



Counterparty credit risk and the credit default swap market[☆]

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ARTICLE INFO

Article history:

Received 19 February 2010

Received in revised form

8 April 2011

Accepted 9 June 2011

Available online 19 October 2011

JEL classification:

G12

G13

G24

Keywords:

Counterparty credit risk

Credit default swaps

Collateralization

ABSTRACT

Counterparty credit risk has become one of the highest-profile risks facing participants in the financial markets. Despite this, relatively little is known about how counterparty credit risk is actually priced. We examine this issue using an extensive proprietary data set of contemporaneous CDS transaction prices and quotes by 14 different CDS dealers selling credit protection on the same underlying firm. This unique cross-sectional data set allows us to identify directly how dealers' credit risk affects the prices of these controversial credit derivatives. We find that counterparty credit risk is priced in the CDS market. The magnitude of the effect, however, is vanishingly small and is consistent with a market structure in which participants require collateralization of swap liabilities by counterparties.

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1. Introduction

During the past several years, counterparty credit risk has emerged as one of the most important factors driving financial markets and contributing to the global credit crisis. Concerns about counterparty credit risk were significantly heightened in early 2008 by the collapse of Bear Stearns, but then skyrocketed later in the year when Lehman Brothers declared Chapter 11 bankruptcy and defaulted on its debt

and swap obligations.¹ Fears of systemic defaults were so extreme in the aftermath of the Lehman bankruptcy that Euro-denominated CDS contracts on the U.S. Treasury were quoted at spreads as high as 100 basis points.

Despite the significance of counterparty credit risk in the financial markets, however, there has been relatively little empirical research about how it affects the prices of contracts and derivatives in which counterparties may default. This is particularly true for the \$57.3 trillion notional credit default swap (CDS) market in which defaultable counterparties sell credit protection (essentially insurance) to other counterparties.² The CDS markets have been the focus of much attention recently because it was AIG's massive losses on credit default swap positions

[☆] The authors are grateful for the comments of Darrell Duffie, Chris Jones, Peter Knez, Peter Meindl, Derek Schaeffer, Victor Wong, and seminar participants at the 2010 NYU Moody's Conference, the 2010 Moody's Risk Practitioner Conference in San Francisco, the 2010 SIAM conference on Financial Mathematics and Engineering, and the 2010 USC/UCLA Financial Research Conference. We are particularly grateful for the comments and advice of the editor Bill Schwert and an anonymous referee. All errors are our responsibility.

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¹ Lehman Brothers filed for Chapter 11 bankruptcy on September 15, 2008. During the same month, American International Group (AIG), Merrill Lynch, Fannie Mae, and Freddie Mac also failed or were placed under conservatorship by the U.S. government.

² The size of the CDS market as of June 30, 2008 comes from estimates reported by the Bank for International Settlements.

that led to the Treasury's \$182.5 billion bailout of AIG. Furthermore, concerns about the extent of counterparty credit risk in the CDS market underlie recent proposals to create a central clearinghouse for CDS transactions.³

This paper uses a unique proprietary data set to examine how counterparty credit risk affects the pricing of CDS contracts. Specifically, this data set includes contemporaneous CDS transaction prices and quotations provided by 14 large CDS dealers for selling protection on the same set of underlying reference firms. Thus, we can use this cross-sectional data to measure directly how a CDS dealer's counterparty credit risk affects the prices at which the dealer can sell credit protection. A key aspect of the data set is that it includes most of 2008, a period during which fears of counterparty defaults in the CDS market reached historical highs. Thus, this data set provides an ideal sample for studying the effects of counterparty credit risk on prices in derivatives markets.

Four key results emerge from the empirical analysis. First, we find that there is a significant relation between the credit risk of the dealer and the prices at which the dealer can sell credit protection. As would be expected, the higher the dealer's credit risk, the lower is the price that the dealer can charge for selling credit protection. This confirms that prices in the CDS market respond rationally to the perceived counterparty risk of dealers selling credit protection.

Second, although there is a significant relation between dealer credit risk and the cost of credit protection, we show that the effect on CDS spreads is vanishingly small. In particular, an increase in the dealer's credit spread of 645 basis points only translates into a one-basis-point decline on average in the dealer's spread for selling credit protection. This small effect is an order of magnitude smaller than what would be expected if swap liabilities were uncollateralized. In contrast, the size of the pricing effect is consistent with the standard practice among dealers of having their counterparties fully collateralize swap liabilities.

Third, the Lehman bankruptcy in September 2008 was a major counterparty credit event in the financial markets. Accordingly, we examine how the pricing of counterparty credit risk was affected by this event. We find that counterparty credit risk was priced prior to the Lehman bankruptcy. After the Lehman event, the point estimate of the effect increases but remains very small in economic terms. The increase is significant at the 10% level (but not at the 5% level).

Fourth, we study whether the pricing of counterparty credit risk varies across industries. In theory, the default correlation between the firm underlying the CDS contract and the CDS dealer selling protection on that firm should affect the pricing. Clearly, to take an extreme example, no investor would be willing to buy credit protection on Citigroup from Citigroup itself. Similarly, to take a less extreme example, we might expect the pricing of CDS

dealers' credit risk to be more evident in selling credit protection on other financial firms. Surprisingly, we find that counterparty credit risk is priced in the CDS spreads of all firms in the sample except for the financials.

These results have many implications for current proposals to regulate the CDS market. As one example, they argue that market participants may view current CDS risk mitigation techniques such as the overcollateralization of swap liabilities and bilateral netting as largely successful in addressing counterparty credit risk concerns. Thus, proposals to create a central CDS exchange may not actually be effective in reducing counterparty credit risk further.

This paper contributes to an extensive literature on the effect of counterparty credit risk on derivatives valuation. Important research in this area includes Cooper and Mello (1991), Sorensen and Bollier (1994), Duffie and Huang (1996), Jarrow and Yu (2001), Hull and White (2001), Longstaff (2004, 2010), and many others. The paper most closely related to our paper is Duffie and Zhu (2009) who study whether the introduction of a central clearing counterparty into the CDS market could improve on existing credit mitigation mechanisms such as bilateral netting. They show that a central clearing counterparty might actually increase the amount of credit risk in the market. Thus, our empirical results support and complement the theoretical analysis provided in Duffie and Zhu.

The remainder of this paper is organized as follows. Section 2 provides a brief introduction to the CDS market. Section 3 discusses counterparty credit risk in the context of the CDS markets. Section 4 describes the data. Section 5 examines the effects of dealers' credit risk on spreads in the CDS market. Section 6 summarizes the results and presents concluding remarks.

2. The credit default swap market

In this section, we review briefly the basic features of a typical CDS contract. We then discuss the institutional structure of the CDS market.

2.1. CDS contracts

A CDS contract is best thought of as a simple insurance contract on the event that a specific firm or entity defaults on its debt. As an example, imagine that counterparty A buys credit protection on Amgen from counterparty B by paying a fixed spread of, say, 225 basis points per year for a term of five years. If Amgen does not default during this period of time, then B does not make any payments to A. If there is a default by Amgen, however, then B pays A the difference between the par value of the bond and the post-default value (typically determined by a simple auction mechanism) of a specific Amgen bond. In essence, the protection buyer is able to put the bond back to the protection seller at par in the event of a default. Thus, the CDS contract "insures" counterparty A against the loss of value associated with default by Amgen.⁴

³ For example, see the speech by Federal Reserve Board Chairman Ben S. Bernanke at the Council on Foreign Relations on March 10, 2009. For an in-depth discussion of the economics of CDS clearinghouse mechanisms, see Duffie and Zhu (2009).

⁴ For a detailed description of CDS contracts, see Longstaff, Mithal, and Neis (2005).

