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Time-varying contributions by the corporate bond and CDS markets to credit risk price discovery

Niko Dötz

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Deutsche Bundesbank, Wilhelm-Epstein-Strasse 14, 60431 Frankfurt am Main,
Postfach 10 06 02, 60006 Frankfurt am Main

Tel +49 69 9566-1
Telex within Germany 41227, telex from abroad 414431

Please address all orders in writing to: Deutsche Bundesbank,
Press and Public Relations Division, at the above address or via fax +49 69 9566-3077

Internet http://www.bundesbank.de

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Abstract

This paper looks at the dynamic price relationship between spreads in the corporate bond market and credit default swaps (CDS). It picks up where Blanco et al (2005) leave off but is focused on European credit markets. The study is based on companies listed in the iTraxx CDS index and thus on new data on a more liquid CDS market. Unlike previous studies, which look at price formation in a time-invariant context, the contributions of both markets to price discovery are analysed in a time-variant context. We devote particular attention to the question of whether such information input is stable in times of crisis and find that, although the CDS market slightly dominates the price discovery process, its contribution fell visibly during the turbulence on the credit markets in early 2005 in favour of that of the bond market.

Keywords: price discovery, credit risk, corporate bonds, credit derivatives, Kalman filter

JEL classification: C32, G10 and G14

Non-technical summary

Credit default swap (CDS) spreads have now joined bond spreads as key indicators of the credit quality of corporates, banks and sovereigns. To the extent that they correctly and quickly reflect default risks and their rate of change, CDS spreads contribute to improving the allocation of credit risk. Since banks and, most recently, institutional investors, such as hedge funds, have come to be the key players on the CDS market, they can also improve the resilience of the banking and financial system at the same time.

This paper studies to what extent the markets for corporate bonds and credit default swaps contribute to price discovery in credit markets. Following Blanco et al (2005), we look at the extent to which a theoretical arbitrage relationship between CDS prices and the corresponding bond prices exists and which market leads in price discovery. Unlike previous studies, which look chiefly at international or US credit markets, our paper focuses exclusively on European corporates. This study is based on companies listed in the iTraxx CDS index and thus on new data on a more liquid CDS market, which should make it easier to detect an arbitrage relationship.

The decisive factor in the quality and reliability of bond spreads and CDS spreads as indicators is that they can also be a stable source of information even in times of financial tension. Although studies on other markets, such as Upper and Werner (2002), show that the contributions by spot markets and their corresponding derivative markets to price discovery fluctuate over time and can vary, especially in times of crisis, the previous studies on credit markets are based on time-invariant price formation. This paper attempts to close the gap by analysing both markets' contribution to price discovery not only in a time-invariant context but also in a time-varying context, devoting special attention to financial tension.

On the whole, the results support the argument in favour of an arbitrage relationship in European credit markets and strongly suggest that both markets contribute to price discovery, with the CDS market dominating by a slight margin. At the same time, we find that both markets' contributions visibly fluctuate over time. Since the CDS market's contribution fell significantly in favour of that of the bond market during the credit market turbulence in spring 2005, a degree of caution is warranted when interpreting the CDS market's pricing signals during times of crisis.

Nicht-technische Zusammenfassung

Credit Default Swap (CDS)-Prämien ergänzen mittlerweile die traditionellen Bond-Spreads als wichtige Indikatoren für die Kreditqualität von Unternehmen, Banken und Staaten. In dem Ausmaß, wie die CDS-Prämien die Ausfallrisiken und ihre Veränderung korrekt und rasch widerspiegeln, helfen sie die Allokation der Kreditrisiken zu verbessern. Da Banken und zuletzt zunehmend auch institutionelle Investoren wie z.B. Hedgefonds zu den wichtigsten CDS-Markt-Teilnehmern zählen, könnten sie gleichzeitig die Widerstandskraft des Banken- und Finanzsystems stärken.

Das Forschungspapier untersucht, in welchem Umfang die Märkte für Unternehmensanleihen und Credit Default Swaps zur Preisfindung an den Kreditmärkten beitragen. In Anlehnung an Blanco et al. (2005) wird darauf abgestellt, inwieweit die theoretische Arbitragebeziehung zwischen CDS-Prämien und entsprechenden Bond-Spreads wirksam ist und welcher Markt die Preisfindung anführt. Im Unterschied zu den bisherigen Untersuchungen, die überwiegend internationale bzw. US-amerikanische Kreditmärkte betrachten, konzentriert sich das Papier ausschließlich auf europäische Unternehmen. Die Untersuchung stützt sich auf im CDS-Index iTraxx vertretene Unternehmen und damit auf neue Daten zu einem liquideren CDS-Markt, was den Nachweis einer Arbitragebeziehung erleichtern sollte.

Für die Qualität und Verlässlichkeit der Bond-Spreads und CDS-Prämien als Indikatoren ist entscheidend, dass sie auch in Zeiten finanzieller Anspannungen einen stabilen Informationsbeitrag leisten. Obwohl Studien zu anderen Märkten wie z.B. Upper/Werner (2002) zeigen, dass die Preisfindungsbeiträge von Kassainstrument und zugehörigem Derivat im Zeitablauf schwanken und sich insbesondere in Krisenzeiten ändern können, stellen die bisherigen Untersuchungen zu den Kreditmärkten auf die Preisbildung für eine feste Zeitspanne ab. Indem das Papier die Preisfindungsbeiträge beider Märkte nicht nur in einem konstanten, sondern auch in einem zeitvariablen Kontext analysiert und finanziellen Anspannungen besondere Aufmerksamkeit schenkt, versucht es zur Schließung dieser Lücke beizutragen.

Die Ergebnisse stützen insgesamt das Argument der Arbitragebeziehung an den europäischen Kreditmärkten und legen nahe, dass bei einer leichten Dominanz des

CDS-Markts beide Märkte zur Preisfindung beitragen. Gleichzeitig zeigt sich, dass die Beiträge beider Märkte im Zeitablauf merklich schwanken. Da der Beitrag des CDS-Markts während der Turbulenzen an den Kreditmärkten im Frühjahr 2005 deutlich zugunsten des Bondmarkts abnahm, erscheint in Krisenzeiten bei der Beurteilung der Preissignale des CDS-Markts eine gewisse Vorsicht geboten.

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Time-varying contributions by the corporate bond and CDS markets to credit risk price discovery[*]

1 Introduction

The market for tradable default risk has grown strongly in the past few years. Credit default swap (CDS) spreads have now joined traditional bond spreads as important indicators of the credit quality of corporates, banks and sovereigns. To the extent that they correctly and quickly reflect default risks and their change, CDS spreads help to improve the allocation of default risk. Since banks and, most recently, institutional investors, have come to be the key players on the CDS markets, they can simultaneously strengthen the resilience of the banking and financial system.[1]

This paper studies the extent to which the markets for corporate bonds and credit default swaps contribute to credit market price discovery. Following Blanco et al (2005), we look at the extent to which the theoretical arbitrage relationship between CDS prices and their corresponding bond prices exists and which market dominates the price discovery process. Unlike previous studies, which look chiefly at international or US credit markets, our paper focuses exclusively on European corporates. The study is based on companies listed in the iTraxx CDS index and thus on new data on a more liquid CDS market, which should make it easier to detect an arbitrage relationship.

The quality and reliability of bond spreads and CDS spreads as indicators hinge on their ability to function as a stable source of information even in times of financial distress. Although studies on other markets, such as Upper and Werner (2002), show that the contributions of spot markets and their corresponding derivatives fluctuate over time and can change, especially in times of crisis, the previous studies on credit markets are based on time-invariant price formation. This paper attempts to close the gap by analysing both markets' contribution to price discovery not only in a time-

[*] I thank Jörg Breitung, Joachim Grammig, Ulrich Grosch, Heinz Herrmann and Christian Upper for helpful comments and suggestions. The views expressed in this paper are solely my own and do not necessarily represent the views of the Deutsche Bundesbank.

