Synthetic or Real?

The Equilibrium Effects of Credit Default Swaps

on Bond Markets [*]

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Abstract

We provide a model of non-redundant credit default swaps (CDSs), building on the observation that CDSs are more liquid than bonds. CDS introduction involves a trade-off: It crowds out demand for the bond, but improves the bond allocation because it allows long-term investors to become levered basis traders. CDS introduction raises bond prices only when there is a significant liquidity difference between bond and CDS (both across and within firms). Our framework predicts a negative CDS-bond basis, turnover and price impact patterns that are consistent with empirical evidence, and shows that a ban on naked CDSs can raise borrowing costs.

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1 Introduction

Credit Default Swap (CDS) markets have grown enormously over the last decade. However, while there is a relatively large literature on the pricing of CDSs, much less work has been done on the economic role of these markets. For example, in most pricing models, CDSs are redundant securities, such that the introduction of a CDS market has no effect on the underlying bond market. This irrelevancy feature makes a meaningful analysis of the economic role of CDS markets difficult.

In this paper, we develop a theory of *non-redundant* CDS markets, building on a simple, well-documented empirical observation: Trading bonds is expensive relative to trading CDSs. Based on this observation, we develop a theory of the interaction of bond and CDS markets and the economic role of CDSs. Our model provides an integrated framework that matches many of the stylized facts in bond and CDS markets: the effect of CDS markets on the price of the underlying bond (and therefore financing cost for issuers), the relative pricing of the CDS and the underlying bond (the CDS-bond basis), and trading volume in the bond and CDS markets. Our model also provides a tractable framework to assess policy interventions in CDS markets, such as the recent E.U. ban of naked CDS positions.

In our model, investors differ across two dimensions. First, investors differ in their investment horizons: Some investors are unlikely to have to sell their position in the future and are therefore similar to buy-and-hold investors, such as insurance companies. Other investors are more likely to receive liquidity shocks and therefore have shorter investment horizons. These investors can be interpreted as active traders, such as speculators or hedge funds. Second, investors have heterogeneous beliefs about the bond's default probability: Optimistic investors view the default of the bond as unlikely, while pessimists think that a default is relatively more likely. If only the bond is traded, relatively optimistic investors with sufficiently long trading horizons buy the bond, whereas relatively pessimistic investors with sufficiently long trading horizons take short positions in the bond. Investors with short

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investment horizons stay out of the market, because for them the transaction costs of trading the bond are too high.

The introduction of a CDS affects the underlying bond market through three effects: (1) Some investors who previously held a long position in the bond switch to selling CDS protection, putting downward pressure on the bond price. (2) Investors who previously shorted the bond switch to buying CDS protection because, in equilibrium, the relatively illiquid bond trades at a discount compared to the CDS. The resulting reduction in short selling puts upward pressure on the bond price. (3) Some investors become "negative basis traders" who hold a long position in the bond *and* purchase CDS protection (i.e., the model endogenously generates the negative basis trade, which has been an immensely popular trading strategy in recent years). If basis traders cannot take leverage, they do not affect the price of the underlying bond. If basis traders can take leverage—a natural assumption given that they hold hedged positions—they push up the bond price. In practice, basis trades are often highly levered and their leverage varies with financial conditions, leading to time-series variation in the strength of this third effect.

Taken together, these three effects imply that, in general, CDS introduction is associated with an ambiguous change in the price of the underlying bond. This prediction is consistent with the empirical literature, which has found no unconditional effect of CDS introduction on bond or loan spreads (Hirtle (2009), Ashcraft and Santos (2009)). More importantly, our model identifies the underlying economic trade-off that determines the effect of CDS introduction. One the one hand, CDS introduction can crowd out demand for the bond, while on the other hand it leads to an allocational improvement in the bond market, because the presence of the CDS allows long-term investors to hold more of the bond supply. The balance of this trade-off critically depends on the relative liquidity of the bond and the CDS: When the bond and the CDS are similar in terms of their liquidity, the crowding out effect dominates and CDS introduction lowers bond prices. On the other hand, when there is a substantial difference in the liquidity of the CDS and the underlying bond, the introduction of the CDS tends to raise bond prices. The same logic implies that, for firms with multiple bond issues of

differing liquidity (e.g., "on-the-run" and "off-the-run" bonds), illiquid bonds benefit relatively more from CDS introduction. In fact, the price effect of CDS introduction can go in opposite directions for bonds of differing liquidity issued by the same company; the price of the illiquid bond increases while the price of the liquid bond decreases.

The endogenous emergence of leveraged basis traders highlights a novel economic role of CDS markets: The introduction of a relatively more liquid derivative market allows buy-and-hold investors, who are efficient holders of the illiquid bond, to hedge undesired credit risk in the more liquid CDS market. In the CDS market, the average seller of CDS protection is relatively optimistic about the bond's default probability, but is not an efficient holder of the bond because of more frequent liquidity shocks. The role of CDS markets is thus similar to liquidity transformation—by repackaging the bond's default risk into a more liquid security, they allow the transfer of credit risk from efficient holders of the bond to relatively more optimistic shorter-term investors, such as hedge funds. Hence, when bonds are illiquid, a liquid CDS can improve the allocation of credit risk and thus presents an alternative to recent proposals that aim at making the corporate bond market more liquid, for example through standardization.[1] This liquidity view of CDS markets differs from the traditional view that the main function of CDSs is simply the separation of credit risk and interest rate risk.[2] However, because the separation of interest rate risk from credit risk is also possible via a simple interest rate swap, it is unlikely that this traditional view captures the full economic role of CDS markets.

Beyond the price effects of CDS introduction, our model generates testable predictions regarding trading volume in bond and CDS markets that are consistent with recent empirical evidence. First, our model predicts that CDS turnover is higher than bond turnover, which is consistent with the evidence in Oehmke and Zawadowski (2013), who show that average monthly CDS turnover is around 50%, whereas average monthly turnover in the associated bonds is around 7.5%. Second, consistent with the findings of Das, Kalimipalli, and Nayak (2014), our model predicts that CDS introduction decreases turnover in the underlying bond. Third, despite this decrease in turnover, CDS introduction can reduce

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[1]Standardized bonds were recently proposed by the investment management firm BlackRock (BlackRock (2013)).
[2]See, e.g., the "Credit Derivatives Handbook" (JPMorgan (2006)).

price impact in the bond market, such that, consistent with Das, Kalimipalli, and Nayak (2014), the effect of CDS introduction on bond market liquidity can differ depending on which particular illiquidity measure is used.

From an asset pricing perspective, the prediction that the equilibrium price of the bond is (weakly) less than the price of a synthetic bond consisting of a risk-free bond and a short position in the CDS replicates a well-documented empirical phenomenon known as the negative CDS-bond basis (see, e.g., Bai and Collin-Dufresne (2010) and Fontana (2011)). Here our model generates a number of predictions regarding both the time-series and cross-sectional variation in the CDS-bond basis: The basis is more negative if the bond is more illiquid, when there is more disagreement about the bond's default probability, and when basis traders are restricted in the amount of leverage they can take.

Finally, our model provides a framework to study regulatory interventions with respect to CDS markets. For example, a ban on naked CDS positions, as recently imposed by the European Union on sovereign bonds through EU regulation 236/2012, may, in fact, raise yields for affected issuers. This can happen because, if pessimistic investors cannot take naked CDS positions, some of them will short the bond instead. This exerts downward price pressure on bond prices: Due to the liquidity difference between bonds and CDSs, naked CDS positions and short bond positions are not equivalent because a different set of investors takes the other side.[3]

Our paper contributes to a growing literature on derivatives as non-redundant securities.[4] In our framework, the source of non-redundancy is a difference in the market liquidity of the underlying security and the derivative, which we model using the classic framework of Amihud and Mendelson (1986). Given the well-documented illiquidity of corporate bonds, we view liquidity as a source of non-redundancy to be particularly important in the context of the CDS market. Other contributions to this literature have focused on different (and potentially complementary) sources of non-redundancy,

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[3]In addition to the naked CDS ban, we also briefly explore the effects of banning CDS markets altogether and banning both CDS markets and short positions in the underlying bond. In general, also these interventions have ambiguous effects on bond yields.

[4]Hakansson (1979) provides an early discussion of why derivatives should be studied in settings where they are not redundant.

including market incompleteness (Detemple and Selden (1991)), the informational effects of derivative markets (Grossman (1988), Biais and Hillion (1994), Easley, O'Hara, and Srinivas (1998), and Goldstein, Li, and Yang (2014)), the possibility that derivatives generate sunspots (Bowman and Faust (1997)), and changes in the relative bargaining power of debtors and creditors (Bolton and Oehmke (2011), Arping (2014)).

In addition, a number of recent papers have investigated the role of derivatives in the presence of short-sale and collateral constraints. Banerjee and Graveline (2014) show that derivatives can relax binding short-sales constraints when the underlying security is scarce (i.e., on "special"). Fostel and Geanakoplos (2012) show that, in the presence of collateral constraints in the spirit of Geanakoplos (2010) and Simsek (2013), the introduction of CDSs can lead to financial busts because they allow pessimistic investors to bet more effectively against the underlying asset. Che and Sethi (2013) show that naked CDSs facilitate leveraged negative bets that can increase a firm's cost of capital. In contrast to these papers, our approach does not rely on explicit short-sale or collateral constraints (or their relaxation). This means, for example, that our framework applies also in situations where the underlying asset can be shorted relatively easily.[5] Gârleanu and Pedersen (2011) explore the relative pricing of derivatives and underlying assets when derivatives have lower margin requirements and apply this framework to the CDS-bond basis. Shen, Yan, and Zhang (2013) develop a model of financial innovation based on differences in collateral requirements. However, these papers do not focus on the consequences of derivative introduction on the underlying asset, which is the main focus of our paper. While, leaning on empirical evidence, we take the difference in market liquidity between the CDS and the underlying bond as given, a number of search-theoretic models have explored endogenous differences in liquidity between assets with identical payoffs (Vayanos and Wang (2007), Vayanos and Weill (2008), Weill (2008)). In this context, Praz (2013) studies the interaction between a (liquid)

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[5]In contrast to some markets where short selling is indeed difficult to impossible, this feature of our model may be relevant when it comes to corporate bond markets: Asquith, Au, Covert, and Pathak (2013) document that shorting costs in the corporate bond market are modest on average and comparable to those in the stock market.

Walrasian and a (less liquid) OTC market, while Sambalaibat (2013) studies the effect of naked CDS trading in search markets.

More generally, our paper contributes to a growing literature on the economic effects of CDS markets. Duffee and Zhou (2001), Morrison (2005), Parlour and Plantin (2008), Parlour and Winton (2013), and Thompson (2009) explore how CDS markets allow banks to lay off credit risk and affect funding and monitoring outcomes. Allen and Carletti (2006) investigate how the availability of CDSs affects financial stability. Yorulmazer (2013) develops a model of CDSs as a means of regulatory arbitrage. Zawadowski (2013) develops a model in which CDSs are used to hedge counterparty exposures in a financial network. Atkeson, Eisfeldt, and Weill (2012) provide a model of the market structure of CDS and other OTC derivative markets. Overviews of CDS markets and current policy debates can be found in Stulz (2010), Jarrow (2011), and Bolton and Oehmke (2013).[6]

2   Model Setup

We consider a financial market with (up to) two assets: (i) a defaultable bond and (ii) a CDS that references the bond. The main assumption of our model is that the bond and the CDS, which offer exposure to the same credit risk, differ in liquidity. This difference in liquidity makes the CDS non-redundant.[7]

Illiquidity and high transaction costs in the corporate bond market have been widely documented.[8]

In contrast, CDS markets tend to be relatively liquid. In fact, it has become standard in the asset

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[6]There is also a growing empirical literature on price discovery in CDS markets (Acharya and Johnson (2007), Hilscher, Pollet, and Wilson (2014)), the effect of CDSs on leverage and maturity (Saretto and Tookes (2013)), the determinants of CDS market existence and CDS positions (Oehmke and Zawadowski (2013)), the CDS-bond basis (Blanco, Brennan, and Marsh (2005), Bai and Collin-Dufresne (2010), Fontana (2011), Li, Kim, and Zhang (2010)).

[7]This liquidity view of CDS markets echoes Ashcraft and Santos (2009) who, in their empirical study of the effects of CDS introduction, point out that "Liquidity in the bond market has been limited because many investors hold their bonds until maturity. The secondary market for loans has experienced rapid growth in the recent years, but bank loans remain largely illiquid. Under these circumstances, the development of the CDS market provided banks and investors with a new, less expensive, way to hedge or lay off their risk exposures to firms."

[8]See, e.g., Bessembinder, Maxwell, and Venkataraman (2006), Edwards, Harris, and Piwowar (2007), Mahanti, Nashikkar, Subrahmanyam, Chacko, and Mallik (2008), Bao, Pan, and Wang (2011). Effective trading costs for bonds include both bid-ask spreads and the market impact of trading and are usually much larger than quoted bid-ask spreads. In a sample that contains the most liquid bonds in the TRACE database, Bao, Pan, and Wang (2011) estimate effective trading costs for corporate bonds to be between 74 and 221 basis points, depending on the size of the trade. Transactions costs for less liquid

pricing literature to assume that the CDS market is perfectly liquid (see Longstaff, Mithal, and Neis (2005)).[9] Following Amihud and Mendelson (1986), we model illiquidity by assuming that investors incur trading costs, which we interpret broadly as reflecting both bid-ask spreads and market impact costs. Our main assumption, based on the evidence discussed above, is that these trading costs are lower for the CDS than the associated bond.

