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Market Signals and the Cost of Credit Risk Protection: An Analysis of CDS Settlement Auctions

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Abstract

We study the link between the probability of default implied by Credit Default Swaps (CDS) spreads and the final prices of the defaulted bonds as established at the CDS settlement auctions. We observe that the post-default recovery rates at the observed spreads imply markets were often "surprised" by the credit event. We find that the prices of the bonds that are deliverable at the auctions imply probabilities of default that are systematically different than the default probabilities estimated prior to the event of default using standard methodologies. We discuss the implications for CDS pricing models. We analyze the discrepancy between the actual and theoretical CDS spreads and we find it is significantly associated both to the CDS market microstructure at the time of the settlement auction and to the general macroeconomic background. We discuss the potential for strategic bidding behavior at the CDS settlement auctions.

JEL Classification Numbers: G10, G14, G17

Keywords: Credit Default Swaps, Market signals, Derivative Markets.

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Contents

I. INTRODUCTION

During the past decade, derivatives known as Credit Default Swap or CDS have become one of the most actively quoted instruments in financial markets. In particular, CDS spreads have mostly replaced bond prices to signal market sentiment vis-à-vis single borrowers, be these corporations or sovereigns. One important, and often quoted, feature of these instruments is that they help isolate pure default risk of a single entity from other factors that may otherwise be affecting the prices of its bonded obligations such as liquidity, market microstructure etc. The relatively lower administrative burden associated with CDS trades have also made them a popular instrument in markets where other instruments are often subject to registration requirements.

Market quotes of CDS "spreads" have become a common measure of default risk. Based on market data, the pricing formulas allow estimating the implied default probabilities of single borrowers. These may then enter the decision making process of market participants and politicians alike. CDS spreads have become widely followed by professionals seeking to extract signals from market data on default probabilities, on liquidity conditions, and also on systemic risk (Acharya 2009). The number of empirical studies making use of CDS data has grown considerably in recent times, such as, Longstaff (2005), Zhang (2008) and Diaz (2013) among many others.

The objective of this paper is to study whether one of the general assumptions made on the models generally used to estimate default probabilities using CDS spreads is appropriate given post-default data. We also use post-default data to analyze whether the cost of credit risk protection quoted by the CDS market prior to the default reflected appropriately the probability of default as estimated using post-default data.

We thus compare the (*risk-neutral*) default probabilities calculated from CDS spreads through standard valuation models with the probability of default calculated using recovery rates as established by the final bond prices at CDS settlement auctions. We find that adjusting the estimations of the implied default probabilities for the actual recovery rates yields estimates of default probabilities that are significantly different than those estimated using standard assumptions. The implication is that, if quoted CDS spreads are computed using standard expected values on recoveries, market participants may be paying too little or too much for default protection than they would if the default probabilities were estimated using actual recovery values received at the auctions.

Some recent studies analyze whether the recovery values established at the auctions used to settle CDS claims are effective as mechanisms of price disclosure on the bonds underlying the CDS swaps.[2] We investigate the determinants of what we call the "excess spread", the difference we compute between the cost of protection CDS buyers should have been paying

[2] Examples are Chernov et al. (2014), who provide a theoretical model for the action process, and Du and Zhu (2013), Helwege et al (2009), and Gupta and Sundaram (2012), who empirically compare bond prices prior to the auction with the actual auction outcomes, sometimes including the bidding behavior at the auctions.

given the final bond prices and the actual CDS cost they were charged in the market. We observe "excess spreads" on the cross-section of default experiences where a CDS auction was held. We conclude that large miss-matches between demand and supply of bonds at the CDS settlement auctions may be biasing the final recovery prices of the bonds and thus generating the excess spreads. We also briefly discuss auction participants' payoffs and possible strategic behaviors that may be driving our results.

The rest of the paper is organized as follows: Section I briefly reviews the main characteristics of CDS contracts, the settlement auction mechanism and the main literature on credit event auctions. Section II describes the dataset and the recovery outcomes. Section III presents the econometric methodology and results. Section IV briefly draws some conclusions.

II. Brief review of CDS contracts and how they are priced

The term "CDS" refers to an agreement among two parties for the exchange of financial flows. One party agrees to pay a fixed pre-determined periodic amount over the length of the contract. The other party agrees to pay a lump sum only at the occurrence of a specified "credit event" of a third party nominated in the contract ("Reference Entity"). For the contract to exist, the third party or "Reference Entity" does need to have an outstanding obligation ("Reference Obligation") in the form of a bond or a syndicated loan. The "credit event" is legally defined in the CDS contract and encompasses different concepts of a "default".[3] Neither party of the CDS contract needs to hold a "Reference Obligation" in order to enter in the CDS contract, however the financial flows involved in the CDS contract replicate those generated by the holding of securities. For this reason CDS are derivative instruments.

The cost of a CDS, or premium, may be expressed as an annual amount in basis points.[4] Contracts are usually written for standard maturities, which are, most commonly, of one, three, and five years. Upon the occurrence of a default, a "credit event determination" decision is made by a particular committee of the International Swap and Derivative Association (ISDA) and the CDS settlement procedure takes place through a special "protocol". ISDA establishes the nature of the credit event and the list of deliverable obligations. The securities eligible for delivery are from a single class of debt (senior unsecured bonds, senior loans, and subordinated bonds). The lump sum payment due upon

[3] There are several different concepts of "default" in the legal literature and CDS contracts have evolved to incorporate different notions. The most common events are bankruptcy filings or Chap 11 filings in the US, failure to pay, and restructuring. The legal definition of restructuring in most complex and some CDS contracts effectively exclude restructurings.

[4] Following an ISDA standardization decision, in market quotes the cost of CDSs is many times expressed by the sum of points paid upfront and a "running spread" which has been standardized. For historical record keeping, data is stored in spread terms but the relationship between points and spread is simply related through the standard ISDA model. In other words, it is still possible to back out the "spread" from the points up front using the standard model and standard recovery assumption. In this study we will refer to the "spread" as the cost of the CDS they way it is kept in databases (rather than how it is quoted in the market) to simplify comparisons and for reference purposes.

the occurrence of a credit event is set to be equal to the par value of an outstanding obligation issued by the referenced third party, upon delivery of that obligation (or another obligation of similar characteristics).

In the early days of CDSs, after the determination of a credit event, the settlement of CDS contracts took place exclusively through the physical delivery of the reference obligation in exchange of the payment of the full face value amount. The payoff for the party holding the protection claim and the physical obligation will be equal to the face value of the bond less the recovery amount of the security in the market. The party offering the credit protection in exchange for the premium payment would have a cash outflow equal to the face value of the security but would be left holding an asset with a recovery value equal to the market value of the security. The recovery value implicit in the CDS contract (i.e. the value of the reference security after the event of default) was set entirely on the value the protection seller was able to obtain from the security following the settlement of the CDS contract.

However, as the market for CDSs developed, the value of outstanding CDS far outstripped the outstanding stock of debt of the reference entities and this cause issues and concerns at the time these claims had to be settled in the event of default (Helwege et al. 2009). The experience during the settlement of CDS contracts on Delphi in 2005 was particularly troublesome as the price of the defaulted bonds increased after the event of default. This occurred because many “naked” protection buyers sought to source the scarce deliverable bonds in the secondary markets. Not only did this give rise to distortions in the securities markets but also yielded highly different payoffs to the different market participants depending on the price they were able to source or sell the reference obligation (Helwege et al 2009).

Following such experiences, ISDA developed a process that aimed at avoiding physical delivery by uniquely establishing the recovery value for the reference obligation and ensure equal payoffs across CDSs buyers.[5] Once the recovery value is uniquely established, CDS contracts can be liquidated on a cash basis without the need to recur to physical delivery.

