DOCUMENTO DE TRABAJO

AN EMPIRICAL ANALYSIS OF THE DYNAMIC RELATIONSHIP BETWEEN INVESTMENT-GRADE BONDS AND CREDIT DEFAULT SWAPS

Documento de Trabajo n.º 0401

Roberto Blanco, Simon Brennan
and Ian W. Marsh

BANCO DE ESPAÑA

SERVICIO DE ESTUDIOS

AN EMPIRICAL ANALYSIS OF THE DYNAMIC RELATIONSHIP BETWEEN INVESTMENT-GRADE BONDS AND CREDIT DEFAULT SWAPS

Documento de Trabajo n.º 0401

Roberto Blanco
BANCO DE ESPAÑA

Simon Brennan
BANK OF ENGLAND

Ian W. Marsh
BANK OF ENGLAND AND CEPR

This paper represents the views and analysis of the authors and should not be thought to represent those of the Bank of England, Monetary Policy Committee members or the Banco de España. Any errors and omissions are the responsibility of the authors. The authors would like to thank Bill Allen, Eva Catarineu, Charles Goodhart, Andrew Haldane, Simon Hayes, Kevin James, David Rule, Hyun Shin, Michela Vecchi, Geoffrey Wood and seminar participants at the Bank of England and Banco de España for useful comments. Karen Goff and Andrew Paterson provided very able research assistance. CreditTrade and J.P. Morgan Securities kindly allowed us to use their credit default swap data. Numerous people at Banc of America Securities, Bloomberg, BNP Paribas, CreditTrade, Deutsche Bank and J.P. Morgan answered our questions and corrected our misunderstandings. They know who they are and that we are very grateful.

BANCO DE ESPAÑA
SERVICIO DE ESTUDIOS

ISSN: 0213-2710 (print)
ISSN: 1579-8666 (online)
Depósito legal:M. 6322-2004
Imprenta del Banco de España

Contents

Abstract

This paper analyses the behaviour of credit default swaps (CDS) for a sample of firms and finds support for the theoretical equivalence of CDS prices and credit spreads. When this is violated, the CDS price can be viewed as an upper bound on the price of credit risk, while the spread provides a lower bound. The paper shows that the CDS market is the main forum for credit risk price discovery and that CDS prices are better integrated with firm-specific variables in the short run. Both markets equally reflect these factors in the long run, and this is primarily brought about by bond market adjustment.

Key words: Credit default swaps, credit spreads, price discovery.

Summary

Risky corporate and sovereign bonds are among the most recent securities to benefit from the trading of associated derivative contracts. Credit derivatives are financial instruments that can be used to transfer credit risk from the investor exposed to the risk (the protection buyer) to an investor willing to assume that risk (the protection seller). Single-name credit default swaps (CDS) are the most liquid of the several credit derivatives currently traded and form the basic building blocks for more complex structured credit products. A single-name CDS is a contract that provides protection against the risk of a credit event by a particular company or country. The buyer of protection makes periodic payments to the protection seller until the occurrence of a credit event or the maturity date of the contract, whichever is first. If a credit event occurs the buyer is compensated for the loss (possibly hypothetically) incurred as a result of the credit event, which is equal to the difference between the par value of the bond or loan and its market value after default.

This paper addresses the validity and implications of a theoretical relationship equating credit default swap prices and credit spreads using data for a small cross-section of US and European firms for which high-quality data are available. For this sample of investment-grade firms, the theoretical arbitrage relationship linking credit spreads over the risk-free rate to CDS prices holds reasonably well on average for most of the companies (but especially for US firms), when the risk-free rate is proxied by the swap rate. Where the relationship does not hold, imperfections in the CDS market or measurement errors in the credit spread may be responsible. Due to contract specifications in credit default swaps, particularly in Europe, a cheapest-to-deliver option may also be included in the CDS price making it an upper bound on the true price of credit risk. We are unable to incorporate the repo cost of corporate bonds in our analysis due to a lack of reliable data. As a result, the measured credit spread may underestimate the true credit spread, and so forms a lower bound on the true price of credit risk. Subject to these caveats, for most reference entities, both the cash bond and credit default swap markets appear to price credit risk equally on average. We demonstrate, however, that price discovery takes place primarily in the CDS market. We speculate that price discovery occurs in the CDS market because of (micro)structural factors that make it the most convenient location for the trading of credit risk, and because there are different participants in the cash and derivative market who trade for different reasons.

The second part of the paper examines the determinants of changes in the two measures of the price of credit risk. Variables suggested by the structural literature on credit risk are capable of explaining around one quarter of the weekly changes in credit default swap prices. The same variables are less successful in capturing changes in credit spreads. Firm-specific equity returns and implied volatilities are statistically more significant and of greater economic importance for CDS prices than for credit spreads. The pricing discrepancy between CDS prices and credit spreads is closed primarily through changes in the credit spread, reflecting the CDS market's lead in price discovery. It is through this error correction mechanism that both CDS and credit spreads price credit risk equally in the long run. We argue that these findings are supportive of the structural models of credit risk.

1 Introduction

Risky corporate and sovereign bonds are among the most recent securities to benefit from the trading of associated derivative contracts. Credit derivatives are financial instruments that can be used to transfer credit risk from the investor exposed to the risk (the protection buyer) to an investor willing to assume that risk (the protection seller). The payoffs to a credit derivative are conditional on the occurrence of a credit event. The credit event is defined with respect to one or more reference entities and one or more reference assets issued by the reference entity.

Single-name credit default swaps (CDS) are the most liquid of the several credit derivatives currently traded and form the basic building blocks for more complex structured credit products.(1) A single-name CDS is a contract that provides protection against the risk of a credit event by a particular company or country. The buyer of protection makes periodic payments to the protection seller until the occurrence of a credit event or the maturity date of the contract, whichever is first. If a credit event occurs the buyer is compensated for the loss (possibly hypothetically) incurred as a result of the credit event, which is equal to the difference between the par value of the bond or loan and its market value after default. The economic effect of a credit default swap is similar to that of an insurance contract. The legal distinction comes from the fact that it is not necessary to hold an insured asset (eg the underlying bond or loan) in order to claim 'compensation' under a CDS. Speculators can take long (short) positions in credit risk by selling (buying) protection without needing to trade the cash instrument.

Credit derivatives are almost exclusively over-the-counter transactions that can be designed to meet the specific needs of the counterparties to the contract. However, recognising that the standardisation of a contract can act as a major spur to the growth of a market, the International Swaps and Derivatives Association (ISDA) released sets of Credit Derivatives Definitions in 1999 (which were amended in 2001) and 2003. The majority of credit derivatives transactions are documented according to ISDA definitions. Accordingly, having only been introduced in 1992, the British Bankers' Association (BBA) estimated the total notional value of outstanding credit derivatives (excluding asset swaps) to be US$1.19 trillion at the end of 2001.(2)

(1) Other basic credit derivatives include total return swaps, where the return from one asset or group of assets is swapped for the return on another, and credit spread options, which are options on the spread between the yield earned on two assets.
(2) The rapid growth rate should not disguise the fact that the credit derivatives market is still relatively small. The total notional outstanding value of interest rate swaps was estimated to be US$49 trillion at the end of 2000 (Bank for International Settlements (2000)), or around two to three times the value of the underlying cash instrument. Outstanding credit derivatives only amount to some 2%-3% of the value of underlying assets.

Single-name credit default swaps accounted for 45% of this total (BBA (2002)).

Credit default swaps arguably provide the easiest way to trade credit risk. Many corporate bonds are bought by investors who simply hold them to maturity (Alexander, Edwards and Ferri (1998)). Secondary market liquidity is therefore often poor making the purchase of large amounts of credit risk in the secondary cash market difficult and costly (Schultz (1998)). Shorting credit risk is even more difficult in the cash market. The repurchase agreement (repo) market for risky bonds is often illiquid, and even if a bond can be shorted on repo the tenor of the agreement is usually very short, leaving the investor looking to short a bond for a long period of time exposed to changes in the repo rate. Credit derivatives, especially credit default swaps allow investors to short credit risk over a long period of time at a known cost by buying protection.

We think that credit default swaps warrant study for two reasons. The first relates to the issue of price discovery. As we discuss further below, there are approximate arbitrage relationships that mean bond spreads and CDS prices should normally be closely linked. For other asset classes where an arbitrage relationship exists between the derivative and underlying instrument, price discovery can take place in either market. It is interesting to see whether the new, small but dynamic credit derivatives market is a better source of information on the price of credit risk than the much larger and more established cash bond market. Diamond and Verrecchia (1987) argue that, in the presence of short-sales constraints, good and particularly bad news is impounded into the price more slowly than in the absence of constraints. The less constrained derivatives market might then conceivably be the forum within which the majority of price discovery takes place. Indeed, this is what we demonstrate below.

Second, recent empirical work has suggested that the yield offered by defaultable securities in excess of the risk-free rate is only partly related to credit risk. Elton, Gruber, Agrawal and Mann (2001) find that taxation and risk premia compensating for systematic risk on corporate bonds together account for two-thirds of the spread between ten-year US corporate bonds and treasuries. The expected loss from default accounts for only 18%. Collin-Dufresne, Goldstein and Martin (2001) show that the factors suggested by traditional models of default risk explain only one quarter of the variation in credit spreads, and that the majority of the remaining variance is captured by a single principal component. They hypothesise that aggregate shocks are the source of the common factor. While credit derivatives prices are usually closely related to credit spreads, we show that a higher proportion of the variation in CDS prices can be explained by default-risk related factors.

The empirical literature on credit default swaps is quite small. Cossin, Hricko, Aunon-Nerin and Huang (2002) consider the factors that determine the level of CDS prices using a cross-section of transactions prices, and suggest that the integration between equity and credit markets was less than perfect, at least until September 2000 when their data end. Houweling and Vorst (2002) fit a reduced-form model to CDS quotations with parameters extracted from the bond markets. They conclude that cross-sectionally the CDS and cash bond market price credit risk equally for investment-grade bonds. Finally, Skinner and Townend (2002) interpret credit default swaps as put options and regress CDS prices on factors that should influence their price in this framework with modest success.

In this paper we add to this literature by examining the time series properties of credit default swap prices in conjunction with matching credit spread data. The paper addresses three main issues. First, it questions whether bond and credit default swap markets price default risk equally. Second, it examines whether credit risk price discovery takes place predominantly in the cash bond or credit derivative market. Third, it examines the factors that influence short-run changes in CDS prices and credit spreads. The paper is organised as follows. Section 2 describes the credit default swap market and the relationship between CDS prices and credit spreads. Section 3 describes the data used. Section 4 investigates empirically the short and long-term relationships between CDS prices and spreads. Section 5 considers the determinants of changes in credit spreads and CDS prices. Section 6 contains concluding comments.