[1] Cf BBA Credit Derivatives Report 2006 and Deutsche Bundesbank (2004a).

invariant context but also in a time-varying context, devoting special attention to financial tension.

On the whole, the results support the argument in favour of an arbitrage relationship in European credit markets and strongly suggest that both markets contribute to price discovery, with the CDS market slightly dominating the process. At the same time, we find that both markets' contributions visibly fluctuate over time. Since the CDS market's contribution fell significantly in favour of that of the bond market during the credit market turbulence in spring 2005, a degree of caution is warranted when interpreting the CDS market's pricing signals during times of crisis.

The rest of this paper is structured as follows. In the next section, we will present previous studies which cover similar ground. Section II will discuss possible reasons for incomplete arbitrage or difficulties in detecting an arbitrage relationship. We will present the underlying data of the iTraxx Europe CDS index in Section III. In Section IV, we will analyse the price relationship between CDS and bond spreads first in a time-invariant context and then in a time-varying context, and Section V will present findings and concluding remarks.

2 Review of the literature

What the previous studies covering arbitrage relationships and the dynamic relationship between CDS spreads and bond spreads mostly have in common is that they identify a long-run relationship between both types of financial market prices.[2] With regard to the type of price discovery, CDS seems to make a greater contribution to price discovery in US companies than in European companies.[3] According to Blanco et al (2005), who study a sample of 16 US firms and 17 European firms for the January 2001 to June 2002 period, price discovery mainly takes place in the CDS market. The CDS market's dominance is greater for US firms than for European

[2] The study by Chan-Lau and Kim (2004), who analyse the relationship between CDS, bond and equity markets in several emerging economies, is a notable exception. They do not find a stable relationship for most of the countries in their study.

[3] "Price discovery" may be defined as the efficient and rapid processing of information which passes through trade into market prices (cf Lehman 2002). When trading related instruments in two markets, price discovery is divided into these two markets, and the market with the larger contribution to price discovery is said to lead the other market.

firms. A similar study by Zhu (2004), which examines 24 (mostly) US firms for the 1999-2002 period, shows clear differences between the firms studied, with the liquidity of the instruments seeming to play a role. It suggests, on the whole, that the CDS market dominates among US firms whereas the bond market is predominant among European and Asian firms. An estimation in the *Monthly Report* of the Bundesbank (2004b) (24 European firms, October 2001-August 2004) confirms a price leadership of the CDS market yet also identifies a meaningful contribution by the bond market to price discovery. The study also reaches different findings depending on the sector being examined. Finally, Norden and Weber (2005), who study price discovery for 35 European firms and 20 US firms in the 2000-2002 period, find that CDS is the leader in price discovery with respect to US firms whereas for European firms the contributions by the CDS and bond markets to price discovery are rather similar.

Levin et al (2005) and De Wit (2006) focus on the difference between CDS spreads and corporate bond spreads (the CDS-bond basis). Without delving any further into the contributions of the two markets to price discovery, they study the possibilities for arbitrage between these markets. According to Levin et al, who study the role of market frictions in the US, the basis is time-varying but often differs widely between the firms in their study, and their variance can be explained particularly through firm-specific factors (bond issuance volume, ratings). For US and European firms, De Wit identifies the cheapest-to-deliver option, the transactions costs of shorting cash bonds and liquidity premiums as the key determinants of the basis.

The studies on the price relationship between CDS and bonds listed above give a point (time-invariant) estimation of price discovery. Studies of other markets to date, however, suggest that the price relationship between a spot instrument and its corresponding derivative can fluctuate over time. Upper and Werner (2002) study the price relationship between Federal bonds (Bunds) and Bund futures in a time-varying context. They find out that the highly liquid Bund future generally dominates the spot market in price discovery but that the spot market also generally makes a key contribution to price discovery. However, these contributions seem to fluctuate heavily over time, and during the LTCM hedge fund's crisis in 1998, the spot market made a much smaller contribution, or no key contribution at all, to price discovery.

The results produced by Hodgson et al (2003), who study the price relationship between share prices and share price index futures using Australia as an example, indicate time-varying contributions to price discovery. Futures thus tend to dominate the price discovery process, though the dominance is less pronounced during a bull market than during a bear market. Lastly, Foster (1996) shows that the dynamic relationship between the spot and futures price in the oil market changed fundamentally during the 1990-91 Gulf conflict and that the futures market had to surrender its hitherto large lead to the spot market, at least temporarily. Although all studies point to fluctuating contributions to price discovery, the markets under review vary with respect to whether the spot instrument or its derivative dominates price discovery in times of financial distress.

The fact that the results vary depending on the market being observed lead us to ask to what extent such turbulent periods impact on price relationships in credit markets.

3 Why arbitraging opportunities are incomplete and/or an arbitrage relationship is difficult to detect

In a CDS, the protection buyer pays a quarterly premium to the protection seller; in return, the buyer obtains compensation if the reference instrument defaults during the contract's lifetime. The annualised premium is the CDS premium used here. If the default event occurs, physical settlement is effected by having the protection buyer deliver the reference instrument at par to the protection seller. In cash settlement, the protection buyer is paid the difference between the par value of the reference instrument and the market value at the time of the default event occurring.

Since CDS spreads and bond spreads are key indicators of the default risk of a given firm, for no-arbitrage reasons they should not deviate from one another – with the possible exception of short-term differences based on information processing. The no-arbitrage condition is based on the idea that investing in a corporate bond corresponds to an investment in a secure bond plus the position of a CDS protection seller.[4] On balance, the basis (CDS spread minus bond spread) should therefore either be close to or equal to zero.

However, older studies have often failed to detect arbitrage, especially among European firms. This is associated with the following problems.

- In Europe, in particular, until just recently the CDS market was still a nascent and relatively illiquid market. The resultant high bid-ask spreads diminished the possibilities for arbitrage and made it difficult to detect it, especially over a short sample period.[5]

- Measurement and data problems additionally hampered efforts to empirically detect arbitrage. Owing to the lack of availability of transaction data for CDS and bond prices, studies of the price relationship are generally based on quotes; it is therefore fundamentally unclear to what extent trading corresponding to the price data in the analysis actually occurred.[6] Given the lower level of liquidity some years ago, this has reduced the meaningfulness of quotes.

Although some of these flaws have been eradicated in this paper (see below), still other market features and practices, whose impact on the basis offsets (at least in part) but which still can still prevent arbitrage, are relevant.

- Because the market is illiquid, it is usually only possible to enter short positions in corporate bonds or risk-free bonds at relatively high costs. This means that credit risk protection buyers often revert to the CDS market but, in return, have to pay higher CDS premiums. This results *ceteris paribus* in a positive basis and favours price discovery in the CDS market.

[4] For the event that the CDS spread exceeds the bond spread, an arbitrageur acting as a CDS protection seller could take over the CDS premium, sell the corporate bond short and invest the funds in a risk-free bond. In the converse scenario – with the bond spread exceeding the CDS spread – it would be profitable to sell the risk-free bond short, use the proceeds to buy the corporate bond and hedge the default risk with a CDS.
[5] Cf Blanco et al (2005).
[6] Cf similar studies on price relationships by Blanco et al (2005), Norden and Weber (2004) and Zhu (2004).

- Despite its fast growth, the CDS market is a highly concentrated market with a small number of participants, which can put a strain on liquidity particularly in times of financial distress.[7] The volume of corporate bonds, in turn, is limited; these bonds are also often held by investors until maturity, which can adversely affect liquidity and information processing.

- To prevent market squeezes, in a default event the protection buyer, in physical settlement, has the right to deliver either the reference instrument or another instrument issued by the same debtor at the same par value (the cheapest-to-deliver option). To offset the risk of receiving a less valuable bond, the protection seller demands higher CDS premiums, thereby enlarging the basis.