2.2. The structure of the CDS market

Like interest rate swaps and other fixed income derivatives, CDS contracts are traded in the over-the-counter market between large financial institutions. During the past 10 years, CDS contracts have become one of the largest financial products in the fixed-income markets. As of June 30, 2008, the total notional amount of CDS contracts outstanding was \$57.325 trillion. Of this notional, \$33.083 trillion is with dealers, \$13.683 trillion with banks, \$0.398 trillion with insurance companies, \$9.215 trillion with other financial institutions, and \$0.944 trillion with nonfinancial customers.⁵

Early in the development of the CDS market, participants recognized the advantages of having a standardized process for initiating, documenting, and closing out CDS contracts. The chartering of the International Swaps and Derivatives Association (ISDA) in 1985 led to the development of a common framework which could then be used by institutions as a uniform basis for their swap and derivative transactions with each other. Currently, ISDA has 830 member institutions. These institutions include virtually every participant in the swap and derivatives markets. As the central organization of the privately negotiated derivatives industry, ISDA performs many functions such as producing legal opinions on the enforceability of netting and collateral arrangements, advancing the understanding and treatment of derivatives and risk management from public policy and regulatory capital perspectives, and developing uniform standards and guidelines for the derivatives industry.⁶

3. Counterparty credit risk

In this section, we first review some of the sources of counterparty credit risk in the CDS market. We then discuss ways in which the industry has attempted to mitigate the risk of losses stemming from the default of a counterparty to a CDS contract.

3.1. Sources of counterparty credit risk

There are at least three ways in which a participant in the CDS market may suffer losses when their counterparty enters into financial distress. First, consider the case in which a market participant buys credit protection on a reference firm from a protection seller. If the reference firm underlying the CDS contract defaults, the protection buyer is then owed a payment from the counterparty. If the default was unanticipated, however, then the protection seller could suddenly be faced with a large loss. If the loss was severe enough, then the protection seller could potentially be driven into financial distress. Thus, the protection buyer might not receive the promised protection payment.

⁵ Data obtained from Table 4 of *OTC Derivatives Market Activity for the First Half of 2008*, Bank for International Settlements.

⁶ This discussion draws on the information about ISDA provided on its Web site www.isda.org.

Second, even if the reference firm underlying the CDS contract does not default, a participant in the CDS market could still experience a substantial loss in the event that the counterparty to the contract entered financial distress. The reason for this is that while CDS contracts initially have value of zero when they are executed, their mark-to-market values may diverge significantly from zero over time as credit spreads evolve. Specifically, consider the case where counterparty A has an uncollateralized mark-to-market liability of X to counterparty B. If counterparty A were to enter bankruptcy, thereby canceling the CDS contract and making the liability immediately due and payable, then counterparty B's only recourse would be to attempt to collect its receivable of X from the bankruptcy estate. As such, counterparty B would become a general unsecured creditor of counterparty A. Given that the debt and swap liabilities of Lehman Brothers were settled at only 8.625 cents on the dollar, this could result in counterparty B suffering substantial losses from the default of counterparty A.⁷

A third way in which a market participant could suffer losses through the bankruptcy of a counterparty is through the collateral channel. Specifically, consider the case where counterparty A posts collateral with counterparty B, say, because counterparty B is counterparty A's prime broker. Now imagine that the collateral is either not segregated from counterparty B's general assets (as was very typical prior to the Lehman default), or that counterparty B rehypothecates counterparty A's collateral (also very common prior to the Lehman default). In this context, a rehypothecation of collateral is the situation in which counterparty B transfers counterparty A's collateral to a third party (without transferring title to the collateral) in order to obtain a loan from the third party. *Buhlman and Lane (2009)* argue that under certain circumstances, the rehypothecated securities become part of the bankruptcy estate. Thus, if counterparty B filed for bankruptcy after rehypothecating counterparty A's collateral, or if counterparty A's collateral was not legally segregated, then counterparty A would become a general unsecured creditor of counterparty B for the amount of the collateral, again resulting in large potential losses. An even more precarious situation would be when the rehypothecated collateral itself was seized and sold by the third party in response to counterparty B's default on the loan obtained using the rehypothecated securities as collateral. Observe that because of this collateral channel, counterparty A could suffer significant credit losses from counterparty B's bankruptcy, even if counterparty B does not actually have a mark-to-market liability to counterparty A stemming from the CDS contract.

3.2. Mitigating counterparty credit risk

One of the most important ways in which the CDS market attempts to mitigate counterparty credit risk is

⁷ The settlement amount was based on the October 10, 2008 Lehman Brothers credit auction administered by Creditex and Markit and participated in by 14 major Wall Street dealers. See the Lehman auction protocol and auction results provided by ISDA.

through the market infrastructure provided by ISDA. In particular, ISDA has developed specific legal frameworks for standardized master agreements, credit support annexes, and auction, closeout, credit support, and novation protocols. These ISDA frameworks are widely used by market participants and serve to significantly reduce the potential losses arising from the default of a counterparty in a swap or derivative contract.⁸

Master agreements are encompassing contracts between two counterparties that detail all aspects of how swap and derivative contracts are to be executed, confirmed, documented, settled, etc. Once signed, all subsequent swaps and derivative transactions become part of the original master swap agreement, thereby eliminating the need to have separate contracts for each transaction. An important advantage of this structure is that it allows all contracts between two counterparties to be netted in the event of a default by one of the counterparties. This netting feature implies that when default occurs, the market value of all contracts between counterparties A and B are aggregated into a net amount, leaving one of the two counterparties with a net liability to the other. Without this feature, counterparties might have incentives to demand payment on contracts on which they have a receivable, but repudiate contracts on which they have a liability to the defaulting counterparty.

Credit support annexes are standardized agreements between counterparties governing how credit risk mitigation mechanisms are to be structured. For example, a specific type of credit risk mitigation mechanism is the use of margin calls in which counterparty A demands collateral from counterparty B to cover the amount of counterparty B's net liability to counterparty A. The credit support annex specifies details such as the nature and type of collateral to be provided, the minimum collateral transfer amount, how the collateral amount is to be calculated, etc.

ISDA protocols specify exactly how changes to master swap agreements and credit support annexes can be modified. These types of modifications are needed from time to time to reflect changes in the nature of the markets. For example, the increasing tendency among market participants to closeout positions through novation rather than by offsetting positions motivated the development of the 2006 ISDA Novation Protocol II. Similarly, the creation of a standardized auction mechanism for settling CDS contracts on defaulting firms motivated the creation of the 2005–2009 ISDA auction protocols and the 2009 ISDA closeout amount protocol.

An important second way in which counterparty credit risk is minimized is through the use of collateralization. Recall that the value of a CDS contract can diverge significantly from zero as the credit risk of the reference firm underlying the contract varies over time. As a result, each counterparty could have a significant mark-to-market liability to the other at some point during the life of

the contract. In light of the potential credit risk, full collateralization of CDS liabilities has become the market standard. For example, the *ISDA Margin Survey (2009)* reports that 74% of CDS contracts executed during 2008 were subject to collateral agreements and that the estimated amount of collateral in use at the end of 2008 was approximately \$4.0 trillion. Typically, collateral is posted in the form of cash or government securities. Participants in the Margin Survey indicate that approximately 80% of the ISDA credit support agreements are bilateral, implying two-way transfers of collateral between counterparties. Of the 20 largest respondents to the survey (all large CDS dealers), 50% of their collateral agreements are with hedge funds and institutional investors, 15% are with corporations, 13% are with banks, and 21% are with others.

The data set used in this study represents the CDS spreads at which the largest Wall Street dealers actually sell, or are willing to sell, credit protection. Both discussions with CDS traders and margin survey evidence indicate that the standard practice by these dealers is to require full collateralization of swap liabilities by both counterparties to a CDS contract. In fact, the CDS traders we spoke with reported that the large Wall Street dealers they trade with typically require that their non-dealer counterparties overcollateralize their CDS liabilities slightly. This is consistent with the *ISDA Margin Survey (2009)* that documents that the 20 largest firms accounted for 93% of all collateral received, but only 89% of all collateral delivered, suggesting that there was a net inflow of collateral to the largest CDS dealers. Furthermore, the degree of overcollateralization required can vary over time. As an example, one reason for the liquidity problems at AIG that led to emergency loans by the Federal Reserve was that AIG would have been required to post additional collateral to CDS counterparties if AIG's credit rating had downgraded further.⁹

At first glance, the market standard of full collateralization seems to suggest that there may be little risk of a loss from the default of a Wall Street credit protection seller. This follows since the protection buyer holds collateral in the amount of the protection seller's CDS liability. In actuality, however, the Wall Street practice of requiring non-dealer protection buyers to slightly overcollateralize their liabilities actually creates a subtle counterparty credit risk. To illustrate this, imagine that a protection buyer has a mark-to-market liability to the protection seller of \$15 per \$100 notional amount. Furthermore, imagine that the protection seller requires the protection buyer to post \$17 in collateral. Now consider what occurs if the protection seller defaults. The bankruptcy estate of the protection seller uses \$15 of the protection buyer's collateral to offset the \$15 mark-to-market liability. Rather than returning the additional \$2 of collateral, however, this additional capital becomes part of the bankruptcy estate. This implies that the protection buyer is now an unsecured creditor in the

⁸ Bliss and Kaufman (2006) provide an excellent discussion of the role of ISDA and of netting, collateral, and closeout provisions in mitigating systemic credit risk.

