-1} - \alpha_2 d_{t-1}\right) + \sum_{j=1}^{p-1} \beta_{3j} \Delta x_{t-j} + \sum_{j=1}^{p-1} \delta_{3j} \Delta \mu_{t-j} + \sum_{j=1}^{p-1} \gamma_{3j} \Delta d_{t-j}$$

where x is credit risk, μ is CDS net notional, and d is the bond bid-ask spread. The reported results are for the set of countries for which the the Johansen trace test statistics rejects the null hypothesis that the cointegration rank is at most zero and cannot reject that the null hypothesis that cointegration rank is at most 1. The lag order, p, is selected to optimize Akaike information criterion for each country.

	λ_{bond}	t-Stat	λ_{CDS}	t-Stat
Bulgaria	-0.18	-4.40	0.01	0.46
Czech Republic	-0.16	-6.17	0.02	2.15
Denmark	0.00	0.53	0.00	0.40
France	-0.09	-2.16	0.95	1.77
Germany	-0.59	-5.93	-0.65	-0.80
Netherlands	-0.45	-6.53	-0.22	-1.30
Portugal	-0.03	-1.10	-0.03	-2.47
Romania	0.01	0.61	0.00	3.73
United Kingdom	-0.31	-3.88	-1.55	-2.62

Table 22: Granger Causality: CDS Bid-Ask Spreads and Bond Bid-Ask Spreads

The table reports Granger causality test results from the underlying vector autoregressive regressions:

$$y_t = \beta_0 + \sum_{j=1}^{p} y_{t-j} + \epsilon_t$$

where y_t is a vector of three variables: 1) the first difference in CDS price, 2) the absolute CDS bid-ask spread, and 3) the bond bid-ask (% of mid). The lag order, p, is selected to optimize SBIC for each country. The table reports p-values of the Wald test statistics of the null hypotheses that, in column 1, H0: the bond market bid-ask spread does not Granger-cause the CDS bid-ask spread, and in column 2, H0: CDS bid-ask spread does not cause the bond bid-ask spread.

	Bond Causes CDS	CDS Causes Bond
Austria	0.08	0.01
Belgium	0.15	0.14
Bulgaria	0.00	0.00
Croatia	0.42	0.00
Czech_Republic	0.00	0.00
Denmark	0.22	0.15
Finland	0.53	0.26
France	0.05	0.00
Germany	0.00	0.00
Greece	0.00	0.00
Hungary	0.27	0.00
Ireland	0.10	0.20
Italy	0.01	0.01
Latvia	0.22	0.00
Lithuania	0.11	0.00
Netherlands	0.58	0.00
Poland	0.33	0.00
Portugal	0.00	0.00
Romania	0.00	0.00
Slovak_Republic	0.45	0.26
Slovenia	0.51	0.94
Spain	0.72	0.03
Sweden	0.18	0.09
United_Kingdom	0.67	0.01

D Appendix: Data Figures

Figure 11: The Permanent EU Naked CDS Ban and the Amount of CDS Purchased, 2011.01 - 2012.08

The solid line plots the total CDS purchased (CDS net notional, $bln) across countries that were subject to the EU ban. The dashed line plots the total for countries that were not affected by the ban and CDS could still be purchased. The vertical line is drawn at October 18, 2011 and shows when the EU passed the naked CDS ban legislation.