The procedure developed by ISDA, or “protocol”, first entails a decision on whether an entity has suffered a “credit event” and, following such determination, an auction of the bonds of the defaulted entity which are determined to be deliverable. In such auction, *all market agents who hold both the security and the protection claim and can participate* by asking to physically deliver the security to claim for the payment of the CDS. In addition, all those agents that have sold protection and require physical delivery of the CDS to settle their dues can ask to participate. All auction participants can require physical delivery of their respective derivative position but no more than that. This implies that a protection holder that

[5] ISDA has made efforts to harmonize procedures and practices with respect to CDS contracts. It first developed a Master CDS Agreement to standardize contracts. Then, as of 2006, ISDA instituted a protocol for CDS settlement. Whithin this protocol a special ISDA Committee (the credit determination committee) assesses wether an event of default has taken place and then publishes the procedures for the settlement of the claims and the list of deliverable obligations. With the help of Creditex, it was decided that the recovery value for the purposes of liquidation of CDS claims be established through an auction.

desires to settle physically through the auction can commit to deliver no more bonds than those covered by his or hers CDS contracts. This feature is designed to ensure that only CDS buyers with bond holdings participate in the auction and there will be no impact on bond prices from market players needing to source short positions. However, this feature also limits greatly access to the auction by interested parties that might otherwise submit buy or sell orders depending on their estimates of the underlying bond value following the auction.

The auction process occurs in two steps and is best illustrated in Creditex (2009) and Gupta and Sundaram (2012), Chernov (2014), Helwege et al (2009). In the auction process, potential bond buyers (CDS sellers) and sellers (CDS buyers) place their price quotes for bid/offers for the deliverable obligations and their volume requests for physical settlement. [6] An initial mid market point for the security's price is established as well as a Net Open Interest (NOI) for physical settlement requests.[7] In a second stage, buyers and sellers submit their limit orders for the security at the mid market point price. The orders are filled beginning with the higher/lowest price depending on whether the NOI was to buy/sell. The final price at which the NOI is exhausted is the adjusted price for the reference obligation. All CDS claims of agents participating in the auctions are liquidated through the auction mechanism. All other CDS contracts will be settled given the recovery value set at the auction for the reference obligation.

A. Pricing CDS contracts

To illustrate how the post-default recovery prices would influence the valuation of CDS contracts if they were known, we review the basics of the CDS pricing literature (Duffie 1999, Jarrow and Turnbull 1995, Hull and White 2000, etc.). The CDS contract is identical to a forward sale, by the CDS buyer, of the reference obligation at its face value: i.e. as if it was a default free bond, on the occurrence of a credit event. The CDS buyer or "protection holder" has the right to receive the face value of the reference obligation at a future undetermined date. The protection seller, who agrees to buy forward the obligation as if it were default free, will require to be compensated along the life of the contract for the potential payout it will have to face in the event of a default. The payment he will require should be equivalent to the difference between the market value of the defaulted security and its forward value. In financial terms, the amount of the compensation for the financial risk the protection seller holds will have to be exactly equal to the difference in the yields of a defaultable and default free security. Therefore, extent of the spread that the protection seller will charge will depend on the *risk-neutral* probability of default and also on the post default recovery value.

For the practical purpose of calculating the spread on a CDS contract, we will also remember that the value of every swap must be zero at inception for a market no-arbitrage condition.

[6] The bids/offers contain a certain, pre-established bid/ask spread, and the size of the orders.

[7] The Net Open Interest (NOI) is the net volume of bid (+) and offers (-). That is the only volume that is physically traded at the auction, as the rest is settled in cash.

For this condition to hold, the present value of the stream of payments by the CDS buyer (protection holder) must be equal to the present value of the lump sum payment of the CDS seller (protection seller). As long as the reference entity survives, the CDS buyer will face a pre-established flow of payments, the lump sum payment of the protection seller will occur at an uncertain date and only if the reference entity defaults. We adopt the framework developed by Duffie (1999), Jarrow and Tornbull (1995), Hull and White (2000) and used by the Bloomberg-developed software to derive the CDS pricing equation. Since these are the most common valuation methods, it is most likely that pricing signals will be extracted by using this methodology.

We note that the CDS buyer will be facing a constant stream of payments S_T, (the CDS spread) for the life of the contract (T) as long as *RE*, reference entity survives. If we assume that *RE* has a probability P_t of defaulting at time *t* and a probability $(1- P_t)$ of surviving until *t,* the present value of the stream of payments of the protection buyer over the life of the contract (*T* maturity of the CDS contract) will be equal to:

$$\text{PV}_{\textit{protection payments}} = s_T \cdot \sum_t^T \frac{(1-P_t)}{(1-r_t)} \qquad (1)$$

Where r_t is the risk free interest rate at time *t*.

In the event *RE* cannot honor its obligations, the protection seller will face a lump sum payment of *(1-R)* , where *R* is the recovery rate expressed in percent of par. Defining the probability of defaulting in each period *t* (discrete) as the probability of default up to period *t* (P_t) conditional on the probability of having survived until the period before ($1-P_{t-1}$), it is then possible to express the net present value of the lump sum payment of the protection seller in a discrete time world as:

$$\text{PV}_{\textit{payout payment}} = (1-R) \cdot \sum_t^T \frac{P_t - P_{t-1}}{(1-r_t)} \qquad (2)$$

Setting the value of the swap to zero, it is possible to derive the equation for the spread of the T period CDS as:

$$s_T = (1-R) \frac{\sum_{t=1}^T \frac{(P_t - P_{t-1})}{1+r_t}}{\sum_{t=1}^T \frac{1-P_t}{1+r_t}} \qquad (3)$$

It is important to note that this equation has two unknowns, one is the probability of default up to period *t* and the other is the extent of the recovery rate *R*.[8]

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[8] This specification can be easily be transformed for a continuous time environment, but for purposes of our paper, which uses discrete time observations we maintain the discrete time formulation.

(continued…)

B. Evaluating Default Probabilities: Reduced-Form Models

The probability of default required for the pricing of the CDS can be modeled as dependent on firms' characteristics (as so-called structural models do) or can be assumed to follow a certain stochastic process (as reduced-form models do). Since structural models of the probability of default are quite complex and often do not fit the data, it is customary in CDS valuation models, to use a reduced-form model assuming as Poisson process with certain assumptions on the hazard rate. [9]

In this study, we concentrate on entities that suffered an event of default. Therefore, the common assumption that the hazard rate is constant does not appear to be appropriate in our case. For this reason, we model the (*risk-neutral*) default probability using a flexible parameterization, used in a number of empirical studies, which allows for a negative slope in the default probability consistent with the intuitive structure for a distressed entity.

For the purposes of this study, we will make use of the formulation used in Merrick (2005) and Vrugt (2011) which consists of a special case of the functional form proposed by Nelson and Siegel (1987) for the term structure of the default free discount rates. This form is flexible enough to capture both upward and *downward-sloping term structure* that may arise due to stress in the credit markets:

$$\chi_{in} = \alpha_i + \beta_i \cdot (1 - e^{-t_n}) / t_n \qquad (4)$$

Where: χ_{it} is the probability of entity i of defaulting in each period n; t_n is the number of years until the cash flow at time n; $\alpha_i + \beta_i$ is the default rate of entity i as t approaches 0; and the infinity maturity default probability is equal to α_i.

Using the specification above it is possible to solve Equation 3 after making an assumption on expected recovery rate R. In the most common formulations used by market participants, *the recovery rate is assumed to be a constant fraction of par* at any given period in time (see Bloomberg CDSW function). It thus enters the CDS pricing equation adjusted only for the time value of money. In the most standard formulation it is typically assumed to take a value

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[9] By far the most popular model is to assume that the probability of default is a Poisson arrival process with a constant arrival rate. This implies that there is a constant default intensity at every period in time and therefore to expressed as: $P_{it} = e^{-\lambda_i \cdot t}$ where P_{it} is the probability that entity i defaults at time t and λ_i is the risk-neutral constant hazard rate of entity i, modeled as the arrival rate of a Poisson process. However, this expression entails the assumption that there is a constant default risk to the entire term structure of the different maturities of the reference entities outstanding obligations.

of 0.4. [10] This has been set in empirical applications on the basis of the average recovery expectation, as estimated through a large dataset collected and published by Moody's on defaults and recoveries for rated companies (Moody's 2014). In this dataset, the long term average of average loss rate on senior unsecured debt is around 60 percent. It is important to note that senior unsecured debt instruments are the type of instruments which constitute the reference obligations in the CDS contracts we are analyzing. [11]

III. Data and Empirical Methodology

In this paper we use data from CDS settlement auctions as coordinated and disclosed by ISDA between 2005 and 2014 and run by Creditex. [12] In particular, we use the final published prices of the deliverable bonds by "reference entities", and data on physical request settlements and the related net open interest (NOI see above) at the auction. The auctions are administered by Markit and relevant data is published by ISDA.[13]

In the period between 2005 and June 2014, auctions were held for 116 reference entities for which a credit event was established. There are 156 final auction results, as for some entities more than one auction had to be conducted for different types of referenced obligations (and for different maturity buckets). Data on final recovery prices are available for 93 unsecured notes (senior and subordinated bonds)[14] and 24 first lien loan obligations. [15] In 73 cases the credit event was determined to be a bankruptcy, in 35 cases there was a failure to pay, and the remainder 32 cases are restructurings. [16][Figure 1]

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[10] It is important to note that there are other types of credit instruments, and in particular LCDS. These are credit default swaps which use outstanding syndicated loans as reference obligations. In the case of loans, the average recovery value as implied in most market software is 70 percent.