⁹ For example, see the speech by Federal Reserve Chairman Ben S. Bernanke before the Committee on Financial Services, U.S. House of Representatives, on March 24, 2009.

amount of the \$2 excess collateral. Thus, in this situation, the protection buyer could suffer a significant loss even though the buyer actually owed the defaulting counterparty on the CDS contract.

This scenario is far from hypothetical. In actuality, a number of firms experienced major losses on swap contracts in the wake of the Lehman bankruptcy because of their net exposure (swap liability and offsetting collateral) to Lehman.¹⁰

4. The data

Fixed-income securities and contracts are traded primarily in over-the-counter markets. For example, Treasury bonds, agency bonds, sovereign debt, corporate bonds, mortgage-backed securities, bank loans, interest rate swaps, and CDS contracts are all traded in over-the-counter markets. Because of the inherent decentralized nature of these markets, however, actual transaction prices are difficult to observe. This is why most of the empirical research in the financial literature about fixed-income markets has typically been based on the quotation data available to participants in these markets.

We were fortunate to be given access to an extensive proprietary data set of CDS prices by one of the largest fixed-income asset management firms in the financial markets. A unique feature of this data set is that it contains both actual CDS transaction prices for contracts entered into by this firm as well as *actionable* quotations provided to the firm by a variety of CDS dealers. These quotations are actionable in the sense that the dealers are keenly aware that the firm expects to be able to trade (and often does) at the prices quoted by the dealers (and there are implicit sanctions imposed on dealers who do not honor their quotations). Thus, these quotations should more closely represent actual market prices than the indicative quotes typically used in the fixed-income literature.

In this paper, we study the spreads associated with contracts in which 14 major CDS dealers sell five-year credit protection to the fixed-income asset management firm on the 125 individual firms in the widely followed CDX index. The sample period for the study is March 31, 2008 to January 20, 2009. This period covers the turbulent Fall 2008 period in which Fannie Mae, Freddie Mac, Lehman Brothers, AIG, etc. entered into financial distress and counterparty credit fears reached their peak. Thus, this sample period is ideally suited for studying the effects of counterparty credit risk on financial markets.

The transactions data in the sample are taken from a file recording the spreads on actual CDS contracts executed by the firm in which the firm is buying credit protection. There are roughly 1,000 transactions in this file. The average transaction size is \$6.5 million and the average maturity of these contracts is 4.9 years. All 14 of the major CDS dealers to be studied in this paper are

included in this file. Thus, all 14 of these dealers sold credit protection to the asset management firm during the sample period. Of these transactions, however, most involve either firms that are not in the CDX index, or contracts with maturities significantly different from five years. Screening out these trades results in a sample of several hundred observations.

To augment the sample, we also include quotes provided directly to the firm by the CDS dealers selling protection on the firms in the CDX index. As described above, these quotes represent firm offers to sell protection and there can be sanctions for dealers who fail to honor their quotes. For example, if the asset management firm finds that a dealer is often not willing to execute new trades (or unwind existing trades) at quoted prices, then that dealer could be dropped from the list of dealers that the firm's traders are willing to do business with. Given the large size of the asset management firm providing the data, the major CDS dealers included in the study have strong incentives to provide actionable quotes.

There are a number of clear indications that the dealers respond to these incentives and provide reliable quotes. First, the dealers included in the study frequently update their quotes throughout the trading day. The total number of quotations records in the data set for firms in the CDX index is 673,060. This implies an average of 2.19 quotations per day per dealer for each of the firms in the sample. Thus, quotes are clearly being refreshed throughout the trading day. Second, the fact that all 14 of the CDS dealers sold protection to the asset management firm during the sample period suggests that each was active in providing competitive and actionable quotes during this period. Third, we compare our sample of transaction prices directly to the quotes available in the market on the same day. This comparison is necessarily a little noisy since the transaction prices are not time-stamped within the day, and we are comparing them to quotes available in the market at roughly 11:30 AM. Despite this, however, the average transaction price is only 0.26 basis points below the minimum quote available in the market. The standard deviation of the difference is 5.87 basis points and the difference between the mean transaction price and minimum quote is not statistically significant.

As mentioned, dealers frequently update their quotations throughout the day to insure that they are current. Since our objective is to study whether the cross-sectional dispersion in dealer prices is related to counterparty credit risk, it is important that we focus on dealer prices that are as close to contemporaneous as possible. To this end, we extract quotes from the data set in the following way. First, we select 11:30 AM as the reference time. For each of the 14 CDS dealers, we then include the quote with time-stamp nearest to 11:30 AM, but within 15 minutes (from 11:15 to 11:45 AM). In many cases, of course, there may not be a quote within this 30-minute period. Thus, we will generally have fewer than 14 prices or quotes available for each firm each day. For a firm to be included in the sample for a particular day, we require that there be two or more prices or quotes for that firm. We repeat this process for all days and firms in the sample.

¹⁰ From the October 7, 2008 *Financial Times*: "The exact amount of any claim is determined by the difference between the value of the collateral and the cost of replacing the contract.... Moreover, many counterparties to Lehman who believe it owes them money have joined the ranks of unsecured creditors."

This algorithm results in a set of 13,383 observation vectors of synchronous prices or quotations by multiple CDS dealers for selling protection on a common underlying reference firm. Since there are 212 trading days in the sample period, this implies that we have data for multiple CDS dealers for an average of 63.13 firms each day. Table 1 presents summary statistics for the data. As shown, the number of synchronous quotes ranges from two to nine. On average, an observation includes 3.073 dealer quotes for the reference firm for that day. Table 1 also shows that the variation in the quotes provided by the various dealers is relatively modest. For most of the observations, the range of CDS quotations is only on the order of two to three basis points, and the median range is three basis points.

In addition to the prices and quotes provided by the dealers selling protection, we also need a measure of the counterparty credit risk of the dealers themselves. To this end, we obtain daily midmarket five-year CDS quotes referencing each of the 14 major CDS dealers in the study. The midmarket spreads for these CDS contracts are obtained

from the Bloomberg system and reflect the market's perception of the counterparty credit risk of the dealers selling credit protection to the asset management firm.

Table 2 reports summary statistics for the CDS spreads for these dealers. As shown, the average CDS spread ranges from a low of 59.40 basis points for BNP Paribas to a high of 355.10 basis points for Morgan Stanley. Note that CDS data for Lehman Brothers and Merrill Lynch are included in the data set even though these firms either went bankrupt or merged during the sample period. The reason for including these firms is that both were actively making markets in selling credit protection through much of the sample period. Thus, their spreads may be particularly informative about the impact of perceived counterparty credit risk on CDS spreads.

5. Empirical analysis

In this section, we begin by briefly describing the methodology used in the empirical analysis. We then test

Table 1

The distribution of dealer prices and quotations.

This table provides summary statistics for the distribution of dealer prices or quotations for CDS contracts referencing the firms in the CDX index. The panel on the left summarizes the distribution in terms of the number of dealer prices and quotations on a given day for a CDS contract referencing a specific firm. The panel on the right summarizes the distribution in terms of the range R of prices and quotations (measured in basis points) provided by dealers on a given day for a CDS contract on a specific reference firm. Only days on which two or more simultaneous prices or quotations are available for a specific firm are included in the sample as an observation. The sample period is March 31, 2008 to January 20, 2009.

