# CREDIT RISK DISCOVERY IN THE STOCK AND CDS MARKET: WHO, WHEN AND WHY LEADS?[*]

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**Abstract**

This paper analyzes the dynamic relationship between CDS spreads and stock market implied credit spreads (ICS) for a large international set of companies during the period 2002-2004. We find the relationship between these credit spread measures to be stronger, and the probability of the stock market leading credit risk discovery to be higher, at the lower credit quality levels. However, consistent with the argument of insider trading in credit derivatives, we document a positive relationship between the frequency of severe credit downturns and the probability of the CDS market leading price discovery. Apart from these findings, our results suggest a slight informational dominance of the stock market that declines over time.

Key words: Credit risk, credit default swap, price discovery

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## INTRODUCTION

Credit risk concerns almost all financial activities and by definition should be reflected in the market prices of different credit sensitive claims: credit default swaps, bonds, stocks, etc. These assets are traded in structurally different markets implying probable differences in relative speed with which respective markets respond to the changes in credit conditions. In an attempt to solve this riddle empirical work has so far mainly focused on the dynamic relationship between CDS and bond market (Zhu, 2004; Blanco et al., 2005; Norden and Weber, 2005) suggesting that for the majority of the cases theoretical parity relationship holds as an equilibrium condition while, in the same time, price discovery mainly takes place in the CDS market. Yet, research involving stock market in the prism of the efficiency and accuracy of the credit risk pricing has not been that extensive.

Longstaff et al. (2003) in a VAR framework examine the lead-lag relationship between changes in bond spreads, CDS spreads and stock returns for a sample of US firms. Although they do find that stock and credit derivatives market are more informationally efficient in respect to bond market no clear lead of either stock or credit derivatives market was detected. In contrast, Norden and Weber (2005), applying the same econometrical framework to an international sample of 58 companies do find that stock returns lead CDS and bond spread changes. Finally, Forte and Peña (2007) on the basis of VECM framework and stock market implied credit spreads corroborate the finding that the stock market leads CDS and bond market more frequently than vice versa. Still, in many situations nascent and less liquid CDS market not only contributes to price discovery but also leads this process.

Further examination of such cases gains on the importance especially in the light of the currently popular capital structure arbitrage that exploits price inefficiencies among stock and CDS market (Yu, 2006).

Nevertheless, extensive analysis of the dynamic relationship between stock market on one hand, and CDS market on the other is not that straightforward. Apart from the implicit nature of the credit risk in the stock market, two markets differ substantially across several dimensions: organization, participants, liquidity, stage in the development, etc. Stock market could be considered as relatively matured, while CDS market has just started its ascending phase. All these facts considerably hinder more direct comparison between the price of the credit risk reflected in the two markets but in the same time pose the challenge on answering crucial questions: which of these markets provides more timely information regarding the credit risk of particular reference entity and what factors influence the dynamic relationship between the stock and the CDS market.

This paper precisely deals with the aforementioned issues examining a large international sample of companies during the period 2002-2004. Analysis is performed on the basis of CDS spreads and stock market implied credit spreads (ICS) derived by the Forte and Peña (2007) methodology, thus, allowing for more extensive insight in the stock - CDS market relationship through one homogeneous and comparable measure of credit risk. In addition, departing from the proposition that factors underlying price discovery do not differ only on a cross-sectional basis but also change along time we apply a time-varying framework. Namely, in stock vs. CDS market stream of literature a number of studies reveals the implications of the changes in underlying credit conditions. Odders-White and Ready (2006) show that there is a negative relationship between credit quality and stock liquidity. Norden and

Weber (2005), show that the CDS market (as opposed to the cash bond market) is considerably more sensitive to the stock market and that the magnitude of sensitivity increases with the decrease in the creditworthiness of the reference entity. In a recent study, Acharya and Johnson (2007) analyzing 79 North American companies find evidence of an information flow from the credit derivatives market to the stock market, especially for the entities that experience or are more likely to experience credit deterioration.

Our main results are the following: First, the relationship between stock and CDS market appears to be stronger at the lower levels of the credit quality. Second, both markets contribute to credit risk discovery process with slight dominance of the stock market that declines over time. Third, examination of the factors underlying relative market dominance in terms of credit risk price discovery reveals that the probability of the stock market leadership is positively related with the credit risk level. Forth, consistent with the argument of insider trading in credit derivatives, we document a positive relation between the frequency of severe credit deterioration shocks and the probability of the CDS market leading price discovery.