- CDS are building blocks for structured financial instruments such as synthetic Collateralised Debt Obligations (CDO), the issuance of which has surged in the past few years.[8] The CDO issuer usually enters the CDS market as a protection seller and passes on the credit risk of individual tranches. The resultant supply of credit risk hedging in the CDS market *ceteris paribus* impacts negatively on CDS premiums and the basis.

- Although the exact definition of default is specified by the ISDA rules, there can still be disagreement about whether a default has happened. The resultant legal risk could impair arbitrage.

- The conclusion of a CDS contract involves counterparty risk for both parties, though the protection buyer bears a greater risk than the seller.[9] This asymmetry is likely to reduce CDS premiums and thus the basis.

- In a default event, the protection buyer delivers the bond at par to the protection seller; in practice, accrued interest is not taken into consideration. The protection

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[7] Cf Deutsche Bundesbank (2004b). For an analysis of the CDS spreads of listed German banks see Düllmann and Sosinska (2007).

[8] For information on reasons for market growth see Fabozzi et al (2006), p 229. Some of the cited advantages of synthetic CDO over cash CDO – in which bonds and loans form the pool of collateral – include better availability of CDS relative to bonds or loans and heavy demand among investors for unfunded supersenior tranches.

[9] The counterparty risk requires market participants to have a higher credit rating, which in turn contributes to the aforementioned high concentration in the CDS market.

buyer could demand a discount on CDS premiums as compensation, which would adversely affect the basis.

- The theoretical arbitrage relationship does not hold for a fixed-rate bond but only for a floating-rate instrument. As the protection seller is obliged to pay the face value of the bond in a default event, he will demand, for instance, a higher CDS premium as compensation for a CDS on a bond quoted below par, causing the basis to increase. However, as floating-rate bonds are not very widespread, the empirical studies generally use fixed-coupon bonds.

4 Data pool: iTraxx Europe CDS index

The creation of the iTraxx CDS index in mid-2004 made an important contribution to the development of the CDS market. This tradable index was born of the merger of Trac-x and the Dow Jones iBoxx, the two hitherto most important providers of CDS indices. Market watchers hold that iTraxx gives market participants key improvements regarding liquidity, transparency and diversification opportunities. It has consequently afforded many non-banks access to the CDS market, where banks had previously been the main agents. It is particularly iTraxx Europe, with its 125 European firms, which is characterised by ample market liquidity and very small bid-ask spreads. On the basis of regular dealer surveys, it reflects the most liquid instruments in the European CDS market in terms of trading volumes. The new index has apparently favoured not only the growth of portfolio products but also single-name CDS.[10] This probably reflects the fact that market participants and intermediaries are taking major single-name positions to hedge their exposure from a CDS portfolio or index.

Part of the problem detecting arbitrage relationships can be resolved by analysing the CDS contracts mapped in iTraxx. Although arbitrage can still be hampered by the above listed market features and practices, whose relevance remains undiminished, the particularly highly liquid nature of the iTraxx instruments eradicates some of the gaps of earlier studies. By enhancing the meaningfulness of the CDS quotes used,

[10] Cf Fitch, Global Credit Derivative Survey 2004.

the very liquid CDS contracts mitigate the problem of the lack of availability of transaction data for CDS prices. In addition, the higher liquidity should also coincide with low bid-ask spreads. In fact, the iTraxx firms' bid-asks spreads have fallen distinctly in the past few years.[11] This should lead to more precise measurement results and improve the ability to detect arbitraging possibilities in comparison to the aforementioned older studies based on less liquid CDS prices.

Of the 125 companies listed in iTraxx Europe, suitable daily data on CDS spreads and bond spreads can be obtained from Bloomberg and Thomson Financial Datastream for 36 European enterprises.[12] Both series are closing prices. For all selected companies, data for the period from 21 January 2004 to 31 October 2006 (725 observations) are available. A longer data history is available for some firms; the longest time series date back to 1 January 2003. The limited availability of suitable bonds is the main reason for the reduction in the sample size. Table 1 presents a list of the selected 36 firms which cover the most important industrial sectors, and all of which have are rated investment grade by S&P, as well as of the average volume of the selected bonds.

CDS contracts are traded over-the-counter. The most liquid contracts have a 5-year lifetime; we will therefore use the premiums of 5-year CDS.[13] The mid-prices of the indicative bid-ask prices (Bloomberg Generic Average Prices) provided by Bloomberg are used as CDS spreads.

In order to calculate the spread of a synthetic corporate bond with a residual maturity of 5 years, at least two bonds are chosen for each firm. Only listed euro-denominated bonds with a fixed coupon and a bullet payment were taken into consideration. Convertible bonds were not included in the dataset. Linear interpolation was used to calculate the synthetic 5-year bond spread. This was based on two selected bonds, the residual maturity of one of the bonds being less than 5 years and that of the other

[11] On the basis of 26 iTraxx companies for which longer time series are available, it turns out that the average bid-ask spread fell from over 20 basis points to around 3 bp between mid-2002 and autumn 2006.
[12] Composition of iTraxx accurate on 20 September 2006.
[13] CDS premiums are usually paid quarterly (on the 20th of March, June, September and December), which means that a 5-year CDS matures 5 to 5¼ years after the conclusion of the transaction.

bond over 5 years.[14] In those cases where several bonds were available, we kept the residual maturities as close to 5 years as possible.[15]

Table 1: Overview of the sample

The table provides an overview of the 36 European companies contained in the sample, their rating, their average market value over the reporting period and average volume of the bonds used to calculate the 5-year bond spread.

	Country	Sector	S&P rating	Market value (€ mill)	Volume of selected bonds (€ mill)
Allianz (ALL)	Germany	Financial	AA-	42137	950
Altadis (ALT)	Spain	Consumers	BBB+	8996	550
Arcelor (ARC)	France	Industrials	BBB	13702	567
Bayer (BAY)	Germany	Industrials	BBB+	21250	2500
Bco Bilbao (BBI)	Spain	Financial	AA-	46639	3000
BMW (BMW)	Germany	Autos	A+	22731	750
Bco Santander Central Hispano (BSA)	Spain	Financial	AA	59251	1718
Carrefour (CAR)	France	Consumers	A	28854	750
Casino Guichard-Perrachon & Cie (CAS)	France	Consumers	BBB-	5938	600
Commerzbank (COM)	Germany	Financial	A	12996	200
DaimlerChrysler (DAI)	Germany	Autos	BBB	38799	1250
Deutsche Bank (DBA)	Germany	Financial	AA-	40315	684
Deutsche Telekom (DET)	Germany	TMT	A-	61232	2000
Energias de Portugal (EDP)	Portugal	Energy	A	8719	551
Éltectricité de France (ELT)	France	Energy	AA-	74718	1667
Energie Baden Württemberg (ENB)	Germany	Energy	A-	4006	875
Endesa (END)	Spain	Energy	A	21379	550
Fortum Oyj (FOR)	Finland	Energy	A-	12816	500
France Télécom (FRAT)	France	TMT	A-	52663	2000
Lafarge (LAF)	France	Industrials	BBB	13614	470
LVMH (LOU)	France	Consumers	BBB+	32119	613
National Grid (NAT)	UK	Energy	A	22138	550
Organisation societe anonyme (OTE)	Greece	TMT	BBB+	7388	1175
Peugeot (PSA)	France	Autos	BBB+	11436	550
Repsol (REP)	Spain	Energy	BBB	25499	917
RWE (RWE)	Germany	Energy	A+	27283	1500
St Gobain (STG)	France	Industrials	BBB+	16520	552
Telefonica (TELE)	Spain	TMT	BBB+	64376	833
Telecom Italia (TELI)	Italy	TMT	BBB+	29862	1000
ThyssenKrupp (THY)	Germany	Industrials	BBB+	9441	625
Telenor (TNOR)	Norway	TMT	BBB+	12803	450
Vattenfall (VAT)	Sweden	Energy	A-	7467	375
Vivendi (VIV)	France	TMT	BBB	27043	1167
Vodafone (VOD)	UK	TMT	A-	122473	625
VW (VW)	Germany	Autos	A-	13518	1000
Wolters Kluwer (WOL)	Netherlands	TMT	BBB+	4804	463