While we take the difference in liquidity between the bond market and the CDS market as given, a number of factors contribute to the relative liquidity of CDS markets when compared to bonds or loans. The first is standardization: The bonds issued by a particular firm are usually fragmented into a number of different issues which differ in their coupons, maturities, covenants, embedded options, and other features. The resulting fragmentation reduces the liquidity of these bonds. The CDS market, on the other hand, provides a standardized venue for the firm's credit risk (for a more detailed description see Stulz (2010)). Consistent with this argument, Oehmke and Zawadowski (2013) show that, CDS markets are more active and more likely to exist for firms whose outstanding bonds are fragmented into many separate bond issues. Second, a CDS investor who has to terminate an existing CDS position prior to maturity rarely sells his CDS in the secondary market; rather than selling the original contract he simply enters an offsetting CDS contract, which is usually cheaper. Third, inventory management for market makers is generally cheaper for CDS dealers than for market makers in bond markets.

bonds are even higher. Very large trades ($10M+) are hard to execute in the bond market and usually have large transaction costs (Randall (2013)). CDS trades, on the other hand, are routinely at least $10M, which is the typical unit of trade.

[9]While this assumption is not literally true, traders and other market participants generally view the CDS market as more liquid than the market for the underlying bonds. Unfortunately, transaction data to calculate the effective trading costs of CDSs is not available. However, a rough comparison of CDS and bond trading costs can be obtained by comparing CDS bid-ask spreads to effective bond trading costs. For CDSs, the bid-ask spread should capture most of the effective trading costs: Because CDS spreads are generally quoted for large trade sizes, market impact is less important for CDS trading costs than for bond trading costs. To compare CDS bid-ask spreads to bond trading costs, the CDS bid-ask spread has to be multiplied by the tenor (maturity) of the CDS. In fact, this approach likely overstates effective CDS roundtrip costs, because investors typically shop around for the best bid and ask prices, such that the roundtrip cost is the inside bid-ask spread (lowest ask minus highest bid) instead of the average bid-ask spread which is typically reported. Hilscher, Pollet, and Wilson (2014) report bid-ask spreads of 4-6 basis points for five-year credit default swaps on IG bonds, which thus implies trading costs of around 20-30 basis points, significantly lower than the implied spreads reported by Bao, Pan, and Wang (2011). In fact, often the liquidity advantage of CDSs can be seen by simply comparing bid-ask spreads. For example, even in the sample of sovereign bonds (which are usually relatively liquid) in Sambalaibat (2013), 75% of the CDSs have lower bid-ask spreads than the associated bonds. Finally, the liquidity advantage of CDS markets is also reflected by the fact that CDS markets incorporate information before bond markets (see Blanco, Brennan, and Marsh (2005) and Acharya and Johnson (2007)).

Because the CDS is a derivative, no ex-ante inventory has to be held. Moreover, regulatory capital charges for inventory are often larger for bonds than for derivatives.

2.1 Bond

A defaultable bond is traded in positive supply $S > 0$. We denote the bond's equilibrium ask price by p. The bond matures with Poisson arrival rate λ. As will become clear below, the assumption of Poisson maturity is convenient because is guarantees stationarity. However, none of our results depend on this assumption.[10] For simplicity we assume that the bond does not pay coupons.[11] At maturity, the bond pays back its face value of $1 with probability $1 - \pi$. With probability π, the bond defaults and pays 0.[12]

We capture illiquidity of the bond market in terms of a bond trading cost c_{B} that arises when the bond is traded. Specifically, following Amihud and Mendelson (1986), we assume that the bond can be bought at the ask price p and sold (or short sold) at the bid price $p - c_{\mathrm{B}}$. As discussed above, we interpret these trading costs broadly as reflecting both the relatively large bid-ask spreads for bonds and the market impact of executing the bond trade. Beyond the trading cost c_{B} we do not impose any additional cost on short selling. While it would be straightforward to add this to the model, treating long and short positions symmetrically highlights that, in contrast to a number of existing paper on CDS or derivative introduction (Banerjee and Graveline (2014), Che and Sethi (2013), Fostel and Geanakoplos (2012)), our results do not require short-sale restrictions.[13]

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[10]For other papers that use Poisson maturity as a tool to guarantee stationarity, see He and Xiong (2012) and Chen, Cui, He, and Milbradt (2013).

[11]It would be straightforward to allow for coupons. We omit them because the presence of coupons does not affect any of our results and therefore merely adds notation.

[12]This implies that default only occurs at maturity. Alternatively, one could assume that default can occur continuously with Poisson arrival rate. We chose the setup with default only at maturity because it is particularly tractable and yields the same economic insights as a model with continuous default.

[13]In fact, the evidence in Asquith, Au, Covert, and Pathak (2013) suggests that on average shorting corporate bond is not significantly more costly than shorting stocks, which makes a framework that does not explicitly rely on significant shorting costs appealing.

2.2 Credit default swap

In addition to the bond, a CDS that references the bond is available in zero net supply. The CDS is an insurance contract on the bond's default risk: It pays off \$1 if the bond defaults at maturity and zero otherwise.[14] For simplicity we assume that the CDS matures at the same time as the bond. We denote the CDS's equilibrium ask price by q.[15]

The (relatively low) trading cost in the CDS market is denoted by c_{CDS}. Hence, an investors can purchase CDS protection at the ask price q and sell protection at the bid $q - c_{\mathrm{CDS}}$. Trading costs in the CDS market are lower than in the bond market, such that

$$c_{\mathrm{B}} \geq c_{\mathrm{CDS}} \geq 0. \tag{1}$$

For most of our analysis, we follow Longstaff, Mithal, and Neis (2005) in assuming, for simplicity, that the CDS market involves no transaction costs, such that $c_{\mathrm{CDS}} = 0$. In Section 4.4, we then extend our analysis to the case in which $c_{\mathrm{CDS}} > 0$

2.3 Investors

There is a mass of risk-neutral, competitive investors who can trade the bond and the CDS. For simplicity, we set the investors' rate of time preference to zero. Investors are heterogeneous across two dimensions: (i) expected holding periods and (ii) beliefs about default probabilities.[16]

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[14]Hence, the CDS pays off an amount that is exactly equal to the loss given default of \$1. We therefore abstract away from potential discrepancies between the CDS payoff and the loss given default that can arise as part of the CDS settlement auction (see Chernov, Gorbenko, and Makarov (2013), Du and Zhu (2013), and Gupta and Sundaram (2013)).

[15]In practice, CDS contracts have fixed maturities (also known as tenors), the most common being 1, 5 and 10 years. Our setup, where both the bond and the CDS randomly mature at the same time is comparable to a setup in which investors match maturities of finite-maturity bonds and CDSs. Moreover, CDS premia are usually paid over time (quarterly), with a potential upfront payment at inception of the contract. The CDS price q should thus be interpreted as the present value of future CDS premia and the upfront payment.

[16]This assumption captures that both a security's default risk and its transaction costs matter for investors, and that the degree two which they matter differs across investors. As we will see below, both dimensions of heterogeneity play an important role in our analysis.

Expected holding periods differ across investors because investors are hit by liquidity shocks with Poisson intensity $\mu_i \in [0, \infty]$. Investors with low μ_i can be interpreted as buy-and-hold investors (for example, insurance companies or pension funds), whereas investors with high μ_i are investors subject to more frequent liquidity shocks (for example, hedge funds or other investors that are expressing shorter-term views). When hit by a liquidity shock, an investor has to liquidate his position exits the model. To preserve stationarity, we assume that a new investor with the same characteristics enters.

With respect to investor beliefs, we assume that investors agree to disagree about the bond's default probability in the sense of Aumann (1976). Specifically, investor i believes that the bond defaults at maturity with probability $\pi_i \in [\bar{\pi} - \frac{\Delta}{2}, \bar{\pi} + \frac{\Delta}{2}]$. These differences in subjective default probabilities among investors lead to differences in valuation of the bond's cash flows, thereby generating a motive to trade. More generally, these differences in valuation of the bond could also be generated by differences in investors' non-traded endowment risks, which would result in risk-based (rather than beliefs-based) private valuations of the bond.[17]

We assume that investors are uniformly distributed on the plane spanned by π and μ, with a mass one of investors at each liquidity shock intensity μ_i. This assumption implies a particularly simple density function $f(\mu, \pi) = \frac{1}{\Delta}$, which allows us to calculate equilibrium prices in closed form.

Investors can take positions in the bond (the "real" asset) and the CDS (the synthetic asset), but are subject to portfolio restrictions that reflect risk management constraints.[18] Specifically, we assume that each investor can hold up to one unit of credit risk. Accordingly, each investor can either go long one bond, short one bond, buy one CDS, or sell one CDS. In addition, investors can enter hedged portfolios. One such option is to take a long position in the bond and insure it by also purchasing a CDS (a so-called negative basis trade). Alternatively, investors can take a hedge position by taking a short position in the bond and selling CDS protection (a so-called positive basis trade). Because hedged positions do not involve credit risk, we allow investors to lever up hedged positions up to

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[17]The differences-in-beliefs setup we use in our model implies that investors do not learn from prices. For a model that studies the informational consequences of derivatives such as CDSs see Goldstein, Li, and Yang (2014).

[18]Given risk neutrality and differences in beliefs among investors, absent portfolio restrictions investors would take infinite positions.

a maximum leverage of $L \geq 1$. Hence, $L = 1$ implies that hedged investors cannot take leverage, whereas $L > 1$ implies that hedged investors can lever up their positions. Finally, as an outside option investors can always hold cash, which yields a zero return.

3 Benchmark: No CDS Market

In this Section, we first briefly consider the benchmark case in which only the bond trades. Building on this benchmark, we then turn to joint equilibrium in bond and CDS markets and the effects of CDS introduction in Section 4.

Investors maximize their utility subject to their portfolio constraints. When only the bond is trading, this means that investors choose between a long or a short position in the bond and holding cash. Investor i's net payoff from a long position in the bond is given by

$$V_{\text{longBOND},i} = -p + \frac{\mu_i}{\mu_i + \lambda}(p - c_{\text{B}}) + \frac{\lambda}{\mu_i + \lambda}(1 - \pi_i). \tag{2}$$

The interpretation of this expression is as follows. The investor pays the ask price p to purchase the bond. With probability $\frac{\mu_i}{\mu_i + \lambda}$ the investor has to sell the bond before maturity. Here, the stationarity property of Poisson maturity implies that a non-matured bond at some future liquidation date t trades at the same price p as the bond today. Hence, the investor receives the bid price $p - c_{\text{B}}$ when he has to sell the bond before maturity. If the bond matures before the investor receives a liquidity shock, the investor receives an expected payoff of $1 - \pi_i$, where π_i is the investor's subjective belief about the bond's default probability. This happens with probability $\frac{\lambda}{\mu_i + \lambda}$.

Similarly, investor i's net payoff from a short position in the bond is given by

$$V_{\text{shortBOND},i} = p - c_{\text{B}} - \frac{\mu_i}{\mu_i + \lambda}p - \frac{\lambda}{\mu_i + \lambda}(1 - \pi_i). \tag{3}$$

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An investor who takes a short position in the bond receives the bid price $p - c_{\text{B}}$ today. If the investor has to cover his short position before maturity, the investor has to purchase the bond at the ask price p (again using the stationarity property), whereas if the bond matures the investor has to cover his short position at an expected cost of $1 - \pi_i$. The probabilities of these two events are $\frac{\mu_i}{\mu_i + \lambda}$ and $\frac{\lambda}{\mu_i + \lambda}$, respectively.

Figure 1 illustrates the resulting demand for long and short positions.[19] Investors that are optimistic about the bonds' default probability and have sufficiently long trading horizons purchase the bond, forming a triangle of buyers. On the boundary of the "buy" triangle, investors are indifferent between a long position in the bond on holing cash, which requires that $V_{\text{longBOND},i} = 0$. Similarly, pessimistic investors with sufficiently long trading horizons short the bond, with the boundary of the resulting "short" triangle defined by $V_{\text{shortBOND},i} = 0$. All other investors simply hold cash. The gap between the triangle of long bondholders and short sellers arises because the bond trading cost c_{B} drives a wedge between the payoffs from long and short positions, which makes it optimal even for some investors who do not face liquidity shocks to stay out of the market.

Market clearing requires that the bond price p adjusts such that the overall amount bought by long investors is equal to the amount shorted plus bond supply S. Solving this market clearing condition for the bond price p leads to the following Lemma.