[11] There are a number of papers that review CDS pricing results in light of stochastic recovery rates and conclude that recovery assumptions are crucial for the actual market pricing of the CDS contracts Delianedis and Lagnado 2002, O'Kane and Turnbull 2003 among others.

[12] As of July 2014.

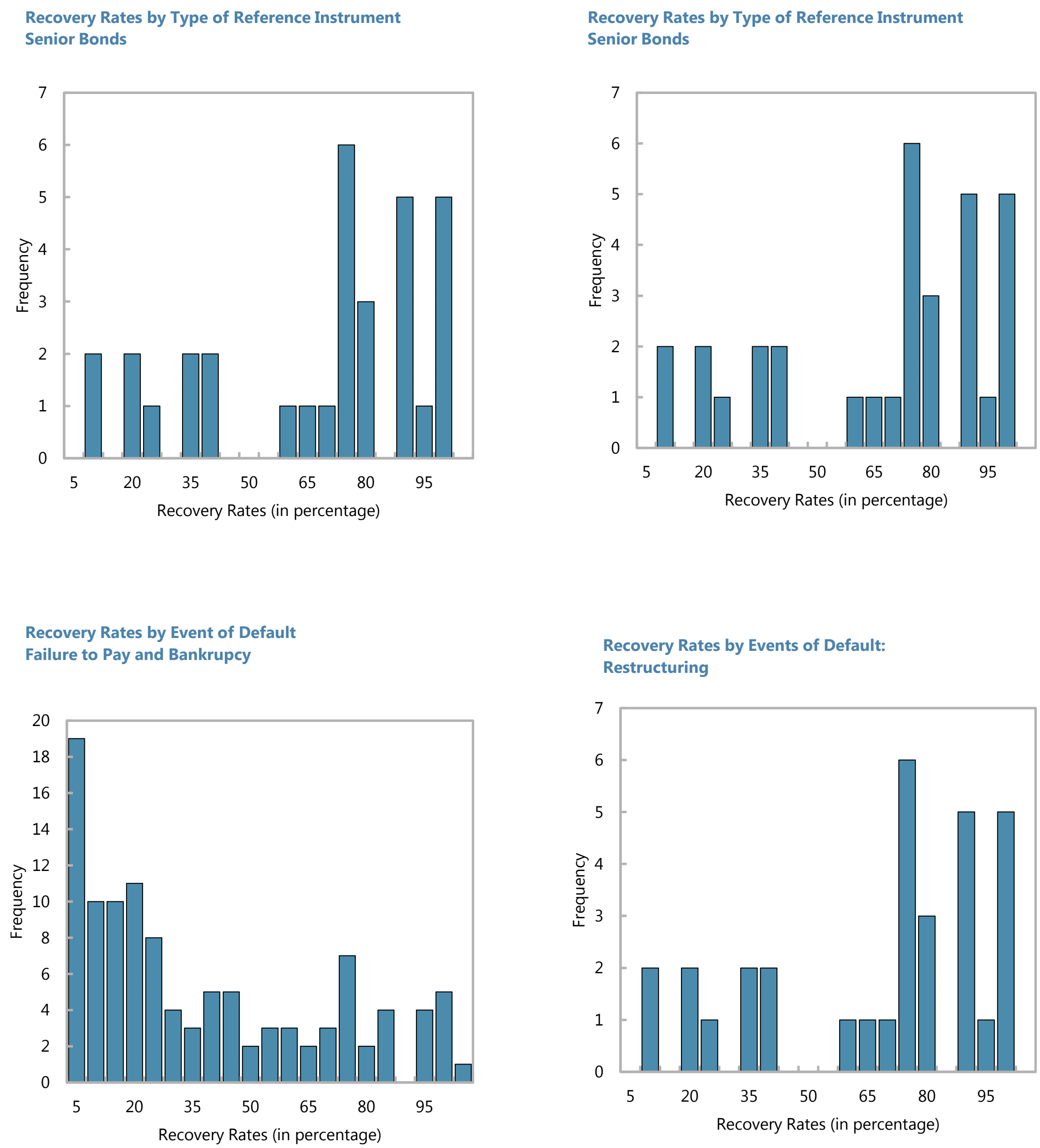
[13] Details can be found at www.isda.org and www.creditex.com.

[14] To settle Senior CDS contracts.

[15] To settle LCDS (Loan CDS contracts).

[16] We consider restructurings as a "special" credit event because discussions on recoveries have been taking place prior to the auction. We control for this in some of our empirical estimations.

Figure 1. Recovery Rates at CDS Settlement Auctions [1/2/3/]



Sources: Creditex, ISDA and authors' calculations

1/ Expressed in percent of par values.

2/ Senior CDS: Auction held for deliverable senior unsecured bonds.

3/ LCDS: Auction held for deliverable secured senior loans.

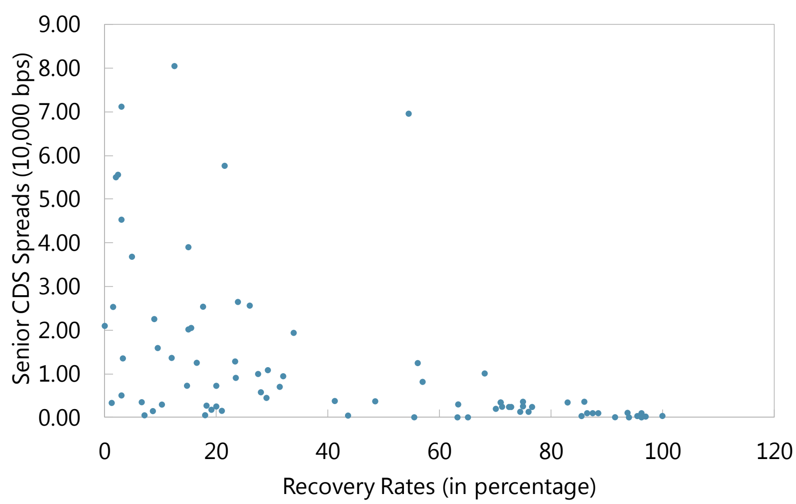
In the dataset described the average recovery price for senior bonds is 42.74,[17] while for loans it is 51.47, both of which are consistent with standard assumptions on recovery values in CDS valuation models. The data appears also to be consistent with the common notions finance literature that restructurings tend to yield higher recovery rates than outright defaults, including and that recoveries on loans are higher than recovery on bonds.[18] However, while auctions held after "restructuring" credit events, yield significant higher outcomes, on average, than bankruptcies, the standard deviation in the sample is actually rather high.

Data published on the auctions on creditex website also includes the total volume of physical settlement requests, divided in buy and sell orders, and the corresponding net open position (NOI). In particular, we note that, out of the156 auctions in our sample, 93 have a negative NOI, implying and interest to sell. We also find that the NOIs are highly correlated (0.99) with the total volume of physical settlement requests, suggesting that CDS settlement auctions tend to be "one sided". This is potentially a troublesome feature as auction results may to tend be dominated by large demand and supply mismatches, as suggested in Gupta and Sundaram (2012), and as predicted by the theoretical models developed by Chernov et al (2014) and Du and Zhu (2012). [19]

Figure 2.

Senior CDS Spreads and Recovery Rates

One year maturity contracts on the day of the credit event



Sources: Creditex, ISDA, Datastream, and Bloomberg.

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[17] Prices are expressed in percent of par.

[18] Such outcome is consistent with the legal nature of the instrument since loans are normally secured but bonds are unsecured.