Number	Observations	Percentage	Range	Observations	Percentage
2	4907	36.66	0	1175	8.78
3	4518	33.78	$0 < R \leq 1$	1952	14.59
4	2566	19.17	$1 < R \leq 2$	2298	17.17
5	1012	7.56	$2 < R \leq 3$	1925	14.38
6	267	1.99	$3 < R \leq 4$	1065	7.96
7	84	0.62	$4 < R \leq 5$	1800	13.44
8	21	0.16	$5 < R \leq 10$	2209	16.51
9	8	0.06	$10 < R \leq 20$	748	5.59
			$20 < R$	211	1.58
Total	13,383	100.00	Total	13,383	100.00

Table 2

Summary statistics for CDS contracts referencing dealers.

This table provides summary statistics for the CDS spreads (in basis points) for contracts referencing the dealers listed below. The spreads are based on daily observations obtained from the Bloomberg system. N denotes the number of days on which Bloomberg quotes are available for the indicated dealer. The sample period is March 31, 2008 to January 20, 2009.

Dealer	Mean	Standard deviation	Minimum	Median	Maximum	N
Barclays	122.65	43.33	53.27	122.17	261.12	212
BNP Paribas	59.40	13.29	34.24	59.08	107.21	212
Bank of America	121.60	35.77	61.97	119.75	206.85	209
Citigroup	180.67	71.13	87.55	162.90	460.54	207
Credit Suisse	111.66	37.20	57.59	101.40	194.22	212
Deutsche Bank	96.88	29.70	51.92	90.11	172.00	212
Goldman Sachs	230.58	110.62	79.83	232.69	545.14	177
HSBC	75.41	21.94	41.84	67.59	128.30	212
JP Morgan	110.86	27.96	62.54	107.68	196.34	209
Lehman	291.79	89.01	154.04	285.12	641.91	84
Merrill Lynch	243.19	71.34	114.35	218.43	472.72	193
Morgan Stanley	355.10	236.22	108.06	244.98	1360.00	187
Royal Bank of Scotland	116.45	45.16	55.17	110.69	304.89	212
UBS	139.09	56.81	55.45	126.24	320.80	212

whether counterparty credit risk is reflected in the prices of CDS contracts. Finally, we study whether the pricing of counterparty credit risk by dealers varies by industry as would be implied by a correlation-based credit model.

5.1. Methodology

For each reference firm and for each date t in the sample, we have simultaneous prices from multiple CDS dealers for selling five-year credit protection on that firm. Thus, we can test directly whether counterparty credit risk is priced by a straightforward regression of the price of protection sold or quoted by a dealer for a reference firm on the price of protection for the dealer itself providing that quotation. In this panel regression framework, we allow for reference-firm-specific date fixed effects. Specifically, we estimate the following regression:

$$CDS_{i,j,t} = \alpha_{i,t} + \beta \text{ Spread}_{j,t-1} + \epsilon_{i,j,t}, \tag{1}$$

where $CDS_{i,j,t}$ denotes the CDS spread for credit protection on reference firm i sold or quoted by dealer j at date t , $\alpha_{i,t}$ is a fixed effect parameter specific to firm i at time t , and $\text{Spread}_{j,t-1}$ is the CDS spread for dealer j as of the end of the previous day.¹¹ Under the null hypothesis that counterparty credit risk is not priced, the slope coefficient β is zero. The t -statistics for β reported in the tables are based on the White (1980) heteroskedastic-consistent estimate of the covariance matrix.

As shown in Table 1, there are a total of 13,383 observation vectors in the sample. On average, each observation vector consists of 3.073 distinct quotations for selling credit protection on the reference firm, giving a total of 41,122 observations collectively. Thus, there are 339.85 observations on average for each of the 121 reference firms in the sample.

5.2. Is counterparty credit risk priced?

Although a formal model of the relation between a dealer’s credit risk and the price at which the dealer could sell credit protection could be developed, the underlying economics of the transaction makes it clear that there should be a negative relation between the two. Specifically, as the credit risk of a protection seller increases, the value of the protection being sold is diminished and market participants would not be willing to pay as much for it. Thus, if counterparty credit risk is priced in the market, the slope coefficient β in the regressions should be negative.

Table 3 reports the results from estimating the regression in Eq. (1) (which is designated specification I). The slope coefficient β is -0.001548 with a t -statistic of -7.31 . Thus, the empirical results strongly support the hypothesis that counterparty credit risk is priced in the

¹¹ We use the dealer’s spread as of $t-1$ rather than t since the dealer data are as of the end of the day while the CDS quotation data are taken from a narrow timeframe centered at 11:30 AM. Thus, using the dealer’s spread as of the end of day $t-1$ avoids using ex post data in the regression.

Table 3

Results from the regression of CDS spreads on the CDS spread of the corresponding dealer.

This table reports the results from the regressions of CDS prices or quotations for the firms in the CDX Index on the CDS spread of the dealer providing the CDS price or quotation. The sample period is March 31, 2008 to January 20, 2009. Regression specification II includes a dummy variable I_t that takes value one for the post-Lehman period beginning September 15, 2008, and zero otherwise. The t -statistics are based on the White (1980) heteroskedasticity-consistent estimate of the covariance matrix. The superscript ** denotes significance at the 5% level; the superscript * denotes significance at the 10% level.

$$I: CDS_{i,j,t} = \alpha_{i,t} + \beta \text{ Spread}_{j,t-1} + \epsilon_{i,j,t},$$

$$II: CDS_{i,j,t} = \alpha_{i,t} + \beta \text{ Spread}_{j,t-1} + \gamma I_{t-1} \text{ Spread}_{j,t-1} + \epsilon_{i,j,t}.$$

Variable	Regression specification I		Regression specification II with post-Lehman dummy	
	Coefficient	t-Statistic	Coefficient	t-Statistic
Spread	-0.001548	-7.31**	-0.000991	-3.73**
I_t Spread			-0.000713	-1.92*
N		41,122		41,122

CDS market. Furthermore, the sign of the coefficient is negative, consistent with economic intuition.

We acknowledge, however, that we cannot completely rule out the possibility that the relation between CDS spreads and the credit risk of protection sellers may actually be due to some other factor that is correlated with dealer spreads.¹² For example, since CDS contracts are traded in over-the-counter markets, the search costs associated with finding trading partners could play a role in determining equilibrium CDS spreads (see Duffie, Gârleanu, and Pedersen, 2002, 2005, 2008 and others). If these search costs were inversely related to dealer CDS spreads, then they could potentially affect CDS spreads in a way consistent with the results reported in Table 3. We will explore some of these possibilities in a later section on robustness.

5.3. Why is the effect so small?

Although statistically very significant, the slope coefficient is relatively small in economic terms. In particular, the value of -0.001548 implies that the credit spread of a CDS dealer would have to increase by nearly 645 basis points to result in a one-basis-point decline in the price of credit protection. As shown in Table 2, credit protection on most of CDS dealers in the sample never even reached 645 basis points during the period under study. These results are consistent with the results in Table 1 suggesting that the cross-sectional variation in the dealers’ quotes for selling credit protection on a specific reference firm is only on the order of several basis points.

A number of papers have explored the theoretical magnitude of counterparty credit risk on the pricing of interest rate swaps. Important examples of this literature

¹² We are grateful to the referee for raising this issue.

include Cooper and Mello (1991), Sorensen and Bollier (1994), and Duffie and Huang (1996). Typically, these papers find that since the notional amount is not exchanged in an interest rate swap, the effect of counterparty credit risk on an interest rate swap is very small, often only a basis point or two.

Unlike an interest rate swap, however, a CDS contract could involve a very large payment by the protection seller to the protection buyer. For example, sellers of protection on Lehman Brothers were required to pay \$91.375 per \$100 notional to settle their obligations to protection buyers. Thus, the results from the interest rate swap literature may not necessarily be directly applicable to the CDS market.