**Lemma 1. *Benchmark: Bond market equilibrium in absence of CDS market.* ** *When only the bond trades, the equilibrium bond price is given by*

$$p_{\text{noCDS}} = 1 - \overline{\pi} + \frac{c_B}{2} - \frac{c_B}{\lambda} \frac{\Delta}{\Delta - c_B} S. \tag{4}$$

Lemma 1 shows that, in the absence of the CDS, the bond price is given by the average investor's belief about the bond's expected payoff, $1 - \overline{\pi}$, plus two additional terms that capture the effect of the bond's trading costs and supply. The term $\frac{c_{\text{B}}}{2}$ captures the wedge that the bond trading cost puts

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[19]We focus on the case in which, in the absence of the CDS, both long and short investors are present. This is the case as long as the bond supply S is not too large. The exact condition is given in the appendix.
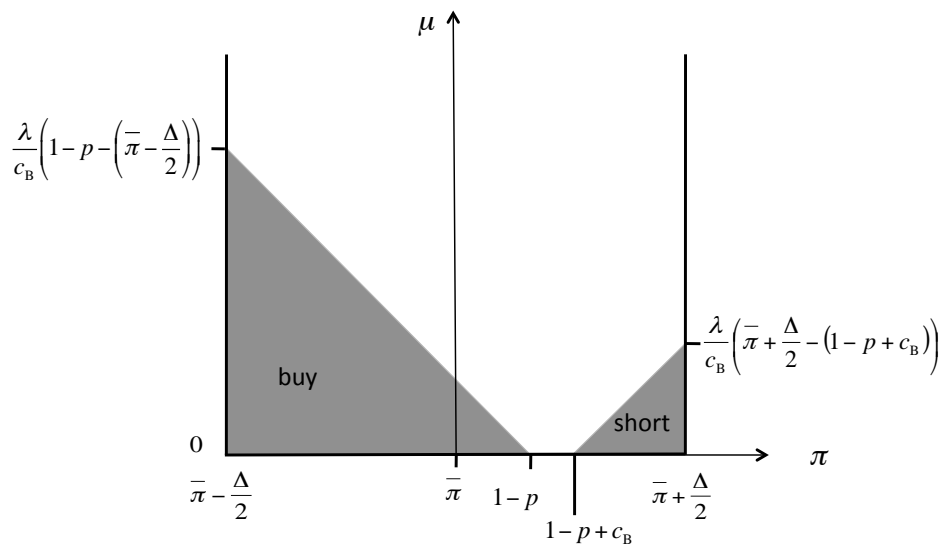
Figure 1: **Bond market equilibrium in the absence of a CDS.**
The figure illustrates the equilibrium when only the bond is trading. Investors who are sufficiently optimistic about the bond's default probability and have sufficiently long holding horizons form a "buy" triangle. Investors who are pessimistic about the bond's default probability and have sufficiently long holding horizons form a "shorting" triangle. Market clearing requires that the bond price adjust such that demand from long investors is equal to bond supply plus short positions.

between the payoff from a long and a short position, which increases the bond's ask price by exactly half of the bond's trading cost. The term $-\frac{c_B}{\lambda}\frac{\Delta}{\Delta - c_B}S$ captures that, as the bond supply S increases, the marginal bond investor becomes less optimistic and has shorter trading horizons, leading to a decrease in the bond price. Note that unless the bond supply is very small, the bond trades at a discount to its expected payoff under the average default probability. For the remainder of the paper we will assume that this condition holds, such that $p_{\text{noCDS}} < 1 - \overline{\pi}$. More formally, this assumption can be stated as:

Assumption 1. *The bond supply satisfies* $S > \frac{\lambda}{2}\frac{\Delta - c_B}{\Delta}$.

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4   Introducing a CDS Market

We now introduce the CDS contract to the analysis. Analogously to before, we determine the demand for the CDS by calculating the payoffs from positions that involve the CDS: long and short CDS positions as well as hedged positions in the bond and the CDS. Combining these payoffs with the payoffs to going long or short in the bond, derived in equations (2) and (3), we then solve for joint equilibrium in the bond and the CDS market.

The net payoff to investor i of purchasing a CDS on the bond is given by

$$V_{\text{buyCDS},i} = -q + \frac{\mu_i}{\mu_i + \lambda}\left(q - c_{\text{CDS}}\right) + \frac{\lambda}{\mu_i + \lambda}\pi_i. \tag{5}$$

This expression reflects the purchase price q of the CDS, the payoff $q - c_{\text{CDS}}$ from early liquidation at the bid with probability $\frac{\mu_i}{\mu_i + \lambda}$ (using stationarity) and the expected CDS payoff of π_i in the case of default at maturity, which happens with probability $\frac{\lambda}{\mu_i + \lambda}$. Analogously, the payoff to investor i of selling a CDS on the bond is given by

$$V_{\text{sellCDS},i} = q - c_{\text{CDS}} - \frac{\mu_i}{\mu_i + \lambda}q - \frac{\lambda}{\mu_i + \lambda}\pi_i. \tag{6}$$

In addition to taking directional positions in the bond or the CDS, investors can enter hedged "basis trade" positions. Because hedged positions can be levered L times, these hedged portfolios pay off $L \cdot (V_{\text{buyCDS},i} + V_{\text{longBOND},i})$ in the case of a negative basis trade and $L \cdot (V_{\text{sellCDS},i} + V_{\text{shortBOND},i})$ for a positive basis trade. Finally, investors can still hold cash as an outside option with zero return.

Solving for equilibrium in the bond and CDS market requires calculating the demand for bond and CDS positions from the above payoffs and then imposing market clearing to determine the equilibrium prices of the bond and the CDS. In our main analysis, we will focus on the case in which the CDS market is frictionless ($c_{\text{CDS}} = 0$). After establishing our main results in the context of this particularly

tractable case, we discuss the case where also the CDS market is subject to trading frictions ($c_{\mathrm{CDS}} > 0$) in Section 4.4.

4.1   The effect of CDS introduction on prices and trading in the bond market

The advantage of assuming that CDS markets are frictionless is that the equilibrium in the CDS market becomes particularly simple: When $c_{\mathrm{CDS}} = 0$, equations (5) and (6) imply that all investors with beliefs $\pi_i < q$ are willing to sell CDS protection, while all investors with $\pi_i > q$ are willing to purchase CDS protection. Given that above any level of μ there is an infinite mass of agents willing to buy and sell CDS protection, this implies that the equilibrium price of the CDS must be equal to the average investor belief about the bond's default probability,[20]

$$q = \overline{\pi}. \tag{7}$$

To determine the equilibrium bond price, it therefore suffices to investigate how the availability of the CDS priced at $q = \overline{\pi}$ affects investors' incentives to take long or short positions in the bond.

Consider first the case in which basis traders cannot take leverage ($L = 1$), depicted in Figure 2. The figure shows that the introduction of the CDS has three effects on the equilibrium in the bond market. First, when the CDS is available, investors with relatively short trading horizons who in absence of the CDS used to purchase the bond now prefer to sell CDS protection. This can be seen in Figure 2 by observing that the triangle of long bondholders has been cut off at the top (for ease of comparison, the triangle of long bond positions in the absence of the CDS is depicted by the dashed line). This crowding out of long bond investors leads to a reduction in demand for the bond, exerting downward pressure on the bond price.

Second, the introduction of the CDS eliminates short selling in the bond. In the figure, the triangle of investors that formerly shorted the bond (depicted by the dotted line on the right) vanishes, because

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[20]Strictly speaking, we are making a limit argument: Consider and upper bound $\overline{\mu}$ for the frequency of the liquidity shock and take the limit $\overline{\mu} \to \infty$. As the mass of traders in the CDS market grows, the CDS price q converges to $\overline{\pi}$.
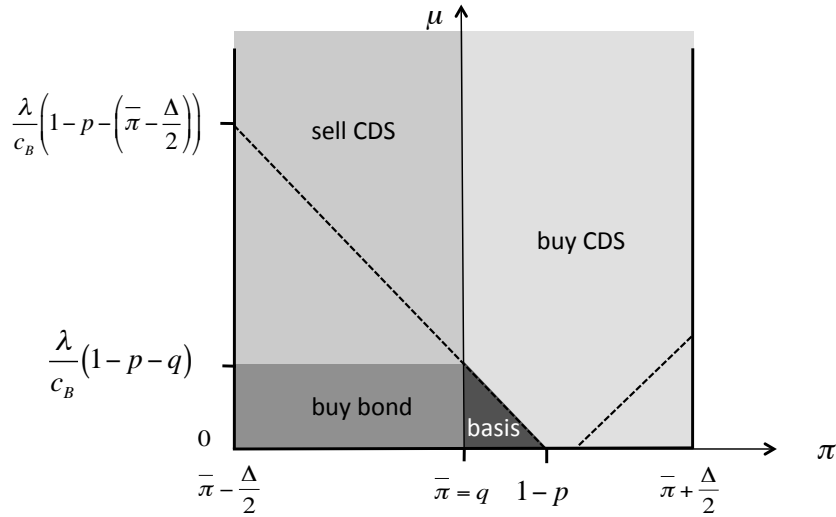
Figure 2: **Bond and CDS market equilibrium (basis traders cannot take leverage)**
This figure illustrates the equilibrium when both the bond and the CDS are trading and basis traders cannot take leverage ($L = 1$). The introduction of the CDS has three effects: (i) Some investors who absent the CDS would purchase the bond now choose to sell CDS protection, cutting off the top of the bond buying triangle. (ii) Because the bond trades at a discount relative to the CDS, all former short sellers prefer to purchase CDS protection, which eliminates the shorting triangle. (iii) Investors who formerly bought the bond but whose beliefs about the bond's default probability are below the median belief $\bar{\pi}$ become basis traders who purchase the bond and buy CDS protection. The dashed lines illustrate the long and short triangles in the absence of the CDS (holding prices constant).

those investors now prefer to purchase CDS protection instead of shorting the bond. The reason why investors prefer to use the CDS market to take bearish bets works through the equilibrium price: Because of its trading costs, in equilibrium the bond trades at a discount relative to the CDS. Hence, investors that wish to take a bearish bet on the bond prefer to do this in the CDS market rather than via a short position in the bond. By eliminating short sellers, the introduction of the CDS exerts upward pressure on the bond price.

Third, the introduction of the CDS generates a new class of investors: hedged basis traders. Specifically, when $L = 1$ we see that investors who in the absence of the CDS would have taken a long position in the bond but whose beliefs about the bond's default probability is less optimistic than the average belief $\bar{\pi}$ now find it optimal to purchase both the bond and the CDS. These investors

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thus become negative basis traders: They hold a hedged position in the bond and the CDS, thereby locking in the equilibrium price differential between the underlying bond and the derivative. Rather than taking bets on credit risk, these investors act as arbitrageurs.

When basis traders cannot take leverage ($L = 1$), as assumed in Figure 2, their presence does not affect the bond price. The reason is that the investors in the basis trade triangle would have purchased the bond anyway, even in absence of the CDS. When basis traders can take leverage ($L > 1$), on the other hand, the ability to hedge with the CDS allows basis traders to demand more of the bond, such that they exert upward pressure on the bond price. This is illustrated in Figure 3. More specifically, the figure shows that the ability of basis traders to take leverage raises the equilibrium bond price in two ways. First, holding constant the number of basis traders (i.e., keeping the size of the basis trader triangle as in Figure 2), the ability to take leverage increases the demand for the bond from this given set of basis traders, thereby putting upward pressure on the bond price. Second, the ability to take leverage makes the basis trade more profitable and thereby increases the number of basis traders: As illustrated in Figure 3, the basis trader triangle expands. In fact, when basis traders can take leverage, even some investors to the left of $\bar{\pi}$ become basis traders. Even though for these investors the CDS priced at $q = \bar{\pi}$ has a negative payoff when seen in isolation, they purchase the CDS because it allows them to lever up their position in the bond.[21]

The emergence of basis traders highlights a novel economic role of CDS markets in our model: The CDS improves the allocation in the bond market by allowing buy-and-hold investors to purchase more of the bond, thereby allowing efficient holders of the illiquid bond to hold a larger share of the bond supply. This is possible because the liquid CDS allows buy-and-hold investors to lay off the credit risk to investors with shorter trading horizons in the CDS market. By allowing to lay off credit risk to investors with shorter trading horizons the CDS therefore essentially serves as a vehicle for liquidity transformation. Note that this liquidity-based view of CDSs goes beyond the traditional view that

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[21]When the basis trade becomes extremely profitable, it is possible that the basis trade region extends all the way to the $\pi_i = \bar{\pi} + \Delta/2$. While this would not affect our results, we rule out this case for simplicity. The exact condition, which requires that bond supply or basis trader leverage are not too large, is given in the appendix.
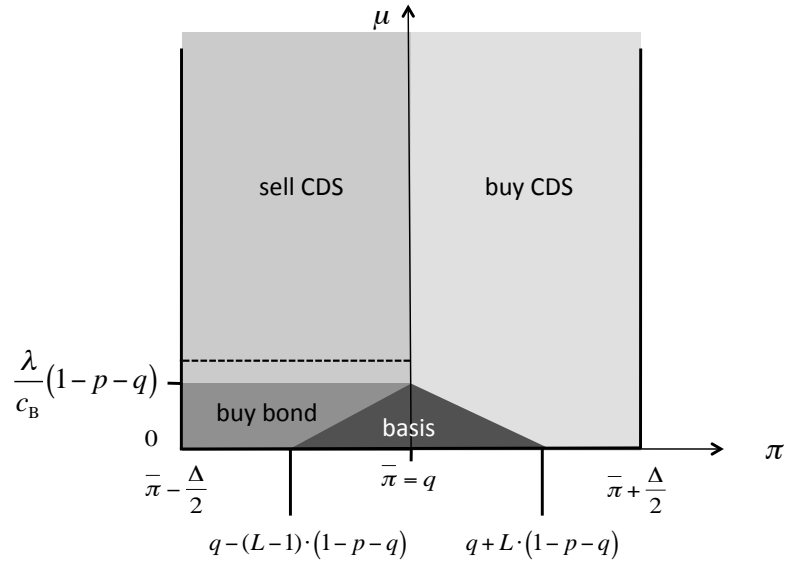
Figure 3: **Bond and CDS market equilibrium (basis traders can take leverage)**
The figure illustrates the equilibrium when both the bond and the CDS are trading and basis traders can take leverage $(L > 1)$. The ability to take leverage makes the basis trade more attractive, such that the basis trade triangle expands compared to Figure 2. Because of the increased demand from basis traders, more of the bond can be held by investors with long trading horizons, improving the allocation in the bond market. compared to the case when $L = 1$. For ease of comparison, the dashed line illustrates the rectangle of investors who purchase the bond when basis traders cannot take leverage $(L = 1)$.