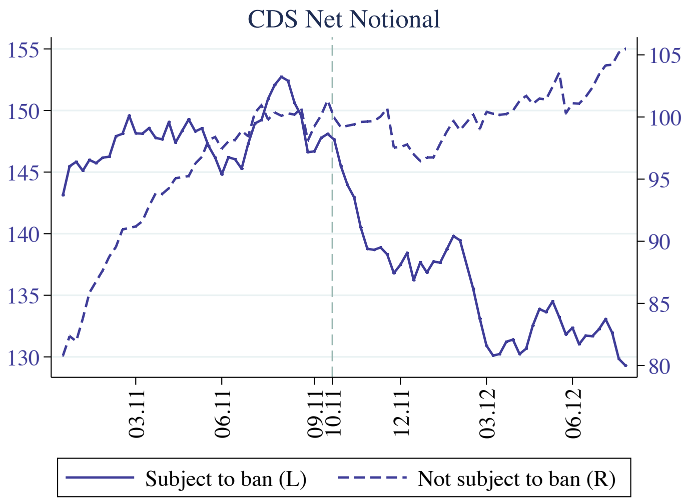


Figure 12: The Permanent EU Naked CDS Ban and Bond Illiquidity, 2011.01 - 2012.08

The vertical line drawn at October 18, 2011 shows when the EU passed the naked CDS ban legislation. The solid line plots the cross-country average bond bid-ask spread (% of the mid price) for the countries subject to the ban (the EU countries). The dashed line plots the average bond bid-ask spread for countries that were not affected by the ban (outside the EU). We see that the countries affected by the ban experienced an increase in their bond bid-ask spread.

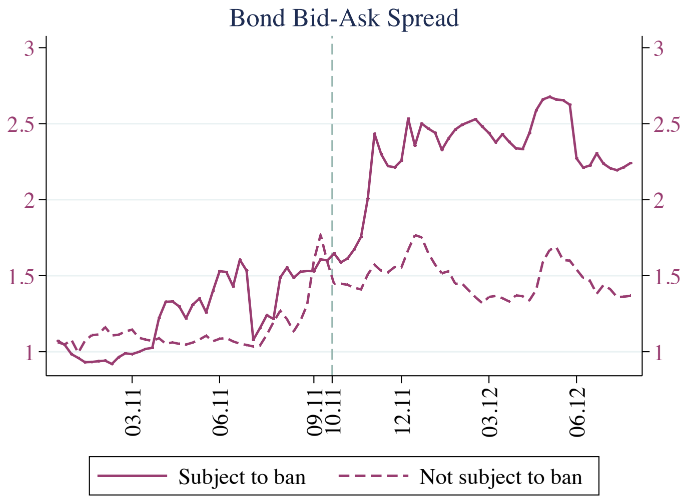


Figure 13: The Temporary CDS Ban and Bond Illiquidity, Mar 2010 - Aug 2010

The solid line plots the cross-country average bond bid-ask spread (% of the mid price) for the EU countries that were subject to the ban (i.e. Eurozone countries). The dashed line shows the average for the EU countries not affected by the ban (i.e. naked CDS referencing these countries could still be purchased). The vertical lines are drawn at the week before and after the German ban is instituted. We see that the countries affected by the ban experienced an immediate decrease in their bond bid-ask spread.

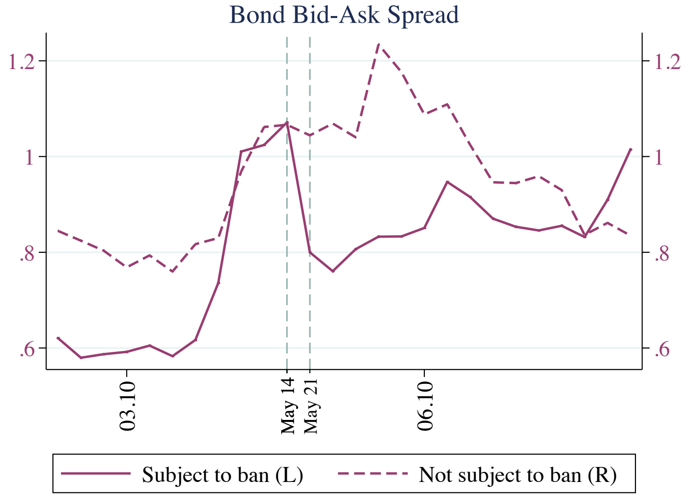


Figure 14: The Temporary German CDS Ban and the Amount of CDS Purchased, Mar 2010 - Aug 2010

The solid line plots the time series of the total CDS net notional ($billion) across EU countries that were subject to the ban (i.e. Eurozone countries). The dashed line shows the total for EU countries that were not affected by the ban (i.e. naked CDS referencing these countries could still be purchased). The vertical lines are drawn at the week before and after the German ban is instituted.