2 Credit default swaps and credit spreads

2.1 The credit default swap market

In a credit default swap, the protection seller agrees to pay the default payment to the protection buyer if a default event has happened before maturity of the contract. If there is no default event before maturity, the protection seller pays nothing. The protection seller charges a fee for the protection. This is typically a constant quarterly fee paid until default or maturity, whichever is first. Should a default event happen, the accrued fee is also paid. We refer to the annualised fee as the credit default swap price. The default payment is either repayment at par against physical delivery of a reference asset (physical settlement) or the notional amount minus the post-default market value of the reference asset determined by a dealer poll (cash settlement). Physical delivery is the dominant form of settlement in the market. A broad set of debt obligations is deliverable as long as they rank *pari passu* with the senior unsecured indebtedness of the reference entity. Default events for CDS might include some or all of the following:

A. Bankruptcy

B. Failure to pay

C. Obligation default or acceleration

D. Repudiation or moratorium (for sovereign entities)

E. Restructuring

The first four are not contentious, although the evolving ISDA documentation has dropped events C and D in some jurisdictions since they have been deemed subsumed by events A and B. Restructuring has been and remains a source of controversy in the CDS market. The 1999 ISDA documentation defines restructuring to constitute a default event if either the interest rate or principal paid at maturity are reduced or delayed, if an obligation's ranking in payment priority is lowered or if there is a change in currency or composition of any payment (excluding adoption of the euro by a member state of the European Union). The key problem is that not all deliverable assets necessarily become due and payable should restructuring occur and it is conceivable that some deliverable obligations will be cheaper than others. This is likely to be particularly acute where deliverable assets include very long-dated or convertible bonds that often trade at a discount to shorter-dated straight bonds. This means that where there is a non-negligible probability of a restructuring that falls short of making all debt due and payable and where some obligations trade at a substantial discount to others, then a physically-settled CDS price also contains a cheapest-to-deliver (CTD) option and is not a pure measure of credit risk. European CDS traded on the basis of this definition throughout our data sample. US CDS have been subject to a Modified Restructuring definition since 11 May 2001 that, among other aspects, restricted the scope of deliverable assets and specifically prevents the delivery of very long-dated bonds. This reduces the value of the delivery option in US default swaps.

2.2 Pricing of credit risk

There is a large and growing literature on the pricing of credit risk, within which two approaches dominate. Structural models are based on the value of the firm and are usually derived from Merton (1974). In this class of models default occurs when the process describing the value of the firm hits a given boundary. Black and Cox (1976), Geske (1977) and Longstaff and Schwartz

(1995) are three of many important references. Das (1995) and Pierides (1997) apply structural models to the pricing of credit derivatives. The second approach, usually termed reduced-form or intensity-based models, instead assume that the timing of default is specified in terms of a hazard rate. Leading reduced-form frameworks would include Jarrow and Turnbull (1995), Jarrow, Lando and Turnbull (1997) and Duffie and Singleton (1999). Das and Sundaram (1998), Duffie (1999) and Hull and White (2000a, 2000b) apply reduced-form models to credit derivative pricing issues. Both structural and reduced-form approaches are very comprehensively surveyed in Lando (1997) and Schonbucher (2000).

This paper does not contribute to the literature on credit risk pricing. Instead it will make use of the approximate arbitrage relationship that exists between credit default swap prices and credit spreads for a given reference entity discussed in Duffie (1999) and Hull and White (2000a). Begin with a loose approximate arbitrage relationship. Suppose an investor buys a T-year par bond with yield to maturity of y issued by the reference entity, and buys credit protection on that entity for T-years in the credit default swap market at a cost of p_{CDS}. The investor has eliminated most of the default risk associated with the bond. If p_{CDS} is expressed as an annual payment as a percentage of the notional principal then the investor's net annual return is $y - p_{CDS}$. By arbitrage, this net return should approximately equal the T-year risk-free rate, denoted by x. For $y - p_{CDS}$ less than x, shorting the risky bond, writing protection in the CDS market and buying the risk-free instrument would be a profitable arbitrage opportunity. Similarly, for $y - p_{CDS}$ greater than x, buying the risky bond, buying protection and shorting the risk-free bond is profitable. This suggests that the price of the CDS, p_{CDS}, should equal the credit spread, $y - x$.

This is the relationship used in the empirical analysis that follows, although we recognise that the arbitrage is only perfect in some instances. Duffie (1999) shows that the spread on a par risky floating-rate note over a risk-free floating-rate note exactly equals the CDS price. Unfortunately, floating-rate notes are rare. The spread on par fixed-coupon risky bond over the par fixed-coupon risk-free bond exactly equals the CDS price if the payment dates on the CDS and bond coincide and recovery on default is a constant fraction of face value (Houweling and Vorst (2002)). Alternatively, with a flat risk-free curve and constant interest rates, the arbitrage is perfect if the payout from a CDS on default is the sum of the principal amount plus accrued interest on a risky par yield bond times one minus the recovery rate (Hull and White (2000a)). As noted above, however, the payout from a CDS usually equals the principal amount minus the recovery rate times the sum of principal and accrued interest on the reference obligation. Nevertheless the referenced papers show that the arbitrage is reasonably accurate for assets trading close to par when interest rates are not high and yield curves are relatively flat.

Three other considerations are relevant. First, physically-settled CDS prices, especially for European entities, may contain CTD options as noted above. Other things equal, this will lead CDS prices to be greater than the credit spread. Unfortunately, it is impossible to value this option analytically since there is no benchmark for the post-default behaviour of deliverable bonds, and hence we cannot simply subtract its value from the CDS price. Second, the arbitrage relationship that should keep the two prices together can rely on short selling the cash bond. This is not always costless and indeed is not always even possible in illiquid corporate bond markets. If the repo cost of shorting the cash bond is significant then the credit spread we have computed (bond yield minus the risk-free rate) underestimates the true credit spread (bond yield minus risk-free rate plus the repo cost). Again, the CDS price will tend to be greater than the measured credit spread (Duffie (1999)). Although both the CTD option and non-zero repo costs can occur independently, when a firm's credit risk increases the demand to short sell the bond rises, driving up the repo cost, and the value of the CTD option rises. Neither market then provides a pure measure of credit risk. Quantifying these two factors is difficult in the absence of reliable repo cost data or a valuation model for the option. However, since both the repo cost and the option value are bounded at zero, we can say that the CDS price is an upper limit on the price of credit risk while the credit spread provides a lower limit.

Third, liquidity premia exist in both the cash bond and CDS markets. The cash bond market is often described as relatively illiquid, particularly outside the United States. Movements in liquidity premia may explain a large proportion of the total variation in credit spreads (Collin-Dufresne, Goldstein and Martin (2001)). The CDS market is still relatively small despite its rapid recent growth and so demand-supply imbalances can often cause short-term price movements unrelated to default expectations. We make strenuous efforts to reduce the importance of CDS and bond market liquidity premia for the reference entities we examine, as detailed in the following section.

3 Data description

3.1 Credit default swap data

Credit default swaps are over-the-counter derivatives traded mainly in London and New York. We use daily indicative bid and ask prices from CreditTrade, a CDS broker, for single-name CDS that they deem to be liquid. The data run from 2 January 2001 through 20 June 2002. The prices are for a notional value of $10 million and are based on ISDA benchmark contracts for physical settlement. All prices are for five years, which is by far the most liquid maturity in the CDS market. The prices hold at 'close of business' (approximately 5pm local time) in London for European reference entities, or New York for US names. Some time series have missing or, very occasionally, suspicious values. We use mid-market data supplied by J.P. Morgan, one of the leading players in the CDS market, to fill in missing values, check suspicious entries and for general confirmation of the CreditTrade data.(3) J.P. Morgan's mid-market prices are only rarely outside the bid-ask quotes from CreditTrade. We retain all US and European companies for which we can compute a consistent series of mid-market quotes for at least 250 days by combining data sources.

3.2 Risky bond yield data

In order to match the constant five-year maturity of the CDS contracts we need five-year bond yields. For each reference entity with suitable CDS data we search Bloomberg for a bond with between three and five years left to maturity at the start of our sample period, and another bond with more than six and a half years to maturity at the start of the sample. By linearly interpolating these yields we are able to estimate a five-year yield to maturity for the full sample without extrapolating. We exclude floating-rate securities and all bonds that have embedded options, step-up coupons, sinking funds or any special feature that would result in differential pricing. We are also concerned to minimise the possible impact of illiquidity that appears problematic in previous studies using corporate bonds and only use yields calculated from so-called 'generic' Bloomberg mid-market bond prices. These are a weighted average of firm and indicative quotes submitted by at least five brokers or dealers. The exact weighting method is proprietary but firm quotes receive a higher weight than merely indicative quotes. The risky bond data are also at close of business but this tends to be slightly later than the close in the CDS market (eg 5:50pm New York time for US corporate bonds).

---

(3) J.P. Morgan was the most active trader in the Cossin, Hricko, Aunon-Nerin and Huang (2002) CDS transactions database.

Where a choice of liquid bond yields is available we use bonds trading relatively close to par and, if a choice remains, whose maturity more closely corresponds with our needs. We prefer par bonds due to the imperfect arbitrage considerations mentioned above. We prefer to minimise the difference between maturities to reduce the errors caused by our choice of linear interpolation.

3.3 Reference rate yield data

The reference rate is used to proxy the risk-free interest rate when credit spreads are calculated. Government bond yields are the obvious choice, and we use five-year government bond mid-market yields. The curves are constructed using Treasuries for US reference entities and German government bonds for European entities. However, it is well known that government bonds are no longer an ideal proxy for the unobservable risk-free rate. Taxation treatment, repo specials, scarcity premia and benchmark status issues are usually cited. As an alternative proxy we also collect five-year swaps rates for dollars and euros. Swaps, being synthetic, are available in virtually unlimited quantities so that liquidity is not an issue, and they have the further advantage of being quoted on a constant maturity basis. McCauley (2002) contains a discussion of the swap rate's role as a benchmark. However, swaps contain credit premia because (i) the floating leg is indexed to LIBOR, which is itself a default-risky interest rate (Sundaresan (1991)), and (ii) the presence of counterparty risk (although Duffie and Huang (1996) show this accounts for just 1-2 basis points). Hull, Predescu and White (2003) note that the *n*-year swap rate should be thought of as the rate of interest on an *n*-year loan that is structured such that the obligor is certain to have an acceptable credit rating at the beginning of each accrual period. This accrual period is six months for plain vanilla swaps in the United States but may be as high as twelve months in other markets. Since one-year default probabilities of AA-rated institutions is very low it is clear that swap rates are very low but not quite risk-free rates. Duffie (1999) and Houweling and Vorst (2002) recommend using general collateral or repo rates in preference to swaps, arguing that these are liquid and virtually risk free. Accordingly, they lie below maturity matched swap rates. Unfortunately, general collateral rates are only available for maturities up to one year, and since the term structure is typically upward sloping during our data period we prefer to use swaps rates.

The 33 reference entities for which we can find both CDS and interpolated bond yields are listed in Table A together with some basic description. This is a small cross-section of the 157 US and European reference entities in the CreditTrade CDS database. Of these, 38 have been dropped due to insufficient CDS data and 86 due to a lack of bond data. In many cases matrix bond prices are available but we are reluctant to use these due to problems relating to the accuracy, reliability

Table A

Descriptive statistics

This table lists the reference entities in our sample, together with basic descriptive information and the number of observations in the credit default swap and credit spread series. See Section 2 of the paper for details on the criteria for inclusion in the sample.