A few recent papers have focused on the theoretical impact of counterparty credit risk on the pricing of CDS contracts. Important examples of these papers include Jarrow and Yu (2001), Hull and White (2001), Brigo and Pallavicini (2006), Kraft and Steffensen (2007), Segoviano and Singh (2008), and Blanchet-Scalliet and Patras (2008). In general, estimates of the size of the effect of counterparty credit risk in this literature tend to be orders of magnitude larger than those in the literature for interest rate swaps. For example, estimates of the potential size of the pricing effect range from 7.0 basis points in Kraft and Steffensen to more than 20 basis points in Hull and White, depending on assumptions about the default correlations of the protection seller and the underlying reference firm. Thus, this literature tends to imply counterparty credit risk pricing effects many times larger than those we find in the data.

It is crucial to recognize, however, that this literature focuses almost exclusively on the case in which CDS contract liabilities are not collateralized. As was discussed earlier, the standard market practice during the sample period would be to require full collateralization by both counterparties to a CDS contract. This would be particularly true for CDS contracts in which one counterparty was a large Wall Street CDS dealer.

In theory, full collateralization of CDS contract liabilities would appear to imply that there should be no pricing of counterparty credit risk in CDS contracts. In reality, however, there are several reasons why there might still be a small pricing effect even if counterparties require full collateralization. First, as became clear after the Lehman bankruptcy, counterparties who post collateral in excess of their liabilities risk becoming unsecured creditors of a defaulting counterparty for the amount of the excess collateral. As discussed earlier, however, Wall Street CDS dealers often require a small amount of overcollateralization from their counterparties (typically on the order of several percent) thus creating the possibility of a slight credit loss (ironically, however, only when the counterparty owes the bankrupt firm money). Second, the Lehman bankruptcy also showed that there were a number of legal pitfalls that many market participants had not previously appreciated. These include the risk of unsegregated margin accounts or the disposition of rehypothecated collateral.

In summary, the size of the counterparty pricing effect in the CDS market appears too small to be explained by

models that abstract from the collateralization of CDS contracts. Rather, the small size of the pricing effect appears more consistent with the standard market practice of full collateralization, or even overcollateralization, of CDS contract liabilities.

5.4. Did pricing of counterparty credit risk change?

The discussion above suggests that the Lehman bankruptcy event may have forced market participants to reevaluate the risks inherent in even fully collateralized counterparty relationships. If so, then the pricing of counterparty credit after the Lehman bankruptcy might differ from the pricing in the CDS market previous to the bankruptcy. To explore this possibility, we reestimate the regression described above using a dummy slope coefficient for the post-Lehman period. Specifically, we estimate the regression

$$CDS_{i,j,t} = \alpha_{i,t} + \beta \text{Spread}_{j,t-1} + \gamma I_{L,t} \text{Spread}_{j,t-1} + \epsilon_{i,j,t}, \quad (2)$$

where I_L is a dummy variable that takes value one for the post-Lehman period beginning September 15, 2008, and zero otherwise. Table 3 also reports the results from this regression (which is designated specification II). Note that in this specification, the coefficient β represents the regression slope during the pre-Lehman period, while the coefficient γ measures the change in the slope after the Lehman bankruptcy. Thus, we can test for whether there was a significant change in the pricing of counterparty credit risk after the Lehman bankruptcy by simply testing whether γ is statistically significant. The regression slope during the post-Lehman period can be obtained by simply summing the pre-Lehman slope coefficient β and the post-Lehman change in the slope coefficient γ .

The results provide some support for the hypothesis that the pricing of counterparty credit risk changed after the Lehman bankruptcy. Specifically, the pre-Lehman slope coefficient is -0.000991 and has a t -statistic of -3.73 . After the Lehman bankruptcy, the change in the slope coefficient is -0.000713 , making the pricing of counterparty credit risk in the post-Lehman period roughly twice as large as in the pre-Lehman period. The t -statistic for the change, however, is only -1.92 . Thus, the change is significant at the 10% level, but not the 5% level.

5.5. Robustness of the results

To provide some robustness checks for these results, we also estimate several alternative specifications. In the first of these, we include the total number of trades executed by each dealer each day as a control for trading activity. Specifically, we estimate the following regression specifications:

$$CDS_{i,j,t} = \alpha_{i,t} + \beta \text{Spread}_{j,t-1} + \eta \text{Volume}_{j,t} + \epsilon_{i,j,t}, \quad (3)$$

$$CDS_{i,j,t} = \alpha_{i,t} + \beta \text{Spread}_{j,t-1} + \gamma I_{L,t} \text{Spread}_{j,t-1} + \eta \text{Volume}_{j,t} + \epsilon_{i,j,t}, \quad (4)$$

where $\text{Volume}_{j,t}$ denotes the total number of trades executed by dealer j on date t . Table 4 reports the results from the regressions.

Table 4

Results from the regression of CDS spreads on the CDS spread of the corresponding dealer with control for dealer trading volume.

This table reports the results from the regressions of CDS prices or quotations for the firms in the CDX index on the CDS spread of the dealer providing the CDS price or quotation and on the total number of trades executed by the dealer in all CDX index firms that day as a control variable (denoted as volume). The sample period is March 31, 2008 to January 20, 2009. Regression specification II includes a dummy variable I_t that takes value one for the post-Lehman period beginning September 15, 2008, and zero otherwise. The t -statistics are based on the White (1980) heteroskedasticity-consistent estimate of the covariance matrix. The superscript ** denotes significance at the 5% level; the superscript * denotes significance at the 10% level.

$$I: \text{CDS}_{i,j,t} = \alpha_{i,t} + \beta \text{Spread}_{j,t-1} + \eta \text{Volume}_{j,t} + \epsilon_{i,j,t},$$

$$II: \text{CDS}_{i,j,t} = \alpha_{i,t} + \beta \text{Spread}_{j,t-1} + \gamma I_{L,t} \text{Spread}_{j,t-1} + \eta \text{Volume}_{j,t} + \epsilon_{i,j,t}.$$

Variable	Regression specification I		Regression specification II with post-Lehman dummy	
	Coefficient	t -Statistic	Coefficient	t -Statistic
Spread	-0.001548	-7.30**	-0.000990	-3.73**
I_L Spread			-0.000714	-1.92*
Volume	0.008122	0.12	0.009988	0.14
N		41122		41122

Even after controlling for dealer trading activity, Table 4 shows the regression coefficients and t -statistics for the dealers' CDS spreads are virtually the same as they are in Table 3. Thus, the results provide evidence that the dealer spread is not simply proxying for dealer liquidity effects.

As another robustness check, we reestimate the regressions in Table 3, but with dummy variables for individual dealers. This specification controls for dealer fixed effects. Thus, the relation between CDS spreads for the firms in the CDX index and dealer CDS spreads is identified using only the times-series variation in spreads. The regressions estimated are

$$\text{CDS}_{i,j,t} = \alpha_{i,t} + \beta \text{Spread}_{j,t-1} + \sum_{j=1}^{13} \delta_j I_j + \epsilon_{i,j,t}, \quad (5)$$

$$\text{CDS}_{i,j,t} = \alpha_{i,t} + \beta \text{Spread}_{j,t-1} + \gamma I_{L,t} \text{Spread}_{j,t-1} + \sum_{j=1}^{13} \delta_j I_j + \sum_{j=1}^{13} \eta_j I_j I_L + \epsilon_{i,j,t}, \quad (6)$$

where I_j is the dummy variable for the j -th dealer. Note that we only include 13 dealer dummies rather than all 14. This is because inclusion of all 14 dummies results in a collinearity with the firm and date fixed effects. Thus, the regression coefficients for dealer dummies have the interpretation of the marginal effect relative to that of the omitted dealer, which is chosen to be the dealer with the highest trading activity throughout the sample period. The results from these regressions are reported in Table 5.

The results indicate that the previous results are robust to the inclusion of dealer fixed effects. The coefficient for dealer CDS spread is -0.001338 for the first specification, which is only slightly less than the

Table 5

Results from the regression of CDS spreads on the CDS spread of the corresponding dealer with fixed effects for individual dealers.