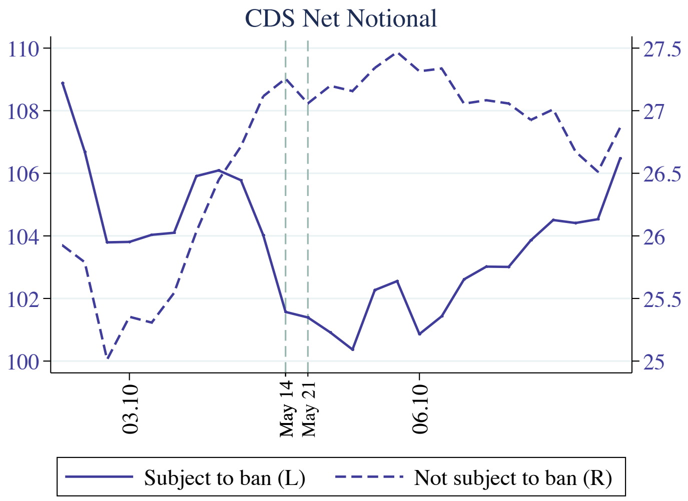


Figure 15: Bond (il)liquidity and CDS Net Notional, Italy (Dec 2008 - Aug 2012)

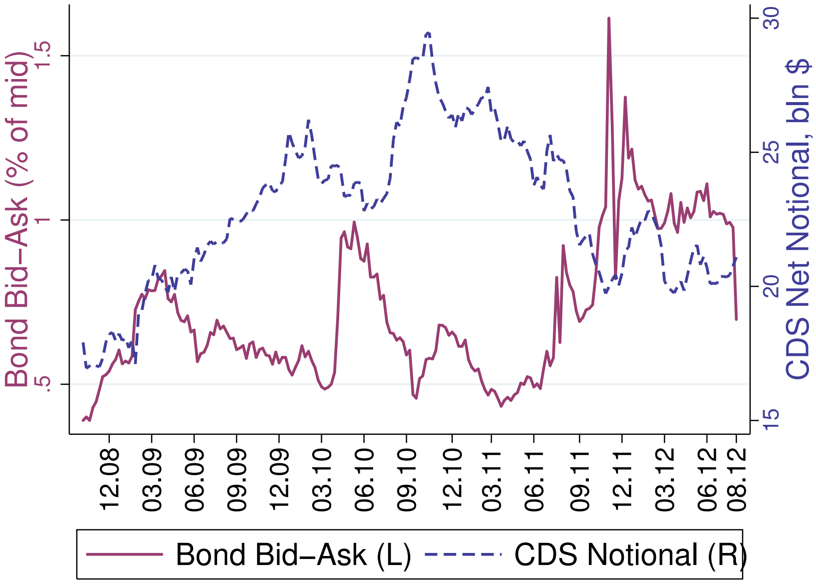


Table 23: Anecdotal Evidence of How the EU Ban Affected the Bond Market

In February 2013, the European Securities and Market Authority (ESMA) surveyed market participants on the effects of the EU naked CDS ban. Below are some responses to Question 15 in the survey that asked *Have you noticed any effect of the prohibition on entering into an uncovered sovereign CDS transaction on the price and on the volatility of the sovereign debt instruments?* For more information on the survey and the responses received from private institutions and industry associations see: http://www.esma.europa.eu/consultation/Call-evidence-evaluation-Regulation-short-selling-and-certain-aspects-credit-default-sw#responses and ESMA (2013).