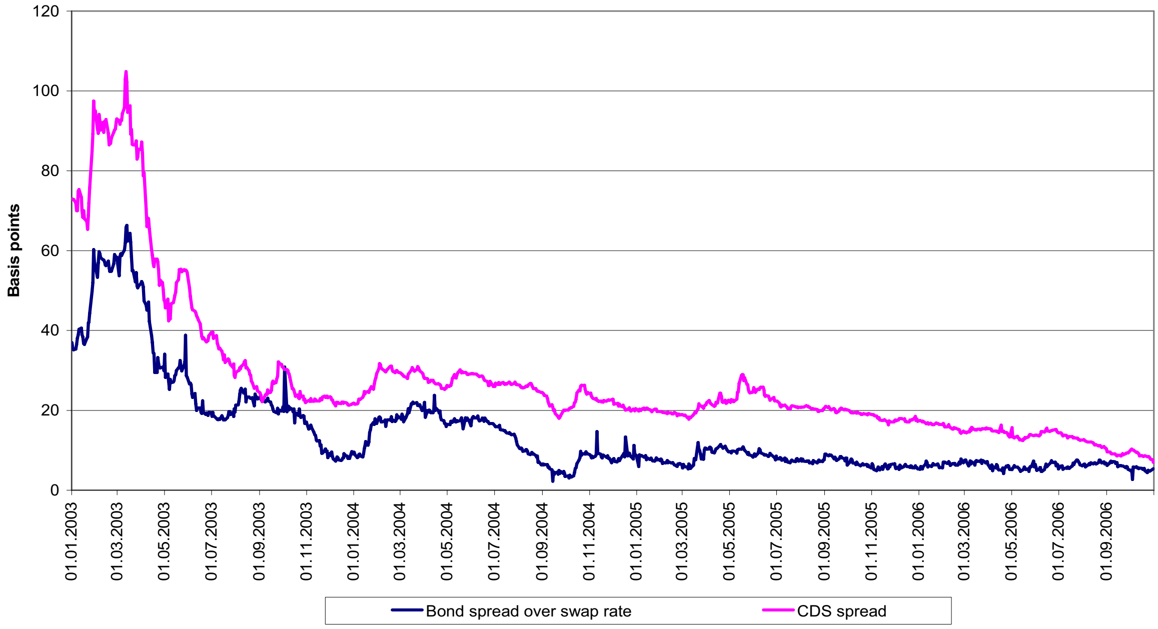
How the risk-free rate of interest is chosen determines the calculation of the spread. The swap rate is often chosen over other benchmarks such as government bond

[14] The weighting was adapted over time, making the synthetic residual maturity 5 years at any given time.
[15] Avoiding using long-dated bonds wherever possible mitigates the distortions from bonds not quoted at par.

yields in the literature because swaps are regarded as highly liquid, government bonds can be distorted by repos and swap rates often reflect the financing costs of many market participants.[16] For this reason, we will use the swap rate as the risk-free rate of interest in the following.[17] Figure 1 charts the bond spread and the CDS spread using Allianz AG as an example.

Figure 1: Bond spread and CDS spread using Allianz AG as an example

The bond spread is the difference between the yield on a synthetic five-year corporate bond and the swap rate, the five-year spread having been calculated using a linear interpolation. The CDS spread is the mid-price of a CDS with a maturity of five years.



5 Price discovery

5.1 Cointegration analysis

The bond spreads and CDS spreads calculated on the basis of the swap rates are very similar. With the exception of the end of the reporting period, the CDS spreads are mostly somewhat higher than the corresponding bond spreads. The arithmetic

[16] Cf Blanco et al (2005), p 2261.
[17] The bond spreads correspond to the "Spread over Swap Curve" data type provided by Datastream. In addition, the time series analysis (estimation of the VECM in a time-invariant context) was conducted based on government bond yields as a riskless interest rate, leading to largely the same results.

average of the basis is 3.6 basis points, a magnitude that is consistent with the results of comparable earlier studies.[18]

Table 2 shows the time series characteristics of bond spreads and CDS spreads. Of the 36 firms in all, ADF and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests for 34 firms show that both time series are I(1) and thus potentially cointegrated. In the case of cointegrated prices, the common factor can be interpreted as an implied efficient price of credit risk which can be used to calculate the contributions of each market to price discovery. In the Engle-Granger cointegration analysis, ADF and Phillips-Perron cointegration tests are run on these firms in a first step. The Engle-Granger procedure is supplemented by the Johansen cointegration tests. What the individual tests have in common is that they strongly indicate cointegrated CDS and bond spreads for a clear majority of firms. For 22 firms, at least one Engle-Granger test, as well as the Johansen test, indicate a cointegrating relationship.

In a second step of the Engle-Granger procedure, the following vector error correction model (VECM) is estimated for these firms.

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

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

Here, Δp_{CDS} and Δp_{CS} represent the differences of the CDS and bond spreads respectively; λ_1, λ_2, α_0, α_1, β_1, β_2, δ_1 and δ_2 are the coefficients to be estimated, *p* the number of lags determined according to the Akaike information criterion, and ε_{1t} and ε_{2t} are independent, identically distributed shocks.[19]

[18] Blanco et al (2005), De Wit (2006), Levin et al (2005), Norden and Weber (2004) and Zhu (2004) therefore calculate average basis values of between -2 bp und 14 bp.

[19] A maximum of 8 lags were permitted. For three firms (ALL, REP, RWE) the number of lags was determined according to the Schwarz criterion because a satisfactory time-varying parameter estimation using the larger number of lags according to Akaike was not possible (see section on time-varying parameter estimation).

Table 2: Time series characteristics of bond spreads and CDS spreads

Columns 2 to 5 show the results of the unit root test (ADF test with H_0: I(1), Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test with H_0: I(0)) on CDS and bond spreads; a trend was included where appropriate. Cointegration tests were run using the Engle-Granger and Johansen procedure. Columns 6 and 7 show the results of the Phillips-Perron (PP-) and ADF test of the null hypothesis that the residuals ε_t of equation $p_{CDS,t} = \alpha_0 + \alpha_1 p_{CS} + \varepsilon_t$ have a unit root (MacKinnon values). Column 8 shows the Trace statistic on the null hypothesis of the Johansen test that CDS and bond spreads do not have a cointegrating relationship. ***, ** and * indicate that the null hypothesis can be rejected at the 1%, 5% and 10% levels respectively.