This table reports the results from the regression of CDS prices or quotations for the firms in the CDX index on the CDS spread of the dealer providing the CDS price or quotation. The regression also includes a separate fixed effect dummy variable for each dealer (except for the dealer with the largest number of quotes, arbitrarily designated dealer 14). The sample period is March 31, 2008 to January 20, 2009. Regression specification II includes a dummy variable I_t that takes value one for the post-Lehman period beginning September 15, 2008, and zero otherwise. The t -statistics are based on the White (1980) heteroskedasticity-consistent estimate of the covariance matrix. The superscript ** denotes significance at the 5% level; the superscript * denotes significance at the 10% level.

$$I: \text{CDS}_{i,j,t} = \alpha_{i,t} + \beta \text{Spread}_{j,t-1} + \sum_{j=1}^{13} \delta_j I_j + \epsilon_{i,j,t},$$

$$II: \text{CDS}_{i,j,t} = \alpha_{i,t} + \beta \text{Spread}_{j,t-1} + \gamma I_{L,t} \text{Spread}_{j,t-1} + \sum_{j=1}^{13} \delta_j I_j + \sum_{j=1}^{13} \eta_j I_j I_L + \epsilon_{i,j,t}.$$

Variable	Regression specification I		Regression specification II with post-Lehman dummy	
	Coefficient	t -Statistic	Coefficient	t -Statistic
Spread	-0.001338	-4.49**	-0.001786	-2.35**
I_1	-1.4154	-3.87**	-0.1130	-0.23
I_2	0.6574	4.17**	0.7774	4.34**
I_3	0.1707	1.56	0.1923	1.88*
I_4	0.4062	4.95**	0.5837	7.50**
I_5	0.2106	1.95*	0.0086	0.09
I_6	0.0326	0.64	-0.0461	-0.82
I_7	0.4728	2.28**	0.4227	2.07**
I_8	0.6006	6.03**	0.2026	2.28**
I_9	-0.1701	-1.66*	-0.1136	-0.82
I_{10}	0.1041	1.49	0.3960	3.75**
I_{11}	0.1862	3.60**	0.1982	3.05**
I_{12}	0.9453	6.96**	0.6462	3.74**
I_{13}	0.1922	1.64	0.0659	0.65
I_L Spread			0.000347	0.36
$I_1 I_L$			-1.4112	-2.21**
$I_2 I_L$			-1.0839	-2.78**
$I_3 I_L$			-0.0857	-0.30
$I_4 I_L$			-0.7415	-2.90**
$I_5 I_L$			0.4342	1.47
$I_6 I_L$			0.7280	2.58**
$I_7 I_L$			0.5204	0.32
$I_8 I_L$			1.6748	4.68**
$I_9 I_L$			-	-
$I_{10} I_L$			-1.1010	-4.79**
$I_{11} I_L$			0.0423	0.17
$I_{12} I_L$			0.6155	2.08**
$I_{13} I_L$			2.6544	1.87*
N		41,122		41,122

corresponding estimate in Table 3. The t -statistic for dealer CDS spread in this regression is -4.49. In the second specification with the post-Lehman dummy variable, the CDS spread of the dealer is again significantly negative during the pre-Lehman period, and there is no significant change in the variable after the Lehman bankruptcy. This again provides support for the result that dealer credit risk is priced in the market, although the effect is very small.

The coefficients for the individual dealer dummy variables are also interesting. Although many of the coefficients in the first specification are significant, almost all of them are much less than one basis point in magnitude. The same is also true for the pre-Lehman coefficients for the second specification. On the other hand, the results indicate that a number of the coefficients change in the post-Lehman period by one or more basis points. These changes, however, are essentially equally divided between positive and negative values. Thus, these results provide some evidence of greater heterogeneity in dealer fixed effects in the post-Lehman period.¹³

5.6. Are there differences across firms?

A number of recent papers have emphasized the role that the default correlation between the protection seller and the reference firm should play in determining CDS spreads. To illustrate the importance of correlation, let us take it to an extreme and imagine that Citigroup is willing to sell credit protection against the event that Citigroup itself defaults. Clearly, no one would be willing to pay Citigroup for this credit protection.¹⁴ Similarly, a financial institution selling credit protection on another financial institution might not be able to charge as much as a nonfinancial seller might.¹⁵

To explore the effects of correlation on the price of credit protection, we do the following. First, we classify the firms in the CDX index that are in our sample into one of five broad industry sectors or categories: consumer, energy, financials, industrials, and technology. We then reestimate the regressions using the following specifications:

$$CDS_{i,j,t} = \alpha_{i,t} + \sum_{k=1}^5 \beta_k I_{Sector_k} Spread_{j,t-1} + \epsilon_{i,j,t}, \tag{7}$$

$$CDS_{i,j,t} = \alpha_{i,t} + \sum_{k=1}^5 \beta_k I_{Sector_k} Spread_{j,t-1} + \sum_{k=1}^5 \gamma_k I_{Sector_k} I_L Spread_{j,t-1} + \epsilon_{i,j,t}, \tag{8}$$

where I_{Sector_k} are dummy variables that take value one if firm i is in sector k , and zero otherwise. The regression results are reported in Table 6.

As shown in the first specification, counterparty credit risk is priced for the consumer, energy, industrial, and technology firms in the sample. The t -statistics for the corresponding coefficients are -4.83 , -7.25 , -3.61 , and -5.41 , respectively. These results are clearly consistent with the previous results.

Table 6

Results from regression of CDS spreads on the CDS spreads of the corresponding dealer interacted with sector dummy variables for the underlying firms.

This table reports the results from the regression of CDS prices or quotations for the firms in the CDX index on the CDS spread of the dealer providing the CDS price or quotation interacted with five sector dummy variables where the dummy variables take value one if firm i is in the consumer, energy, financial, industrial, or technology sectors, respectively, and zero otherwise. The sample period is March 31, 2008 to January 20, 2009. Regression specification II includes a dummy variable I_L that takes value one for the post-Lehman period beginning September 15, 2008, and zero otherwise. The t -statistics are based on the White (1980) heteroskedasticity-consistent estimate of the covariance matrix. The superscript ** denotes significance at the 5% level; the superscript * denotes significance at the 10% level.

$$I: CDS_{i,j,t} = \alpha_{i,t} + \sum_{k=1}^5 \beta_k I_{Sector_k} Spread_{j,t-1} + \epsilon_{i,j,t},$$

$$II: CDS_{i,j,t} = \alpha_{i,t} + \sum_{k=1}^5 \beta_k I_{Sector_k} Spread_{j,t-1} + \sum_{k=1}^5 \gamma_k I_{Sector_k} I_L Spread_{j,t-1} + \epsilon_{i,j,t}.$$

Variable	Regression specification I		Regression specification II with post-Lehman dummy	
	Coefficient	t -Statistic	Coefficient	t -Statistic
$I_{Consumer}$ Spread	-0.001161	-4.83**	-0.000015	-0.04
I_{Energy} Spread	-0.002313	-7.25**	-0.002253	-5.14**
$I_{Financial}$ Spread	0.001097	0.77	-0.000910	-0.67
$I_{Industrial}$ Spread	-0.001324	-3.61**	-0.001245	-2.42**
$I_{Technology}$ Spread	-0.002553	-5.41**	-0.003173	-4.69**
$I_{Consumer} I_L$ Spread			-0.001719	-3.65**
$I_{Energy} I_L$ Spread			-0.000079	-0.09
$I_{Financial} I_L$ Spread			0.003183	1.27
$I_{Industrial} I_L$ Spread			-0.000096	-0.14
$I_{Technology} I_L$ Spread			0.000674	0.80
<i>N</i>		41,122		41,122

The most puzzling result, however, is that for the financial sector. As described above, the correlation argument suggests that the counterparty credit risk for the CDS dealers should be most evident when they are selling protection on firms in the financial industry. In contrast to this intuition, however, the results show that the CDS dealers' counterparty credit risk is not priced in the spreads of CDS contracts on financial firms. Furthermore, likelihood ratio tests strongly reject the hypotheses that the slope coefficient for the financial sector is equal to that of the consumer, energy, industrial, and technology sectors, with p -values of 0.00026, 0.00000, 0.00012, and 0.00000, respectively. Thus, the pricing of counterparty credit risk for financial firms is significantly different from that of the other four categories of firms in the sample. In summary, far from being the most sensitive to counterparty credit risk, financial firms in the CDX index represent the only category in the sample for which counterparty credit risk is not priced.