				Observations	
	Country	Sector	Rating	CDS	Bond yield
AOL	US	Internet	BBB	370	381
Bank of America	US	Banking	A	378	381
Bank One	US	Banking	A	378	376
Bear Stearns	US	Banking	A	371	376
Citigroup	US	Banking	AA	378	383
FleetBoston	US	Banking	A	353	329
Ford Motor Credit Corp	US	Automobile/Finance	BBB	378	359
GE Capital Corp	US	Finance	AAA	365	382
General Motors Credit Corp	US	Automobile/Finance	BBB	350	374
Goldman Sachs	US	Banking	A	378	381
J.P. Morgan Chase	US	Banking	AA	350	369
Lehman Brothers	US	Banking	A	378	377
Merrill Lynch	US	Banking	AA	378	378
Morgan Stanley	US	Banking	AA	378	375
Wal-Mart	US	Retail	AA	378	371
Wells Fargo	US	Banking	A	367	350
Barclays	UK	Banking	AA	367	271
British Telecom	UK	Telecommunications	A	378	377
Commerzbank	Germany	Banking	A	367	258
DaimlerChrysler	Germany	Automobile	BBB	360	376
Deutsche Telecom	Germany	Telecommunications	BBB	378	382
Dresdner Bank	Germany	Banking	AA	367	382
Endesa	Spain	Utilities	A	367	349
Fiat	Italy	Automobile	A	367	383
France Telecom	France	Telecommunications	BBB	378	380
Iberdrola	Spain	Utilities	A	367	379
Metro AG	Germany	Retail	BBB	287	337
Siemens	Germany	Telecommunications	AA	367	265
Telefonica	Spain	Telecommunications	A	378	382
Total Fina Elf	France	Oil	AA	367	374
United Utilities	UK	Utilities	A	365	365
Vodafone	UK	Telecommunications	A	378	379
Volvo	Sweden	Automobile	A	367	382

and timeliness of such data. The data we use are not ideal. For example, we would have preferred to use transactions prices rather than quotes. Cossin, Hricko, Aunon-Nerin and Huang (2002) consider CDS transactions data but do not have enough observations on particular reference entities to perform time series analysis. Month-end corporate bond transactions data are available from Capital Access International (used by Schultz (1998), Hong and Warga (2000) and Blume, Lim and MacKinlay (1998)) but we need a daily frequency to match the CDS data. The data we use are then the best we think available for our purpose.

4 The empirical relationship between credit default swaps and credit spreads

4.1 Average pricing of credit risk

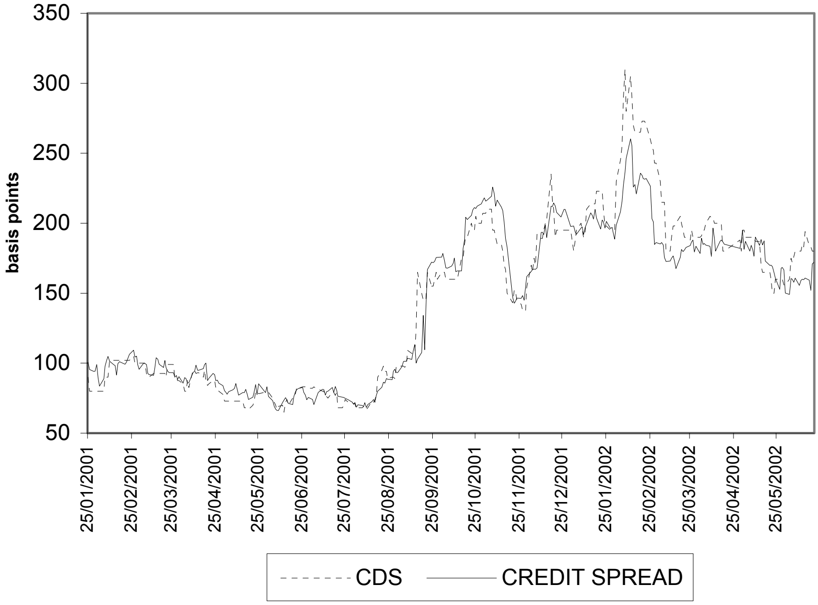
If both CDS and cash bonds price default risk equally then, subject to the arbitrage imperfections noted above, the spread on the risky bond over a risk-free reference rate should equal the CDS price of the same maturity. Define the basis to be the difference between the time t CDS price, $p_{CDS,t}$, and the credit spread, $p_{CS,t}$:

$$\begin{aligned} basis_t^{swaps} &= p_{CDS,t} - p_{CS,t}^{swaps} = p_{CDS,t} - \left(\hat{y}_t - x_t^{swaps}\right) \\ basis_t^{govt} &= p_{CDS,t} - p_{CS,t}^{govt} = p_{CDS,t} - \left(\hat{y}_t - x_t^{govt}\right) \end{aligned} \qquad \textbf{(1)}$$

where $\hat{y}$ denotes the interpolated five-year yield on the risky bond, x^{swaps} denotes the five-year swap rate, and x^{govt} is the five-year government bond yield. In the first panel of Table B we give the average basis and the average absolute basis for each of our reference entities using both swap rates and government bond yields as candidate reference rates. Chart 1 gives a representative plot of daily CDS prices and credit spreads over swaps for Ford.

The cross-sectional mean of the time series average bases is -41 basis points using five-year government bond yields as a proxy for the reference rate. The mean average basis is just +6 basis points if five-year swap rates are used. Similarly the mean average absolute basis falls from 46 basis points over government bonds to 15 basis points over swaps. Using median values does not alter the story. These results are consistent with Houweling and Vorst (2002) who found an average absolute pricing error of around 11 basis points when using swap rates and of around 33 basis points when using treasury yields for bonds rated A and AA. The second panel of Table B gives mean average basis and mean average absolute basis with the data split by credit rating and location. The mean average absolute basis over swaps rises as credit quality (proxied by rating) declines, a finding also emphasised by Houweling and Vorst (2002). Similarly, the basis over swaps is higher for European corporates (partly because the average rating of the European corporates is lower). Given these results we compute credit spreads using swap rates as the proxy for default-free interest rates in our subsequent analysis.

Chart 1
Credit default swap price and credit spread over swaps for Ford



The previous results suggest that the theoretical relationship linking credit spreads over the risk-free rate to CDS prices holds reasonably well on average for most reference entities (and especially for US firms). However, for some reference entities the average basis over swaps is meaningfully greater than zero. The two extreme cases are France Telecom (64 basis points) and Fiat (45 basis points), with the former plotted in Chart 2. Traders indicate that large and persistent positive bases such as these are due to the presence of the two imperfections noted above – non-zero repo costs in the bond market mean we have underestimated the true credit spread and the cheapest-to-deliver option inflates the CDS price. J.P. Morgan (2002) illustrates the importance of including repo costs for a cross-section of 19 bonds with the largest basis from their universe of priced bonds on 16 August 2002 (unfortunately just after our sample ends). A France Telecom eight-year bond had the highest basis on that day (186 basis points) but it was impossible to borrow this bond on repo making the true credit spread impossible to calculate.

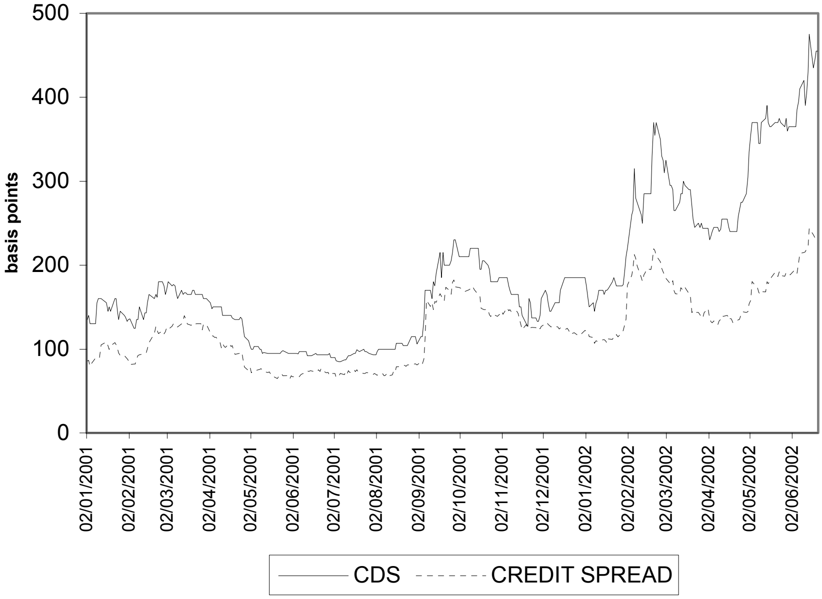
Table B
Discrepancies in the average pricing of credit risk in credit default swap and cash bond markets

Panel A provides descriptive statistics of the basis, defined to be the difference between the credit default swap price and the credit spread, for each reference entity and expressed in basis points. The credit spread is calculated as the difference between the interpolated five-year yield on the risky bonds and either the five-year treasury bond rate or the five-year swap rate. Panel B provides summary statistics for groups of bonds according to rating and nationality.

Panel A:	Treasury rates		Swap rates	
	Average basis	Average absolute basis	Average basis	Average absolute basis
AOL	-49.4	51.1	13.0	16.6
Bank of America	-66.1	66.1	-3.6	10.0
Bank One	-68.0	68.0	-5.6	8.9
Bear Stearns	-67.6	67.6	-9.6	12.7
Citigroup	-56.8	56.8	5.7	7.6
FleetBoston	-60.6	60.6	7.1	8.5
Ford Motor Credit Corp	-59.5	59.8	2.6	11.1
GE Capital Corp	-38.7	38.9	23.2	23.2
General Motors Credit Corp	-51.8	51.8	10.7	12.1
Goldman Sachs	-66.3	66.3	-3.8	7.7
J.P. Morgan Chase	-65.0	65.0	0.9	11.5
Lehman Brothers	-70.2	70.2	-7.8	10.4
Merrill Lynch	-57.5	57.5	6.3	10.2
Morgan Stanley	-63.0	63.0	-0.4	9.4
Wal-Mart	-42.0	42.0	20.6	20.8
Wells Fargo	-66.8	66.8	-3.8	7.0
Barclays	-17.8	17.8	5.9	6.1
British Telecom	-73.3	73.3	-10.1	15.0
Commerzbank	-11.6	12.0	12.8	12.9
DaimlerChrysler	-54.9	54.9	7.9	11.3
Deutsche Telecom	-5.2	22.5	23.2	24.1
Dresdner Bank	-22.2	22.2	5.0	6.8
Endesa	-37.1	37.1	-9.9	9.9
Fiat	15.6	51.8	44.0	45.3
France Telecom	35.8	42.0	64.2	64.2
Iberdrola	-45.2	45.2	-16.7	16.7
Metro AG	-30.6	30.6	-17.3	17.9
Siemens	-13.4	14.5	10.9	11.0
Telefonica	-16.1	17.8	12.3	12.5
Total Fina Elf	-37.2	37.2	-9.2	9.9
United Utilities	-33.0	33.0	-4.6	5.7
Vodafone	-14.1	16.6	14.4	14.4
Volvo	-35.8	35.8	-7.3	10.1
Mean	-40.8	45.9	5.5	14.6
Median	-45.2	51.1	5.0	11.1

Panel B:	Treasury rates		Swap rates	
Means	Average basis	Average absolute basis	Average basis	Average absolute basis
AAA-AA	-41.4	41.5	6.9	11.6
A	-44.8	49.3	0.5	13.0
BBB	-30.8	44.7	14.9	22.5
US	-59.3	59.5	3.0	11.7
Europe	-23.3	33.2	7.5	17.9

Chart 2
Credit default swap price and credit spread over swaps for France Telecom

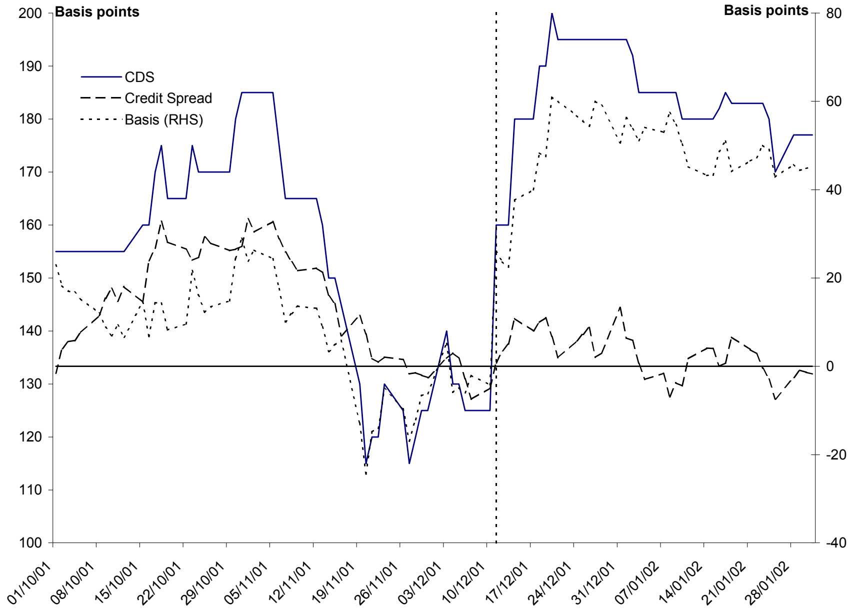


The average basis for the remaining 18 bonds was 103 basis points but once the repo cost was added to the credit spread over swaps the average repo-adjusted basis fell to 13 basis points.