CDSs simply allow separate interest rate risk from default risk. In fact, separation of credit risk from interest rate risk is possible with an interest rate swap and does not require a CDS. In contrast, the allocational improvement through basis traders that is highlighted here is only possible via a (liquid) CDS contract.

Given the discussion above, we now solve for the equilibrium bond price. Market clearing in the bond market requires that the demand from investors with a long position in the bond and the demand from basis traders add up to the bond supply S. Solving for the bond price p that satisfies this condition yields the following Lemma.

Lemma 2. *Bond price in presence of frictionless CDS market.* *When both the bond and a frictionless CDS are traded, the CDS price is given by $q = \overline{\pi}$ and the equilibrium bond price is equal to*

$$p_{\text{withCDS}} = 1 - \overline{\pi} - \frac{\Delta}{2} \frac{\sqrt{1 + 8\Phi \frac{c_B}{\lambda} \frac{S}{\Delta}} - 1}{\Phi}, \tag{8}$$

where we define $\Phi \equiv 1 + 2L(L-1)$.

Similar to Lemma 1, the bond price in the presence of the CDS is equal to the average expected payoff $1 - \overline{\pi}$, plus an adjustment for the bond's trading cost and bond supply. Note however that in the presence of the CDS, this supply adjustment depends on the amount of leverage that basis traders can take. In addition, the ability to (synthetically) short the bond via the CDS without incurring a trading cost eliminates the wedge between long and short positions and therefore the $\frac{c_B}{2}$ term that was present when no CDS is available.

Based on Lemmas 1 and 2, we are now in a position to characterize the effect of CDS introduction on the price of the underlying bond.

Proposition 1. *The effect of CDS introduction on the bond price.* *The change in the bond price due to CDS introduction is given by*

$$p_{\text{withCDS}} - p_{\text{noCDS}} = -\frac{c_B}{2} + \frac{c_B}{\lambda} \frac{\Delta}{\Delta - c_B} S - \frac{\Delta}{2} \frac{\sqrt{1 + 8\Phi \frac{c_B}{\lambda} \frac{S}{\Delta}} - 1}{\Phi}. \tag{9}$$

The price effect of CDS introduction on the underlying CDS is ambiguous. CDS introduction is more likely to raise the bond price when

(i) basis trader leverage L is high,

(ii) disagreement about the default probability Δ is low, and

(iii) the bond trading cost c_B is high.

Equation (9) summarizes the effect of CDS introduction on the price of the underlying bond. First, setting $c_B = 0$, note that the CDS is redundant when the bond is perfectly liquid and $p_{\text{withCDS}} -$

$p_{\text{noCDS}} = 0$. In this case, the CDS has no liquidity advantage over the bond and therefore does not affect the pricing of the bond. As we show in Section 4.4, this generalizes to the case in which both the bond and the CDS have trading costs: The CDS is redundant whenever trading costs in the CDS market are equal to trading costs in the bond market.[22]

Second, for the CDS to increase the bond price, the liquidity difference between the bond and the CDS must be sufficiently large. Specifically, when the bond trading cost c_{B} is sufficiently small, the introduction of the CDS reduces the bond price. This can be seen by differentiating equation (9) with respect to the bond trading cost and evaluating the resulting expression at $c_{\text{B}} = 0$, which yields $-\frac{1}{2} - \frac{S}{\lambda} < 0$. Hence, given that the price change at $c_{\text{B}} = 0$ is zero, for bond trading costs close enough to zero CDS introduction reduces the bond price. The reason is that when the bond and the CDS are sufficiently similar in liquidity, the crowding out effect of the CDS dominates, such that the bond price drops when the CDS is introduced.[23]

When c_{B} is sufficiently large, on the other hand, CDS introduction can increase the bond price. However, for CDS introduction to increase the bond price it has to be the case that basis traders can take sufficient leverage: When $L = 1$ such that basis traders cannot take leverage, the crowding out effect of the CDS market dominates and the bond price decreases when the CDS introduced. When L is sufficiently large, on the other hand, the introduction of the CDS increases the bond price because a larger share of the bond supply is absorbed by buy-and-hold investors that are less likely to incur the trading costs of the bond. When basis traders do not face any leverage constraints ($L \to \infty$), the bond price is given by the bond's average expected payoff $1 - \overline{\pi}$. Under Assumption 1, the bond price therefore increases in response to CDS introduction when basis trader leverage L is sufficiently high.

Corollary 1. *CDS introduction raises the bond price when basis traders can take sufficient leverage.*

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[22]More generally, in our model the CDS is redundant whenever trading costs in the CDS market are weakly larger than trading costs in the bond market: When CDS trading costs exceed bond trading costs, investors do not take positions in the CDS market because, intuitively speaking, the bond market dominates the CDS market. Hence, CDS markets that are less liquid than the bond require additional frictions, such as restrictions on short selling.

[23]While in Proposition 1 we keep the CDS trading cost c_{CDS} fixed at 0 and vary the bond trading cost c_{B} we show in Section 4.4 that this insight carries over to the setting where both the bond and the CDS are subject to strictly positive trading costs.

The comparative statics with respect to c_B and L highlight the main economic trade-off that arises when the CDS is introduced. On one hand, CDS introduction crowds out demand for the bond which puts downward pressure on the equilibrium bond price. On the other hand, CDS introduction improves the allocation in the bond market because it allows investors with long horizons to hold more off the illiquid bond, which puts upward pressure on the equilibrium bond price. As shown above, when the liquidity differential between the bond and the CDS is sufficiently large and when basis traders can take sufficient leverage, the second effect dominates and the bond price increases when the CDS is introduced. While we have focused on the uniform investor distribution in characterizing the trade-off between the crowding out effect and the allocational improvement that is possible in the presence of the CDS, the underlying economic insight is not distribution-specific. What is distribution specific, is the result that CDS introduction always reduces the bond price when $L = 1$ (i.e., that the crowding out of long bond positions outweighs the reduction in short selling).[24]

Finally, Proposition 1 shows that CDS introduction is less likely to increase the bond price when disagreement about the bond's default probability Δ is substantial. The intuition for this finding is as follows. Absent the CDS, the bond price is increasing in disagreement. As can be seen from Figure 1, an increase in Δ increases the area of the "buy" triangle more than the area of the "short" triangle, resulting in an increase in the bond price. This reverses once the CDS is available: After CDS introduction the bond price is decreasing in disagreement about the bond's default probability, which can be seen by inspecting Figure 2. An increase in Δ leaves the mass of investors in the "buy bond" rectangle unchanged, but drains investor mass out of the "basis" triangle, thereby leading to a decrease in the bond price.[25]

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[24]There are alternative distributions for which the reduction in short selling outweighs the crowding out of long positions, such that CDS introduction raises the bond price even for $L = 1$. Relative to the uniform distribution, these distributions have a larger mass of traders with infrequent liquidity shocks (i.e., there are relatively more buy-and-hold investors), such that there is a larger mass of investors in the shorting triangle that is eliminated by CDS introduction (low μ) than in the triangle of long bondholders that are crowded out by the CDS market (higher μ). See Figure 2.

[25]Note that, even when the CDS is available, we have continued to assume that investors need to liquidate their positions when hit by a liquidity shock. One could enrich the framework by assuming that sometimes it suffices that long bond investors *hedge* their bond position with a CDS when hit by a shock. This reduces the effective expected bond trading costs and therefore introduces an additional positive effect of CDS markets on bond markets: investors are more likely to purchase

The main empirical prediction of Proposition 1 is that the price effect of CDS introduction on bond prices is generally ambiguous and depends crucially on bond and firm characteristics. This is consistent with an emerging empirical literature on the effect of CDSs on the cost of financing for firms. Ashcraft and Santos (2009) find no evidence that the introduction of CDS contracts has lowered financing costs for the average borrower, but document modest reductions in spreads for safe firms. Hirtle (2009) finds only limited evidence that CDSs have improved firms' access to financing, with positive effects of CDSs on access to credit concentrated among larger term borrowers. Moreover, the specific empirical patterns regarding which types of borrowers benefit from CDS introduction are in line with the predictions of our model. Consistent with the prediction that CDS introduction is less likely to increase bond prices when there is substantial disagreement, Ashcraft and Santos (2009) find that firms with high earnings forecast dispersion face increased funding costs once a CDS is introduced. Ashcraft and Santos (2009), Nashikkar, Subrahmanyam, and Mahanti (2011), and Shim and Zhu (2014) show evidence consistent with the prediction that bond and CDS must differ sufficiently in liquidity for CDSs to reduce funding costs. Because we have set $c_{\text{CDS}} = 0$, the relative liquidity difference in our benchmark model is captured simply by the bond trading cost c_{B}. In Section 4.4 we extend our model to allow for positive CDS trading costs $c_{\text{CDS}} > 0$ and provide a more detailed discussion of the role of the relative liquidity of the bond and the CDS and the associated empirical evidence there.

In addition to the result on the effects of CDS introduction on the bond price, our model generates implications for turnover in the bond and the CDS market. First, our model predicts that CDS introduction reduces turnover in the bond market (defined as bond trading volume divided by the supply of the bond S). This can be seen directly from Figure 2. As a result of CDS introduction, bond investors with relatively short trading horizons switch to selling the CDS, thereby reducing bond turnover. In addition, the introduction of the CDS eliminates short sellers, which also leads to a reduction in bond turnover. Second, our model predicts that when both the bond and the CDS are

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the bond because sometimes they can use the CDS to hedge ex post. However, subject to this adjustment, all other effects described above would remain at work.

available, turnover in the CDS market (defined as the amount of CDS trading divided by the notional amount of outstanding CDSs) exceeds turnover in the bond market. This implication follows from a clientele effect a la Amihud and Mendelson (1986), whereby investors with higher average trading frequencies hold the CDS whereas investors who trade less hold the bond.[26]

However, while CDS introduction reduces turnover in the bond market, this does not imply that the bond market becomes less liquid when looking at price impact. Specifically, when basis traders can take sufficient leverage, the sensitivity of the bond price with respect to a supply shock, $|\frac{dp}{dS}|$, is smaller when a CDS is available. Hence, while the allocational changes that results from the introduction of the CDS reduce bond turnover, the fact that basis traders stand ready to absorb supply shocks reduces price impact in the bond market. Accordingly, the effect of CDS introduction on bond liquidity may differ depending on which liquidity measure (e.g., turnover or price impact) is used. We summarize these results in the following proposition.

Proposition 2. *Turnover and price impact in bond and CDS markets.*

(i) *Turnover in the CDS market is higher than turnover in the bond market.*

(ii) *Turnover in the underlying bond decreases when the CDS is introduced.*

(iii) *Price impact in the bond market decreases when the CDS is introduced if basis traders can take sufficient leverage.*

The first two predictions in Proposition 2 follow relatively directly from the differences in trading costs between the bond and the CDS and the resulting clientele effect that arises as investors sort themselves into these two assets depending on the frequency of their liquidity shocks. Nonetheless, these additional predictions are useful because they offer additional dimensions along which we can link our model to empirical evidence. In fact, consistent with the first prediction in Proposition 2, Oehmke and Zawadowski (2013) document that average monthly CDS turnover (based on CDS trading data from the DTCC) is 50.8% per month, whereas average turnover in the associated bonds

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[26]This simple comparison of average trading frequencies of investors suffices because there is no short selling when the CDS trades.