The German Banking Industry Committee:

> "The market has become less liquid; the bid-offer spread has widened. Volatility is unchanged, but has tended to shift to the spot/cash markets."

The Association for Financial Markets in Europe (AFME) and the International Swaps and Derivatives Association (ISDA):

> "Market participants have already observed that seemingly due to the SSR Regulation (restrictions it imposed on sovereign debt and sovereign CDS markets), Asian participation in the European bond market fell by around 50% immediately after the introduction of the SSR, thus demonstrating neatly one adverse impact of the SSR in general in driving investors away."
>
> "Some buy side market participants have already remarked that even though there is still liquidity in sovereign debt, it is more difficult to source this liquidity."

Alternative Investment Management Association (AIMA) and Managed Funds Association (MFA):

> "Some of our members have reported that they have stopped trading European sovereign CDS and bonds, given the regulatory and reputational risks."
>
> "Restrictions on CDS positions over the medium term will generally make it more difficult for sovereign issuers to borrow through long-dated securities, leading to a shortening of the average maturity profile of sovereign issuance as investors seek to limit their risk exposure, thereby increasing the vulnerability of sovereigns to short term liquidity and funding crises. This sentiment is reflected in the responses to AIMA and MFA's poll of their members."
>
> "At worst, the ban could ultimately undermine liquidity in the underlying sovereign debt markets, undermining the ability of sovereigns to raise finance through debt issuance."

Deutsche Bank

> "We observed anecdotally that as investors began to understand the details of the regulation, cash volumes reduced with a resultant increase in volatility, although this was not significant."

References

Acharya, Viral V, and Lasse Heje Pedersen, 2005, Asset pricing with liquidity risk, *Journal of Financial Economics* 77, 375–410.

Admati, Anat R, and Paul Pfleiderer, 1988, A theory of intraday patterns: Volume and price variability, *Review of Financial Studies* 1, 3–40.

Afonso, Gara, 2011, Liquidity and congestion, *Journal of Financial Intermediation* 20, 324–360.

Amihud, Yakov, and Haim Mendelson, 1986, Asset pricing and the bid-ask spread, *Journal of Financial Economics* 17, 223–249.

Ammer, John, and Fang Cai, 2011, Sovereign CDS and bond pricing dynamics in emerging markets: Does the cheapest-to-deliver option matter?, *Journal of International Financial Markets, Institutions and Money* 21, 369–387.

Arce, Oscar, Sergio Mayordomo, and Juan Ignacio Peña, 2012, Credit risk valuation in the sovereign CDS and bonds markets: Evidence from the Euro area crisis, *Working Paper.*

Arping, Stefan, 2013, Credit protection and lending relationships, *Journal of Financial Stability.*

Ashcraft, Adam B, and Joao Santos, 2009, Has the CDS market lowered the cost of corporate debt?, *Journal of Monetary Economics* 56, 514–523.

Atkeson, Andrew G, Andrea L Eisfeldt, and Pierre-Olivier B Weill, 2012, The market for OTC credit derivatives, *Working Paper.*

Augustin, Patrick, 2014, Sovereign credit default swap premia, *Forthcoming, Journal of Investment Management.*

Back, Kerry, 1993, Asymmetric information and options, *The Review of Financial Studies* 6, 435–472.

Bai, Jennie, and Pierre Collin-Dufresne, 2011, The determinants of the CDS-bond basis during the financial crisis of 2007-2009, *Working Paper.*

Bai, Jennie, Christian Julliard, and Kathy Yuan, 2012, Eurozone sovereign bond crisis: Liquidity or fundamental contagion, *Working Paper.*

Bao, Jack, Jun Pan, and Jiang Wang, 2011, The illiquidity of corporate bonds, *The Journal of Finance* 66, 911–946.

Beber, Alessandro, Michael W Brandt, and Kenneth Kavajecz, 2009, Flight-to-quality or flight-to-liquidity? Evidence from the Euro-area bond market, *Review of Financial Studies* 22, 925–957.