The remainder of the paper is structured as follows. Section I describes credit spread measures in the CDS and stock market together with the description of the data set. Section II presents and applies the methodology of the price discovery process. Section III examines the factors underlying the credit risk discovery in a time-varying context. Section IV concludes.

## I CREDIT SPREADS IN THE CDS AND STOCK MARKET

### 1.1. The CDS market

Recent financial innovation, the credit derivatives market, represents the place where credit risk is explicitly traded. For this reason, literature is increasingly considering CDS spreads as superior and preferred measure of the price of the credit risk in relation to the so far usually employed corporate bond spreads. Single-name credit default swap (CDS) is the most liquid credit derivative instrument traded in the over-the-counter market. It represents a type of bilateral insurance contract that provides protection against the risk of credit event by the particular reference entity (company or sovereign). Credit events, usually generally named as "default", are defined by International Swaps and Derivatives Association (ISDA) and include: bankruptcy, obligation acceleration, obligation default, failure to pay and repudiation or moratorium[1].

Credit default swaps are drowned on the particular company or a sovereign that usually has debt outstanding while reference obligation is in the most of the cases an unsubordinated bond. The buyer of the protection pays a constant fee, usually called CDS premium (or CDS spread), expressed as an annualized fraction of the notional value of the underlying debt. Therefore, a fee i.e. a compensation for the protection against the default risk is undoubtedly linked to the credit quality of the reference entity and will be higher for the entities with poor credit quality and vice versa. CDS premium is paid periodically, usually on quarterly basis until the eventual predefined credit event or until the maturity of the contract whichever happens the first.

[1] Restructuring was removed from the terms of the standard contract in 2002.

In the case when the predefined credit event occurs the insured pays to the insurer the accrued fee and, as a compensation for the incurred loss receives a payoff equal to the difference between the notional amount and the post-default market value of the reference obligation. In the case of physical settlement procedure, which up to now dominates the CDS market, the protection buyer actually delivers the underlying reference bond. If cheapest-to-deliver option exists then the protection buyer can choose the deliverable bond, which other things being equal, might imply higher CDS premiums. If no credit event occurs before maturity protection seller pays nothing.

The CDS market is growing rapidly especially in terms of the liquidity, number and diversity of participants (banks, insurance companies, hedge funds) and contract standardization. So far, the most standard and liquid maturity of the CDS contract is 5 years, typical notional amount is $10 million of dollars, while trading mainly takes place in London and New York. The most popular CDS contracts are on BBB rated reference entities that comprised 51.7% of the available 5-Year CDS spread quotes during the period 2001-2005 (Das et al. 2006).

CDS market, enables debt owners to hedge against credit events, and as opposed to bond market, allows them to flexibly buy and sell credit risk protection and in the same time synthetically form the liquidity of the underlying relatively illiquid portfolios. In addition, there is no an up-front payment and credit risk is traded in the CDS market separately from the underlying debt. These characteristics of the CDS market have been crucial for its rapid development. However, as pointed out by Acharya and Johnson (2007), CDS as a form of insurance is subject to moral hazard and asymmetric information risk, especially taking into consideration that the major participants in the market are mainly insiders.

CDS spreads are closely linked to the credit quality of the reference entity and therefore represent a measure of the credit risk of the particular reference entity. Theoretically, credit derivatives market as place where credit risk is traded should give a proper price of credit risk. In practice, it might not be the case given that other factors different from credit risk might drive the prices. CDS market despite its rapid growth is still relatively small and short term price movements might be caused by demand-supply imbalances. As a result, CDS spread might contain liquidity premia. Chen, Cheng and Wu (2005) have shown that low liquidity issuers have on average lower credit risk, and the liquidity premia in CDS spread for these issuers has a higher impact. Still, despite its imperfections, CDS spreads are increasingly used in literature as a preferred and more direct measure of credit risk (Blanco, et al., 2005; Longstaff et al., 2005; Ericsson et al., 2005).