Company	Unit root tests ADF test H_0: I(1) KPSS test H_0: I(0)				Cointegration tests H_0: no cointegrating equation		
	CDS spreads		Bond spreads		Engle/Granger		Johansen
	ADF	KPSS	ADF	KPSS	PP	ADF	Trace stat
Allianz (ALL)	-	***	-	***	***	**	0,016**
Altadis (ALT)	-	***	-	**	-	-	0,811
Arcelor (ARC)	-	***	-	***	*	-	0,249
Bayer (BAY)	-	***	-	***	***	**	0,076*
Bco Bilbao (BBI)	-	***	-	***	***	**	0,083*
BMW (BMW)	-	***	-	*	-	-	0,584
Bco Santander Central Hispano (BSA)	-	***	-	***	*	-	0,000***
Carrefour (CAR)	-	***	-	***	-	**	0,044**
Casino Guichard-Perrachon & Cie (CAS)	-	**	-	***	-	-	0,017**
Commerzbank (COM)	-	***	-	***	*	**	0,02**
DaimlerChrysler (DAI)	-	***	*	-			
Deutsche Bank (DBA)	-	**	-	***	***	-	0,065*
Deutsche Telekom (DET)	-	***	-	***	***	***	0,000***
Energias de Portugal (EDP)	-	***	-	***	-	*	0,030**
Éltectricité de France (ELT)	-	**	-	***	***	**	0,068*
Energie Baden Württemberg (ENB)	-	***	-	***	***	***	0,007***
Endesa (END)	-	***	-	***	**	-	0,035**
Fortum Oyi (FOR)	-	**	-	***	**	-	0,338
France Télécom (FRAT)	-	***	-	***	***	**	0,000***
Lafarge (LAF)	-	***	-	***	*	*	0,053*
LVMH (LOU)	-	***	-	***	***	**	0,000***
National Grid (NAT)	-	***	-	***	**	*	0,295
Organisation societe anonyme (OTE)	-	***	-	***	*	*	0,006***
Peugeot (PSA)	-	***	-	***	*	-	0,457
Repsol (REP)	-	***	-	***	***	**	0,000***
RWE (RWE)	-	***	-	***	***	***	0,008***
St Gobain (STG)	-	***	-	***	***	-	0,000***
Telefonica (TELE)	-	**	-	***	-	-	0,000***
Telecom Italia (TELI)	-	***	-	***	*	*	0,271
ThyssenKrupp (THY)	-	***	-	***	***	**	0,058*
Telenor (TNOR)	-	**	-	***	***	-	0,002***
Vattenfall (VAT)	**	-	-	***			
Vivendi (VIV)	-	***	-	***	-	-	0,285
Vodafone (VOD)	-	***	-	***	-	-	0,315
VW (VW)	-	***	-	***	***	**	0,214
Wolters Kluver (WOL)	-	**	-	**	***	***	0,000***

The model takes account of both the long-run relationship between CDS and bond spreads (cointegrating relationship) as well as the short-run dynamics. The coefficients α_0 and α_1 describe the long-run relationship between the two variables.[20] The loadings λ_1 and λ_2 indicate how quickly CDS and/or bond spreads reconverge to the long-run relationship after a deviation. A significant negative coefficient λ_1 (positive coefficient λ_2) indicates a major adaptation in the CDS (bond) market and thus price domination by the bond (CDS) market. The estimation results are summed up in columns 2 and 3 of Table 3.

With one exception, at least one loading is significant for all firms, and all significant loadings have the intuitive sign. Judging by the frequency of the significant loadings, price discovery takes place in both markets. Two additional measurement variables – the Gonzalo-Granger (GG) measure and the Hasbrouck measures (HAS1, HAS2, MID) – can be used to measure contributions to price discovery more precisely.

The GG measure is based on the ratio of the two loadings, with GG = $\frac{\lambda_2}{\lambda_2 - \lambda_1}$. If GG > 0.5, the CDS market leads the price discovery process; GG < 0.5 indicates that the bond market leads in price discovery. GG ≥ 1 (GG ≤ 0) means that price discovery takes place only in the CDS market (bond market). The average value of GG is 0.58 (column 4). A Wald test can be run (column 5) to determine the extent to which the GG measurements indicate a clear dominance. In all cases in which the null hypothesis of identical contributions (GG = 0.5) can be rejected at the 5% level, GG > 0.5. For the GG measure, we can therefore say, in summary, that the CDS market contributes slightly more to price discovery than the bond market, on the whole, and that it clearly dominates price discovery in some cases.

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[20] The hypotheses α_0 =0 and α_1 =1 cannot be rejected at the 5% significance level in 5 and 7 cases respectively. In the other cases, both coefficients deviate from these theoretical values, yet an arbitrage relationship also exists.

Table 3: Measures of contributions to price discovery

The table shows different measures (λ_1, λ_2, GG, Hasbrouck measures) of the contributions of the CDS and bond markets to price discovery using those firms for which the tests in Table 2 indicate a cointegrating relationship. The contributions are calculated on the basis of the following error-correction model:

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

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

The t-values for λ_1 and λ_2 are given in parentheses, and ***, ** and * denote 1%, 5% and 10% level of significance respectively. Column 5 (9) shows the p-values for the null hypothesis that, according to the GG measure (MID measure), both markets contribute equally to price discovery.

	λ_1	λ_2	GG[21]	H_0: GG=0.5 p-value	Hasbrouck lower	Hasbrouck upper	Hasbrouck MID	H_0: MID=0.5 p-value
ALL	-0.007 [-1.06]	0.026*** [3.43]	0.780	0.098	0.686	0.935	0.810	0.049
BAY	-0.037 [-1.42]	0.018 [0.5]	0.328	0.712	0.019	0.844	0.432	0.542
BBI	-0.036*** [-4.1]	0.011 [0.87]	0.227	0.186	0.040	0.043	0.041	0.000
BSA	-0.013** [-2.38]	0.057 [1.42]	0.810	0.014	0.251	0.299	0.275	0.462
CAR	-0.007* [-1.72]	0.028*** [2.88]	0.802	0.005	0.672	0.759	0.715	0.381
COM	-0.014*** [-3.67]	0.048 [1.15]	0.775	0.084	0.087	0.114	0.101	0.009
DBA	-0.007* [-1.95]	0.028** [2.46]	0.801	0.004	0.591	0.650	0.620	0.714
DET	0.014 [1.68]	0.022*** [2.99]	2.853	0.515	0.688	0.990	0.839	0.059
EDP	-0.008** [-2.41]	0.010 [1.55]	0.547	0.803	0.263	0.365	0.314	0.523
ELT	-0.005 [-1.59]	0.032*** [3.15]	0.858	0.000	0.772	0.803	0.788	0.199
ENB	-0.012** [-2.13]	0.045*** [3.73]	0.783	0.002	0.705	0.770	0.738	0.215
END	-0.004 [-1.07]	0.018** [2.49]	0.836	0.017	0.769	0.858	0.814	0.230
FRAT	-0.020** [-2.27]	-0.005 [-0.72]	-0.358	0.227	0.083	0.175	0.129	0.000
LAF	-0.023*** [-2.85]	0.007 [0.57]	0.234	0.403	0.030	0.254	0.142	0.038
LOU	-0.011** [-2.05]	0.017** [2.02]	0.609	0.513	0.356	0.634	0.495	0.983
OTE	-0.028** [-2.21]	0.003 [0.28]	0.107	0.262	0.011	0.276	0.144	0.079
REP	-0.011 [-1.15]	0.026** [2.33]	0.708	0.300	0.503	0.878	0.691	0.383
RWE	-0.022*** [-3.13]	0.028*** [2.84]	0.558	0.624	0.263	0.679	0.471	0.834
STG	-0.006 [-1.06]	0.020** [2.46]	0.767	0.147	0.692	0.871	0.782	0.261
THY	-0.047***	0.009	0.166	0.054	0.042	0.443	0.243	0.094

[21] GG values > 1 (or negative GG values) were set to 1 to calculate the average (or equal to 0).