(as reported by TRACE) is around 7.5% per month. Consistent with the second prediction, Das, Kalimipalli, and Nayak (2014) show that CDS introduction is indeed associated with a decrease in turnover in the underlying bond. Hence, the observed turnover patters in bond and CDS markets match the predictions of our model. Finally, the third prediction in Proposition 2 provides a potential explanation of why Das, Kalimipalli, and Nayak (2014) find that the effect of CDS introduction on bond liquidity differs depending on which specific liquidity measure is used: While our framework predicts a reduction in bond turnover, the effect of CDS introduction on price impact depends on model parameters, such as basis trader leverage and the outstanding supply of the underlying bond. Consistent with this prediction, Das, Kalimipalli, and Nayak (2014) do not find a clear directional effect when investigating the effect of CDS introduction on the Amihud price impact measure (Amihud (2002)).

4.2 The CDS-bond basis

In this section, we investigate the relative pricing of the bond and the CDS once both instruments trade. The relative pricing of bonds and CDSs is captured by the CDS-bond basis, which has attracted considerable attention in the wake of the financial crisis of 2007-2009. The CDS-bond basis is defined as the difference between the spread of a synthetic bond (composed of a long position in a risk-free bond of the same maturity and coupon as the risky bond and a short position in the CDS) and the spread of the actual risky bond. Intuitively speaking, when the CDS-bond basis is negative, the bond spread is larger than the CDS spread, which means that the physical bond is cheaper than the payoff-equivalent synthetic bond.

Absent frictions, the CDS-bond basis should be approximately zero. The reason is that a portfolio consisting of a long bond position and a CDS that insures the default risk of the bond should yield the risk-free rate.[27] Since the financial crisis, the CDS-bond basis has been consistently negative for most

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[27]See Duffie (1999) for conditions under which this arbitrage relationship holds exactly.

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reference entities, as documented by Bai and Collin-Dufresne (2010), Fontana (2011) and Gârleanu and Pedersen (2011).[28]

In our framework, a negative basis between bonds and CDSs arises endogenously from the difference in trading costs of the bond and the CDS. To calculate the basis, note that in our setting a risk-free bond with the same maturity as the risky bond trades at a price of one (since there is no discounting). We can then calculate the spread of the risky bond above the risk-free rate by calculating the price difference between the risk-free and the risky bond and dividing it by the expected time to maturity $1/\lambda$, which yields $\text{spread}_{\text{bond}} = \lambda(1-p)$. Analogously, given the CDS price q we can calculate the CDS spread (the flow cost of CDS protection) as $\text{spread}_{\text{CDS}} = \lambda q$. Hence, the CDS-bond basis is given by

$$\text{basis} = \text{spread}_{\text{CDS}} - \text{spread}_{\text{bond}} = -\lambda\left(1 - p - q\right). \tag{10}$$

Based on the bond and CDS market equilibrium derived above, the CDS-bond basis then satisfies the following properties.

Proposition 3. *The CDS-bond basis.* *The CDS-bond basis in the presence of frictionless CDS markets ($c_{CDS} = 0$) is given by*

$$basis = -\lambda\frac{\Delta}{2}\frac{\sqrt{1 + 8\Phi\frac{c_B}{\lambda}\frac{S}{\Delta}} - 1}{\Phi} \leq 0, \tag{11}$$

where $\Phi \equiv 1 + 2L(L-1)$. The CDS-bond basis is more negative when

(i) bond supply S is large,

(ii) basis traders can take less leverage (small L),

(iii) bond trading costs c_B are high,

(iv) disagreement about the bond's default probability Δ is high.

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[28]Note, however, that positive bases do occur in some cases. They are usually attributed to frictions that are outside of our model, such as short-selling constraints that arise from imperfections in the repo market, the cheapest-to-deliver option, and control rights associated with the underlying bond (see JPMorgan (2006)).

The source of the negative basis in our model is straightforward. Because trading costs for the bond are higher than those of the CDS, the bond trades at a discount relative to the CDS. This prediction is in line with a growing empirical literature that documents a negative CDS-bond basis. In addition, Proposition 3 makes a number of time-series and cross-sectional predictions on the CDS-bond basis. First, the basis becomes more negative in response to supply shocks in the bond market. Such supply shocks may capture situations in which investors subject to regulatory constraints are forced to sell some of their holdings as documented, for example, in Ellul, Jotikasthira, and Lundblad (2011). Second, higher basis trader leverage compresses the negative basis. This is because higher leverage for basis traders increases the demand for the bond, pushing up the bond price and thereby reducing the negative basis. In the time series, this implies that at times when basis traders can take substantial leverage, the basis should be less negative and closer to zero. In contrast, during times of tough financing conditions for basis traders, the equilibrium basis will be driven away from zero and becomes more negative. Empirical evidence suggests that this mechanism was indeed a major contributor to the widening of the negative basis during the financial crisis, when margins rose and arbitrageurs had to delever (see Gârleanu and Pedersen (2011), Fontana (2011), and Mitchell and Pulvino (2012)). Choi and Shachar (2014) provide evidence that it was specifically the unwinding of CDS-bond basis trades by arbitrageurs that was a main cause of the large negative basis in 2008. Oehmke and Zawadowski (2013) provide evidence that basis traders became relatively more active again when financing conditions eased in mid 2009.

The remaining two comparative statics in Proposition 3 make cross-sectional predictions on the CDS-bond basis. First, bonds with high trading costs (relative to trading costs in the associated CDS) are predicted to have more negative CDS-bond bases. This is consistent with the empirical evidence in Bai and Collin-Dufresne (2010). Second, our model predicts that bonds for which investors disagree significantly on default probabilities have more negative bases. In practice, high-yield bonds tend to be characterized by more disagreement about default probabilities and have higher trading costs. For both of these reasons, our model therefore predicts that lower-rated bonds should have a more

negative basis, which is consistent with the evidence in Bai and Collin-Dufresne (2010) and Gârleanu and Pedersen (2011).

4.3   Two bond issues

In this subsection, we extend our model to a setting where an issuer has multiple bonds outstanding: a liquid issue and a less liquid issue. One interpretation of this setting is that the liquid issue is a recently issued "on-the-run" bond, while the less liquid issue is an older "off-the-run" bond. Alternatively, the liquid bond may be a relatively standard bond issue, whereas the illiquid bond represents a bond that is more custom-tailored towards a particular clientele and therefore less liquid. Finally, based on empirical evidence that longer-term bonds are less liquid, the illiquid bond could be interpreted as a long-term bond.

We continue to assume that the CDS is frictionless ($c_{\mathrm{CDS}} = 0$) and is therefore more liquid than either of the two bonds, which have strictly positive trading costs of c_{B}^L (low trading cost) for the liquid bond and $c_{\mathrm{B}}^H > c_{\mathrm{B}}^L$ (high trading cost) for the illiquid bond.[29] Figure 4 illustrates the holding regions, which can be derived in analogous fashion to the one-bond case. The figure shows that the illiquid bond is held by investors with longer trading horizons. Moreover, in equilibrium the less liquid bond has a larger illiquidity discount and therefore a more negative CDS-bond basis.

Because of the difference in ownership patterns for the two bonds, CDS introduction affects the prices of the two bonds differently. The liquid bond and the CDS are relatively close substitutes (in terms of liquidity), which means that the liquid bond is affected disproportionately by the crowding-out effect of CDS introduction. The illiquid bond and the CDS, on the other hand, are less close substitutes, which implies that the illiquid bond benefits disproportionately from the increased demand from basis traders. Hence, the illiquid bond generally benefits more from CDS introduction (in a

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[29]To reduce the number of cases discussed in this extension, we assume that c_{B}^L is not too small. This simplifies the analysis because it ensures that absent the CDS investors do not take long-short positions (similar to on-the-run/off-the-run strategies) in the two bonds. However, this could be incorporated without affecting the main insights of this section.

relative sense). Moreover, as we illustrate below, it is possible that the price effect of CDS introduction goes in opposite directions for the liquid and the illiquid bonds.
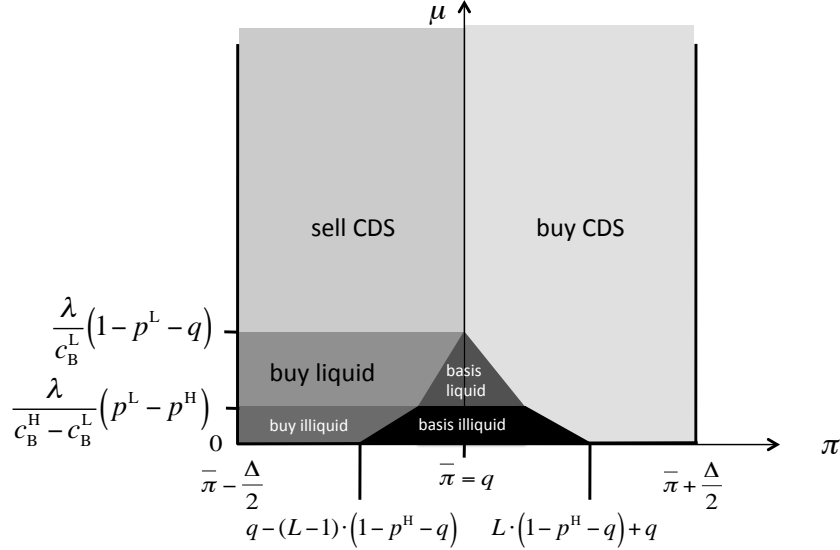

Figure 4: **Bond and CDS market equilibrium with two bonds of different liquidity.**
The figure illustrates the equilibrium when two bonds of different liquidity and a (more liquid) CDS are traded. Relative to the liquid bond, the illiquid bond is held by investors and basis traders with longer trading horizons. Because the two bonds are held by different investor clienteles, they are affected differently by CDS introduction. The liquid bond is disproportionately affected by the crowding out effect of the CDS market, the illiquid bond benefits disproportionately from the emergence of basis traders. The illiquid bond therefore benefits more from CDS introduction.

Figure 5 illustrates the price effect of CDS introduction on two bonds of differing liquidity for specific parameter values. When basis trader leverage is sufficiently small ($L < L^*$), CDS introduction reduces the price of both the liquid and the illiquid bond. However, because the liquid bond is affected more strongly by the crowding out effect of the CDS, the price of the liquid bond drops by more than the price of the illiquid bond. For an intermediary range of basis trader leverage ($L^* < L < L^{**}$), the prices of the two bonds move in opposite directions when the CDS is introduced—the illiquid bond benefits from CDS introduction, while the price of the liquid bond decreases. Finally, when basis

trader leverage is sufficiently high ($L > L^{**}$), the prices of both bonds increase in response to CDS introduction, but the price of the illiquid bond increases by more then the price of the liquid bond.
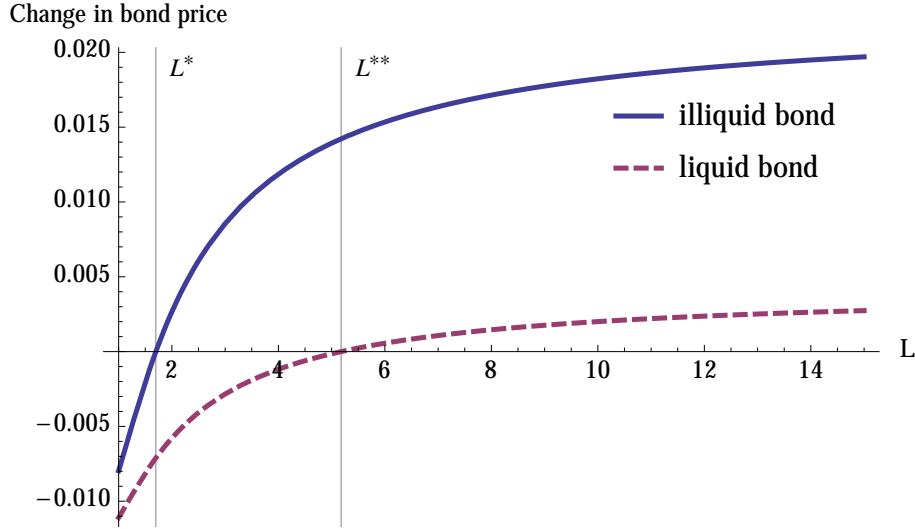

Figure 5: **Price change of liquid and illiquid bond due to CDS introduction**

This figure illustrate the price change for a liquid and an illiquid bond in response to CDS introduction, as a function of basis trader leverage L. For low levels of basis trader leverage, both bond prices drop in response to CDS introduction, but the price of the illiquid bond drops by less. For an intermediary range of basis trader leverage, the price of the illiquid bond increases but the price of the liquid bond decreases in response to CDS introduction. When basis trader leverage is sufficiently high, both bond prices increase, but the price of the illiquid bond increases by more when the CDS is introduced. Parameters: $S^H = 0.2$, $S^L = 0$ $c^H = 0.02$, $c^L = 0.01$, $\bar{\pi} = 0.1$, $\Delta = 0.1$, $\lambda = 0.2$. Note that the supply of the liquid bond is set to zero simply because it allows for a particularly tractable way to solve for bond prices when two bonds are trading.

Formally, we can summarize the results on CDS introduction in the presence of two bonds in the following proposition.

Proposition 4. *The effect of CDS introduction on liquid and illiquid bonds of the same issuer. Assume an issuer has a liquid and an illiquid bond outstanding, with trading costs c_B^L and $c_B^H > c_B^L$, respectively. The price change from CDS introduction is larger for the illiquid bond than for the liquid bond,*

$$p_{withCDS}^H - p_{noCDS}^H > p_{withCDS}^L - p_{noCDS}^L. \tag{12}$$

Hence, the illiquid bond is more likely to benefit from CDS introduction than the liquid bond.