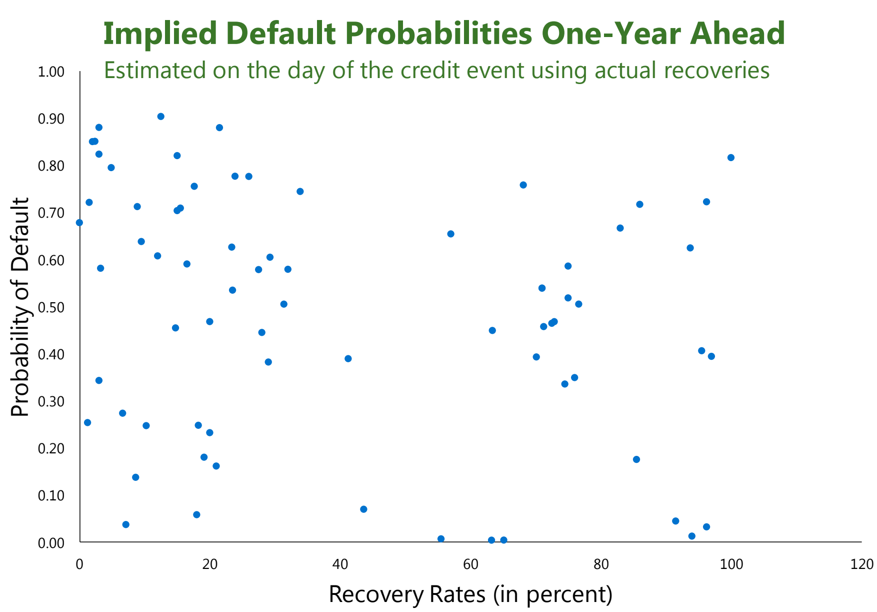
[19] The high correlation between NOI and physical settlement requests could be a factor in Sundaram and Gupta estimations, who find no significant impact of the NOI with respect to the final bond prices in the auction. In addition their sample is limited to 20 observations.

A. Credit Risk Protection Payments and Implied Default Probabilities

We are interested in the analyzing link between market expectations on default probabilities which determine the CDS spreads prior to the event of default and the actual fair value of default protection as computed from ex-post recovery rates established at the auctions. As a first step, we plot the distribution of the CDS spreads with one year maturity vis-à-vis the final prices of the deliverable bonds at the auctions. This is shown in Figure 2. By the nature of the relationship between CDS spreads and recovery rates, we would expect that close to the event of a default, (or for any given default probability) there would be a strong negative relationship between CDS spreads and recovery rates: one would expect to observe higher default probabilities associated with low recovery values and lower default probabilities associated with high recovery values. However, this does not seem to hold for the sample under consideration and there appears to be quite a number of occasions where very low values of recovery rates are associated with very low CDS spreads.

We take another point of view. Since all of the CDS data points in the sample are companies that experienced an event of default observed on the day the credit event was announced, the implied default probabilities should be uniformly high for all the post-default actual recovery rates at the observed spreads. The actual distribution of estimated default probabilities suggests that the market at times has been 'surprised' by the default because lower than average recovery rates were experienced when pre-default CDS spreads were low, implying the expected default probabilities were very low.

Figure 3.



The commonly held belief that for high risk companies "CDS trade at recoveries" does not appear to hold on the basis of post-default recoveries, since, should that be true, for any given spread, the probability of default should be relatively high for ex-post recovery rates on

defaulted companies. On the contrary, a significant amount of datapoints seems to suggest that, ex-post, the expected probability of default was relatively low.

To analyze the extent of the "surprise" in each credit event, we *assume that market expectations are formed using standard recovery rates*. [20]Therefore the spreads should reflect the expected probability of default at the standard recovery rates. To gauge the extent to which the probability of default implied by the recovery rates at the auctions differs from the probability of default that would be implied by market quoted spreads at standard assumptions, we use the theoretical relationship between CDS spreads and expected recovery rates (Equation 3) to compute ex ante implied probabilities of default. We assume that the CDS spreads on the day of the credit event reflect the best informed default expectations by market participants, and that these expectations are formed using average recovery rates on senior unsecured bonds found in Moody's publications therefore imply a recovery value of 0.4. Thus, the expected (*risk-neutral*) T -years ahead probability of default on the day of the credit event (which we assume is at a maximum) is obtained by solving for $P_{t\,exp}$ given by:

$$s_T \cdot \sum_t^T \frac{(1-P_{t\,\exp})}{(1-r_t)} = (1-0.4) \cdot \sum_t^T \frac{P_{t\,\exp} - P_{t-1\,\exp}}{(1-r_t)} \qquad (5)$$

The term structure of the market quotes for CDS spreads (s_T) allow to compute the market-implied default probability, as commonly done in empirical literature, solving recursively for the probability of default one-year ahead, three-year ahead etc. (Turnbull, 2003) with a so-called boostrapping methodology. [21] Following this practice, we computed the market-implied default probability one-year ahead, using data on one year maturity CDS contracts. We use the estimated value for the one year ahead default probability to extract the three year ahead market-implied default probability, and so forth.

We also apply an alternative methodology, as presented in Vrugt (2009), which requires estimating the parameters of a reduced form model for the default probability (Equation 4). [22] We estimate parameters α and β for each entity that suffered a credit event, under the assumption all market participants have the standard expectation of a 0.4 recovery rate. Both methodologies follow the advice in Duffie (1999), of using the entire term structure of the hazard rates when estimating default probabilities. We will use both estimations of the implied default probabilities to check for robustness of our results.

We repeat both the estimations using the set of CDSs spreads observed prior to the event of default and final bond prices at settlement auctions as actual recovery rates. We compare the

[20] Were standard recovery rates are based on historical experiences as published by Moodys and other rating companies.

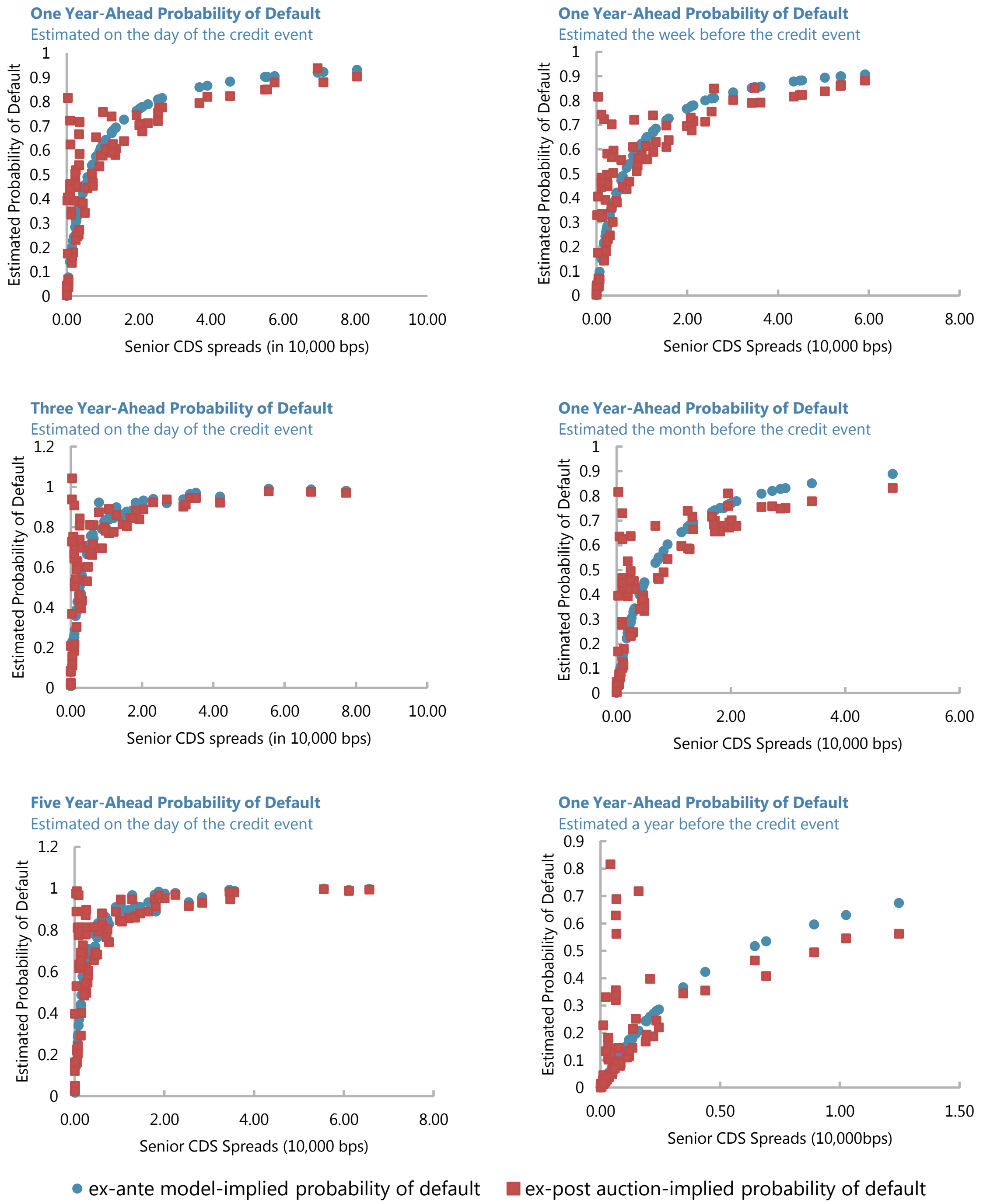
[21] This is also the standard procedure followed by Bloomberg Corp.