Beber, Alessandro, and Marco Pagano, 2013, Short-selling bans around the world: Evidence from the 2007-09 crisis, *The Journal of Finance.*

Berndt, Antje, and Anurag Gupta, 2009, Moral hazard and adverse selection in the originate-to-distribute model of bank credit, *Journal of Monetary Economics* 56, 725–743.

Biais, Bruno, and Pierre Hillion, 1994, Insider and liquidity trading in stock and options markets, *Review of Financial Studies* 7, 743–780.

Blanco, Roberto, Simon Brennan, and Ian Marsh, 2005, An empirical analysis of the dynamic relation between investment grade bonds and credit default swaps, *The Journal of Finance* 60, 2255–2281.

Boehmer, Ekkehart, Charles M Jones, and Xiaoyan Zhang, 2013, Shackling short sellers: The 2008 shorting ban, *Review of Financial Studies* 26, 1363–1400.

Bolton, Patrick, and Martin Oehmke, 2011, Credit default swaps and the empty creditor problem, *Review of Financial Studies* 24, 2617–2655.

Bongaerts, Dion, Frank De Jong, and Joost Driessen, 2011, Derivative pricing with liquidity risk: Theory and evidence from the credit default swap market, *The Journal of Finance* 66, 203–240.

Brennan, Michael J, and Henry Cao, 1996, Information, trade, and derivative securities, *Review of Financial Studies* 9, 163–208.

Calice, Giovanni, Jing Chen, and Julian Williams, 2011, Liquidity spillovers in sovereign bond and CDS markets: An analysis of the Eurozone sovereign debt crisis, *Journal of Economic Behavior & Organization.*

Chakravarty, Sugato, Huseyin Gulen, and Stewart Mayhew, 2004, Informed trading in stock and option markets, *The Journal of Finance* 59, 1235–1258.

Chen, Long, David Lesmond, and Jason Wei, 2007, Corporate yield spreads and bond liquidity, *The Journal of Finance* 62, 119–149.

Chen, Ren-Raw, Frank J Fabozzi, and Ronald Sverdlove, 2010, Corporate credit default swap liquidity and its implications for corporate bond spreads, *The Journal of Fixed Income* 20, 31–57.

Cheung, Yiu Chung, Barbara Rindi, and Frank De Jong, 2005, Trading European sovereign bonds: The microstructure of the MTS trading platforms, *ECB Working Paper.*

Chowdhry, Bhagwan, and Vikram Nanda, 1991, Multimarket trading and market liquidity, *Review of Financial Studies* 4, 483–511.

Comotto, Richard, 2010, A white paper on the operation of the European repo market, the role of short-selling, the problem of settlement failures and the need for reform of the market infrastructure, *ICMA ERC white paper* pp. 1–84.

Das, Sanjiv, Madhu Kalimipalli, and Subhankar Nayak, 2013, Did CDS trading improve the market for corporate bonds?, *Journal of Financial Economics (Forthcoming).*

Delatte, Anne Laure, Mathieu Gex, and Antonia López-Villavicencio, 2011, Has the CDS market influenced the borrowing cost of European countries during the sovereign crisis?, *Working Paper.*

Duffee, Gregory R, and Chunsheng Zhou, 2001, Credit derivatives in banking: Useful tools for managing risk?, *Journal of Monetary Economics* 48, 25–54.

Duffie, Darrell, N Garleanu, and Lasse Heje Pedersen, 2005, Over-the-counter markets, *Econometrica* 73, 1815–1847.

Duffie, Darrell, Nicolae Gârleanu, and Lasse Heje Pedersen, 2007, Valuation in over-the-counter markets, *The Review of Financial Studies* 20, 1865–1900.