High basis levels remain for some bonds even after including repo costs. For example, the eight European reference entities on the list had an average basis of 96 basis points and an average repo-adjusted basis of 29 basis points.(4) This rather large residual is, we argue, primarily due to the cheapest-to-deliver option. A natural experiment illustrates the potential value of such options. On 11 December 2001, Fiat issued a bond convertible into the stock of General Motors. This bond traded at a substantial discount to existing straight Fiat bonds. If restructuring was thought possible for Fiat (and press reports around the time suggest it was) this would increase the value of the CTD option since under ISDA documentation this was a deliverable bond. Chart 3

(4) The US entities had an average basis of 109 basis points and an average repo-adjusted basis of –0.5 basis points, consistent with the hypothesis that CTD options are less important in this jurisdiction.

Chart 3
Fiat's convertible bond issue and the value of the cheapest-to-deliver option



illustrates the behaviour of the CDS price, credit spread and basis around this time. The average basis for Fiat from the start of the sample to 10 December 2001 was just 8.8 basis points. In the period immediately before the issue the basis fluctuated around this level, suggesting no large repo costs or valuable CTD option. Immediately following the issue, the basis jumped to 50 basis points, due almost entirely to the increase in the CDS price since the credit spread was relatively stable over the issue. Since we have no evidence that Fiat's extant straight bonds went special after the issue, we ascribe this jump in the basis to the newly emerged CTD option value.(5)

These cases of large average basis levels are the exception rather than the rule in our sample. A more formal test of the equivalence of the price of credit risk across the two markets can be motivated in terms of transitory and permanent price movements. Suppose that the unobservable efficient price of credit risk, m_t, follows a random walk:

$$m_t = m_{t-1} + u_t \qquad \textbf{(2)}$$

(5) The basis also jumped in subsequent months when Fiat was affected by rating agency actions and equity issuance likely to have altered the valuation of the option.

where u_t is i.i.d. with zero mean and constant variance. The observed price in each market j at time t, $p_{j,t}$, is equal to this efficient price plus a component containing microstructural noise, $s_{j,t}$, assumed to be transient, plus a component reflecting other possibly non-transient factors included in the observed price, $c_{j,t}$:

$$p_{j,t} = m_t + s_{j,t} + c_{j,t} \qquad\qquad j = CDS, CS \qquad\qquad \textbf{(3)}$$

If the two markets price credit risk equally in the long run, then their prices should be cointegrated with cointegrating vector [1, -1, c], suggesting a stationary basis, and ideally the constant in the cointegrating space, c, should equal zero. Since we know our proxy for the risk-free rate is imperfect, however, we do not require that the constant equal zero. If the prices do not cointegrate with the [1, -1, c] restriction imposed then either (i) the two markets price risk differently (in excess of a constant amount), (ii) at least one market price contains time-varying non-transient factors that reflect something other than credit risk or (iii) at least one market price contains time-varying non-transient measurement error. From our discussion of CDS contract specifications in Section 2.1, we suspect *a priori* that some CDS prices may contain a cheapest-to-deliver option related to restructuring likely to result in a case (ii) failure of the cointegration tests. Further, from Section 2.2 we know that the credit spread as measured ignores the repo cost of the bond. If this cost is significant and not purely a short-term phenomenon we might expect a case (iii) failure of the cointegration tests.

We report Johansen cointegration test results for each reference entity in Table C. There is evidence of cointegration under the imposed restriction of a stationary basis for each US reference entity examined.(6) For these firms, the CDS and bond market appear to price risk equally on average, at least up to a constant term that possibly reflects mismeasurement of the risk-free rate. Further, we cannot reject the additional restriction that the constant is zero in the cointegrating vector for 11 of the 16 US entities at the 1% level, suggesting for these names that the credit spread over swaps equals the CDS price over the long run.

We find support for cointegration for only 10 of the 17 European entities, although a stationary basis cannot be rejected at the 1% level for any of these. The 'usual suspects' – France Telecom and Fiat – are included in the list of firms that reject cointegration, together with Vodafone, another firm with a large average basis over swaps from Table B. As we have noted, Fiat clearly suffers from the sudden emergence of a CTD option and we cannot reject the null of a stationary

(6) The presence of a cointegrating vector is suggested for all 16 US companies. Of these, three reject the restriction of a stationary basis at the 5% level but none reject at the 1% level.

Table C

The long-run relationship between the price of credit risk in CDS and bond markets

The first two columns of Panel A present Johansen trace test statistics for the number of cointegrating relationships between the credit default swap price and the credit spread over swap rates. A constant is included in the long-term relationship, and the number of lags in the underlying vector autoregression is optimised using the AIC for each entity. The third and fourth columns give test statistics for restrictions on the cointegrating space for those entities where a cointegrating vector appears to be present. The first restriction is that the credit default swap price minus the credit spread over swaps is constant, and is distributed as chi-squared with one degree of freedom. The second restriction is that the credit default swap price equals the credit spread over swaps, and is distributed as chi-squared with two degrees of freedom. Panel B reports similar tests for Fiat over a restricted sample period. Rejection of the null at 1, 5 or 10% level is indicated by a superscript A, B or C respectively.

Panel A:	Number of cointegrating vectors		Restrictions on vector	
	None	At most 1	[1, -1, *c*]	[1, -1, 0]
AOL	42.20^{A}	3.62	3.30^{C}	11.08^{A}
Bank of America	22.43^{B}	5.14	5.61^{B}	5.84^{C}
Bank One	19.19^{C}	2.85	0.16	7.19^{B}
Bear Stearns	25.58^{A}	4.44	0.53	7.38^{B}
Citigroup	21.28^{B}	8.63^{C}	3.53^{C}	8.57^{B}
FleetBoston	20.85^{B}	8.28^{C}	0.02	4.61
Ford Motor Credit Corp	22.68^{B}	2.12	1.46	2.44
GE Capital Corp	24.42^{B}	1.92	6.60^{B}	10.29^{A}
General Motors Credit Corp	27.90^{A}	2.26	0.36	16.11^{A}
Goldman Sachs	27.50^{A}	5.03	3.39^{C}	6.79^{B}
J.P. Morgan Chase	25.09^{A}	5.23	3.02^{C}	4.12
Lehman Brothers	54.67^{A}	7.11	0.71	18.60^{A}
Merrill Lynch	21.33^{B}	4.30	0.16	3.73
Morgan Stanley	22.25^{B}	4.80	6.47^{B}	6.59^{B}
Wal-Mart	27.96^{A}	7.39	1.68	14.81^{A}
Wells Fargo	25.53^{A}	6.44	3.42^{C}	6.62^{B}
Barclays Bank	15.01	2.37	NA	NA
British Telecom	19.59^{C}	4.88	0.90	4.26
Commerzbank	23.93^{B}	4.48	6.50^{B}	11.26^{A}
DaimlerChrysler	20.43^{B}	2.53	0.01	5.95^{C}
Deutsche Telekom	19.38^{C}	1.10	6.14^{B}	9.09^{B}
Dresdner Bank	17.30	7.70^{C}	NA	NA
Endesa	10.92	3.69	NA	NA
Fiat	7.12	1.61	NA	NA
France Telecom	10.11	2.27	NA	NA
Iberdrola	23.06^{B}	5.39	3.31^{C}	15.99^{A}
Metro AG	22.97^{B}	2.56	3.61^{C}	13.39^{A}
Siemens	19.31^{C}	3.08	1.71	6.86^{B}
Telefonica	24.34^{B}	5.07	3.12^{C}	9.26^{A}
Total Fina Elf	13.87	4.20	NA	NA
United Utilities	19.60^{C}	4.99	0.24	8.97^{B}
Vodafone	10.86	2.17	NA	NA
Volvo	21.49^{B}	1.40	1.61	11.85^{A}

Panel B:	Number of cointegrating vectors		Restrictions on vector	
	None	At most 1	[1, -1, *c*]	[1, -1, 0]
Fiat (Jan 2001 – Nov 2001)	27.51^{A}	2.22	1.97	11.05^{A}

basis using data up to the emergence of the delivery option (see panel B). Surprisingly, four entities with small average bases also reject cointegration. We suspect that this is because bid-ask spreads are proportionately so wide that the CDS price and credit spread have moved in seemingly unrelated ways without arbitrage forces coming into effect.

4.2 Price discovery

One of the most important functions of financial markets is price discovery, defined by Lehmann (2002) to be the efficient and timely incorporation of the information implicit in investor trading into market prices. When there is only one location for trading an asset, by definition all price discovery takes place in that market place. When closely related assets trade in different locations, order flow is fragmented and price discovery is split between markets. We have demonstrated that both the cash bond and the credit default swap markets usually appear to price credit risk equally on average. CDS prices and credit spreads are cointegrated $I(1)$ variables for most of our sample of companies and the common factor can be viewed as the implicit efficient price of credit risk. Which of the two markets contributes most to the credit risk price discovery process is a question that we attempt to resolve in this section.

The appropriate method to investigate the mechanics of price discovery is not clear. The two popular common factor models due to Hasbrouck (1995) and Gonzalo and Granger (1995) both rely on vector error correction models of market prices. Hasbrouck's model of 'information shares' assumes that price volatility reflects new information, and so the market that contributes most to the variance of the innovations to the common factor is presumed to also contribute most to price discovery. Gonzalo and Granger's approach decomposes the common factor itself and ignoring the correlation between the markets attributes superior price discovery to the market that adjusts least to price movements in the other market. When price change innovations are correlated, Hasbrouck's approach can only provide upper and lower bounds on the information shares of each market. However, Baillie, Booth, Tse and Zabotina (2002) argue that the average of these bounds provides a sensible estimate of the markets' roles in the discovery of the efficient price. Since neither method is considered universally superior we report both.