Proposition 4 makes the empirical prediction that for firms that have multiple bond issues, the price effects of CDS introduction should differ for bonds of differing liquidity, with more illiquid bonds more likely to benefit from CDS introduction. Because of the relative price changes in response to CDS introduction, the availability of a CDS may affect the types of bonds that firms issue. In particular, because more illiquid bonds benefit disproportionately from CDS introduction, this may lead firms to issue more of these types of bonds. For example, to the extent that liquidity arises from custom tailoring bonds to particular investor clienteles, the presence of the CDS may allow firms to tailor their bonds more to particular holders, such as insurance companies or pension funds, given that the availability of the CDS allows them the take levered hedged positions. Similarly, the result in Proposition 4 provides a potential explanation of the finding that CDS introduction is associated with an increase in the average maturity at which firms borrow (Saretto and Tookes (2013)): Because longer maturity bonds are typically less liquid,[30] a larger positive price effect of CDS introduction on more illiquid bonds makes issuing long-term bonds more attractive.

4.4   CDS market with frictions ($c_{\mathrm{CDS}} > 0$)

In the analysis above, we focused on the particularly tractable case in which CDSs involve no trading costs ($c_{\mathrm{CDS}} = 0$). This assumption made solving for the equilibrium in the CDS market particularly easy because it ensured that $q = \overline{\pi}$, which allowed us to solve sequentially for equilibrium prices in the CDS and in the bond market. When $c_{\mathrm{CDS}} > 0$, on the other hand, we can no longer solve sequentially for the CDS price q and the bond price p. Rather, we have to solve jointly for the bond and CDS price pair (p, q). Because now also the CDS price reflects trading frictions it is generally the case that $q \neq \overline{\pi}$. While closed-form solutions are not available for this case, in this section we demonstrate the main economic results derived above continue to hold. An advantage of extending our model to $c_{\mathrm{CDS}} > 0$

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[30]For empirical evidence on the positive relationship between maturity and illiquidity of corporate bonds see Longstaff, Mithal, and Neis (2005), Chen, Lesmond, and Wei (2007), Edwards, Harris, and Piwowar (2007), and Bao, Pan, and Wang (2011).

is that it allows us to link our findings more precisely to empirical evidence that has investigated the role of CDS market liquidity on pricing in the bond market.

Figure 6 illustrates the effect of introducing trading costs also in the CDS market. In contrast to the frictionless CDS case, it is no longer the case that all investors for which $\pi_i < \bar{\pi}$ are willing to sell CDS protection and that all investors with $\pi_i > \bar{\pi}$ are willing to purchase CDS protection. The "sell CDS" and "buy CDS" regions are now triangles—rather than rectangles as in Figures 2 and 3—because some investors now prefer to stay out of the market altogether and hold cash.

Despite these differences, the main qualitative results derived in the frictionless CDS setting above remain valid. As before, the introduction of a CDS affects the bond market through three effects: (i) the CDS crowds out some long bondholders, (ii) the CDS eliminates short sellers, and (iii) the CDS leads to the emergence of hedged, potentially leveraged basis traders. As in the frictionless model, basis traders are price neutral when $L = 1$, whereas basis traders exert upward pressure on the bond price when they can take leverage $L > 1$.

Proposition 5. *CDS introduction when also the CDS market is subject to trading costs.*
When also the CDS market is subject to trading costs ($0 < c_{CDS} \leq c_B$), then:

- *the CDS is redundant when $c_{CDS} = c_B$,*

- *for c_{CDS} sufficiently close to but less than c_B, CDS introduction leads to a reduction in the bond price,*

- *for CDS introduction to raise bond price, (i) there must be a sufficient difference in liquidity between the CDS and the bond and (ii) basis traders have to be able to take sufficient leverage.*

Proposition 5 highlights that the main trade-off between a crowding-out effect and an improvement in the allocation of the bond to investors with longer holding horizons survives also in the case when $c_{\text{CDS}} > 0$: The bond market benefits from CDS introduction only if the bond and the CDS are sufficiently different with respect to their trading costs and when basis traders can take on sufficient leverage.
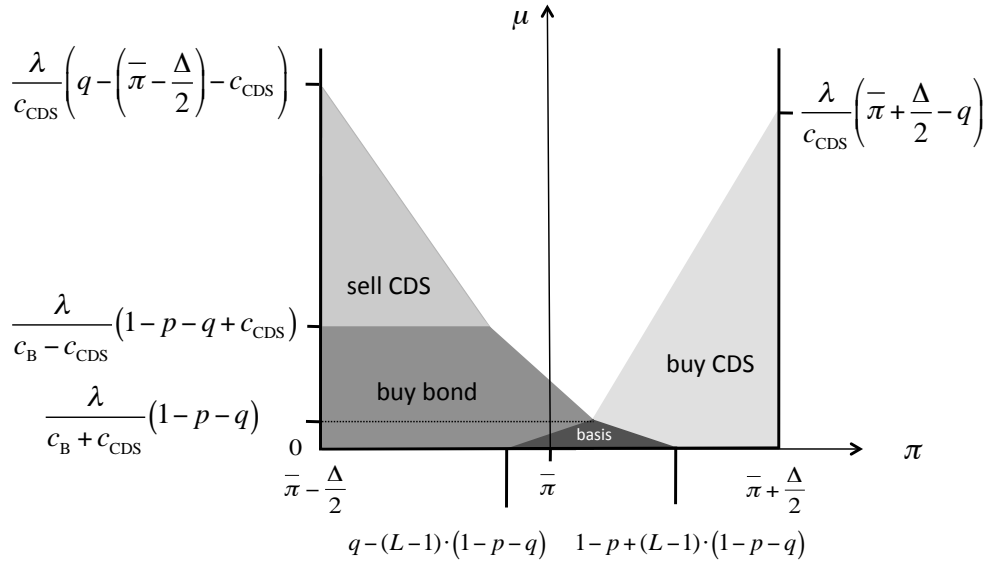
31

Figure 6: **Bond and CDS market equilibrium when $c_{\text{CDS}} > 0$ and $L > 1$**

The figure illustrates the equilibrium when also the CDS involves trading frictions ($c_{\text{CDS}} > 0$) and basis traders can take leverage ($L > 1$). Compared to Figure 3 (where $c_{\text{CDS}} = 0$) the "sell CDS" and "buy CDS" regions are now triangles, reflecting higher expected CDS trading costs for investors with more frequent trading needs (higher μ). As in the case with frictionless CDS, the introduction of the CDS has three effects: (i) Some investors who absent the CDS would purchase the bond now choose to sell CDS protection, cutting of the top of the bond buying triangle. (ii) Because of the negative CDS-bond basis, all former short sellers prefer to purchase a CDS, which eliminates the shorting triangle. (iii) Basis traders (who purchase the bond and buy CDS protection) emerge, putting upward pressure on the bond price.

This is illustrated in the left panel of Figure 7, which plots the effect of CDS introduction on the bond price as a function of the CDS trading cost c_{CDS}. Each of the three lines in the plot corresponds to different levels of basis trader leverage L. When the CDS has the same trading cost as the bond ($c_{\text{CDS}} = 0.02$), the CDS is redundant and CDS introduction has no effect on the price of the bond.[31] When c_{CDS} is slightly smaller than the bond trading cost, the crowding-out effect of the CDS dominates and CDS introduction leads to a decrease in the bond price, independent of the amount of leverage that basis traders can take. However, as the liquidity differential between the bond and the CDS

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[31]More generally, the CDS is redundant in our framework whenever CDS trading costs are weakly larger than trading costs in the bond.

widens, basis traders emerge in equilibrium. When basis traders can take leverage (the figure depicts $L = 3$ and $L = 20$), they improve the allocation in the bond market and put upward pressure on the bond price. For the parameter values in this example, basis trader leverage of $L = 3$ is not sufficient to generate an increase in the bond price, even as c_{CDS} approaches 0. When $L = 20$, on the other hand, CDS introduction increases the bond price when the CDS trading cost c_{CDS} is sufficiently small. The right panel illustrates the associated equilibrium CDS-bond basis. When calculated at ask prices,[32] the CDS-bond basis is positive when c_{CDS} is sufficiently close to c_{CDS}. In this region, basis traders are not active. Once c_{CDS} is sufficiently smaller than c_{B}, the basis becomes negative and basis traders enter. As the Figure illustrates, the more leverage basis traders can take, the more aggressively they lean against the negative CDS-bond basis and compress it towards zero.

The prediction that a more liquid CDS market makes it more likely that CDS introduction has a positive effect on bond prices is indeed borne out in the data. Ashcraft and Santos (2009) show that, while there is no reduction in funding costs for average firms in response to CDS introduction, firms whose CDSs become liquid experience a reduction in the cost of bank loans, which, just like bonds, are less liquid than CDS contracts.[33] Nashikkar, Subrahmanyam, and Mahanti (2011) show that bonds of firms that have more liquid CDS contracts have lower yields than those of firms for which the associated CDS is less liquid even after controlling for bond and issuer characteristics. Finally, using Asian CDS and bond data, Shim and Zhu (2014) find that firms with more liquid CDSs face lower costs in primary bond markets.

Economically speaking, the prediction that sufficiently liquid CDS markets can improve the allocation in the bond market provides an interesting angle on the recent discussion on standardization in the bond market. For example, in a recent proposal, BlackRock (2013) argues for more standardized corporate bonds in order to improve liquidity in the secondary bond market. However, as some have argued, such standardization may come at the expense of tailoring bond issues to particular clienteles.

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[32]We calculate the basis at ask prices because this reflects the tradeable strategy of a negative basis trader who has to purchase both the bond and the CDS at ask prices.

[33]Ashcraft and Santos do not find the same effect when looking at at-issue bond spreads, which they attribute to lack of data.
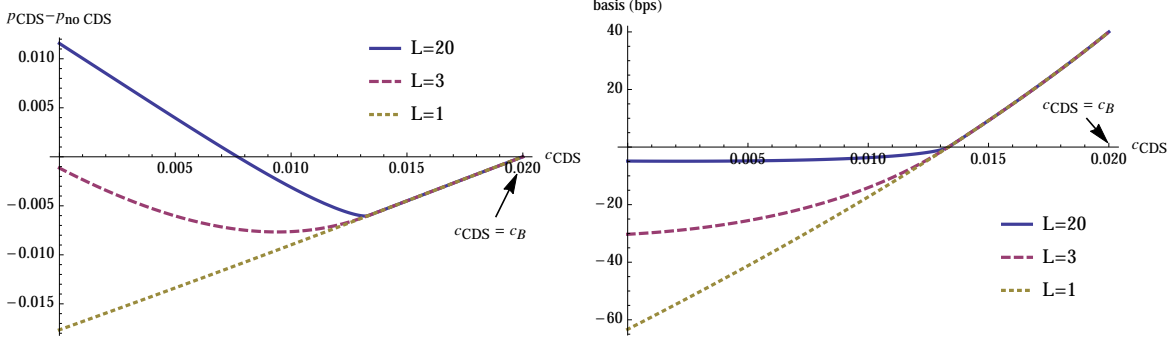
Figure 7: **Price effect of CDS introduction and CDS-bond basis when $c_{CDS} > 0$**

The **left panel** shows the bond price change in response to CDS introduction as a function of the CDS trading cost c_{CDS}. The CDS is redundant when $c_{CDS} = c_B$ and reduces the bond price when the bond and the CDS have similar liquidity. When the CDS is sufficiently more liquid than the bond, CDS introduction can increase the bond price if basis traders can take sufficient leverage. The **right panel** illustrates the CDS-bond basis. When the CDS trading cost c_{CDS} is close to the bond trading cost c_B, the basis (calculated at ask prices) is slightly positive, but no basis traders are active. When the CDS is sufficiently more liquid than the bond, the basis becomes negative and basis traders become active and lean against the basis. Parameters: $S = 0.2$, $c_l = 0.02$, $\bar{\pi} = 0.1$, $\Delta = 0.12$, $\lambda = 0.2$, uniform investor distribution.

Our analysis suggests that a liquid CDS market can lead to benefits similar to those of bond standardization, while still allowing issuers to cater their bond issues to specific investor clienteles. Hence, the introduction of a liquid zero net supply derivative can be seen as a "backdoor" way to some of the benefits of bond standardization.

5   Policy Implications

In this section, we apply our framework to analyze a number of policy interventions in the CDS market. Specifically, we consider the effects of (i) banning naked CDS positions (as recently implemented by the European Union with respect to sovereign bonds), (ii) banning CDS markets altogether, and (iii) banning both CDSs and short positions in bonds. The motivation for such interventions is usually to achieve a reduction in bond yields (and thereby borrowing costs) for issuers. While our simple framework is not rich enough to yield detailed policy prescriptions, it does suggest that the effects of such interventions on bond yields can be subtle and can potentially go in the "wrong" direction

(i.e., contrary to the policymaker's objective such interventions can in fact increase borrowing costs for issuers).[34]

5.1 Banning naked CDS positions

EU regulation No 236/2012, in effect since November 1, 2012, bans purchasing CDS protection as a means of speculation on sovereign bonds. Specifically, the regulation allows CDS purchases for market participants who own the underlying bond or have other significant exposure to the sovereign, but restrict so-called naked CDS positions. Short selling of the bond is allowed under this regulation as long as the short seller is able to borrow the bond before executing the short sale.