### 1.2. The stock market

The information regarding credit risk is only implicitly reflected through the stock market. Therefore, theoretical modeling should be applied to extract this information. Theoretical valuation of CDS is similar to the valuation of corporate bonds in the sense that it depends on the underlying default risk and recovery rate of the reference entity. For this purpose literature usually follows structural or reduced form approach. Structural models, originated from the seminal work of Merton (1974), are based on the option theory. In the simple framework of Merton firm issues just two types of assets: equity and a zero-coupon bond. Default occurs at maturity whenever the value of the total assets falls below the face value of the bond. Further studies tried to relax simplified assumptions of the original Merton model mainly by allowing default to occur at any time and modeling the default barrier, and/or altering the firm value dynamics. This line of research is followed by: Black and Cox (1976), Geske (1977), Longstaff and Schwartz (1995), Leland (1994), Leland and Toft (1996), Collin-Dufresne and Goldstein (2001), among others.

In a recent paper Forte and Peña (2007) propose a new methodology that allows deriving implied credit spreads from stock prices and small set of financial data (short and long-term liabilities, interest expenses and cash dividends). This methodology lays on a modified version of the Leland and Toft (1996) structural model and a novel procedure for calibrating the default point parameter. Alonso, Forte and Marqués (1996) improve this methodology by allowing bankruptcy costs to be calibrated from historical data on recovery rates by sector. Implied credit spreads estimated by these authors form the base of the present study. Detailed description of the exact procedure is given in the Appendix.

The use of stock market implied credit spreads (ICS) presents several advantages compared to the traditional use of stock returns. Implied credit spreads enable accounting for the effect of other relevant variables (e.g. the risk-free rate) in addition to stock prices, at the same time taking into account highly non-linear functional relationship between credit spreads and considered variables. On the other hand they allow considering the long-run equilibrium relationship between credit spread series. As it has been shown, the Forte and Peña (2007) methodology is able to generate implied credit spread (ICS) series that are in line with the ones observed in the CDS market, providing in this way a solid base for further comparison of the price formation and information revelation in the stock and CDS market.

### 1.3. Sample selection

The initial sample corresponds to the final sample used in Alonso, Forte and Marqués (2006) and includes 96 non-financial European, US and Japanese companies. Daily data on five-year CDS spreads are obtained from CreditTrade, and confine to the period 2001-2004 (from 2 January 2001 to 31 December 2004). The CDS quotes are refer to the "close of business" in London, New York or Tokyo. Implied credit spreads are derived from daily data on market caps and 1-10 year local swap rates, both from Datastream, as well as accounting items (short and long-term liabilities, interest and dividend payments) obtained from WorldScope[2].

For comparison purposes we exclude two companies without available credit rating, as well as, the year 2001 due to the insufficient data (CDS and ICS series are available simultaneously just for 8 companies). Therefore, we are left with the reduced sample containing 94 non-financial companies across the euro, dollar and yen zone and the period 2002-2004. More specifically, the reduced sample includes 40 European, 32 US and 22 Japanese companies tracked from 2 January 2002 to 31 December 2004. Analysis of the price discovery is based on the mid bid-ask quotes not on the actual transaction prices. Although we would prefer to use transaction prices rather than quotes as they reflect market consensus regarding the fair value of the asset, due to the data constraints this was not possible.

First stage of the price discovery analysis considers the entire 2002-2004 sampling period with the average of 631 daily CDS spread observations per company. Second stage divides the whole sample into natural half-yearly periods with the restriction that no half-yearly period for the company is included in the sample unless

[2] We thank Alonso and Marqués for allowing the use of CDS and ICS data. It is worth noting that ICS estimation in Alonso, Forte and Marqués (2006) is based on two steps: In the first step the default barrier is assumed to be constant. In the second step it is allowed to change every year. The data we employ in the present study is that which follows from assuming a constant default barrier. This alternative seems clearly more appropriate for unit roots tests and cointegration analysis.

at least 50 daily observations are available. Hence, when sampling over the half-yearly periods, 123 daily CDS and ICS observations per company are available on average. We find the division by natural half-yearly periods optimal. Firstly, it is sufficiently short to capture eventual changes in underlying factors and address the issue of the consequent influence on the dynamic relationship between stock and CDS market. Secondly, it is sufficiently long to allow for valid statistical conclusions (due to the limited number of observations, division by natural quarters would make the econometric analysis questionable). For each company in the sample the number of period observations ranges from 4 to 6, living us with the total number of 480 firm-period observations and price-discovery tests to be taken on.