These patterns are repeated in the second specification. As shown, counterparty credit risk is significantly

¹³ We are grateful to the referee for suggesting the robustness checks discussed in this section.

¹⁴ It is interesting to note, however, that a number of European banks sell credit protection on the iTraxx index which includes these banks as index components.

¹⁵ Examples of recent papers discussing the role of correlation in the pricing of CDS contracts include Hull and White (2001), Jarrow and Yu (2001), Longstaff, Mithal, and Neis (2005), Yu (2007), and many others.

priced for the energy, industrial, and technology firms during the pre-Lehman period. Furthermore, there is no significant change in how counterparty credit risk is priced for these firms in the post-Lehman period. Counterparty credit risk for firms in the consumer sector is not priced during the pre-Lehman period, but there is a significant change in pricing for these firms after the Lehman event. The results also show that counterparty credit risk for the financial firms is not priced in the pre-Lehman period, and that there is no significant change in this relation after the Lehman event.

What factors might help account for the evidence that counterparty credit risk is not priced for the financial firms? First of all, the financial firms in the CDX index consist primarily of insurance firms, industrial lenders, consumer finance firms, and real estate companies. Thus, it is possible that the default risk of these firms in the CDX index may actually be much less correlated with that of the CDS dealers than one might expect based on their designation as financials. Second, counterparty credit risk might not be priced in the cost of selling protection on the large financial firms in the CDX index if the market believed that the CDS dealers would not fail when the large financial firms in the CDX index became vulnerable to default. Thus, this possibility suggests that there might be a state-contingent aspect to the default risk of CDS dealers. Finally, it is important to acknowledge that there is actually little empirical evidence in the literature about default correlations. Thus, while intuition suggests that the default correlation between financial firms should be higher than the default correlation between financial and nonfinancial firms, there is no direct empirical evidence supporting this intuition. For this reason, the analysis in this section should be viewed more as an exploratory investigation, rather than as a test rejecting specific empirical hypotheses about default correlations.

6. Comparison to model-implied values

The empirical results demonstrate that counterparty credit risk is priced by the market, but that the size of the effect is very small. A natural question to ask is whether these empirical results can be reconciled with those implied by theoretical models of counterparty credit risk.¹⁶

There is a large and rapidly growing literature on the valuation of counterparty credit risk in CDS contracts which is far too extensive for us to review fully here. Gregory (2010) provides an excellent summary of the literature and discusses a number of the modeling approaches that have been applied to the problem of valuing counterparty credit risk. In this section, we compare our empirical results with those implied by a simple simulation-based model of the effects of counterparty credit risk. A key feature of this framework is that it allows us to quantify the size of the effect when CDS counterparties collateralize their mark-to-market liabilities.

In this model, we take the perspective of the protection buyer and model the losses arising from the default of the protection seller. To model default, we use the reduced-form framework of Duffie and Singleton (1997, 1999) in which the default of a firm is triggered by the realization of a jump process. Let λ_t and v_t denote the risk-neutral intensity processes of the firm underlying the CDS contract and the firm selling credit protection (the CDS counterparty), respectively. The risk-neutral dynamics for these intensity processes are given by,

$$d\lambda = (\alpha - \beta\lambda)dt + \sigma\sqrt{\lambda} dZ_\lambda, \quad (9)$$

$$dv = (\mu - \gamma v)dt + s\sqrt{v} dZ_v, \quad (10)$$

where α , β , σ , μ , γ , and s are constant parameters, and $\text{Corr}(dZ_\lambda, dZ_v) = \xi$. Given this model, the marginal distribution for the default time of the underlying firm has a hazard function equal to the realized path of the intensity (see Lando, 1998), and similarly for the firm selling default protection. Modeling the simultaneous distribution of defaults would require a specification of the probability of simultaneous defaults. We will specify the joint distribution of defaults in our discrete-time simulation.

Following Gregory (2010), we distinguish between three types of default scenarios. The first is the case in which the underlying firm defaults but not the counterparty. In this case, the protection buyer receives the protection payment from the protection seller and does not suffer any counterparty credit losses.

The second case is when the counterparty defaults, but the underlying firm does not. For simplicity, we assume that both counterparties are required to post full collateral daily for CDS liabilities, where the mark-to-market liability is computed under the assumption that both counterparties are default free.¹⁷ In addition, we assume that there is zero recovery of uncollateralized liabilities in the event that the protection seller defaults.¹⁸ Given the square-root dynamics in Eq. (9), the value of a CDS contract can be obtained directly from the CDS valuation model in Longstaff, Mithal, and Neis (2005, pp. 2221–2222). There are now two ways in which a protection buyer can suffer a loss when the protection seller defaults. If the mark-to-market value is positive, but the collateral posted the previous day (which equals the previous day's mark-to-market value of the CDS contract) is insufficient, then the buyer's loss is the difference between the two. As discussed earlier, however, the buyer can also lose from a counterparty default when he owes the counterparty on the CDS contract and the amount of collateral posted with the defaulting protection seller exceeds the amount of the buyer's liability. In this situation, the excess collateral becomes part of the bankruptcy estate and represents the protection buyer's loss. Note that the loss of excess collateral does not occur when CDS liabilities are

¹⁷ This assumption greatly simplifies the analysis but has virtually no effect on the total amount of collateral required.

¹⁸ This is consistent with the Lehman default in which CDS contracts referencing Lehman were settled at 8.625 cents on the dollar.

¹⁶ We are grateful to the referee for raising this issue.

uncollateralized. Thus, there are states in which a protection buyer may be worse off with full bilateral collateralization of CDS liabilities.

The third case occurs when both the underlying firm and the counterparty default at the same time. We will make the assumption that joint default occurs if both the firm and the counterparty default within a two-business-day timeframe. This assumption reflects the reality that a discrete period of time is required operationally to post collateral and settle trades. With collateralization, the protection buyer's loss is the difference between the loss on the underlying firm and the amount of collateral held. Again, since the buyer may have posted collateral with the defaulting counterparty, the buyer could actually be worse off in some states in this joint default scenario than without collateralization.

Since we are simulating changes in the intensity processes and the realization of defaults at each time step, we only need to specify local or one-step joint probabilities to simulate joint default events. In particular, conditional on no default having occurred before time t , the marginal probability of the underlying firm defaulting between time t and $t + \Delta t$ is $\lambda_t \Delta t$. Similarly, the marginal probability of the firm selling credit protection defaulting between time t and $t + \Delta t$ is $v_t \Delta t$. Let a , b , c , and d denote the joint probabilities that neither firm defaults, that only the underlying firm defaults, that only the firm selling credit protection defaults, and that both firms default between time t and $t + \Delta t$, respectively. The Appendix shows that these joint probabilities are completely determined by the two marginal probabilities and a default correlation parameter ρ . Thus, we are in essence assuming that the local joint distribution of default events is given by a simple multinomial distribution. Furthermore, this approach explicitly allows for correlated defaults to occur. Given these joint probabilities, we simulate the model in steps of Δt and sample the four joint events based on their multinomial probabilities. We repeat this process at each time step along a simulated path until the first default occurs.¹⁹

Turning to the issue of calibration, it is important to stress that our objective is simply to provide general estimates of the size of counterparty default effects rather than to model specific contracts. As such, we adopt a generic parameterization and estimate counterparty default costs under a broad range of assumptions about default intensities and correlations. The average value of the CDX index during the sample period is 95 basis points, while the average CDS spread for the dealers during the same period is 145 basis points. These values, of course, are high by historical standards but they do provide a realistic benchmark for the calibration of the risk-neutral intensity processes. Accordingly, we parameterize the long-run values of λ_t and v_t to be 100 and 150 basis points, respectively. Furthermore, we assume $\beta = \gamma = 0.50$ and $\sigma = s = 0.20$. These parameters are consistent with

the longer-term properties of the CDX index.²⁰ We also assume that the spread correlation parameter ξ takes on values of 2%, 6%, or 10%. Similarly, we assume that the default correlation ρ takes on values of 2%, 6%, or 10%. These values essentially bracket the default correlations reported by Longstaff and Rajan (2008) implied from the prices of CDX index tranches and the CDS spreads for the constituents of the CDX index.²¹

Table 7 reports the estimated basis-point cost of counterparty default for a range of scenarios. Specifically, we compute the cost of events in which only the counterparty defaults, the cost of joint events in which both the underlying firm and the counterparty default, and the total of these two costs. The default intensity for the underlying firm takes values of 100 or 300 basis points, essentially bracketing the CDX index values during the sample period. Similarly, the default intensity for the counterparty selling protection takes values of 100, 300, and 500 basis points, again paralleling the behavior of broker CDS spreads during the sample period. The results are based on 100,000 simulations for a five-year CDS contract. The details on how the joint distribution of defaults is simulated are described in the Appendix.