The crucial question in assessing the effect of a ban on naked CDS positions is what investors who were previously holding naked CDS protection choose to do instead. Our framework suggests that there are three effects, which are illustrated in Figure 8: First, some of these investors switch from a naked CDS position to a short position in the bond. Hence, as a result of a ban on naked CDSs, short sellers reappear, putting downward pressure on the bond price. Second, some investors who formerly held a naked CDS position become basis traders and hold the bond and the CDS, up to the maximum leverage L. This second effect increases demand for the bond, resulting in upward pressure on the bond price. Third, some investors that previously held naked CDS protection switch to simply holding cash.

The effect of banning naked CDS positions on the cost of borrowing therefore depends on the relative size of these effects and without further restrictions, can go in either direction. We illustrate this in Figure 9: since closed form solutions are not possible, we resort to numerical solutions. The left panel illustrates the effect of a naked CDS ban on the bond spread (solid line) and the CDS spread (dashed line), plotted as a function of the bond trading cost c_{B}. In this case, the naked CDS ban generally leads to a decrease in both bond and CDS spreads. The decrease in spreads is larger, the

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[34]While our framework allows us to investigate the positive effects of certain policy interventions, it does not allow us to determine whether a given policy objective (such as a reduction in yields) is desirable from a normative perspective. This reflects the well-known difficulty of making welfare statements in models with heterogeneous beliefs.
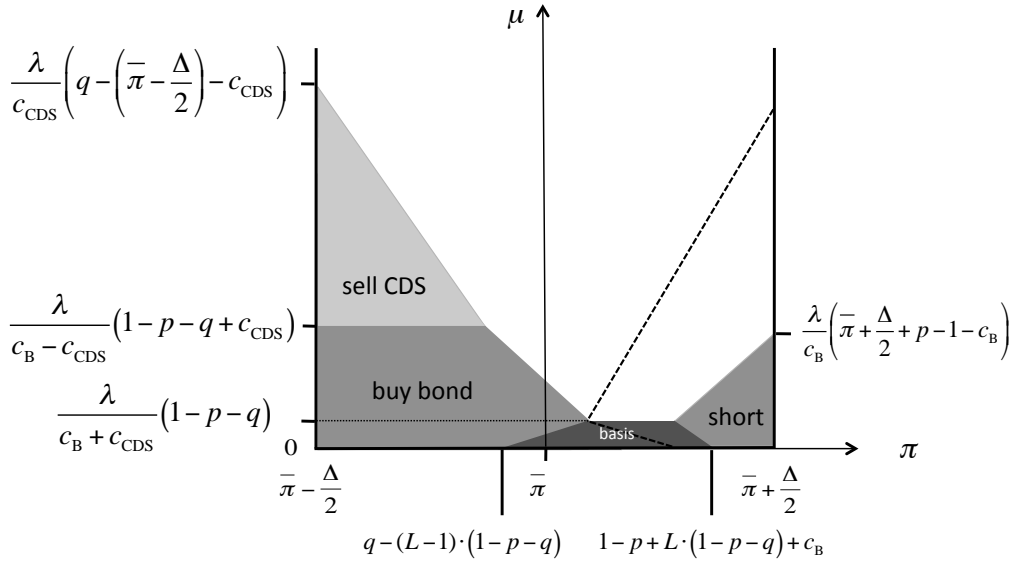
Figure 8: **Banning naked CDS when $c_{CDS} > 0$ and $L > 1$**

The figure illustrates the equilibrium when naked CDS positions are banned. Compared to Figure 6, which depicts the same setup except that naked CDS positions are allowed, there are two major changes. Some investors who used to purchase naked CDS protection now choose to short the bond, exerting downward pressure on the bond price. Some investors who used to purchase naked CDS protection now become basis traders, which exerts upward pressure on the bond price. The dashed line shows the position of CDS buyers and basis traders before the ban (assuming unchanged prices).

more illiquid the underlying bond, whereas the effect of the naked CDS ban are relatively small when the bond is relatively liquid. Moreover, when the bond and the CDS are sufficiently similar in terms of their liquidity, the naked CDS ban eliminates the CDS market altogether. The right panel illustrates a similar example, except that the investor distribution in this example has more mass at low levels of μ_i (i.e., there are more investors with longer holding horizons). In this case, the naked CDS ban still unambiguously reduces the CDS spread, but for low levels of c_B is may lead to an increase in the bond spread, thereby raising the issuer's financing costs. Moreover, even in the region where the naked CDS ban reduces the bond spread, in this example the bond spread is significantly less sensitive to the naked CDS ban than the CDS spread.
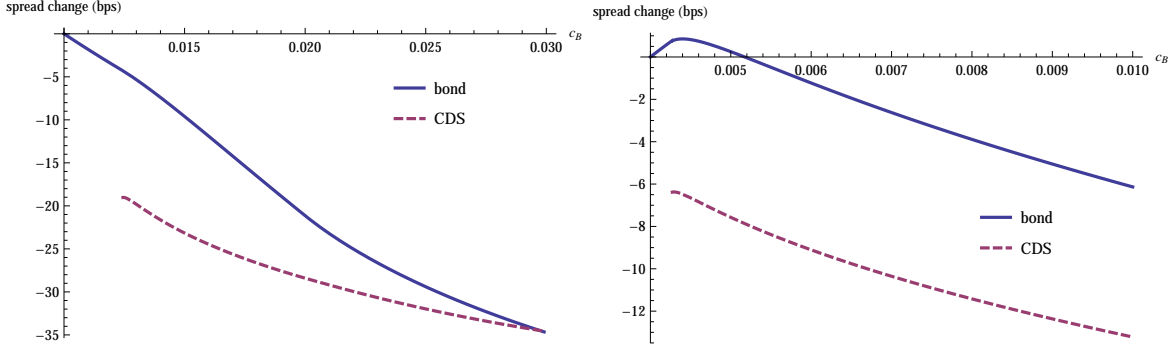
Figure 9: **Effect of naked CDS ban on bond and CDS spreads.**
The **left panel** illustrates the effect of a naked CDS ban on bond and CDS spreads under the uniform investor distribution, as a function of the bond trading cost c_{B}. The remaining parameters are $S = 0.2$, $c_{\text{CDS}} = 0.01$, $\bar{\pi} = 0.1$, $\Delta = 0.10$, $\lambda = 0.2$, and $L = 5$. For c_{B} close to c_{CDS}, the CDS market does not exist after the ban, such that the CDS spread change is missing. The **right panel** illustrates the effect of a naked CDS ban on bond and CDS spreads with an additional mass of 2 of investors with long trading horizons uniformly distributed along $\mu = 0$. The remaining parameters are $S = 1.25$, $c_{\text{CDS}} = 0.004$, $\bar{\pi} = 0.1$, $\Delta = 0.10$, $\lambda = 0.2$ and $L = 5$. For c_{B} close to c_{CDS}, the CDS market does not exist after the ban, such that the CDS spread change is missing.

Figure 9 has two main implications. First, bond spreads and CDS spreads are not affected by the naked CDS ban in a one-for-one fashion. Hence, reductions in CDS spreads in response to a naked CDS ban do not necessarily translate one for one into reductions in borrowing costs. Second, it is possible for bond and CDS spreads to move in opposite directions in response to a naked CDS ban, such that borrowing costs for issuers may rise even if the ban results in lower CDS spreads. These predictions are generally consistent with the evidence in the report by the European Securities and Markets Authority on the naked CDS ban in Europe (ESMA (2013)). Specifically, while the report finds a modest 26 basis point reduction in CDS spreads in response to the ban on naked CDS positions, it finds no evidence that EU sovereign bond yields dropped as a result of the naked CDS ban. Finally, note that our model identifies the channel that can render a naked CDS ban ineffective in lowering bond yields: the re-emergence of short sellers. Hence, in order to guarantee a reduction in borrowing costs, a ban on naked short selling needs to be combined with restrictions on short selling.

5.2 Banning the CDS market altogether

The second policy intervention we consider is an outright ban of the CDS market. This amounts to a comparison of the equilibrium with a CDS market to the equilibrium without CDS. From Proposition 1, we know that the effect of CDS introduction on the bond yield is ambiguous. Hence, banning CDS markets altogether may either increase or decrease borrowing costs for issuers, depending on the size of the effects described in Sections 4.1 and 4.4. Accordingly, a ban on CDSs is more likely to lead to a reduction in funding costs of the liquidity of the bond and the CDS market are similar and when basis traders are restricted in the amount of leverage they can take.

5.3 Banning CDSs and short selling in the bond

Finally, we briefly consider the effect of banning both the CDS market and short positions in the bond. This intervention amounts to a comparison of the bond and CDS market equilibrium market described in Proposition 1 to a setting where only long positions in the bond are allowed and no CDS is available.[35] Perhaps surprisingly even this intervention is not guaranteed to lower bond yields for issuers. While restricting short positions prevents the reemergence of short sellers in response to a ban on CDS positions, a trade-off now emerges from the countervailing effects of (i) increased demand for the bond from investors who formerly sold the CDS but now purchase the bond and (ii) the reduction in demand for the bond that results from the elimination of basis traders. Because basis traders are price neutral when they cannot take leverage ($L = 1$), in this case a joint ban on CDSs and short selling leads to an unambiguous decrease in the bond yield. When basis traders can take leverage, on the other hand, bond yields may increase or decrease, depending on the relative size of the two effects.

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[35]This long-only case can be solved analogously to the no-CDS case in Lemma 1. The main difference is that the shorting triangle in Figure 1 would disappear. Market clearing then requires that demand from the buying triangle equals bond supply.

6 Conclusion

This paper provides a liquidity-based model of CDS markets, bond markets and their interaction. In our framework, CDSs are non-redundant because they are more liquid than the underlying bonds. Our model shows that the introduction of a CDS affects the underlying bond market in a non-trivial way and identifies a fundamental trade-off between a crowding-out effect (the CDS crowds out demand for the bond) and an improvement in the allocation in the bond market (the CDS leads to the emergence of levered basis traders, which allows long-term investors to hold more of the illiquid bond).

CDS introduction is more likely to raise the prices of the underlying bond when there is a significant liquidity difference between the bond and the CDS, and when hedged basis traders can take substantial leverage. For firms with multiple bond issues, more illiquid bonds (such as off-the-run bonds or custom-tailored issues) are more likely to benefit from CDS introduction. Beyond characterizing the impact of CDS introduction on the pricing of the underlying bond, the model also generates empirical predictions regarding trading volume in bond and CDS markets, as well as the cross-sectional and time-series properties of the CDS-bond basis. It therefore provides an integrated framework that matches many of the stylized facts in bond and CDS markets. Finally, our framework can be used to assess a number of policy measures related to CDS markets, such as the recent E.U. ban on naked CDS positions.

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A   Proofs

Proof of Lemma 1. We focus in the case in which, in the absence of the CDS, both long and short positions in the bond emerge in equilibrium. This requires that the supply of the bond is not too large, $S < \frac{1}{2} \frac{\lambda}{c_B} \frac{(\Delta - c_B)^2}{\Delta}$. Evaluating the zero valuation line of a long bond position, $V_{\text{longBOND},i} = 0$, at $\mu_i = 0$ and $\pi_i = \bar{\pi} - \frac{\Delta}{2}$ yields a rectangular "buy" triangle with base $1 - p - (\bar{\pi} - \frac{\Delta}{2})$ and height $\frac{\lambda}{c_B} \left(1 - p - (\bar{\pi} - \frac{\Delta}{2})\right)$. Evaluating the zero valuation line of a short bond position, $V_{\text{shortBOND},i} = 0$, at $\mu_i = 0$ and $\pi_i = \bar{\pi} + \frac{\Delta}{2}$ yields a rectangular "buy" triangle with base $\bar{\pi} - \frac{\Delta}{2} - (1 - p + c_B)$ and height $\frac{\lambda}{c_B} \left(\bar{\pi} - \frac{\Delta}{2} - (1 - p + c_B)\right)$. Given the uniform investor distribution $f = 1/\Delta$, market clearing then requires that

$$\frac{1}{\Delta} \left[\frac{1}{2} \frac{\lambda}{c_B} \left(1 - p - \left(\bar{\pi} - \frac{\Delta}{2}\right)\right)^2 - \frac{1}{2} \frac{\lambda}{c_B} \left(\bar{\pi} - \frac{\Delta}{2} - (1 - p + c_B)\right)^2 \right] = S, \tag{A1}$$

which yields

$$p_{\text{noCDS}} = 1 - \bar{\pi} + \frac{c_B}{2} - \frac{c_B}{\lambda} \frac{\Delta}{\Delta - c_B} S. \tag{A2}$$

Proof of Lemma 2. Given that for any finite μ there is an infinite mass of investors willing to buy and sell the CDS at $q = \bar{\pi}$, the CDS price is pinned down at $q = \bar{\pi}$ irrespective of pricing in the bond markets. This allows us to solve sequentially for prices in the CDS and the bond market. When a CDS priced at $q = \bar{\pi}$ is available, solving $V_{\text{sellCDS},i} > V_{\text{longBOND},i}$ for μ_i show that any investor with $\mu_i > \frac{\lambda}{c_B}(1 - p - q)$ strictly prefers selling a CDS to taking a long position of the bond. Moreover, comparing the payoff from a negative basis trade $L \cdot (V_{\text{sellCDS},i} + V_{\text{shortBOND},i})$ to $V_{\text{longBOND},i}$ and $V_{\text{buyCDS},i}$ yields a basis trade triangle with base $(2L - 1)(1 - p - q)$ and height $\frac{\lambda}{c_B}(1 - p - q)$. Note that, for simplicity, we focus on the case in which the basis trader region is a triangle (i.e., it does not extend to $\pi_i = \bar{\pi} + \frac{\Delta}{2}$), which requires that $S \leq \frac{\Delta\lambda(2L^2+1)}{8L^2 c_B}$. This conditions is satisfied when the bond supply S and basis trader leverage L are not too large. The opposite case could be treated in a similar fashion, but we omit it for brevity as it does not yield any additional insights.