**1.4. Descriptive statistics**

General descriptive statistics for the credit default swap spreads (CDS) and stock market implied credit spread (ICS) series are depicted in *Table 1*. CDS levels and bid-ask spreads exhibit considerable variation over different time periods, regions and ratings. The mean level of CDS reached its maximum in 2002 with the peak in the second half of the year (approximately 132 bp) while subsequent years demonstrate clear downward trend. CDS are on average higher for US companies. Finally, from the rating perspective, the average level of CDS increases with lower rating categories whereas the majority of CDS contracts in the sample refer to the A and BBB rated issuers. Another important characteristic that deserves special attention is the time development of the average bid-ask spread (see *Graph 1.*). Namely, the bid-ask spread peaked in the second half of 2002 reaching 23.73 bp on average and onward successively declined. As a reference, the last examined sub-period (second half of the year 2004) is characterized with the average bid-ask spread of just 7.94 bp. This patterned time evolution of the average bid-ask spread might be associated with the rapid development of the CDS market in terms of the number of players, increasing competition, higher liquidity, improved contract standardization etc.

<Table 1 about here>

<Graph 1 about here>

Derived ICS series in general follow the pattern observed in the CDS market. For the entire sampling period the average level of ICS was around 83 bp, somewhat above the average level of CDS spreads. More formally, average pricing differences between the stock market and the CDS market are measured through basis, defined in this case as the difference between ICS premium from the stock market and CDS spread at time *t*.[3] Accordingly, *Table 2* exhibits standard immediate indicators of the pricing discrepancy: the average basis – *avb,* and the average absolute basis – *avab*. Obtained values indicate that in general ICS tend to be above the CDS levels where the mean basis across all reference entities and time periods reaches 11.1 bp approximately[4]. This difference is not far away from what has been so far exposed in the literature when comparing bond spreads and CDS spreads. For comparison purposes, Zhu (2004) finds the average basis and average absolute basis of 15 and 29 basis points respectively, while Houweling and Vorst (2005) find an average absolute pricing error of around 11 bp in the case when swap rates are used as a benchmark risk-free rate[5]. Nonetheless, although basis spread is on average quite small there is

[3] $basis_t = ICS_t - CDS_t$

[4] Note that the median is considerably lower, 4.38bp.

[5] These figures are substantially higher when Treasury rates are used instead of the swap rates.

substantial variation in the derived basis spread across time, region and rating categories. For instance, the average absolute basis in 2002 exceeds the average absolute basis of the entire sample by almost 14bp. When data is split according to the economic region the lowest discrepancy is present for the Japanese companies (average basis of 4.63 bp) while the highest belongs to the US companies (average basis of 15.76 bp). Similarly, the pricing discrepancy rises with the decline in the average credit quality (proxied by rating). The average basis for AAA-AA issuers is only 2.92 bp. However, observed heterogeneity in average price discrepancies across time, region and rating is not an unexpected phenomenon. Again, literature finds similar patterns in bond and credit default swap spreads differentials. As emphasized by Zhu (2004) price discrepancy during the volatile periods can be large, while Blanco at al. (2005)[6] find substantial differences between economic regions (US and Europe) and rating categories. In respect to mentioned, it seems that the Forte and Peña (2007) methodology applied in this paper could generate quite reasonable series of ICS and we proceed with the more formal approach to testing the pricing equivalency.

<Table 2 about here>

In order to support the argument that using implied credit spreads (ICS) has an advantage over stock returns usually considered in the literature we estimate the following equations:

[6] Blanco at al. (2005) report the mean average basis of 6bp and the mean average absolute basis of 15 bp when using swap rates. However, their analysis is confined to the substantially shorter time period when compared with Zhu (2004), for example.

$$\Delta CDS_{i,t} = \alpha_i + \sum_{k=0}^{5} \beta_{i,t-k} \Delta ICS_{t-k} + \sum_{k=1}^{5} \gamma_{i,t-k} \Delta CDS_{t-k} + \varepsilon_{i,t} \quad \text{(A)}$$

$$\Delta CDS_{i,t} = \alpha_i + \sum_{k=0}^{5} \beta_{i,t-k} R_{t-k} + \sum_{k=1}^{5} \gamma_{i,t-k} \Delta CDS_{t-k} + \varepsilon_{i,t} \quad \text{(B)}$$

$$\Delta CDS_{i,t} = \alpha_i + \sum_{k=0}^{5} \beta_{i,t-k} R_{t-k} + \sum_{k=0}^{5} \delta_{i,t-k} \Delta r_{t-k}^{5} + \sum_{k=1}^{5} \gamma_{i,t-k} \Delta CDS_{t-k} + \varepsilon_{i,t} \quad \text{(C)}$$