To compute the measures of the contributions to price discovery it is necessary first to estimate the following vector error correction model (VECM):

$$\Delta p_{CDS,t} = \lambda_1 \left(p_{CDS,t-1} - \alpha_0 - \alpha_1 p_{CS,t-1} \right) + \sum_{j=1}^{p} \beta_{1j} \Delta p_{CDS,t-j} + \sum_{j=1}^{p} \delta_{1j} \Delta p_{CS,t-j} + \varepsilon_{1t} \qquad \textbf{(4a)}$$

$$\Delta p_{CS,t} = \lambda_2 \left(p_{CDS,t-1} - \alpha_0 - \alpha_1 p_{CS,t-1} \right) + \sum_{j=1}^{p} \beta_{2j} \Delta p_{CDS,t-j} + \sum_{j=1}^{p} \delta_{2j} \Delta p_{CS,t-j} + \varepsilon_{2t} \qquad \textbf{(4b)}$$

where ε_{1t} and ε_{2t} are i.i.d. shocks. If the cash bond market is contributing significantly to the discovery of the price of credit risk, then λ_1 will be negative and statistically significant as the CDS market adjusts to incorporate this information. Similarly, if the CDS market is an important venue for price discovery, then λ_2 will be positive and statistically significant. If both coefficients are significant, then both markets contribute to price discovery. The existence of cointegration means that at least one market has to adjust by the Granger representation theorem (Engle and Granger (1987)). That market is inefficient since the price reacts to publicly available information.

Manipulations of the relative magnitudes of the λ coefficients reveal which of the two markets leads in terms of price discovery. The contributions of market 1 (the CDS market) to price discovery are defined by the following expressions:

$$HAS_1 = \frac{\lambda_2^{\,2}\left(\sigma_1^{\,2} - \dfrac{\sigma_{12}^{\,2}}{\sigma_2^{\,2}}\right)}{\lambda_2^{\,2}\sigma_1^{\,2} - 2\lambda_1\lambda_2\sigma_{12} + \lambda_1^{\,2}\sigma_2^{\,2}} \quad HAS_2 = \frac{\left(\lambda_2\sigma_1 - \lambda_1\dfrac{\sigma_{12}}{\sigma_1}\right)^2}{\lambda_2^{\,2}\sigma_1^{\,2} - 2\lambda_1\lambda_2\sigma_{12} + \lambda_1^{\,2}\sigma_2^{\,2}}$$

$$GG = \frac{\lambda_2}{\lambda_2 - \lambda_1}$$

where HAS_1 and HAS_2 give the two bounds of Hasbrouck's measures and GG stands for the Gonzalo and Granger measure. The covariance matrix of ε_{1t} and ε_{2t} is represented by the terms σ_1^2, σ_{12}, σ_2^2. The price discovery statistics are reported in panel A of Table D for those entities where cointegration is present between CDS prices and credit spreads. Where appropriate, the restrictions that α_1 equals unity and α_0 equals zero are imposed.

In 25 of the 27 cases λ_2 is significantly positive, indicating that the CDS market contributes to price discovery. The cash bond market appears to have a significant role to play in only eight cases. Of these eight, the cash market is the source of all information in only one (United Utilities). In five cases, while both cash and derivatives market contribute significantly the CDS market is dominant (defined as both the Hasbrouck lower bound and the Gonzalo-Granger measure suggesting more than 50% of the discovery occurring in the CDS market), and in the

Table D
Contributions to price discovery

Panel A reports various measures of the contribution to the credit price discovery process made by credit default swap prices for those reference entities where the results in Table C indicate a long-run relationship between credit default swap prices and credit spreads exist. The measures are based on the two regressions:

$$\Delta p_{CDS,t} = \lambda_1 \left(p_{CDS,t-1} - \alpha_0 - \alpha_1 p_{CS,t-1} \right) + \sum_{j=1}^{p} \beta_{1j} \Delta p_{CDS,t-j} + \sum_{j=1}^{p} \delta_{1j} \Delta p_{CS,t-j} + \varepsilon_{1t}$$

$$\Delta p_{CS,t} = \lambda_2 \left(p_{CDS,t-1} - \alpha_0 - \alpha_1 p_{CS,t-1} \right) + \sum_{j=1}^{p} \beta_{2j} \Delta p_{CDS,t-j} + \sum_{j=1}^{p} \delta_{2j} \Delta p_{CS,t-j} + \varepsilon_{2t}$$

Where appropriate according to the results in Table C, the restriction that α_0 equals zero and/or α_1 equals unity are imposed. The Hasbrouck measure provides upper and lower bounds to the price discovery contribution made in the credit default swap market. The table also reports the midpoint of this range. The final column reports the Granger-Gonzalo measure. Panel B reports Granger causality test results for those reference entities where the results in Table C suggest no long-term relationship between credit default swap prices and credit spreads.

Panel A:					Hasbrouck			GG
	λ_1	t-stat	λ_2	t-stat	Lower	Upper	Mid	
AOL	0.00	0.1	0.12	5.9	1.00	1.00	1.00	1.01
Bank of America	0.00	0.1	0.05	2.8	0.99	1.00	1.00	1.02
Bank One	-0.06	-3.2	0.08	2.3	0.32	0.38	0.35	0.59
Bear Stearns	-0.03	-1.2	0.14	4.4	0.93	0.93	0.93	0.84
Citigroup	-0.02	-1.1	0.10	2.6	0.76	0.86	0.81	0.80
FleetBoston	0.00	-0.3	0.12	3.3	0.87	1.00	0.93	0.97
Ford Motor Credit Corp	-0.05	-2.0	0.07	3.1	0.51	0.79	0.65	0.57
GE Capital Corp	0.00	-0.2	0.08	2.8	0.97	0.99	0.98	0.96
General Motors Credit Co	-0.05	-1.6	0.15	4.4	0.74	0.91	0.82	0.75
Goldman Sachs	-0.04	-1.8	0.13	3.9	0.81	0.83	0.82	0.78
J.P. Morgan Chase	0.00	-0.1	0.06	4.0	0.99	1.00	1.00	0.98
Lehman Brothers	-0.05	-2.8	0.21	6.5	0.84	0.86	0.85	0.80
Merrill Lynch	0.00	-0.2	0.09	3.6	1.00	1.00	1.00	0.97
Morgan Stanley	-0.02	-1.4	0.09	4.3	0.91	0.91	0.91	0.83
Wal-Mart	-0.01	-2.6	0.08	3.2	0.55	0.63	0.59	0.85
Wells Fargo	-0.04	-2.0	0.14	3.5	0.74	0.77	0.76	0.78
British Telecom	-0.01	-0.6	0.05	2.6	0.79	0.96	0.88	0.84
Commerzbank	-0.03	-2.2	0.04	1.3	0.22	0.29	0.26	0.64
DaimlerChrysler	-0.03	-1.4	0.07	2.8	0.60	0.86	0.73	0.71
Deutsche Telecom	0.02	0.9	0.04	3.0	0.92	0.94	0.93	2.06
Fiat (Jan 01 – Nov 01)	-0.06	-1.4	0.12	4.0	0.67	0.92	0.79	0.65
Iberdrola	-0.02	-2.3	0.08	2.9	0.59	0.64	0.62	0.77
Metro AG	-0.01	-0.7	0.09	3.8	0.95	0.97	0.96	0.90
Siemens	-0.01	-0.2	0.13	3.4	0.95	1.00	0.97	0.95
Telefonica	-0.03	-1.5	0.04	3.0	0.63	0.84	0.73	0.55
United Utilities	-0.06	-3.6	0.01	0.7	0.03	0.07	0.05	0.19
Volvo AB	-0.05	-1.9	0.06	3.4	0.61	0.80	0.71	0.55
Mean					0.74	0.82	0.78	0.79
Median					0.79	0.91	0.82	0.80

Table D—*Continued*

Panel B:	Ho: CDS causes CS			Ho: CS causes CDS		
	Sum of significant coefficients	F-stat	p-value	Sum of significant coefficients	F-stat	p-value
Barclays	0.41	3.45	0.01	0.07	4.87	0.00
Dresdner	0.84	3.14	0.01	0.06	1.19	0.32
Endesa	0.00	2.07	0.13	0.00	0.52	0.60
France Telecom	0.28	14.17	0.00	0.28	3.08	0.03
Total Fina Elf	0.00	1.49	0.23	0.00	0.62	0.54
Vodafone	0.26	5.16	0.01	0.11	2.69	0.07

remaining two cases the price discovery measures give conflicting signals. On average, the CDS market contributes around 80% of price discovery.(7) Since the prices are measured asynchronously in the bond and CDS markets we re-compute the price discovery measures with the CDS prices lagged by one day to deliberately favour the bond market. While obviously the CDS market's contribution to price discovery is lower in this case, it remains the main forum for price discovery.

For a small subset of our reference entities cointegration is rejected and hence the VECM representation is not valid. We believe that rejection is due to the presence of a substantial cheapest-to-deliver option in the CDS price and/or binding short sales constraints in the cash bond market meaning that we are markedly mismeasuring the credit spread. Since we cannot price the option or more accurately measure the spread, we rely on the simpler concept of Granger causality in a simple VAR in differences to test for price leadership in these cases. These results are given in panel B of Table D. CDS prices Granger-cause credit spreads for four of the six entities. For the other two entities there is no causation in either direction, while credit spreads cause CDS prices for three entities (indicating bi-directional causality). With the exception of France Telecom, the sum of the coefficients on lagged CDS prices is noticeably greater than for lagged spreads suggesting that the economic importance of CDS prices is greater.

Why do we find such strong evidence that credit default swap prices lead credit spreads? Price discovery will occur in the market where informed traders trade most. The CDS market, as we noted above, benefits from being arguably the easiest place in which to trade credit risk. Its synthetic nature means that it does not suffer from the short-sales constraints seen in the cash bond market, and buying (or selling) relatively large quantities of credit risk is possible. The

(7) In three cases the Gonzalo-Granger measure produces a statistic greater than one, which is difficult to interpret. In computing the average value, we replaced these numbers by unity.

standard CDS contract size is $10 million while Schultz (1998) reports the average cash market trade size to be of $1.5 million. Additionally, the participants in the cash and credit derivatives markets are likely to be different. There is no counterparty risk (beyond settlement risk) when trading a cash bond. CDS trading does entail taking on counterparty risk and for this reason is usually restricted to institutions of relatively high credit rating. Perhaps more importantly, the CDS market is the forum for trading credit risk, whereas the cash market trades bond credit risk. Participants hedging loan and counterparty exposures are able to do so in the CDS market. It is this concentration of liquidity from different pools that means the CDS market leads the bond market according to some market participants.

Given that CDS prices and credit spreads are linked by an arbitrage relationship, how can the markets persist in pricing credit risk differently? Our answer is in several parts. First, in the absence of transactions costs data we cannot be sure that the discrepancies are large enough to be profitable to arbitrageurs. Second, the arbitrage relationship is only approximate as noted above and we are using a synthetic five-year bond spread that is not traded in the market. Third, we do not measure the repo costs of shorting the bond. It is possible that when the credit quality of an entity declines, the repo market price increases such that the arbitrage gap is closed. It could be argued that we have only partially captured the price contribution from the cash market by ignoring the repo cost. However, since repos are not traded for terms in excess of one year, let alone the five years necessary in our construct, the repo market cannot contribute towards the discovery of the price of five-year credit risk. Furthermore, even if the holder of a bond sees mispricing in the CDS market there are two reasons why he cannot arbitrage the discrepancy – fund managers are often not permitted to trade CDS contracts either by national law or mandate, and the notional size of the CDS contract is so large that the cash bond holding is unlikely to be large enough (see Dhillon (2002)).