	[-3.02]	[0.83]						
TNOR	-0.028** [-2.14]	0.006 [0.77]	0.181	0.117	0.111	0.146	0.129	0.190
WOL	-0.013** [-2.06]	0.109*** [4.94]	0.896	0.000	0.806	0.860	0.833	0.011
AVG			0.580		0.384	0.575	0.479	

In the information shares model developed by Hasbrouck (1995), it is assumed that price volatility reflects new information. Accordingly, a market's price discovery capability depends on the extent of its contribution to the variance of the common trends of both markets.[22] The Hasbrouck approach is similar to the GG measure in that it is also based on the factor loading of the VECM. Its advantage is that – by additionally allowing for the variance and covariance of price innovations – it reflects more information.[23] Whereas the covariance of the VECM residuals is not included in the GG measures, the parallel price movements that are reflected here must be attributed to one of the two markets in the Hasbrouck approach. To avoid arbitrariness, the Hasbrouck approach therefore does not present a single measure but only a band for the CDS market's contribution to price discovery bounded by two limits (HAS1, HAS2):[24]

$$\text{HAS1} = \frac{\lambda_2^2\left(\sigma_1^2 - \frac{\sigma_{12}^2}{\sigma_2^2}\right)}{\lambda_2^2\sigma_1^2 - 2\lambda_1\lambda_2\sigma_{12} + \lambda_1^2\sigma_2^2} \quad \text{and} \quad \text{HAS2} = \frac{\left(\lambda_2\sigma_1 - \lambda_1\frac{\sigma_{12}}{\sigma_1}\right)^2}{\lambda_2^2\sigma_1^2 - 2\lambda_1\lambda_2\sigma_{12} + \lambda_1^2\sigma_2^2}.$$

Here, σ_1^2, σ_{12} and σ_2^2 are the elements of the covariance matrix of the residuals ε_{1t} and ε_{2t}. Table 3 shows that the CDS market, in terms of HAS1 and HAS2, leads in terms of price discovery for a minimum of 10 and a maximum of 13 firms. Conversely, the bond market leads the price discovery process for at least 9 and at most 12 firms. The mean of HAS1 and HAS2, the MID variable, is regarded in the literature as an adequate measure of the contribution to price discovery. Column 8 in Table 3 shows that MID is > 0.5 on ten occasions and < 0.5 on 12 occasions and thus indicates relatively similar contributions to price discovery. Column 9 shows the results of Wald tests of the null hypothesis of identical contributions (H_0: MID=0.5).

[22] Cf Hasbrouck (1995), Chan-Lau and Kim (2004) and Blanco et al (2005).
[23] For a comparison of the Gonzalo-Granger and Hasbrouck measures, see Baillie et al (2002), de Jong (2002) and Lehmann (2002).
[24] Cf Blanco et al (2005).

This null hypothesis can be rejected 6 times at the 5% level; for 2 firms the CDS market clearly dominates price discovery and for 4 firms the bond market is the dominant market. The average MID across all 22 firms is 0.479. This is less than the GG measure; however, across all firms, both measures are relatively closely correlated at ρ=80%. The lower MID value reflects the fact that the price innovations on the bond market are more highly variable than those in the CDS market.[25] In accordance with the Hasbrouck approach, this variance is assumed to reflect new information. On the whole, the Hasbrouck measures can be interpreted in such a manner that both markets make a very similar contribution to price discovery.

5.2 Granger causality tests

For those firms in the overall sample for whose time series a cointegrating relationship is not indicated by at least one test in the Engle-Granger procedure and the Johansen test, the arbitrage forces are apparently of lesser importance in evaluating credit risks during the reporting period. For these firms, price formation can be measured using Granger causality tests. Although such tests do not necessarily confirm a causal relationship between the variables, they do yield information about the dynamic price relationship. To this end, equations 1) and 2) are not specified as an error correction model but as a vector autoregressive (VAR) model.

3) $$\Delta p_{CDS,t} = c_1 + \sum_{i=1}^{p} \alpha_{1i} \Delta p_{CDS,t-i} + \sum_{i=1}^{p} \beta_{1i} \Delta p_{CS,t-i} + \upsilon_{1t}$$

4) $$\Delta p_{CS,t} = c_2 + \sum_{i=1}^{p} \alpha_{2i} \Delta p_{CDS,t-i} + \sum_{i=1}^{p} \beta_{2i} \Delta p_{CS,t-i} + \upsilon_{2t}$$

Here, c_1 and c_2 are constants, α_1, α_2, β_1, β_2 are the coefficients to be estimated, *p* corresponds to the number of lags according to the Akaike information criterion, and υ_{1t} and υ_{2t} are independent, identically distributed shocks. Table 4 shows the results.

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[25] Under the simplifying assumption that the residuals ε_{1t} and ε_{2t} are uncorrelated (σ_{12}=0), both Hasbrouck bounds converge to $\frac{\lambda_2^2\sigma_1^2}{\lambda_2^2\sigma_1^2 + \lambda_1^2\sigma_2^2}$. MID<0.5 then implies that $\lambda_2^2\sigma_1^2 < \lambda_1^2\sigma_2^2$. If, at the same time, GG > 0.5, then $\lambda_2 > |\lambda_1|$, which means that the variance of the residuals in the bond market must exceed that of the CDS market residuals ($\sigma_2^2 > \sigma_1^2$).

The hypothesis that the bond spread does not Granger-cause the CDS spread can be tested using the $\beta_{11} = \beta_{12} = ... = \beta_{1p} = 0$ coefficient test. It is rejected at the 5% level for 9 of the 14 firms. Consequently, in over half of the cases we cannot rule out the possibility that the lagged values of the bond spread will influence the current CDS spread. The opposite hypothesis – that the CDS premium does not Granger-cause the bond spread ($\alpha_{21} = \alpha_{22} = ... = \alpha_{2p} = 0$) – can be rejected at the 5% level for 13 of the 14 firms. In line with MID and GG, these results for the cases in which arbitrage forces are less effective likewise indicate that both markets are relevant for price discovery and that the CDS market has a slight edge.

Table 4: Results of the Granger causality tests

The table shows the results of Granger causality tests for those firms for which the tests in Table 2 do not distinctly suggest a cointegrating relationship. The tests are based on the following vector autoregressive (VAR) model.

$$\Delta p_{CDS,t} = c_1 + \sum_{i=1}^{p} \alpha_{1i} \Delta p_{CDS,t-i} + \sum_{i=1}^{p} \beta_{1i} \Delta p_{CS,t-i} + \upsilon_{1t}$$

$$\Delta p_{CS,t} = c_2 + \sum_{i=1}^{p} \alpha_{2i} \Delta p_{CDS,t-i} + \sum_{i=1}^{p} \beta_{2i} \Delta p_{CS,t-i} + \upsilon_{2t}$$

The null hypothesis “bond spread does not Granger-cause the CDS spread“ corresponds to a Wald test of $\beta_{11} = \beta_{12} = ... = \beta_{1p} = 0$. Conversely, the null hypothesis “CDS spread does not Granger-cause the bond spread" corresponds to the test of $\alpha_{21} = \alpha_{22} = ... = \alpha_{2p} = 0$. ***, ** and * denote rejection of the null hypothesis at the 1%, 5% and 10% levels of significance respectively.

	H_0: Bond spread does not Granger-cause CDS spread	H_0: CDS spread does not Granger-cause bond spread
	p-value	p-value
ALT	0.002***	0.000***
ARC	0.000***	0.007***
BMW	0.401	0.000***
CAS	0.017**	0.000***
DAI	0.000***	0.000***
FOR	0.001***	0.940
NAT	0.005***	0.000***
PSA	0.012**	0.000***
TELE	0.197	0.000***
TELI	0.380	0.000***
VAT	0.586	0.001***
VIV	0.000***	0.000***
VOD	0.079	0.000***
VW	0.000***	0.000***

5.3 Cross section analysis

In line with previous studies, the results of the time series analysis show that the contributions to price discovery between the enterprises analysed vary significantly. While previous studies have, among other things, revealed a difference between US and European enterprises, it is clear that other firm-specific idiosyncratic factors also play an important role in price formation.[26] We therefore investigate the influence of the following determinants, in line with the literature.