$$\Delta CDS_{i,t} = \alpha_i + \sum_{k=0}^{5} \beta_{i,t-k} R_{t-k} + \sum_{k=0}^{5} \delta_{i,t-k} \Delta r_{t-k}^{5} + \sum_{k=0}^{5} \sum_{j=1}^{4} \eta_{i,t-k}^{j} z_{t-k}^{j} + \sum_{k=1}^{5} \gamma_{i,t-k} \Delta CDS_{t-k} + \varepsilon_{i,t} \quad \text{(D)}$$

Actually, in model (A) changes in CDS are regressed on the contemporaneous and past changes in ICS, as well as on the past changes in CDS. As a counterpart, model (B) instead of ICS takes into account contemporaneous and past stock returns. Model (C) extends model (B) with changes in the five years swap rate while, for completeness, model (D) includes in addition current and past percentual changes in accounting items (short and long term liabilities, interest expenses and cash dividends) [7] used in the structural model. As in line with Acharya and Johnson (2007), the lag length of up to five days seems reasonable for capturing the overall information processing and transmission. Each of the models is estimated separately for every company in the sample. Adjusted $R^2$ statistics on average basis are depicted in *Table 3*. The results undoubtedly show that model (A), which takes into account implied credit spread (ICS) series, is superior to the model (B) that is based only on the stock returns. This actually shows that spreads derived from the structural model better explain changes in the credit default swaps when confronted to the use of the stock returns. Although the adjusted $R^2$ improves when moving from model (B) to

[7] Where j=1 refers to the short-term liabilities, j=2 to the long-term liabilities, j=3 to interest payments and j=4 to cash dividends.

model (C) it is still lower than for model (A). Finally, even a linear model that accounts for all relevant variables (D) is inferior to the model (A).

Furthermore, the explanatory power decreases during period 2002-2004 pointing out to the possible change in the strength of the relationship between stock and CDS market (see *Table 4*). This pattern completely corresponds to the change in the mean (or median) credit spread level and illustrates that the strength of the stock - CDS market relationship is positively related to the level of credit risk (i.e. increases together with the decrease in the average creditworthiness). Similarly, the intersection by credit rating group leads to the same conclusion. The explanatory power evidently rises when moving from AAA-AA to BBB rating group[8]. More formally, the rank correlation between adjusted $R^2$ statistic and the average CDS levels on a half-yearly basis and for the total sample of 480 observations equals 0.45 and is statistically significant at 1% level.

<Table 3 about here>

<Table 4 about here>

## II PRICE DISCOVERY

### 2.1. Cointegration analysis

Price discovery might be defined as incorporation of new information into the price of the security (Hasbrouck, 1995). If related securities are traded in different markets, then the price discovery is fragmented, taking place in both markets. The key

[8] BB rating group includes only 4 companies not allowing for any valid conclusion.

issue then becomes to determine the market that contributes more to price discovery, or in other words, to determine which market more efficiently and more rapidly incorporates new information. Given the linkage between the stock market and the credit default swap market there must be an implicit, unobservable efficient price of credit risk that is common to both markets. If credit risk is priced equally in the stock market and the credit default swap market in the long-run then the two series should be cointegrated, and the common factor can be thought of as the implicit efficient price of credit risk. However, given the possibility that the CDS spreads are not pure measures of credit risk, and the fact that the ICS are generated by the structural model the "no cointegration" should not be interpreted immediately as if there is no long-run equilibrium between the two markets when pricing the credit risk. The "no cointegration" result might be due to the presence of other, non-transient factors in the CDS premium (such as liquidity) or the technical measurement error embodied in the applied structural model and its underlying assumptions (constant default point indicator and constant volatilities).