5 The determinants of changes in credit default swap prices and credit spreads

5.1 Theoretical determinants of credit spread and CDS price changes

From the contingent-claims approach, credit spreads on corporate bonds occur for two reasons. First, there is the possibility of default. Second, should default occur the bondholder receives only a proportion of contracted payments. Factors related to changes in the probability of a bond defaulting or changes in the likely amount recovered should help explain credit spread and CDS price changes since the latter are intimately related with the former. However, Table E shows

Table E

Summary statistics of changes in credit default swap prices and credit spreads

This table reports the standard deviation of weekly changes in credit default swap prices and credit spread over swaps expressed in basis points for each reference entity, together with the correlation coefficient between the two series.

	Standard deviation		Correlation
	CDS	Credit spreads	
AOL	14.57	10.89	0.14
Bank of America	4.62	7.17	0.25
Bank One	4.96	7.79	0.22
Bear Stearns	8.67	8.10	0.05
Citigroup	4.39	7.40	0.35
FleetBoston	5.28	5.74	0.40
Ford Motor Credit Corp	18.51	15.04	0.60
GE Capital Corp	4.88	6.91	0.24
General Motors Credit Corp	12.72	12.61	0.68
Goldman Sachs	6.78	6.92	0.31
J.P. Morgan Chase	6.16	4.67	0.24
Lehman Brothers	8.76	9.15	0.14
Merrill Lynch	6.11	7.58	0.33
Morgan Stanley	7.39	7.59	0.22
Wal-Mart	1.89	5.90	0.13
Wells Fargo	3.16	7.41	0.02
Barclays	1.24	2.58	0.17
British Telecom	10.78	11.14	0.67
Commerzbank	1.86	3.19	-0.05
DaimlerChrysler	13.29	11.53	0.89
Deutsche Telecom	17.03	12.60	0.75
Dresdner Bank	1.58	3.36	0.31
Endesa	2.65	3.01	-0.01
Fiat	26.02	14.60	0.86
France Telecom	26.93	17.22	0.80
Iberdrola	2.33	3.02	0.16
Metro AG	4.66	5.35	0.29
Siemens	4.22	4.16	0.53
Telefonica	8.29	5.48	0.59
Total Fina Elf	1.23	3.59	0.23
Vodafone	6.11	6.61	0.64
Volvo AB	7.97	5.82	0.51

that, for our sample, weekly changes in credit spreads and CDS prices are not highly correlated and frequently have very different standard deviations. These figures suggest that the two measures of the price of credit risk may not react equally to the factors behind default probability and recovery. This finding motivates our tests of the determinants of changes in CDS prices and credit spreads detailed in this section.

We follow Collin-Dufresne, Goldstein and Martin (2001) and consider the following variables as factors driving default probability:

1. *Changes in the spot interest rate*

   The static effect of a higher spot interest rate increases the risk-neutral drift of the firm's valuation process which reduces the risk-neutral (but not necessarily actual) probability of default (Longstaff and Schwartz (1995)). We use changes in the ten-year bond yield on the relevant national Treasury bond.

2. *Changes in the slope of the yield curve*

   While only the spot rate matters in the basic structural models, the process that determines the spot rate may depend upon other factors such as the slope of the term structure. For example, if the short rate mean-reverts around the long rate, an increase in the term structure slope should signal rising future short-term rates and lower default probabilities. We use changes in the spread on ten and two-year Treasury bonds from the relevant countries to capture slope effects.

3. *Changes in the equity price*

   Leverage enters the determination of the default barrier in structural models. However, at a weekly frequency and over a relatively short horizon it is not practical to include a clean measure of firm leverage. Instead we proxy changes in the firm's health with the firm's equity return.

4. *Changes in implied equity volatility*

   An increase in the volatility of the process driving firm value increases the probability of hitting the default boundary and so raises the probability of default. Traded options markets exist for all but one of our panel so we use changes in the implied volatilities from near-the-money put options. We also consider changes in the implied volatilities of the S&P 500 and European Stoxx indices.(8)

We proxy changes in the expected recovery rate with two proxies for changes in the overall business climate. First, we use changes in the slope of the relevant yield curve (defined as

(8) We also considered changes in the option-implied probability of large drops in a firm's value. This is difficult to determine for a particular stock since options on individual firms are only liquid near the money, and unfortunately the implied probability of a 10% drop in the stock index is highly correlated with implied volatilities. Therefore this variable is not included in the reported regressions but its inclusion does not materially affect the conclusions reached.

above). Second, we also consider changes in the S&P 500 or Stoxx index as appropriate. Additionally, though we have tried hard to minimise the effects of illiquidity in both markets, some liquidity premia may remain. Changes in liquidity will also affect changes in our measures of spreads and CDS prices. Liquidity is proxied by the on-the-run/off-the-run spread of long-dated US Treasury yields. An increase in the liquidity proxy suggests that liquidity is more valuable.

5.2 Results

To reduce noise, we measure all changes over a weekly horizon (using Thursday-Thursday changes). For each reference entity, *i*, we first run the following OLS regressions:

$$\begin{aligned}\Delta p^i_{CDS,t} &= \alpha^i + \beta^i_1 \Delta r^l_t + \beta^i_2 \Delta\left(r^l_t - r^s_t\right) + \beta^i_3 \Delta eq_t + \beta^i_4 \Delta eq^i_t + \beta^i_5 \Delta vol_t + \beta^i_6 \Delta vol^i_t + \varepsilon_{CDS,t} \\ \Delta p^i_{CS,t} &= \delta^i + \gamma^i_1 \Delta r^l_t + \gamma^i_2 \Delta\left(r^l_t - r^s_t\right) + \gamma^i_3 \Delta eq_t + \gamma^i_4 \Delta eq^i_t + \gamma^i_5 \Delta vol_t + \gamma^i_6 \Delta vol^i_t + \varepsilon_{CS,t}\end{aligned} \quad \textbf{(5)}$$

where Δ denotes a weekly change in a variable, r^l is the long-term government bond yield, r^s is the short-term government bond yield, *eq* is the log of relevant national equity market index eq^i is the log of the equity price of the reference entity, *vol* is the implied volatility of the S&P 500 index, and vol^i is the implied volatility of the reference entity's equity price. Panel A of Table F summarises the results, reporting the average coefficient estimate and goodness of fit measure across the reference entities, together with *t*-statistics from a cross-sectional regression of the individual coefficient estimates on a constant term. Panel B summarises results from the system augmented by the liquidity proxy and, where cointegration was found between CDS and credit spreads, the lagged basis defined in equation **(1)** and interpreted as an error correction term:

$$\begin{aligned}\Delta p^i_{CDS,t} &= \alpha^i + \beta^i_1 \Delta r^l_t + \beta^i_2 \Delta\left(r^l_t - r^s_t\right) + \beta^i_3 \Delta eq_t + \beta^i_4 \Delta eq^i_t + \beta^i_5 \Delta vol_t + \beta^i_6 \Delta vol^i_t + \\ &\quad \beta^i_7 \Delta liq_t + \beta^i_8 basis^i_{t-1} + \varepsilon_{CDS,t} \\ \Delta p^i_{CS,t} &= \delta^i + \gamma^i_1 \Delta r^l_t + \gamma^i_2 \Delta\left(r^l_t - r^s_t\right) + \gamma^i_3 \Delta eq_t + \gamma^i_4 \Delta eq^i_t + \gamma^i_5 \Delta vol_t + \gamma^i_6 \Delta vol^i_t + \\ &\quad \gamma^i_7 \Delta liq_t + \gamma^i_8 basis^i_{t-1} + \varepsilon_{CS,t}\end{aligned} \quad \textbf{(6)}$$

Panels C and D report the results of pooled estimates of the equations in **(5)** and **(6)** where the coefficients β_j and γ_j are constrained to be equal across entities. Several interesting results emerge. First, most of the significant variables associated with credit default risk are correctly signed. Higher interest rates reduce credit spreads and CDS prices, as do increases in the equity price of the reference entity. Market-wide changes in equity returns (proxying for changes in the

Table F

The sensitivity of credit default swap prices and credit spreads to proxies for default risk, the recovery rate, and liquidity

Panels A and C report the results of regression equation **(5)** as given in the text. Panels B and D report the results of regression equation **(6)** as given in the text. Panels A and B are estimated by ordinary least squares individually for each reference entity. Average coefficients and goodness-of-fit measures are given while t-statistics are from cross-sectional regressions of the individual coefficient estimates on a constant term. Panels C and D report the results of pooled estimates where all coefficients except the intercept terms are restricted to be equal across reference entities.

Panel A:	CDS price		Credit spread	
	Coefficient	t-statistic	Coefficient	t-statistic
Change in long-term interest rate	-6.38	-2.42	-13.19	-5.76
Change in slope of yield curve	8.11	2.75	13.27	4.54
Equity market returns	2.68	0.34	-21.77	-1.83
Firm-specific equity returns	-32.55	-2.60	-14.04	-1.66
Change in market volatility	0.14	1.74	-0.23	-1.48
Change in firm-specific volatility	0.29	3.74	0.10	1.58
Average adjusted R^2	0.20		0.17	

Panel B:	CDS price		Credit spread	
	Coefficient	t-statistic	Coefficient	t-statistic
Change in long-term interest rate	-7.14	-2.77	-13.24	-5.92
Change in slope of yield curve	7.05	2.14	13.22	4.49
Equity market returns	-8.27	-0.91	-13.08	-1.25
Firm-specific equity returns	-30.82	-2.57	-14.66	-1.80
Change in market volatility	0.01	0.14	-0.17	-1.24
Change in firm-specific volatility	0.28	3.47	0.10	1.75
Change in liquidity	0.17	5.49	0.02	0.91
Lagged basis	-0.07	-5.54	0.19	10.47
Average adjusted R^2	0.23		0.25	

Panel C:	CDS price		Credit spread	
	Coefficient	t-statistic	Coefficient	t-statistic
Change in long-term interest rate	-8.38	-5.28	-16.35	-9.08
Changes in slope of yield curve	8.45	2.76	16.93	6.30
Equity market returns	23.74	1.74	-11.08	-0.76
Firm-specific equity returns	-49.60	-6.07	-18.18	-2.79
Change in market volatility	0.24	2.06	-0.14	-1.03
Change in firm-specific volatility	0.19	3.62	-0.06	-1.05
Adjusted R^2	0.14		0.10	

Table F—*Continued*

Panel D:	CDS price		Credit spread	
	Coefficient	t-statistic	Coefficient	t-statistic
Change in long-term interest rate	-8.65	-5.51	-15.62	-9.35
Change in slope of yield curve	7.81	2.57	16.98	6.61
Equity market returns	15.16	1.12	-0.92	-0.07
Firm-specific equity returns	-48.82	-6.02	-20.39	-3.27
Change in market volatility	0.13	1.13	-0.08	-0.62
Change in firm-specific volatility	0.17	3.27	-0.05	-1.07
Change in liquidity	0.18	4.05	0.00	-0.04
Lagged basis	-0.05	-2.40	0.24	10.81
Adjusted R^2	0.15		0.19	

recovery rate) are not usually statistically significant but this could be because expected recovery rates did not vary much over our relatively short sample period.

Changes in firm-specific implied volatility are correctly signed and significant for CDS prices but insignificant and sometimes incorrectly signed for credit spreads. Market-wide volatility changes are correctly signed when significant. A steeper-sloping yield curve increases CDS prices and spreads, which goes against its theoretical sign, either when viewed as a proxy for business conditions or to control for mean-reverting interest rates.