[22] The alternative methodology assumes a default probability distribution, (so called a reduced-form models), and use the observations on term structure of CDS spreads to estimate the corresponding parameters.

estimated market-implied default probability consistent with standard signal extracting methodologies with the default probability we would have estimated from the CDS spreads *if* the final recovery prices form the settlement auctions had been known. We observe how, the default probabilities extracted actual recovery are significantly different with respect to the a-priori default probabilities (Figure 4).[23]

[23] T-stats on pairwise comparison strongly reject the hypothesis of equal means with 99 percent confidence level and reject the hypothesis of same variances at the same significance level.

Figure 4. Implied Default Probabilities Estimated Using Average and Actual Recoveries [1]



Source: Authors' calculations.

1/ The red dots in Figure 3 depict the probability of default as calculated by applying a standard reduced-form model to actual quoted CDS spreads and using the final auction prices as recovery values, while the blue crosses show the implied probability of default extracted under the assumption of average recovery rates. We extend the analysis of the default probabilities to different CDS maturities to extract the 'one-year-ahead', 'three-year-ahead' and 'five-year-ahead' probability of default. We repeat the calculations, for one week prior, one month prior and one year prior to the credit event date.

To analyze these patterns we chose to compare how different are the market quotes for CDS observed prior to the event of default with those computed assuming that *market participants would have known the actual recovery rates at the auctions*. In other words, we calculate the value the protection payments should have had to ensure that, at the inception of the swap, they would have been commensurate with the actual payouts following settlement auction.

We assume that the expected default probability distribution use to calculate the fair value CDS spread will be the same for the observed CDS market quotes and for the recovery values at the auction date. Therefore we can use the quoted CDS spreads over the term structure and the actual recovery rates given the default probability structures estimated from market-quoted spreads.[24]

The final auction prices for the deliverable bonds at the auctions will determine the value of the payment leg of the swap ex-post. This will allow us to compute the CDS spreads that *would have been* quoted by the market if the recovery values of the auction (*RA*) were known, under the assumption that the market's default probability expectations prevailing prior to the event of default fully reflected all information on the defaulting entity except for the auction results.

$$s_{i\ pytR} = (1 - RA)\frac{\sum_{t=1}^{T}\frac{(P_t\exp - P_{t-1}\exp)}{1+r_t}}{\sum_{t=1}^{T}\frac{1-P\exp_t}{1+r_t}} \qquad (6)$$

Since the risk-neutral default probabilities are basically a discount weight for the expected recovery rate at the end of the swap period, the difference between the actual CDS spreads and the payout CDS spreads (s_{pytR}) should mainly reflect the difference between actual and expected recovery rates.

If market participants had expected an average recovery rate, we would expect that the difference between the CDS spreads calculated using the payment leg (average recovery rates) and the payout leg (final auction recovery rates) would *distribute randomly around a zero mean*. This should follow the market efficiency hypothesis, as all information about expected outcomes should be fully reflected in market prices.

We use the data on actual recoveries on the day of the credit event and quoted CDS spreads for one, three and five year maturities quoted on the reference entities in DataStream, Markit

[24] The estimated implied default probabilities would be *risk-neutral*. As these would be the probability of default that would ensure and investor would need to be compensated for to be indifferent between a defaultable and a default-free bond. A wide literature seeks to introduce risk aversion in investor preference and therefore estimate a real world default probability, but this is beyond the scope of our investigation.

and Bloomberg.[25] [26] [27]We include discount factors from four geographical regions in our dataset that are identified by the 'Determination Committee' at the ISDA as the ones where the predominant trading currency of each reference entity is associated with. These four regions are the U.S., E.U., Great Britain, and Japan. Based on this geographical information, we retrieved one-to-five year risk-free interest rates associated with each reference entity's region from Datastream.

We would expect, a priori, that the relative difference between prices of default protection as calculated before and after a credit event, should follow a random distribution centered on a zero mean, if the standard expectations for recovery rates were based on historical averages. However, we find significant skewness and kurtosis in our sample of recovery rates to reject the normality hypothesis.[28] (Appendix B) In CDS valuation terms this implies that the value of the protection leg differs systematically from the value of the payment leg.

We then ask whether the differences in the calculated costs of credit protection before and after the auction still hold for the week, the months and the year prior to the credit event. We thus repeat the same comparison, by using CDS market quoted spreads observed at several dates before the credit event discounting the recovery rate for the appropriate time frame, up to one year before the credit event.

B. Explaining Auction Outcomes

We use the implied probabilities of default computed above to estimate $S_{pytR\,T,i,t}$, the CDS spread that would have prevailed if recovery rates had been known at the prevailing default probabilities. We compute this for the one, three and five year CDS contract maturities. We concentrate in particular on the *one year adjusted spreads at the date of the credit event* as we are interested in observing how well market signals from CDS spreads were anticipating the near-term outcome. We repeat the estimations for all CDS maturities at a number of dates prior to the credit event and up to a year before the credit event.

We define $\Delta S_{T,i,t}$ as $\Delta S_{T,i,t} = \frac{S_{pytR\,T,i,t} - S_{T,i,t}}{S_{T,i,t}}$, the "excess spread", as the relative difference between the protection payments we estimated should have prevailed on the basis of the

[25] It is important to note that the reference date for the calculation is the credit event date as determined by ISDA determinations committee and not the day of the auction, as that follows the credit event date by about three weeks. We do not have quoted data for CDS spreads following the credit event date.

[26] www.markit.com

[27] As there are very little quoted spreads data on LCDS (Loan CDS) and CDS related to subordinated debt, our dataset is restricted to 83 observations, only.

[28] See appendix with Summary Tables.

expected default probabilities and the actual recovery rates and the actual CDS spreads prevailing prior to the event of default ($S_{T,i,t}$). We expect that the estimated difference in the spreads will reflect the impact of the actual and expect recovery rates on the implied probability of default and thus give us a measure of the accuracy of the ex-ante market signal as compared to ex-post auction outcomes.

The in-sample properties of the excess spread suggest a non-zero mean (Appendix III) and a significant skewness. We investigate whether factors at play during the auction may be generating a systematic bias in recovery prices. We conjecture that the excess in spread could be driven both by characteristics of the auction itself and by CDS market and general market sentiment factors that may not have been fully reflected in the CDS prices. In particular, as suggested by Gupta and Sundaram (2012) and Du and Zhu (2012) liquidity of the auction itself could be a main driver of the auction prices.

We thus include: (i) a measure of liquidity of the auction itself (Gupta and Sundaram, 2012; Du and Zhu, 2012), (ii) proxies for market sentiment and the macroeconomic outlook (iii) measures of liquidity of the CDS market for the defaulted entity, (iv) proxy of expectations about the potential future gains from the bonds. [29]

The absolute value of the NOI with respect to the total physical delivery requests can be a good proxy for liquidity as it measures the extent of the miss-match of demand and supply as a share of the size of the market. Our NOI index is thus constructed as the total NOI at the auction as a share of the total sum of bid and offers. The index will be constrained between -1 and +1. We expect that negative values of the index (where the NOI is to sell) will be associated to higher excess spreads (because the lower than expected bond prices will require higher CDS spreads). By contrast, lower and negative values of the excess spread should be associated with either small mismatches or a NOI to buy which would potentially drive auction prices above market expectations. This is actually reflected by the in-sample correlations (Appendix III).