In order to analyze if there is a linear cointegration relationship between the stock market implied credit spreads (ICS) and CDS spreads it is necessary first to perform the test for the presence on unit roots. We perform the Augmented Dickey-Fuller (ADF) test where the corresponding number of lags is selected according to the Akaike information criterion. Results, presented in *Table 5*, show that the null hypothesis i.e. the level time-series are non-stationary, is rejected at 5% significance level for 26 companies in the case of CDS series and for 11 companies in the case of ICS series. The presence of unit roots in both series simultaneously is detected for 66 companies. According to Engle and Granger (1987) if two (or more) time series have unit roots then their linear combination might be stationary. In such a case, those series are said to be cointegrated where cointegrating equation might be understood as a long-run equilibrium relationship. In order to examine the eventual existence of cointegration between the ICS and CDS spread series that simultaneously exhibit I(1) we apply the VAR-based Johansen Cointegration Test. As indicated in *Table 6* significant cointegration relationship is found for 17 firms meaning that for these entities ICS and CDS spreads are driven in the long-run by the same common factor.

<Table 5 about here>

<Table 6 about here>

In the case of the presence of cointegration, cointegrating relationship must be explicitly taken into account in the analysis and the VAR model is extended by an error correction term. Short-term dynamics between the CDS and ICS series is thus examined on the basis of the valid VECM (Vector Error Correction Model) representation. Accordingly, for the respective 17 companies the two-dimensional (VECM) is specified as follows:

$$\Delta ICS_t = \alpha_1 + \lambda_1 \left( ICS_{t-1} - \delta_0 - \delta_1 CDS_{t-1} \right) + \sum_{j=1}^{p} \beta_{1j} \Delta ICS_{t-j} + \sum_{j=1}^{p} \gamma_{1j} \Delta CDS_{t-j} + \varepsilon_{1t}$$

$$\Delta CDS_t = \alpha_2 + \lambda_2 \left( ICS_{t-1} - \delta_0 - \delta_1 CDS_{t-1} \right) + \sum_{j=1}^{p} \beta_{2j} \Delta ICS_{t-j} + \sum_{j=1}^{p} \gamma_{2j} \Delta CDS_{t-j} + \varepsilon_{2t}$$

where, $\varepsilon_1$ and $\varepsilon_2$ are independent and identically distributed shocks and the lag length - $p$ is determined according to the Schwartz information criterion. The long-run relationship is described through the $\delta_0$ and $\delta_1$ coefficients. In the case when $\delta_0$ is equal to 0 and $\delta_1$ is equal to 1 the error correction term becomes the lagged basis spread. The loadings $\lambda_1$ and $\lambda_2$ represent the adjustment coefficients that measure how quickly CDS and ICS spreads adjusts to eliminate the pricing "errors" i.e. the deviations from the long-run equilibrium. They determine the short-term adjustment dynamics of the less efficient market (see for example Zhu, 2004, and Blanco et al., 2005). If $\lambda_1$ is significantly negative ICS spreads adjust to eliminate pricing errors. On the other hand, significantly positive $\lambda_2$ implies that CDS spreads adjust to eliminate pricing errors. If both coefficients are significant, and correctly signed, then both markets contribute to price discovery while their relative magnitude will determine which of these markets absorbs and reflects more rapidly new information regarding the changes in credit conditions of the underlying reference entity.

Estimated $\lambda_1$ and $\lambda_2$ coefficients are presented in *Table 7*. For each firm there is at least one significant loading where, out of the 17 entities, $\lambda_1$ is significantly negative at 5% level for 11 names (ICS adjusts). Contrary effect (CDS adjusts) expressed through significantly positive $\lambda_2$ is also supported for 11 names. However, strong, one-way price adjustments of the CDS market to the stock market is evident in 6 cases while the reverse holds for 6 cases as well. In the same time, both coefficients are correctly signed and significant in 5 cases. At first glance, according to the loading coefficients it seems that both markets almost equally contribute to price discovery.

<Table 7 about here>

More formally, Gonzalo and Granger (1995) and Hasbrouck (1995) introduced two measures of a single market contribution to price discovery. Gonzalo and Granger

(1995) proposed a measure of the individual market contributions to price discovery based on the ratio between the two factor loadings and defined as:

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

The higher the Gonzalo and Granger (GG) measure the higher the stock market contribution and the lower the CDS market contribution to price discovery. Nevertheless, GG measure might sometimes exceed 1 or be below 0. If $GG \geq 1$ then ICS market clearly dominates CDS market in price discovery. For $GG \leq 0$ the inverse situation holds. In the case of 17 examined entities (see *Table 7*), GG measure supports CDS market leadership in terms of price discovery for 11 companies while reverse appears to be true for only 6. Yet, the average GG measure for all considered companies is 0.44[9], pointing out to the slight dominance of CDS market in price discovery process during the entire 2002-2004 sample period.