Second, the liquidity proxy is significant only in the CDS market regressions. While acknowledging that our liquidity proxy may be inadequate, this suggests that our attempts to minimise the problems of illiquidity in the corporate bond market have been successful. Despite selecting reference entities that are among the most actively quoted, however, changes in liquidity appear to impact their CDS prices. Nevertheless, liquidity does not contribute much to the fit of the model since adjusted R^2 only increase slightly when the liquidity measure and lagged basis are added to the model.

Third, the credit spread appears to react more to market-wide variables (eg changes in the interest rate, slope of the yield curve) than the CDS price, both in terms of coefficient estimate and *t*-statistic. CDS prices, conversely, react more to firm-specific factors such as the entity's stock price and implied volatility. We discuss this further below.

Finally, the lagged basis or error correction term is highly significant and correctly signed in both CDS and credit spread equations. However, the absolute magnitude of the coefficient is much greater for credit spreads, confirming the price discovery findings above.[9] Further, the improvement in the goodness of fit for credit spreads when the basis and the insignificant liquidity proxy are added is noticeable, with the adjusted R^2 rising from 0.10 to 0.19 in the pooled regression. This suggests that while the credit spread reacts less to firm-specific factors, their influence feeds through to spreads via the response to the lagged basis.

The average adjusted R^2s in panels A and B are much higher than those from the pooled regressions which, together with the results of firm-by-firm regressions (not reported), suggests that there is considerable heterogeneity not captured in regressions **(5)** and **(6)**. Specifically, the coefficients on changes in firm-specific equity price and volatility differ widely across the panel for CDS prices and credit spreads. The absolute magnitudes of the coefficients increase as the credit quality, proxied by the credit rating, level of the CDS price or credit spread declines.[10] As examples, Charts 4 and 5 plot for each entity the estimated coefficient on firm equity changes (β_3) and firm volatility changes (β_5) from equation **(6)** for CDS prices against the average CDS price for the full sample.

The plots suggest that as credit quality worsens, or firms approach the default barrier in a structural model, the sensitivity of the price of credit risk to these factors increases. To accommodate this in our econometric work we allow each variable to enter independently and to interact with a proxy for the credit quality of the firm in a pooled regression for both CDS and credit spreads.[11] We considered credit ratings and market measures as proxies for credit quality. Credit ratings and the average level of the CDS price or credit spread were rejected since several of our entities experienced swings in credit quality through the sample that would not be captured by an average price or by a slow moving and probably lagging indicator such as the credit rating. Instead we use the one period lagged CDS price (for both cash and derivative markets) and lagged credit spread (for the cash market). We estimate models corresponding to equations **(5)**

---

(9) The Gonzalo-Granger-type average price discovery measure in the pooled augmented model for CDS is 0.83, not far from the 0.79 reported in Table D.

(10) However, note that our findings are not entirely driven by the companies with lower credit quality. Results corresponding to Table F but estimated for just the AAA-A rated companies produce very similar results. While coefficient estimates are typically lower in absolute terms for these higher-rated companies, statistical significance remains. Interestingly, coefficients on the liquidity proxy and the lagged basis are unchanged from the full sample estimates.

(11) This assumes that the relationship between the coefficient estimate and credit quality is linear whereas a structural model would suggest a complex non-linear relationship. We believe that this simplification captures the essence of the heterogeneity without the need to fully specify (and calibrate) a structural model for each reference entity.

Chart 4
Coefficient estimate on firm-specific equity returns versus average level of credit risk

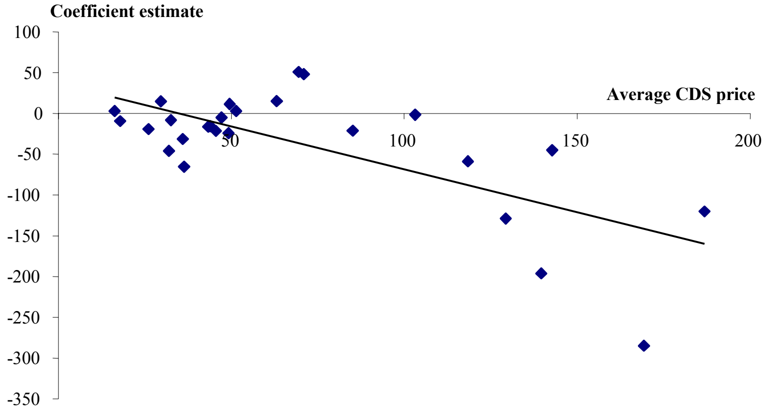


Chart 5
Coefficient estimate on firm-specific volatility versus the average level of credit risk

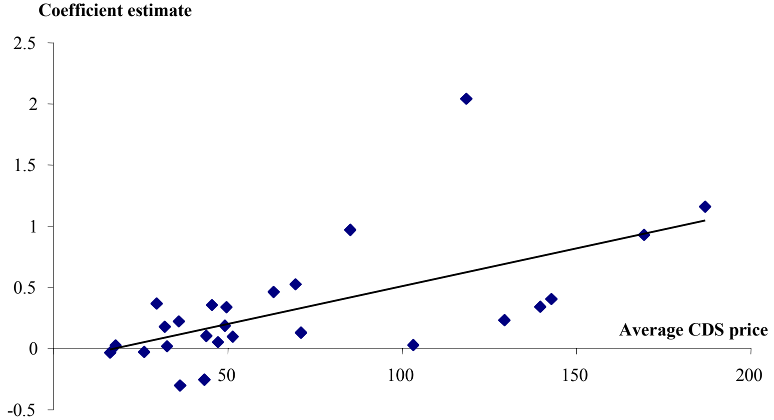


Table G

Sensitivity of credit default swap prices and credit spreads to proxies for default risk, the recovery rate, and liquidity: allowing for heterogeneity according to credit quality

Panel A reports the results of a pooled panel estimate of regression equation **(5)** in the text with the addition of interaction terms where the lagged level of the credit default swap price is multiplied by the independent variable. Panel B reports results of a pooled panel estimate of regression equation **(6)** in the text with additional interaction terms. Panel C reports the results of a parsimonious version of Panel B where insignificant variables are successively excluded from the model using a general-to-specific procedure. In the final column of the table the interaction term is constructed by multiplying the lagged credit spread over swaps by the independent variable.

Panel A:	CDS price		Credit spread		Credit spread	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Change in long-term interest rate	-3.38	-0.95	-8.49	-2.71	-7.29	-2.40
CDS_{t-1}×change in long-term interest rate	-0.08	-1.17	-0.12	-2.07	-0.14	-2.53
Change in slope of yield curve	7.11	1.16	9.90	2.23	15.75	3.87
CDS_{t-1}×change in slope of yield curve	0.10	0.87	0.16	1.79	0.07	0.77
Equity market returns	-19.80	-0.60	-41.47	-1.79	-66.52	-3.13
CDS_{t-1}×equity market returns	0.37	0.70	0.30	0.82	0.75	2.09
Firm-specific equity returns	35.15	2.62	22.89	2.33	28.60	3.48
CDS_{t-1}×firm-specific equity returns	-0.93	-4.59	-0.44	-3.09	-0.59	-4.29
Change in market volatility	0.15	0.62	-0.37	-1.94	-0.63	-3.37
CDS_{t-1}×change in market volatility/100	0.08	0.20	0.28	0.89	0.75	2.26
Change in firm-specific volatility	-0.08	-0.66	-0.10	-1.25	-0.13	-1.45
CDS_{t-1}×change in firm-specific volatility/100	0.49	2.64	0.15	1.14	0.20	1.44
Adjusted R^2	0.26		0.16		0.16	

Panel B:	CDS price		Credit spread		Credit spread	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Change in long-term interest rate	-3.88	-1.09	-7.65	-2.64	-6.23	-2.29
CDS_{t-1}×change in long-term interest rate	-0.07	-1.11	-0.12	-2.34	-0.15	-2.99
Change in slope of yield curve	6.81	1.16	9.37	2.19	14.05	3.73
CDS_{t-1}×change in slope of yield curve	0.10	0.87	0.17	1.99	0.10	1.18
Equity market returns	-27.53	-0.84	-33.22	-1.45	-52.86	-2.64
CDS_{t-1}×equity market returns	0.37	0.71	0.33	0.92	0.70	2.06
Firm-specific equity returns	34.77	2.62	21.43	2.22	26.32	3.35
CDS_{t-1}×firm-specific equity returns	-0.92	-4.59	-0.45	-3.23	-0.59	-4.47
Change in market volatility	0.02	0.10	-0.31	-1.61	-0.51	-2.86
CDS_{t-1}×change in market volatility/100	0.12	0.29	0.28	0.90	0.66	2.07
Change in firm-specific volatility	-0.09	-0.76	-0.13	-1.56	-0.14	-1.70
CDS_{t-1}×change in firm-specific volatility/100	0.48	2.60	0.19	1.49	0.23	1.73
Change in liquidity	0.17	1.91	0.05	0.76	0.09	1.38
CDS_{t-1}×change in liquidity	0.00	0.03	-0.00	-0.69	-0.00	-1.17
Lagged basis	-0.05	-2.32	0.25	11.77	0.25	11.71
Adjusted R^2	0.26		0.25		0.24	

Table G—*Continued*

Panel C:	CDS price		Credit spread		Credit spread	
	Coefficient	t-statistic	Coefficient	t-statistic	Coefficient	t-statistic
Change in short-term interest rate	-10.68	-6.63	-8.31	-3.39	-8.64	-4.29
CDS_{t-1}×change in short-term interest rate			-0.13	-2.77	-0.13	-3.18
Firm-specific equity returns	31.85	3.03	21.96	2.78	25.25	3.91
CDS_{t-1}×firm-specific equity returns	-0.90	-5.77	-0.47	-4.02	-0.59	-5.31
CDS_{t-1}×change in firm-specific volatility/100	0.42	4.20				
Change in liquidity	0.18	4.56				
Lagged basis	-0.05	-2.43	0.25	11.48	0.25	11.40
Adjusted R^2	0.26		0.25		0.24	

and **(6)**, reported in panels A and B of Table G, together with parsimonious specifications of **(6)** where insignificant terms are dropped from the equations (panel C).(12)

The visual impression of Charts 4 and 5 is confirmed by the regression results since the interaction of the lagged level of the CDS price with both firm-specific equity returns and firm-specific volatility are significant in the CDS regressions.(13) Including these terms significantly raises the adjusted R^2. The interaction terms are important in the credit spread equations (as is the interaction with changes in interest rates) but have a less marked effect on explanatory power. Even with these extra interaction terms, the lagged basis remains the most important variable in the credit spread equations since the adjusted R^2 rises noticeably between panels A and B.