Market clearing in the bond market requires that the demand from long bond investors (the "buy bond trapezoid") and basis traders (the "basis trader triangle") equals the supply of the bond (as discussed in the text, buying CDS protection dominates short selling, such that no short sellers appear):

$$\frac{1}{\Delta} \left\{ \frac{1}{2} \left[q - \left(\bar{\pi} - \frac{\Delta}{2}\right) + q - (L-1)(1 - p - q) - \left(\bar{\pi} - \frac{\Delta}{2}\right) \right] \left(\frac{\lambda}{c_B}(1 - p - q)\right) + \frac{1}{2} \frac{\lambda}{c_B}(2L - 1)(1 - p - q)^2 \right\} = S, \tag{A3}$$

which yields

$$p_{\text{withCDS}} = 1 - \overline{\pi} - \frac{\Delta}{2} \frac{\sqrt{1 + 8\Phi \frac{c_{\text{B}}}{\lambda} \frac{S}{\Delta}} - 1}{\Phi}, \tag{A4}$$

where we define $\Phi \equiv 1 + 2L(L-1)$.

Proof of Proposition 1. The bond price change in response to CDS introduction can be calculated directly from Lemmas 1 and 2:

$$p_{\text{withCDS}} - p_{\text{noCDS}} = -\frac{c_{\text{B}}}{2} + \frac{c_{\text{B}}}{\lambda} \frac{\Delta}{\Delta - c_{\text{B}}} S - \frac{\Delta}{2} \frac{\sqrt{1 + 8\Phi \frac{c_{\text{B}}}{\lambda} \frac{S}{\Delta}} - 1}{\Phi}. \tag{A5}$$

The comparative statics then follow from differentiating the price change with respect to L, Δ and c_{B}.

Proof of Corollary 1. The result follows directly from $\lim_{L \to \infty} p_{\text{withCDS}} = 1 - \overline{\pi}$.

Proof of Proposition 2. The introduction of a CDS market changes the bond holding regions in three ways, all of which lead to lower bond turnover (see Figure 2). The elimination of the shorting triangle unambiguously decreases bond trading. However, the amount of bonds outstanding S is unchanged, thus turnover decreases. Also, of the remaining bond buyers (including basis traders) even those with the highest trading frequency have a lower trading frequency than the bond buyers that have been eliminated through introduction of the CDS (above the horizontal line). Because the overall required number of bond buyers decreases (the CDS eliminates short selling), the mass of low turnover investors added to the bond buyers (if any), is smaller than the mass of former bond buyers who are crowded out into the CDS market. Since these new bond buyers all have a lower trading frequency than the bond investors crowded out by the CDS market, the amount of equilibrium trading diminishes. Because the bond supply S is unchanged, turnover in the bond market decreases.

The trading frequency of all investors selling the CDS is higher than the trading frequency of any investor buying the bond either through a long only trade or a basis trade (see Figure 2). Since turnover is calculated as CDS trading over open interest (either short or long), the average turnover from CDS sellers is a lower bound on the turnover of CDS. Trades from CDS buyers further add to the higher turnover of CDS. Thus, turnover of the CDS is unambiguously higher than that of the bond.

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To compare price impact with and without the CDS, we can use the expressions in Lemmas 1 and 2 to calculate

$$\left| \frac{dp_{\text{noCDS}}}{dS} \right| = \frac{c_{\text{B}}}{\lambda} \frac{\Delta}{\Delta - c_{\text{B}}} \tag{A6}$$

$$\left| \frac{dp_{\text{withCDS}}}{dS} \right| = \frac{c_{\text{B}}}{\lambda} \frac{2}{\sqrt{1 + 8\Phi \frac{c_{\text{B}}}{\lambda} \frac{S}{\Delta}}}, \tag{A7}$$

which implies that price impact is lower in the presence of the CDS if

$$\frac{\Delta}{\Delta - c_{\text{B}}} > \frac{2}{\sqrt{1 + 8\Phi \frac{c_{\text{B}}}{\lambda} \frac{S}{\Delta}}}, \tag{A8}$$

where, as before, $\Phi \equiv 1 + 2L(L-1)$. This condition is satisfied if either basis trader leverage L or bond supply S are sufficiently large.

Proof of Proposition 3. As discussed in the main text, basis $= -\lambda(1 - p - q)$. Inserting $p = p_{\text{withCDS}}$ and $q = \pi$ yields

$$\text{basis} = -\lambda \frac{\Delta}{2} \frac{\sqrt{1 + 8\Phi \frac{c_{\text{B}}}{\lambda} \frac{S}{\Delta}} - 1}{\Phi} \leq 0, \tag{A9}$$

where, as before, $\Phi \equiv 1 + 2L(L-1)$. The comparative statics follow from differentiating the basis with respect to S, L, c_{B}, and Δ.

Proof of Proposition 4. The first part of the proof is based on a geometric argument using Figure 10, which illustrates the equilibrium with two bonds before the CDS is introduced. The strategy of the proof is to consider how the equilibrium allocation and equilibrium prices have to change once the CDS is introduced.

Assume for now that basis traders cannot take leverage (L=1) and consider the effect of CDS introduction. Under the uniform investor distribution and $L = 1$, the crowding out effect of CDS introduction dominates the elimination of short sellers. Hence, at pre-CDS prices there is insufficient demand for the liquid bond once the CDS is available. Now consider lowering the price of the liquid bond p^L holding constant the price differential between the two bonds, $p^L - p^H$. We now lower p^L (and thus also p^H) in this fashion until the liquid bond market clears. However, now the market for the illiquid bond cannot clear. Because we held $p^L - p^H$ fixed when lowering the price of the liquid bond, we also lowered the price of the illiquid bond, shifting to the right the boundary of the illiquid bond trapezoid. For the illiquid bond market to clear, we now move downward the liquid bond trapezoid, holding its area fixed, until also the market for the illiquid bond clears. This requires that
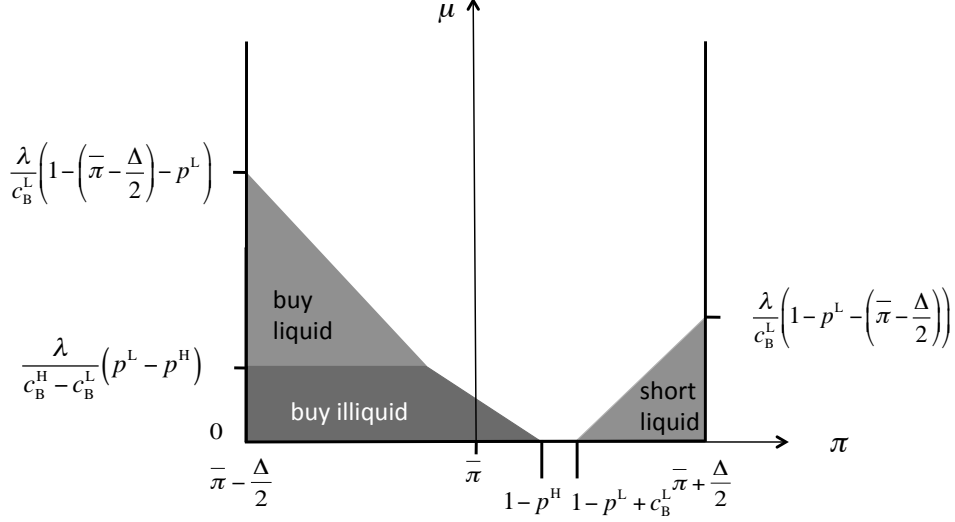
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Figure 10: **Equilibrium with two bonds before CDS introduction.**

$p^L - p^H$ decreases, because the boundary between the liquid bond trapezoid and the illiquid bond trapezoid is given by $\mu = \frac{\lambda}{c_B^H - c_B^L}(p^L - p^H)$. Hence, given $L = 1$, when CDS introduction reduces the price of the liquid bond (as is the case under the uniform investor distribution), then the illiquid bond drops by less than the liquid bond: $p_{\text{withCDS}}^L - p_{\text{noCDS}}^L < p_{\text{withCDS}}^H - p_{\text{noCDS}}^H < 0$.

Having shown that when $L = 1$, the illiquid bond price drops less when the CDS is introduced, we now show that the illiquid bond increases faster in basis trader leverage than the price of the liquid bond. To do this, we solve for the equilibrium prices of the two bonds under the uniform investor distribution in the presence of a frictionless CDS, allowing for $L \geq 1$. Following a similar procedure as before, the equilibrium bond prices are given by

$$p_{\text{withCDS}}^H = 1 - \overline{\pi} - \frac{\Delta}{2} \frac{\sqrt{1 + 8\Phi \frac{S^H c_B^H + S^L c_B^L}{\lambda \Delta}} - 1}{\Phi} \tag{A10}$$

and

$$p_{\text{withCDS}}^L = 1 - \overline{\pi} - \frac{\Delta}{2} \frac{\frac{c_B^L}{c_B^H}\sqrt{1 + 8\Phi \frac{S^H c_B^H + S^L c_B^L}{\lambda \Delta}} + \left(1 - \frac{c_B^L}{c_B^H}\right)\sqrt{1 + 8\Phi \frac{S^L c_B^L}{\lambda \Delta}} - 1}{\Phi} \tag{A11}$$

where we define $\Phi \equiv 1 + 2L(L-1)$. Differentiating these expressions with respect to L, we see that the illiquid bond profits more from basis trader leverage:

$$\frac{\partial p^H_{\text{withCDS}}}{\partial L} > \frac{\partial p^L_{\text{withCDS}}}{\partial L} > 0. \tag{A12}$$

Proof of Proposition 5. To show that the CDS is redundant when $c_{\text{CDS}} = c_{\text{B}}$, we note that when c_{CDS} is sufficiently close to c_{B} there are no basis traders. In this case, we can solve for the equilibrium prices in closed form:

$$p_{\text{withCDS}} = 1 - \bar{\pi} + \frac{\Delta}{2} + \frac{c_{\text{CDS}}(\Delta - c_{\text{CDS}})}{4(c_{\text{B}} - c_{\text{CDS}})} - \frac{2c_{\text{B}} - c_{\text{CDS}}}{4(c_{\text{B}} - c_{\text{CDS}})}\sqrt{(\Delta - c_{\text{CDS}})^2 + 8\Delta\frac{S}{\lambda}(c_{\text{B}} - c_{\text{CDS}})} \tag{A13}$$

$$q = \bar{\pi} + \frac{c_{\text{CDS}}}{2} - \frac{c_{\text{CDS}}(\Delta - c_{\text{CDS}})}{4(c_{\text{B}} - c_{\text{CDS}})} + \frac{c_{\text{CDS}}}{4(c_{\text{B}} - c_{\text{CDS}})}\sqrt{(\Delta - c_{\text{CDS}})^2 + 8\Delta\frac{S}{\lambda}(c_{\text{B}} - c_{\text{CDS}})} \tag{A14}$$

Taking the limit of (A13) as $c_{\text{CDS}} \to c_{\text{B}}$ shows that the derivative is redundant when CDS and bond trading costs are equal, which establishes the first part of the proposition. Differentiating (A13) with respect to c_{CDS} and evaluating the derivative at $c_{\text{CDS}} = c_{\text{B}}$ yields

$$\left. \frac{dp_{\text{withCDS}}}{dc_{\text{CDS}}} \right|_{c_{\text{CDS}} = c_{\text{B}}} > 0, \tag{A15}$$

which establishes the second part of the proposition (i.e., a small reduction of CDS trading costs starting from $c_{\text{CDS}} = c_{\text{B}}$ reduces the bond price.) The final statement in the proposition follows from the observation that when $L = 1$ and when c_{CDS} is closet to c_{B}, CDS introduction unambiguously lowers the bond price. Hence, the only way for the CDS to raise the bond price is that the difference in liquidity between the bond and the CDS is sufficiently large and the basis traders can take sufficient leverage.