Dufour, Alfonso, and Frank Skinner, 2004, MTS time series: Market and data description for the European bond and repo database, *ISMA Centre Discussion Paper.*

ESMA, 2013, ESMA's technical advice on the evaluation of the Regulation (EU) 236/2012 of the European Parliament and of the Council on short selling and certain aspects of credit default swaps, *European Securities and Markets Authority Report.*

Fleming, Michael, and Bruce Mizrach, 2009, The microstructure of a US Treasury ECN: The BrokerTec platform, *The Federal Reserve Bank of New York Staff Reports.*

Fontana, Alessandro, and Martin Scheicher, 2010, An analysis of Euro area sovereign CDS and their relation with government bonds, *ECB Working Paper.*

Glosten, Lawrence R, and Paul R Milgrom, 1985, Bid, ask and transaction prices in a specialist market with heterogeneously informed traders, *Journal of Financial Economics* 14, 71–100.

Gorton, Gary B, and George G Pennacchi, 1993, Security baskets and index-linked securities, *The Journal of Business* 66, 1–27.

He, Zhiguo, and Konstantin Milbradt, 2012, Endogenous liquidity and defaultable bonds, *NBER Working Paper.*

John, Kose, Apoorva Koticha, Marti G Subrahmanyam, and Ranga Narayanan, 2003, Margin rules, informed trading in derivatives, and price dynamics, *Working Paper.*

Kyle, Albert, 1985, Continuous auctions and insider trading, *Econometrica* 53, 1315–1335.

Longstaff, Francis, Sanjay Mithal, and Eric Neis, 2005, Corporate yield spreads: Default risk or liquidity? New evidence from the credit default swap market, *The Journal of Finance* 60, 2213–2253.

Massa, Massimo, and Lei Zhang, 2012, CDS and the liquidity provision in the bond market, *Working Paper.*

Mayhew, Stewart, 2000, The impact of derivatives on cash markets: what have we learned?, *Working Paper.*

Oehmke, Martin, and Adam Zawadowski, 2013a, Synthetic or real? The equilibrium effects of credit default swaps on bond markets, *Working Paper.*

——— , 2013b, The anatomy of the CDS market, *Available at SSRN 2023108.*

Pagano, Marco, 1989, Trading volume and asset liquidity, *The Quarterly Journal of Economics* 104, 255–274.

Parlour, Christine, and Andrew Winton, 2009, Laying off credit risk: Loan sales versus credit default swaps, *Working Paper.*

Pelizzon, Loriana, Marti G Subrahmanyam, Davide Tomio, and Jun Uno, 2013, The microstructure of the European sovereign bond market: A study of the Euro-zone crisis, *Working Paper.*

Sambalaibat, Batchimeg, 2012, Credit default swaps as sovereign debt collateral, *Working Paper.*

Shim, Ilhyock, and Haibin Zhu, 2010, The impact of CDS trading on the bond market: Evidence from Asia, *BIS Working Paper.*

Subrahmanyam, Avanidhar, 1991, A theory of trading in stock index futures, *The Review of Financial Studies* 4, 17–51.

Subrahmanyam, Marti G, Dragon Yongjun Tang, and Sarah Qian Wang, 2011, Does the tail wag the dog? The effect of credit default swaps on credit risk, *Working Paper.*

Tang, Dragon Yongjun, and Hong Yan, 2007, Liquidity and credit default swap spreads, *Working Paper.*

Thompson, James R, 2007, Credit risk transfer: To sell or to insure, *Queen's University working paper* pp. 1195–1252.

Vayanos, Dimitri, and Tan Wang, 2007, Search and endogenous concentration of liquidity in asset markets, *Journal of Economic Theory* 136, 66–104.

Vayanos, Dimitri, and Pierre-Olivier B Weill, 2008, A search-based theory of the on-the-run phenomenon, *The Journal of Finance* 63, 1361–1398.

Weill, Pierre-Olivier B, 2008, Liquidity premia in dynamic bargaining markets, *Journal of Economic Theory* 140, 66–96.