It is noticeable that the highest explanatory power we are able to generate still leaves three-quarters of the variation in both CDS prices and credit spreads unexplained. This corresponds closely to the proportions found by Collin-Dufresne, Goldstein and Martin (2001) in their analysis of monthly changes in credit spreads. They find that the residual terms from their regressions are highly cross-correlated, suggesting the existence of an unidentified common systematic factor, and suggest that credit spreads may be largely driven by market-wide demand and supply shocks. Principal components analysis of portfolios of the residuals of the regressions presented in Table G support similar conclusions. Irrespective of the formation of the portfolios, the first principal component explains a large and essentially identical proportion of the variation

(12) A Wald test confirms that the sum of the coefficients on the change in the long-term interest rate and the change in the slope of the yield curve is insignificantly different from zero. This suggests that only short-term (two-year) interest rates are important. In panel C, therefore, we include the change in the short-term rate and the change in the slope of the yield curve in the general specification, but the latter is insignificant and therefore dropped from the specific model.
(13) Again, these findings are robust to excluding BBB-rated companies from the sample.

of the residuals in both CDS and credit spread equations, with approximately equal weighting on each portfolio. As with Collin-Dufresne, Goldstein and Martin (2001) the regressions appear to be missing a common factor. This factor is common across reference entities and across both cash and credit derivative markets. (14)

One noteworthy feature of the results that carries over from the earlier regressions is the greater impact of macro factors (interest rates, term structure, equity market returns and equity market implied volatilities) on the credit spread than on CDS prices, in terms of both absolute magnitude and level of significance. Conversely, firm-specific factors (equity returns and implied volatilities) have a greater effect on CDS prices than spreads. For example, the coefficient estimates from panel B suggest that a 10% decrease in the equity price of a firm with a CDS price of 150 basis points (typical of a BBB-rated firm at the start of the sample) is associated with a simultaneous 10.3 basis points increase in the CDS price but just 4.6 basis points on the credit spread. A similar equity price drop for a firm with a CDS price of 250 basis points (which was the price quoted for Ford in early 2002) is associated with a 20 basis point jump in CDS prices but just 9 basis points on the credit spread. However, the arbitrage-based equivalence of CDS prices and credit spreads suggests that both are equally sensitive to firm-specific factors in the long run. The large and significant lagged basis term is the mechanism through which the long-run incorporation of firm-specific information takes place. Collin-Dufresne, Goldstein and Martin (2001) note the sensitivity of the credit spread to market-wide factors, and question the validity of structural models of default that focus on firm-specific factors. Our findings suggest that CDS prices react more to firm-specific factors and that credit spreads react to lagged changes in CDS prices, and so lend some support to the structural models.(15)

(14) Residuals of the regressions reported in Table G panel C were collected. The 32 reference entities were repeatedly arbitrarily grouped into eight portfolios, taking simple averages of the residuals for both CDS and credit spread regressions. Principal components analysis was performed on both sets of portfolios for the various groupings. The first principal component explained between 46% and 61% of the variation in the portfolio residuals, depending on the grouping of the reference entities. Detailed results are available on request.
(15) Significant cheapest-to-deliver options due to the existence of convertible bonds would increase the sensitivity of CDS prices to firm-specific factors. The value of the option to convert would increase as the firm-specific stock price and volatility increased. This increase in the value of convertibility would raise the price of the bond and so reduce the value of the delivery option in the CDS price. However, the coefficient on firm volatility should then be negative, rather than the positive coefficient we find. Further, we obtain quantitatively similar results when we only consider US entities where the CTD option is less valuable.

6 Concluding comments

This paper is a contribution to the relatively small empirical literature on credit derivatives. To our knowledge, this paper is the first to examine credit default swap prices in a time series framework. It addresses the validity and implications of the theoretical relationship between credit default swap prices and credit spreads using data for a small cross-section of US and European firms for which high-quality data are available.

For this sample of investment-grade firms the theoretical arbitrage relationship linking credit spreads over the risk-free rate to CDS prices holds reasonably well on average for most of the companies (but especially for US firms) when the risk-free rate is proxied by the swap rate. Where the relationship does not hold, imperfections in the CDS market or measurement errors in the credit spread may be responsible. Due to contract specifications in credit default swaps, particularly in Europe, a cheapest-to-deliver option may also be included in the CDS price making it an upper bound on the true price of credit risk. We are unable to incorporate the repo cost of corporate bonds in our analysis due to a lack of reliable data. As a result the measured credit spread may underestimate the true credit spread, and so forms a lower bound on the true price of credit risk. Subject to these caveats, for most reference entities, both the cash bond and credit default swap markets appear to price credit risk equally on average. We demonstrate, however, that price discovery takes place primarily in the CDS market and that the CDS market Granger causes the credit spread for those entities where the price of credit risk transitorily differs in the two markets. We speculate that price discovery occurs in the CDS market because of (micro)structural factors that make it the most convenient location for the trading of credit risk, and because there are different participants in the cash and derivative market who trade for different reasons.

The second part of the paper examined the determinants of changes in the two measures of the price of credit risk. Variables suggested by the structural literature on credit risk are capable of explaining around one quarter of the weekly changes in credit default swap prices. The same variables are less successful in capturing changes in credit spreads. Firm-specific equity returns and implied volatilities are statistically more significant and of greater economic importance for CDS prices than for credit spreads. The pricing discrepancy between CDS prices and credit spreads is closed primarily through changes in the credit spread, reflecting the CDS market's lead in price discovery. It is through this error correction mechanism that both CDS and credit spreads price credit risk equally in the long run. We argue that these findings are supportive of the structural models of credit risk. Nevertheless, in the absence of higher explanatory power, we must echo the call of Collin-Dufresne, Goldstein and Martin (2001) for further work on the factors that can account for the unexplained portion of CDS and credit spread changes.

This study leaves several avenues open to further analysis. Most obviously, since the credit derivatives market is still small and developing, these results are not necessarily representative of the period before or after our relatively short span of data. Second, we have only analysed investment-grade corporate reference entities, although there are several sovereigns with very liquid CDS and bond markets. Similarly, we have not considered speculative-grade corporate entities, primarily because their bonds typically trade well below par, particularly for fallen angels, which weakens the arbitrage relationship that underpins much of our analysis. Finally, a microstructural analysis of price discovery across credit risk sensitive information releases would help to illuminate the price discovery process that was rather coarsely addressed at a daily frequency in this paper.

References

Alexander, G, Edwards, A K and Ferri, M G (1998), 'Trading volume and liquidity in Nasdaq's high-yield bond market', unpublished manuscript, Securities and Exchange Commission, Washington, D.C.

Baillie, R, Booth, G G, Tse, Y and Zabotina, T (2002), 'Price discovery and common factor models', *Journal of Financial Markets,* Vol. 5, pages 309-21.

Bank for International Settlements (2000), *Regular OTC derivatives market statistics*, Bank for International Settlements.

Black, F and Cox, J C (1976), 'Valuing corporate securities: some effects of bond indentures provisions', *Journal of Finance,* Vol. 31, pages 351-67.

Blume, M, Lim, F and MacKinlay, A C (1998), 'The declining credit quality of US corporate debt', *Journal of Finance,* Vol. 53, pages 1,389-413.

British Bankers' Association (2002), *BBA Credit Derivatives Report 2001/2002,* British Bankers' Association.

Collin-Dufresne, P, Goldstein, R S and Martin, J S (2001), 'The determinants of credit spread changes', *Journal of Finance,* Vol. 56, pages 2,177-207.

Cossin, D, Hricko, T, Aunon-Nerin, D and Huang, Z (2002), 'Exploring for the determinants of credit risk in credit default swap transaction data: is fixed-income markets information sufficient to evaluate credit risk?', unpublished manuscript, University of Lausanne.

Das, S R (1995), 'Credit risk derivatives', *Journal of Derivatives,* Vol. 2, pages 7-23.

Das, S R and Sundaram, R K (1998), 'A direct approach to arbitrage-free pricing of credit derivatives', *NBER Working Paper*, No. 6635.

Dhillon, H (2002), 'From small beginings…', *Credit*, pages 24-26.

Diamond, D W and Verrecchia, R E (1987), 'Constraints on short-selling and asset price adjustment to private information', *Journal of Financial Economics,* Vol. 18, pages 277-311.

Duffie, D (1999), 'Credit swap valuation', *Financial Analysts Journal,* Vol. 55, pages 73-87.

Duffie, D and Huang, M (1996), 'Swap rates and credit quality', *Journal of Finance,* Vol. 51, pages 921-49.

Duffie, D and Singleton, K (1999), 'Modeling term structures of defaultable bonds', *Review of Financial Studies,* Vol. 12, pages 687-720.

Elton, E J, Gruber, M J, Agrawal, D and Mann, C (2001), 'Explaining the rate spread on corporate bonds', *Journal of Finance,* Vol. 56, pages 247-77.

Engle, R F and Granger, C W J (1987), 'Cointegration and error-correction representation, estimation and testing', *Econometrica,* Vol. 55, pages 251-76.

Geske, R (1977), 'The valuation of corporate liabilities as compound options', *Journal of Financial and Quantitative Analysts,* Vol. 12, pages 541-52.

Gonzalo, J and Granger, C W J (1995), 'Estimation of common long-memory components in cointegrated systems', *Journal of Business and Economic Statistics,* Vol. 13, pages 27-35.

Hasbrouck, J (1995), 'One security, many markets: determining the contributions to price discovery', *Journal of Finance,* Vol. 50, pages 1,175-99.

Hong, G and Warga, A (2000), 'An empirical study of bond market transactions', *Financial Analysts Journal,* Vol. 56, pages 32-46.

Houweling, P and Vorst, T (2002), 'An empirical comparison of default swap pricing models', unpublished manuscript, Erasmus University Rotterdam.

Hull, J C, Predescu, M and White, A (2003), 'The relationship between credit default swap spreads, bond yields, and credit rating announcements', unpublished manuscript, University of Toronto.

Hull, J C and White, A (2000a), 'Valuing credit default swaps I: no counterparty default risk', *Journal of Derivatives,* Vol. 8, pages 29-40.

Hull, J C and White, A (2000b), 'Valuing credit default swaps II: modeling default correlations', *Journal of Derivatives,* Vol. 8, pages 12-22.

J. P. Morgan (2002), *CDS Basis Report*, 19 August 2002.

Jarrow, R A, Lando, D and Turnbull, S (1997), 'A Markov model for the term structure of credit spreads', *Review of Financial Studies,* Vol. 10, pages 481-523.

Jarrow, R A and Turnbull, S (1995), 'Pricing derivatives on financial securities subject to credit risk', *Journal of Finance,* Vol. 50, pages 53-86.

Lando, D (1997), 'Modelling bonds and derivatives with default risk', in Dempster, M and Pliska, S (eds), *Mathematics of derivative securities*, Cambridge University Press, Cambridge.

Lehmann, B N (2002), 'Some desiderata for the measurement of price discovery across markets', *Journal of Financial Markets,* Vol. 5, pages 259-76.

Longstaff, F A and Schwartz, E (1995), 'A simple approach to valuing risky fixed and floating rate debt', *Journal of Finance,* Vol. 50, pages 789-821.

McCauley, R N (2002), 'International market implications of declining Treasury debt', *Journal of Money, Credit, and Banking,* Vol. 34, pages 952-66.

Merton, R C (1974), 'On the pricing of corporate debt: the risk structure of interest rates', *Journal of Finance,* Vol. 29, pages 449-70.

Pierides, Y A (1997), 'The pricing of credit risk derivatives', *Journal of Economic Dynamics and Control,* Vol. 21, pages 1,579-611.

Schonbucher, P J (2000), 'The pricing of credit risk and credit derivatives', unpublished manuscript, University of Bonn.

Schultz, P (1998), 'Corporate bond trading costs and practices: a peek behind the curtain', unpublished manuscript, University of Notre Dame.

Skinner, F S and Townend, T G (2002), 'An empirical analysis of credit default swaps', *International Review of Financial Analysis,* Vol. 11, pages 297-309.

Sundaresan, S (1991), 'Valuation of swaps', in Khoury, S (ed), *Recent developments in international banking and finance*, North Holland, Amsterdam.