We include controls to proxy for liquidity in the CDS market for the defaulted entities: (i) the number of CDS contracts outstanding on the day of the credit event, and (ii) the share of net-notional values of CDS to gross notional values on the day of the credit event, this is a measure of liquidity in the CDS market for the entity.[30] This share provides a measure of how many times the CDS contracts have been re-sold in the market, given a certain notional outstanding. [31]

[29] The list of variables and definitions is included in Appendix I.

[30] The Gross notional values of CDS outstanding registered in DTCC have been declining as accounting for CDS positions has improved. We consider that taking the share of Net notional values to Gross notional values avoids then problem generated by the structural trend.

[31] The weekly data can be retrieved from Trade Information Warehouse Report on Depository Trust & Clearing Corporation (DTCC) website. However, these data are available for only the top 1000 reference entities in terms of trading volume each week. As a result, we have 59 observations for these proxy variables for CDS markets' liquidity.

We also include controls to proxy for general markets sentiment at the time of the auction that could be influencing recovery prices, in particular: the CBOE volatility index (VIX) as a proxy of the amount of risk aversion in the system at the time of the credit event; the total amount of defaults per year, as proxy for recessions and the general business cycle; [32] the prevailing 3 month libor rates at the time of the credit event, a proxy for the monetary policy stance; and, the US 5 year zero coupon rates at the time of the credit event, a proxy for long term expectations about the state of the economy.[33] We also include a variable to account for market expectations about the possibility of recovery of the defaulted entity.[34]

Finally, we construct a categorical variable that identifies industrial sector of each reference entity. This sector-specific categorical variable was constructed by retrieving two-digit NAICS code for each reference entity. In our dataset, each entity falls into one of the following 15 industries.[35]

Our empirical specification is the following:

$$\Delta S_{T,i,t} = \frac{S_{pytR\,T,i,t} - S_{T,i,t}}{S_{T,i,t}} = \beta_0 + \beta_1 \cdot NOI\ Index_{i,t} + \beta_2 \cdot Risk\ Aversion_t$$
$$+\beta_3 \cdot Control_{i,t} + \sum_{s=1}^{5} \gamma_s \cdot Industrial\ Sector_{i,s} + \varepsilon_{T,i,t}$$

We call $\Delta S_{T,i,t}$ the excess spread that would be necessary to add to market quoted rates to ensure that two legs of the CDS are appropriately valued after accounting for actual recovery rates. *T* indicates the maturity of the CDS contract, *t* the time at which the spreads are

[32] Total number of Chap.11 filings per year, in Datastream.

[33] For the US, UST zero coupon yield were used, for the EU, EU vs EONIA zero swap rates were uses, for Japan and UK, zero coupon rates bonds were used. Data for interest rates, bankruptcies, as well as VIX were all obtained from DataStream.

[34] One way to do this is to include the 5-year CDS spreads in the set of regressors. However, directly including 5-year CDS spread as a regressor might yield spuriously significant results, since the 5 CDS spreads also depend on the 1 year spreads. To address this concern, we first regress 5-year CDS spread on 1-year CDS spread and 3-year CDS spread as specified: $y5\ CDS\ spread_t = \alpha_0 + \alpha_1 \cdot y1\ CDS\ spread_t + \alpha_2 \cdot y3\ CDS\ spread_t + controls\ _t + \omega_t$. The resulting residuals ω_t represent a variation in 5-year CDS spread that is independent of all the information contained in 1-year CDS spread and 3-year as well as other control variables such as NOI index, defaults per year and sector fixed effects. We use this residual, ω_t, as a proxy for long-run default probability that is independent of short-run default probability

[35] (i) Administrative and Support Services, (ii) Arts, Entertainment, and Recreation, (iii) Construction, (iv) Finance and Insurance, (v) Information, (vi) Management of Companies and Enterprises, (vii) Manufacturing, (viii) Mining, Quarrying, and Oil and Gas Extraction, (ix) Professional, Scientific, and Technical Serivices, (x) Other Services except public administration (xi) Public Administration, (xii) Real Estate and Rental and Leasing, (xiii) Retail Trade, (xiv) Transportation and Warehousing, (xv) Utilities.

observed, i is the defaulting reference entity indicator. We concentrate on the auction characteristics (NOIindex) as our main explanatory variables because we assume that all market available information is already reflected in the CDS quoted prices. We conjecture that if the final recovery rate (β_1), reflects a systematic bias, this may signal the presence of strategic behavior by auction participants.

We use ordinary least squares and include fixed effects at the industry level, fixed effects for the year of default, and we adjust for clustered standard errors.
Results of the estimations are reported in Tables 1, 2, 3 and 4.[36]

Table 1: Determinants of Excess Spreads - Baseline Regressions

Dependent Variable:	$\Delta s_{1,CE}$					
	(1)	(2)	(3)	(4)	(5)	(6)
NOIindex"	-0.410***	-0.352***	-0.354***	-0.333***	-0.195**	-0.300***
	(0.0559)	(0.106)	(0.0787)	(0.0853)	(0.0854)	(0.0576)
vix			0.0178**	0.0162*	0.0155**	0.0155**
			(0.00646)	(0.00751)	(0.00630)	(0.00529)
Constant	-0.146***	-0.460***	-0.646***	-0.730***	-0.405*	-0.532***
	(0.0135)	(0.0671)	(0.178)	(0.214)	(0.181)	(0.135)
FE (Auction Year)	No	Yes	No	No	No	No
FE (CDS region)	No	No	No	Yes	No	No
FE (Industry)	Yes	Yes	Yes	Yes	Yes	Yes
Observations	72	72	72	72	59	84
Sample 1/2/	Senior CDS	Senior CDS	Senior CDS	Senior CDS	Excl. Restr.	Full Sample
R-squared	0.205	0.401	0.368	0.396	0.257	0.270
Adjusted R-squared	0.193	0.314	0.349	0.360	0.230	0.252

1/ Standard errors in parentheses. Significance:"*"denotes proability level p<0.10; "**" p<0.05; and *** p<0.01".
Estimations using reduced form probability structures, and robust standard errors. See Appendix II for variable sources and definitions.
2/ Dependent variable, excess CDS spread, one year maturity: $(S_{1pytR} - S_1)/S_1$

Notes: The baseline regressions are shown in Table 1. In column (1) the excess spread is regressed on the NOIindex for the sample of auctions on senior bonds, including fixed effects included only for the industry of belonging of the defaulting entity;(2) include fixed time effects for the year of default; (3) includes a control for market volatility at the time of default and makes which makes the inclusion of time effects not necessary; (4) includes regional effects for CDS markets; (5) excludes all those credit events that occurred as a result of a restructuring decision between the defaulting entity and its creditors; (6) includes the auctions on subordinated bonds.

[36] A formulation of the dependent variable in logarithmic formulation was tried, all significance was maintained.