- *CDS bid-ask spreads*. Zhu (2004) finds evidence that liquidity of the CDS market affects the basis and contributions to price discovery. He measures liquidity using the CDS bid-ask spreads.
- *Bond volume.* Levin et al (2005) find that bond and firm-specific factors such as the bond issue volume influence the price relationship between bonds and CDS. Large bond issues could improve the bonds' availability on the repo market and thus increase their contributions to price discovery. The bond volume used here is calculated as the mean of the volumes of the bonds used to calculate the synthetic 5-year bond.
- *Rating*. Furthermore, according to Levin et al (2005), market participants may prefer the CDS market to hedge a relatively high-risk investment. If this is the case, conversely, bonds with the highest rating (at least AA or Aa3 according to S&P or Moody's) should involve a large bond market contribution to price discovery.
- *Market value*. According to Linnell/Merritt (2004), in the case of large firms with wide-ranging business activities, demand for hedging the associated counterparty risk is high. If CDS are used, this could favour the price discovery in the CDS market. The average market value of the shares during the reporting period is used as a measure of firm size.

For those firms with cointegrated series, the contributions to price discovery are investigated using the variables GG, MID and the factor loadings λ_1 and λ_2 on which both price discovery measures are based. Large values of the observed variables

[26] See similar results reached by Blanco et al. (2005), Zhu (2004), Deutsche Bundesbank (2004b) and Norden/Weber (2004).

correspond to a large CDS market contribution to price discovery.[27] A simple regression of GG on the aforementioned determinants does not lead to any significant results. By contrast, for the three remaining regressions, as anticipated, bond volumes have a significantly negative influence on the CDS market's contribution to price discovery (see Table 5). In addition, regressing λ_1 also engendered a significant positive influence of the market value and, as expected, a (weakly) negative influence of the CDS bid-ask spreads on the CDS market contribution. By contrast, there is no corresponding evidence for the rating. In summary, it appears that the CDS market is mainly relevant for large firms that issue a small volume of bonds, with the corresponding CDS contract quoted at a low bid-ask spread.

Table 5: Determinants of the price discovery measures

The table shows the results of regressing each price discovery measure (λ_1, λ_2, MID) on a constant and the determinants under review (bond volume, market value, rating of at least AA, CDS bid-ask spread) for firms with cointegrated CDS and bond spreads (cf Table 3). Estimation performed using the Newey-West method adjusted for heteroscedasticity and autocorrelation. t-values of the coefficients in parentheses. ***, ** and * denote a significance level of 1%, 5% and 10% respectively.

Variable	λ_1	λ_2	Hasbrouck MID
C	0.0165 [0.79]	0.0636*** [3.21]	0.3234 [0.65]
CDS bid-ask spread	-0.008* [-1.84]	-0.0063 [-1.58]	0.0334 [0.35]
Bond volume	-1.26E-05*** [-4.07]	-9.73E-06*** [-2.35]	-0.000149** [-2.3]
Rating > AA	-0.0112 [-1.61]	0.0192 [1.44]	-0.0901 [-0.41]
Market value	5.10E-07*** [3.41]	-2.38E-07 [-0.69]	7.37E-06 [1.50]
R^2	0.584	0.127	0.146336

5.4 Time-varying contributions to price discovery

Our analysis thus far has shown that the arbitrage relationship between the two markets is relevant to most firms and that, among these firms, the markets' contributions to price discovery vary. Though the results regarding the dominance of a market may, in some cases, depend on the measures of price discovery used,, on

[27] As λ_1 is normally negative, this corresponds to small absolute values of λ_1.

the whole both markets appear to be important for price discovery. In order to find out how stable these results are over time, we will analyse price discovery in a time-varying context in the following. To do that, we convert the error correction model, consisting of equations 1) and 2), into a state space form and estimate it with time-varying factor loadings using a Kalman filter. We distinguish between two types of equations in this approach. *State equations* describe the development over time of the non-observable *state variables*; *measurement equations* describe how well the observable variables are produced by the *state variables*. This gives us the following state space model with equations 5) and 6) as measurement equations and equations 7) and 8) as state equations.

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

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

7) $$\lambda_{1t} = \lambda_{1t-1} + \eta_{1t}$$

8) $$\lambda_{2t} = \lambda_{2t-1} + \eta_{2t}$$

The factor loadings are assumed to follow a random walk, thereby possibly varying considerably over time. As is shown by Barassi et al (2005), this assumption allows us, with the cointegrating relationship unchanged, to detect any structural changes that may occur in the causal link between two variables. In addition, according to the usual approach, we assume that the error terms ε_{1t}, ε_{2t}, η_{1t} and η_{2t} are independent and have a normal distribution with zero mean and constant variance.[28] Under these conditions, the Maximum Likelihood Estimators produce "optimum" estimation results.[29]

The Kalman filter can be understood as an algorithm with which to calculate the variables needed for the likelihood function.[30] The filter works recursively, with each iteration consisting of a *prediction step* and an *update step*. We begin by setting starting values for λ_0 and its variance matrix according to the method used by Koopman et al (1999). In the *prediction step*, we forecast λ_t and its variance matrix

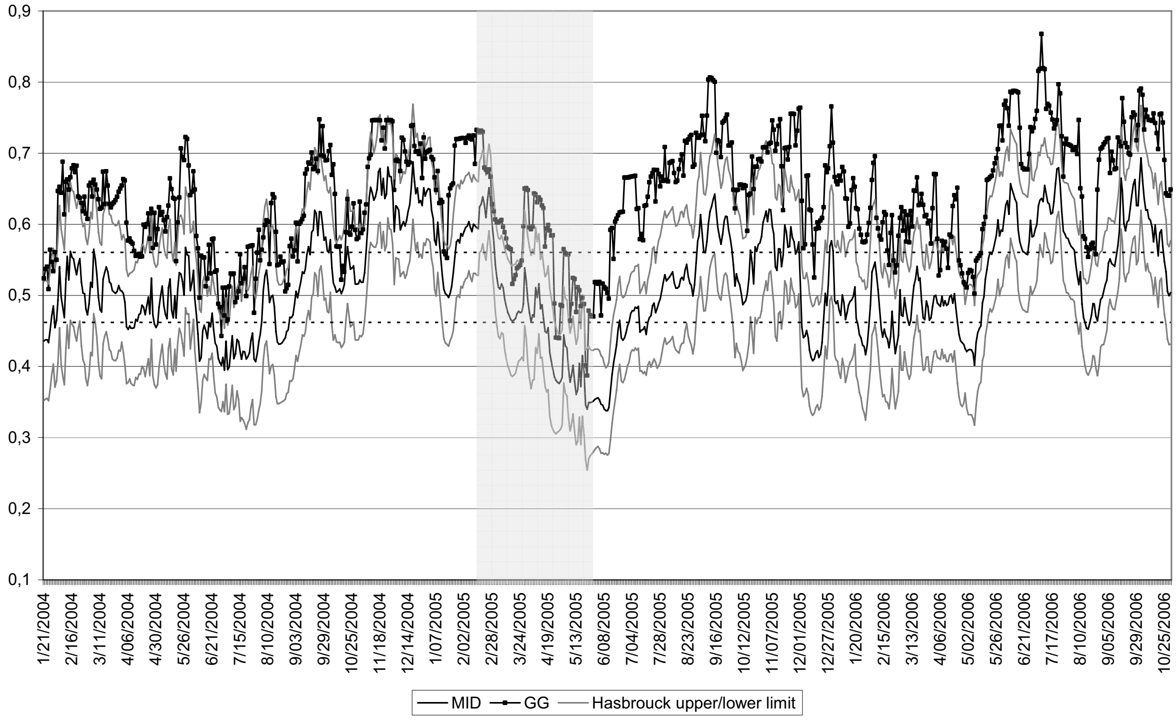
[28] Cf Cuthbertson et al (1992), p 217.
[29] Cf Cuthbertson et al (1992), p 210.
[30] A detailed description of the Kalman filter can be found in Cuthbertson et al (1992), pp 191-225.

using the lagged value for λ_{t-1} and its variance matrix. On this basis, we forecast the dependent variable (here, $\Delta p_{CDS,t}$ and $\Delta p_{CS,t}$). The difference between the predicted and actual value of the dependent variable (the one-step-ahead prediction error) and its covariance enter into the likelihood function. In the *update step* the observed values of $\Delta p_{CDS,t}$ and $\Delta p_{CS,t}$ are used to update the estimated values for λ_t and its variance matrix. Applied to the entire dataset, the maximisation of the likelihood function produces the estimated values for the unobservable λ_t (t=1,2…T). The *state variables* λ_{1t} and λ_{2t}, using all available data, are then "smoothed" until time T. The time-varying estimations of the factor loadings, finally, form the basis for calculating the price discovery measures GG, HAS1, HAS2 and MID over time.