The results in Table 7 imply counterparty credit risk pricing effects that are very consistent with those documented in previous sections of this paper. For example, a 400-basis-point increase in the CDS spread of the protection seller from 100 to 500 basis points maps into an increase in counterparty credit costs of roughly 0.5, 1.0, and 2.0 basis points in the cases where the default correlation is 2%, 6%, and 10%, respectively. Thus, the empirical estimates of the size of the effect of counterparty credit risk on CDS spreads given in this paper harmonize well with those implied by a model in which average default correlations are in the range of, say, zero to 4%.

7. Conclusion

We examine the extent to which the credit risk of a dealer offering to sell credit protection is reflected in the prices at which the dealer can sell protection. We find strong evidence that counterparty credit risk is priced in the market; the higher the credit risk of a dealer, the lower is the price at which the dealer can sell credit protection in the market. The magnitude of the effect, however, is extremely small. In particular, an increase in the credit spread of a dealer of about 645 basis points maps into only a one-basis-point decline in the price of credit protection.

The price of counterparty credit risk appears to be too small to be explained by models that assume that CDS liabilities are unsecured. The pricing of counterparty credit risk, however, seems consistent with the standard market practice of requiring full collateralization, or even the overcollateralization of CDS liabilities. These results

¹⁹ Note that the limiting distribution of this multinomial distribution would likely be of the form of a bivariate exponential distribution as the number of time steps increases (see Johnson and Kotz, 1972). We are grateful to the referee for this insight.

²⁰ Specifically, the moments of normalized monthly changes in the CDX index from 2004 to 2009 imply $\beta = 0.54$ and $\sigma = 0.18$.

²¹ For a few of the 100,000 simulated paths, we assume a smaller value of ρ to insure that simulated joint default probabilities remain positive. See the discussion in the Appendix.

Table 7

Basis point cost of CDS counterparty credit risk

This table reports the basis point cost to the protection buyer from the potential default of the protection seller. The central panel reports the costs when CDS liabilities are not collateralized; the right panel reports the costs when CDS liabilities are collateralized. CP default cost denotes the cost of events where only the counterparty defaults. Joint default cost denotes the cost of events where both the underlying firm and the counterparty default together. Total cost denotes the sum of the costs of the two types of events. The parameter ρ denotes the default correlation between the underlying firm and the counterparty. The parameters λ and η denote the basis point default intensities for the underlying firm and the counterparty, respectively.

Parameters			Uncollateralized			Collateralized			
ρ	λ	η	CP default cost	Joint default cost	Total cost	CP default cost	Joint default cost	Total cost	
0.02	100	100	0.69	0.89	1.58	0.07	0.88	0.95	
		300	0.98	1.02	2.00	0.10	1.00	1.10	
		500	1.31	1.21	2.52	0.14	1.18	1.32	
	300	100	0.68	1.16	1.84	0.08	1.14	1.22	
		300	1.16	1.50	2.66	0.13	1.48	1.61	
		500	1.62	1.56	3.18	0.18	1.53	1.71	
	0.06	100	100	0.68	2.50	3.18	0.07	2.43	2.50
			300	0.99	3.35	4.34	0.10	3.27	3.37
			500	1.32	3.52	4.83	0.13	3.43	3.56
300		100	0.69	3.24	3.93	0.08	3.18	3.26	
		300	1.16	4.15	5.31	0.13	4.07	4.20	
		500	1.63	4.48	6.11	0.18	4.38	4.56	
0.10		100	100	0.71	3.82	4.53	0.07	3.73	3.80
			300	1.02	5.17	6.19	0.10	5.04	5.14
			500	1.35	5.99	7.34	0.13	5.87	6.00
	300	100	0.69	5.11	5.80	0.08	5.00	5.08	
		300	1.15	6.89	8.04	0.13	6.75	6.88	
		500	1.65	7.70	9.35	0.18	7.55	7.73	

also have implications for current proposals about restructuring derivatives markets. For example, since market participants appear to price counterparty credit risk as if it were only a relatively minor concern, this suggests that attempts to mitigate counterparty credit risk through alternative approaches, such as the creation of a central clearinghouse for CDS contracts, may not be as effective as might be anticipated. This implication parallels and complements the conclusions in the recent paper by Duffie and Zhu (2009).

Appendix A

To simulate correlated defaults in the model presented in Section 6, we do the following. First, we define the discretization interval for the simulation to be two days; $\Delta t = 2/260$ (there are approximately 260 trading days per year). Let I_1 denote a random binomial variable that takes value one if the underlying firm defaults during the two-day window, and zero otherwise. Similarly, let I_2 denote a random binomial variable that takes value one if the counterparty defaults during the two-day window, and zero otherwise. Let $\pi_1 = \lambda \Delta t$ denote the probability that the underlying firm defaults during the two-day window, and $\pi_2 = \nu \Delta t$ denote the probability that the counterparty defaults during the two-day window. Thus, with this notation, $E[I_1] = \pi_1$ and $E[I_2] = \pi_2$. Also, $\text{Var}[I_1] = \pi_1 - \pi_1^2$ and $\text{Var}[I_2] = \pi_2 - \pi_2^2$.

Now let a denote the probability that neither the underlying firm nor the counterparty defaults during the

two-day window. Let b denote the probability that the underlying firm defaults during the two-day window, but the counterparty does not. Let c denote the probability that the counterparty defaults during the two-day window, but the underlying firm does not. Finally, let d denote the probability that both the underlying firm and the counterparty default during the two-day window. It is easily shown that the correlation ρ between I_1 and I_2 is given by

$$\text{Corr}[I_1, I_2] = \frac{d - \pi_1 \pi_2}{\sqrt{(\pi_1 - \pi_1^2)(\pi_2 - \pi_2^2)}}. \quad (\text{A.1})$$

Solving this expression for d gives,

$$d = \rho \sqrt{\pi_1 \pi_2 (1 - \pi_1)(1 - \pi_2)} + \pi_1 \pi_2. \quad (\text{A.2})$$

Since the marginal probabilities of default are π_1 and π_2 , and since the total probability must equal one, we have

$$a = 1 - b - c - d, \quad (\text{A.3})$$

$$b = \pi_1 - d, \quad (\text{A.4})$$

$$c = \pi_2 - d. \quad (\text{A.5})$$

Thus, given λ , ν , and ρ , we can solve for the probabilities a , b , c , and d that define the joint default distribution for each two-day window.

To simulate default outcomes for a five-year CDS contract, we simulate a path for the default intensity processes λ and ν using the dynamics given in Eqs. (9) and (10). In doing this, we use two-day discretization

intervals. For each two-day window along the path, we then apply the above algorithm to simulate the joint default outcome (neither defaults, both default, etc.). We then use the simulated joint default probabilities to define the cash flows along the path and evaluate the default costs. We repeat this process using 100,000 simulated paths.

Finally, we note that there is a minor restriction on ρ that is needed to insure that b and c take positive values:

$$\rho < \frac{\min(\pi_1(1-\pi_2), \pi_2(1-\pi_1))}{\sqrt{\pi_1\pi_2(1-\pi_1)(1-\pi_2)}}. \quad (\text{A.6})$$

Whenever ρ exceeds this bound for a two-day window, we set ρ equal to this bound in solving for the joint default probabilities for that two-day window. This restriction, however, only affects a small fraction of the 100,000 simulated paths.

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