Table 2: Determinants of Excess Spreads – Additional Controls

Dependent Variable:	$\Delta s_{1,CE}$							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NOIindex"	-0.359***	-0.352***	-0.413**	-0.416***	-0.351***	-0.352***	-0.250***	-0.248***
	(0.0899)	(0.0722)	(0.154)	(0.112)	(0.0779)	(0.0792)	(0.0731)	(0.0141)
vix	0.0194*	0.0176**	0.0123	0.0112**	0.0172**	0.0175**	0.0130	-0.0103
	(0.0100)	(0.00701)	(0.00789)	(0.00454)	(0.00616)	(0.00632)	(0.00856)	(0.0179)
default year	-0.000385							
	(0.00161)							
3 month libor		0.00525						
		(0.0289)						
N.CDS contracts (DTCC)			-0.00000164					
			(0.0000814)					
NetNotional Index				1.064				
				(2.063)				
Zero coupon 5 rates					-2.059			
					(4.275)			
Default prob. 5 year ahead (instr.)						0.120		
						(0.194)		
Constant	-0.643***	-0.646***	-0.434	-0.493	-0.675***	-0.638***	-0.162	-0.242
	(0.163)	(0.175)	(0.342)	(0.269)	(0.185)	(0.173)	(0.352)	(0.447)
FE (Auction Year)	No	No	No	No	No	No	No	No
FE (CDS region)	No	No	No	No	No	No	No	No
FE (Industry)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	72	72	48	48	72	72	53	32
Sample 1/	Senior CDS	Senior CDS	Senior CDS	Senior CDS	Senior CDS	Senior CDS	Senior CDS	Senior CDS
R-squared	0.370	0.368	0.356	0.360	0.369	0.370	0.566	0.699
Adjusted R-squared	0.342	0.340	0.312	0.317	0.341	0.342	0.539	0.654

1/ Standard errors in parentheses. Significance:"*"denotes proability level p<0.10; "**" p<0.05; and *** p<0.01".
Estimations using reduced form probability structures, and robust standard errors. See Appendix II for variable sources and definitions.
2/ Dependent variable, excess CDS spread, one year maturity: $(S_{1pytR} - S_1)/S_1$

Notes: Table 2 shows results of regression assessing robustness of the baseline regressions controlling for omitted variables. All regressions are run on the sample of auctions on senior bonds.

Table 3: Estimation Using Five-year Ahead Implied Probabilities of Default [1/2/]

Dependent Variable:	$\Delta s_{5,CE}$				$\Delta s_{5,CE-1y}$			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
NOIindex"	-0.399***	-0.323**	-0.343***	-0.324***	-0.416***	-0.357**	-0.384***	-0.329***
	(0.0541)	(0.106)	(0.0795)	(0.0850)	(0.0685)	(0.116)	(0.0846)	(0.107)
vix 3/	…	…	0.0178**	0.0163*	…	…	0.00956***" 4/	0.0162** 4/
	…	…	(0.00643)	(0.00744)	…	…	(0.00201)	(0.00735)
vix _1y 3/	…	…	…	…	…	…	0.00442	-0.00681
	…	…	…	…	…	…	(0.00784)	(0.00792)
Constant	-0.148***	-0.466***	-0.647***	-0.719***	-0.148***	-0.438***	-0.523*	-0.550
	(0.0131)	(0.0706)	(0.176)	(0.208)	(0.0152)	(0.0560)	(0.243)	(0.484)
FE (Auction Year)	No	Yes	No	No	No	Yes	No	Yes
FE (CDS region)	No	No	No	Yes	No	No	No	No
FE (Industry)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	72	72	72	72	76	76	76	76
Sample 1/	Senior CDS	Senior CDS	Senior CDS	Senior CDS	Senior CDS	Senior CDS	Senior CDS	Senior CDS
R-squared	0.196	0.399	0.359	0.380	0.195	0.378	0.261	0.434
Adjusted R-squared	0.184	0.311	0.341	0.343	0.184	0.294	0.230	0.229

1/ Standard errors in parentheses. Significance:"*"denotes proability level p<0.10; "**" p<0.05; and *** p<0.01".
Estimations using reduced form probability structures, and robust standard errors. See Appendix II for variable sources and definitions.
2/ Dependent variable, excess CDS spread, five year maturity: *($S5_{pytR}$ - S5)/ S5*
3/ VIX at the CDS spreads observation date.

Note: Table 3 shows regressions assessing robustness by using as a dependent variable the excess spread computed for five year maturity CDS contracts and by using as a dependent variable the same excess spread observed a year before the credit event on the sample of auctions for senior bonds.

Table 4: Estimations Using Reduced Form Probability Structures [1/2/]

Dependent Variable:	$\Delta s_{1,CE-1m}$	$\Delta s_{5,CE-1m}$	$\Delta s_{1,CE-1y}$	$\Delta s_{5,CE-1y}$
	(1)	(2)	(3)	(4)
NOIindex"	-0.366***	-0.345***	-0.412***	-0.425***
	(0.0935)	(0.102)	(0.0819)	(0.0755)
vix_1m 3/	0.0149**	0.0152**	…	
	(0.00517)	(0.00517)	…	
vix _1y 3/	…	…	0.00473	0.00489
	…	…	(0.00583)	(0.00589)
Constant	-0.555***	-0.563***	-0.273	-0.266
	(0.145)	(0.145)	(0.153)	(0.153)
FE (CDS region)	No	No	No	No
FE (Auction Year)	No	No	No	No
FE (Sector)	Yes	Yes	Yes	Yes
Observations	76	76	76	76
Sample 1/	Senior CDS	Senior CDS	Senior CDS	Senior CDS
R-squared	0.269	0.254	0.190	0.201
Adjusted R-squared	0.249	0.234	0.168	0.179

1/ Standard errors in parentheses. Significance:"*"denotes proability level p<0.10; "**" p<0.05; and *** p<0.01". Estimations using reduced form probability structures, and robust standard errors. See Appendix II for variable sources and definitions.

2/ Dependent variables: excess CDS spread, one year maturity contracts: *($S1_{pytR}$ - S1)/ S1* and excess CDS spreads on five year maturity contracts: *($S5_{pytR}$ - S5)/ S5.*

3/ VIX at the CDS spreads observation date.

Note: Table 4 presents estimation results for the determinants of excess spreads when calculated on CDSs for one year and five year maturity contracts, observed the month and the year preceding the credit event.

We find that our NOIindex has a large negative association with the excess spread, which is statistically significant at conventional levels. Our results suggest that the size of the NOI relative to the auction has a significant impact on the excess spread. This requires some interpretation. It is important to remember that a positive NOI suggests volume of demand for the defaulted bonds is in excess of the supply, the reverse when it is negative. A positive excess spread suggests the payment leg of the CDS underestimated the probability of default and ex-post the recovery rates at the auctions were below expectations, a negative excess spread suggests the contrary. Empirical evidence suggests that at the auctions with significant sell interest (negative NOI) the excess spreads tend to be higher (positive $\Delta S_{T,i,t}$) and thus actual bond prices were below market expectations. By converse, when the volume of demand is greater than supply (positive NOI), a negative impact suggest that excess spread reduces (negative $\Delta S_{T,i,t}$), the probability default implicit in the payment leg becomes closer and even lower than expected and final bond prices tend to be above standard market expectations. An increase in the size of the NOIindex by 1 would reduce the size of the excess spread by 30 percent. As an example, an auction for a bond of a defaulted entity where the NOIindex is to sell would experience an excess spread 30 percent higher than an auction with the same magnitude NOIindex but an interest to buy. A qualitative change in the structure of the auction (from sell to buy) at the same magnitude of volumes and NOI generates significantly higher recovery values.

This result suggests that large miss-matches between supply and demand are affecting prices at the auction, and that the minority group at the auction will see a bias of prices in its favor. Such results appears to be in line with the claim in Gupta and Sundaram (2012) that illiquidity at the auctions is biasing final recovery prices, where illiquidity is seen as the lack of buyer/sellers, so that, in order to "win the action", bids and offers are biased.[37] We also find evidence that market sentiment (VIX) is important at the time of default, and with the right sign: the higher the market volatility at the time of default, the lower the recovery prices with respect to expectations. However, the impact of interest rates and the broader macroeconomic outlook are limited. This result is in line with the expectation that information known to market participants prior to the time of the auction should have influenced the CDS quote and therefore should not have any impact on auction prices. Interestingly, none of the indicators of liquidity in the CDS markets appears to have any influence on the spread differential. This suggesting that the total volume of physical delivery requests is completely independent of the overall micro-structure of CDS market for each defaulted entity.

Finally, the variable to control for the expected price of the bond after final bankruptcy procedures was significant if taken as an average of observed prices. However, the price of

[37] Their study focuses on the difference between deliverable bond prices prior and after the auction and the auction final prices. We assume that part of that difference has to be reflected in the implied default probability as calculated prior to the auction and using the auction results.

the bonds of one year remaining maturity was not significant when clustered errors were used, likely because of significant dispersion in the data.

C. Discussion of results

The question remains open as to why auctions tend to display relatively large NOIs and in particular, why they appear to tend to be NOIs to sell. One possible explanation is that relative payoffs of bidders and sellers *at the actions* with respect to their bond and CDS positions has a tendency to generate sell NOIs. We suggest that the auction structure tends to reduce the number of potential bond buyers and therefore to yield sell NOIs.