We find that the factor loadings and thus also the contributions to price discovery at firm level often fluctuate markedly. This variability over time can be seen in the fact that for all companies in the study at least one of the two variances of the error terms η_{1t} and η_{2t} is significant at the 1% level. For one firm (DET), no satisfactory convergence in the Maximum Likelihood Function could be achieved. The arithmetic average of the contributions to price discovery for the remaining 21 firms reveals a largely parallel development in the two price discovery measures GG and MID (see Figure 2). As in the time-invariant analysis (see the two hatched lines), the measure GG remains somewhat above MID and also generally above the Hasbrouck upper limit (see upper grey line) throughout the entire reporting period. In comparison to the fluctuations at the firm level, price formation at the market level is less volatile. Thus, measured in terms of the average GG of the 21 companies, the CDS market contributed between 39% and 87%, while the contributions according to MID ranged between 34% and 70% and mainly hovered around the 50% mark. While in the reporting period as a whole, both markets contributed to price formation, both measures have shown a slightly rising trend since the beginning of 2004 and therefore indicate that the CDS market is gaining in significance.

Figure 2: Time-varying contributions to price discovery

The figure shows time-varying measures for contributions to price discovery (GG, MID, Hasbrouck upper and lower limits) based on 21 companies with cointegrated CDS and bond spreads (without DET, see Table 2). The measures are based on the time-varying factor loadings λ_{1t} and λ_{2t} of the error-correction model estimated using the Kalman filter (see equations 5) to 8)). For comparison, the upper (lower) dashed line shows the corresponding GG (MID) from the time-invariant estimate. The grey area marks the turbulence in spring 2005.



The changing and time-varying price relationship we find is consistent with the aforementioned earlier studies of Upper and Werner (2002) and Foster (1996). Like those studies, the figure also provides evidence that the relative information contributions can change particularly in times of financial distress. For instance, the CDS market's contribution to price discovery according to GG and MID fell sharply in spring 2005 following visibly growing uncertainty in credit markets after Ford and General Motors were downgraded by Standard & Poor’s (grey zone).[31] Although no company from the European automotive sector is represented in the sample analysed here, the contribution by the entire CDS market to price discovery, at 39% (GG) and 34% (MID), hit an all-time low in the aftermath of this turbulence, which was accompanied by a sudden rise in bond spreads and CDS spreads. This outcome is consistent with observations by market watchers that liquidity in the CDS market can dry out particularly in times of financial distress. One possible explanation is that,

[31] Owing to the increase in uncertainty, spreads of BBB-rated bonds rose by around 70 basis points between mid-February and the end of May. The aggregated bond spreads and CDS spreads of the companies in the dataset each rose by nearly 15 basis points.

although market participants often buy protection via CDS contracts when a company's creditworthiness takes a turn for the worse, at the same time protection sellers are no longer willing to sell from a certain threshold value.[32] In addition, there is evidence that the turbulence in the US car industry apparently put the CDS market in greater danger than the bond market. This could have something to do with the fact that the activities of key players in the CDS market, such as leveraged investors (eg hedge funds and investment banks' proprietary trading desks), exacerbated price movements and that their high concentration and similar valuation and risk management techniques as well as their resultant herding behaviour put a strain on market liquidity.[33] By contrast, the bond market could have had an easier time adapting because market participants such as portfolio managers adjusted to the expected downgrade by Standard & Poor's or oriented themselves to unchanged ratings of other rating agencies.[34]

It is certainly important to note that the tension described in the foregoing has not nullified the arbitrage relationship between the two markets. However, a certain caution is still warranted when assessing the derivative market's information contributions: the quality and reliability of CDS spreads as indicators depend to a degree on their contribution to price discovery remaining stable precisely in times of distress. The volatility of the information contributions shows that the CDS market does not seem to always meet this condition. Another reason to have doubts about the stability is that the distinct decline in the CDS market's contribution to price discovery is based not on an individual sector, such as the car industry, but also could be seen among many other sectors' firms.

By contrast, the CDS market's contribution to price discovery has gone back up visibly since 2005, in an environment in which credit risk initially was on the decline. Its contribution was usually stationary above the contribution according to the time-invariant estimation (dashed lines), reaching relatively high levels in mid-2006 when

[32] Cf Bank for International Settlements (2003), p 16.
[33] Cf European Central Bank (2006), pp 77-79 and Bank for International Settlements (2005), p 8. According to information from the BIS, these investors attempted, for instance, to exploit price discrepancies between the iTraxx equity tranche and the index as a whole, assuming stable or rising default correlations. When, instead, these correlations fell sharply following the downgrading of GM by S&P in May, many investors with similar levels of exposure retreated from their positions at the same time.
[34] Cf Bank for International Settlements (2005).

equity market prices were temporarily slumping. This could indicate, for one thing, that liquidity in the CDS market has risen since then.[35] One contributory factor could be the particularly sharp growth of the market for synthetic CDO products which – as opposed to cash flow CDOs – are not backed by bonds or loans but by CDS.[36] Another factor could be that the credit markets have been relatively calm since then and that the CDS market is generally becoming increasingly more mature.

6 Findings and concluding remarks

The fact that we have been able to find a cointegrating relationship between CDS spreads and bond spreads for most of the iTraxx companies under review lends support to the argument that an arbitrage relationship exists in credit markets. Even though the price discovery contributions by each market at corporate level vary, both markets make net contributions to price discovery, with the CDS market dominating slightly. The CDS market therefore, in macroeconomic terms, helps to fulfil the conditions for correctly valuing and efficiently allocating credit risks. At the same time, the CDS spreads for central banks and market players represent a meaningful complement to other indicators of corporate credit quality. A time-varying view also shows that CDS and bonds have both always been important for price discovery and that the overall informative value of the CDS market has been rising slightly.

However, the relatively large contribution of the CDS market to price discovery is not necessarily tantamount to general and lasting improvement in the processing of information; the turbulence in the credit markets in spring 2005 was apparently handled much better by the bond market than by the CDS market. The weaknesses of the latter are currently likely to consist in the relatively high concentration and homogeneousness of its often leveraged market players, whose herding behaviour, particularly in times of crisis, can strain liquidity, amplify market volatility and hamper price discovery. As the quality and reliability of CDS spreads as financial stability indicators hinge on remaining a stable source of information precisely in times of crisis, a degree of caution is warranted. Anyway, the relatively large fluctuations in

[35] This is consistent with the fact that, according to Bloomberg data, the selected firms' CDS bid-ask spreads fell from almost 5 basis points in mid-2005 to 2½ basis points at the end of October 2006.
[36] Cf European Central Bank (2006).

price discovery contributions at corporate level strongly suggest using the price signals emitted by CDS premiums only in conjunction with other indicators.

Possible starting points for future research could include taking a closer look at the visible differences between individual companies in terms of their contribution to price discovery. In order to run a more detailed cross-sectional analysis, it may make sense to apply a more international sample covering more firms. To obtain a better understanding of the whole markets' contributions to price discovery over time, one could, for instance, analyse the role of liquidity on the two markets more exactly, by, for instance, using variables that reflect diverse facets of liquidity (eg bid-ask spreads, measures based on trading volume).

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