This is better discussed when thinking at the different payoffs generated by the decision between cash settlement and physical delivery. A CDS seller that chooses to settle physically will place a buy order. After the auction he will face payments for 100 on his CDS positions will be delivered bond with an auction price of *R*. Assuming he sits through the bankruptcy proceedings and in final liquidation is awarded a cash payment of *Fr*, his total payoff from choosing to settle physically will be equal to the difference between the auction recovery value and the final payout after bankruptcy or resolution the credit event.[38] A CDS seller will thus choose physical delivery only those occasions in which the condition he expects that after the auction i.e. for example bankruptcy proceedings, the payout will be higher than the auction price.[39] If she expects that auction prices will close to the final payout value of the bond, she will be indifferent between physical delivery and cash settlement, and thus *might not enter the auction*. If the CDS seller believes that the final liquidation value will be lower than the auction price, then she would be better off *by not choosing physical delivery* and simply paying *100-R* in cash settlement.

A CDS buyer that chooses to physical delivery needs either to own or to source the bond to sell at the auction, after he settles in cash will then receive a payout in the size of the net loss after default (100-*R*). The only cases in which the CDS buyer will secure a higher return from not participating in the auction is when he expects the price of the auction to be lower than what he will receive from final payout or lower than the market price at which he can source the bond.

To summarize the strategies, the optimal behavior for CDS sellers would be not to join the auction at all unless there is an expectation that final liquidation values are significantly

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[38] Actually, not all credit events imply bankruptcy procedures to follow the auction. Indeed a significant number of them are connected to restructuring decisions. While we use the language "final payout" here, it is intended to refer to the expected value the obligation will have following the auction.

[39] The reasoning is not different if we assume there is a secondary market for the defaulted bonds after the auction has taken place and CDS sellers can sell their bond.

above the auction prices.[40] Similarly, the only cases in the CDS buyer will not participate in the auction will be if the auction price established at the auction is lower than the acquisition value of the bond and/or the final payout price. Similarly, CDS buyers and seller will participate in the auction if they expect final payout values to be lower than the auction prices.

Auction behavior

As both CDS buyers and sellers have the same strategic options, there will be a tendency of the auction to reflect the expectations of the market in terms the final bond payout values. Should the market, on average, expect low payout values, then the a NOI will be to sell, by contrary if market expectations are for high payout values then the NOI will be to buy. This could explain why NOIs at the auction tend to be highly correlated with the auctioned volumes, as market expectations on the final liquidation values reduce the amount of auction participants.

If we assume expectations on *final liquidation values* distribute normally in the market, with the expected value being the median and the mode of the distribution, then, at each auction, only a minority of agents will be taking different views from those prevailing in the market. Therefore, for any given expected *final liquidation value* agents with the majority view will tend to over/under bid, in order to "win" the auction. This behavior would be in line with the theoretical models of Chernov, Du and Zhu. So that, eventually, the minority of buyers / sellers that have expectations different from the rest of the market will be able to achieve an auction price in the direction that will ensure they have a positive payoff by participating in the auction.

IV. CONCLUSIONS

This paper contributes to the growing empirical research on the auctions used to settle CDS positions following the occurrence of a credit event. We have found evidence that the difference between actual and expect recovery rates on the required CDS spreads given a default probability structure would yield to a systematic bias in the ex-ante market signal of implied probabilities of default. This implies that, should CDSs pricing in the market follow standard modeling and assumptions, there has been a systematic bias in the valuation of the two legs of CDS contracts when compared with the ex-post recovery values of the bonds at the auctions.

We have analyzed the difference in valuations between the two legs of the CDS contract by calculating the excess spread that should have been charged on the basis of the actual recovery rates and expected default probabilities as signaled by market prices prior to the

[40] The CDS seller that does join the auction has an interest in securing low auction recovery prices, she has no interest minimizing her CDS payout because only *what she expects to get after the auction,* will determine her bidding at the auction. The actual final price of the action *R does not enter the total payoff.*

credit event. We have found that both the size of the Net Open Interest at the CDS settlement auction and market sentiment in general tend to have a significant impact on the size of the excess spread. In particular, we find that the NOI at the auctions is inversely associated with the size of the excess spread, suggesting large miss-matches between supply and demand at the auctions tend to bias auction prices. Our findings are consistent with the evidence in Sundaram and Gupta (2012) who find that final auction prices of the deliverable bonds tend to be below their pre- and post auction fair market values.

We explain this result by analyzing the payoffs of the CDS sellers and buyers at the credit event and we conclude that the nature of the strategies is such that auctions tend to be “one sided” and therefore to “win” the auction the bids will tend to come in below or above the target price depending on the sign of the net open interest. In addition, the buy side interest at the auction will tend to be limited both because of the particular specialized nature of investors in defaulted bonds, and because of the auction’ own regulations. These preclude potential bonds buyers from entering the auction absent a sell CDS position. CDS sellers that chose not to settle physically a lower than the fair value prices choose to incur such a loss to avoid withstanding bankruptcy proceedings but thus face higher than expected payouts.

Several interesting avenues for future research remain open. One is to identify a fully fledged model for auction behavior along the lines of Chernov et al (2012) and Du-Zhu (2013) that includes the expectations on the final payout from bonds and CDS positions after the auctions in the reaction function of market agents. The other is to extend our analysis using data on actual CDS spreads (rather than quoted spreads) as charged and valued by market dealers. Should our results be confirmed, the auction mechanism might need to be re-thought, especially if there are significant volumes of CDS sold which are settled in cash because the protection sellers are not active in managing their portfolios and may have little incentive in participating in post-auction bankruptcy procedures.

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Appendix I

Definitions of Variables

Variable Name	Definition
y1cdsce	1-year maturity CDS spread observed on the day of the credit event
y1cds1y	1-year maturity CDS spread observed 1 year before the credit event
NOI	Net Open Interest: bid - ask
NOIindex	Normalized index of NOI : NOI/(bid+ask)
VIX	Volatility index of the US stock market on the day of the credit event
VIX _1y	Volatility index of the US stock market 1 year before the credit event
default year	Number of defaulted firms in a year when the auction is held
3 month libor	3-month libor observed on the day of the credit event
NCDS contract	Number of outstanding CDS contracts in the week of the credit event
NetNotional Index	Outstanding amount of net-notional values divided by gross-notional values in the week of the credit event
Zero coupon 5 rate	Risk-free interest rate on the 5-year maturity US Treasury Bill on the day of the credit event
CDS region	Dummy variable, =1 if the region is associated with the reference entity
Auction Year	Dummy variable, =1 if auction is held that year
Industry	Dummy variable, =1 if the industry is associated with the reference entity

Appendix II

Table 1. Summary Statistics

	Obs	Mean	Std. Dev.	Variance	Skewness	Kurtosis
$\Delta s_{1,CE}$	90	-0.40406	0.964126	0.929538	-2.25842	8.80115
$\Delta s_{3,CE}$	90	-0.34532	0.763891	0.583528	-2.69877	11.0909
$\Delta s_{5,CE}$	90	-0.33006	0.818302	0.669618	-3.01514	12.5763
NOI	156	-362.118	2212.941	489710	-8.22407	72.0268
NOIindex"	142	-0.19802	0.714177	0.510048	0.529657	1.88873
3 month libor	160	1.14821	1.306593	1.70718	1.794249	5.19925
VIX	160	28.0929	13.05827	170.518	0.82258	2.9527
No CDS contracts (DTCC)	79	1873.16	1466.208	214976	1.566567	5.72102
NetNotional Index	79	0.082634	0.037192	0.001383	1.545008	6.44207

Table 2: Selected Correlations

	Physical sttlm req.	NOI	NOIindex	NetNotional Indx	Net Notional	Gross Notio	No CDS contracts	VIX
Physical sttlm req.	1							
NOI	-0.9976	1						
NOIindex	-0.1117	0.1319	1					
NetNotional Index	-0.1469	0.1429	-0.1781	1				
Net Notional	0.1159	-0.0859	-0.1411	0.0116	1			
Gross Notional	0.1569	-0.1309	-0.0989	-0.2826	0.8672	1		
No CDS contracts (DTCC)	0.2494	-0.2305	-0.1261	-0.3032	0.8833	0.892	1	
VIX	-0.0516	0.0495	-0.2629	0.19	0.1096	0.0096	0.0411	1