On the other hand, Hasbrouck (1995) proposed the model of "information shares" which assumes that the market that contributes more to the variance of innovations in the implicit unobservable efficient price[10] (i.e. common factor implied by cointegration), is informationally dominant and contributes more to price discovery. Therefore, information share, as relative measure of the market's contribution to price discovery, is determined as a proportion of the innovation variance that can be attributed to a particular market. When innovations are correlated

[9] In the calculation of the average value for GG measure the values above 1 and below 0 are set to 1 or 0, respectively.

[10] Unobservable efficient price is supposed to follow a random walk.

Hasbrouck suggests only lower (HL) and upper (HU) limits of the market contributions:

$$HL = \frac{\lambda_2^2\left(\sigma_1^2 - \frac{\sigma_{12}^2}{\sigma_2^2}\right)}{\lambda_2^2\sigma_1^2 - 2\lambda_1\lambda_2\sigma_{12} + \lambda_1^2\sigma_2^2} \qquad \text{and} \qquad HU = \frac{\left(\lambda_2\sigma_1 - \lambda_1\frac{\sigma_{12}}{\sigma_1}\right)}{\lambda_2^2\sigma_1^2 - 2\lambda_1\lambda_2\sigma_{12} + \lambda_1^2\sigma_2^2}$$

where $\sigma_1$, $\sigma_2$ and $\sigma_{12}$ are the elements of the variance-covariance matrix of the residuals from the VECM specification. The HL and HU measures show that stock market dominates price discovery in at least 8 and at most 11 cases. Or, expressed reversely, CDS market leads price discovery in at least 6 and at most 9 cases. Interestingly, on average, lower Hasbrouck limit suggests stock market leadership while the upper Hasbrouck limit suggests CDS market leadership. The mid Hasbrouck measure (HM), calculated as the midpoint of the lower and upper bound, is usually taken as an adequate measure of the single market contribution to price discovery (Baillie et al, 2002). Considering only HM, stock market dominates in 10 cases whereas the average HM for all of the examined entities takes the value of 0.55 pointing out to the slight dominance of the stock market in price discovery.

Contrasting average GG and HM measures over the entire sampling period implies that both markets contribute approximately equally to price discovery. Namely, both measures are close to 0.5 limit[11] and apparently no clear conclusion regarding which of the markets is more informationally efficient can be made. However, repeating the same exercise in a time-varying context gives a more profound picture. Half-yearly loadings for each company are estimated by imposing

[11] In addition, both measures are relatively closely correlated, with the correlation coefficient of 0.84.

the entire sample cointegrating vector to the half-year VECM. As for the whole sample, the analysis reveals no leadership concentration in neither of the markets (see *Table 8*) but, interestingly, reveals a downward trend in the leading role of stock market in respect to CDS market. At the beginning of the sampling period (first half of 2002) HM (GG) information share of the stock market was relatively high, approximately 0.67 (0.63). Second half of 2004 according to HM (GG) measures allocates smaller proportion of the price discovery to the stock market with the average information share of 0.46 (0.37). This finding might be the reflection of the ongoing development of the CDS market. Consequently, Section III attempts to reveal and understand the factors underlying the price discovery process taking into consideration cross-sectional differences in a time-varying framework.

<Table 8 about here>

## 2.2. Granger causality test

For the entities that either do not have unit roots or for which the cointegration is rejected the VECM approach is not valid and price leadership is tested by the presence of Granger causality in a VAR model of the following form:

$$\Delta ICS_t = \alpha_1 + \sum_{j=1}^{p} \beta_{1j} \Delta ICS_{t-j} + \sum_{j=1}^{p} \gamma_{1j} \Delta CDS_{t-j} + \varepsilon_{1t}$$

$$\Delta CDS_t = \alpha_2 + \sum_{j=1}^{p} \beta_{2j} \Delta ICS_{t-j} + \sum_{j=1}^{p} \gamma_{2j} \Delta CDS_{t-j} + \varepsilon_{2t}$$

where $\varepsilon_1$ and $\varepsilon_2$ are i.i.d. shocks and $p$ is the number of lags determined according to the Schwartz information criterion. Granger causality test is not aimed at revealing the causality pattern between the considered series, but does yield information regarding the price formation dynamics and information precedence. It actually tests if coefficients of the lagged changes in CDS levels are statistically significant and help in the explanation of the current changes of ICS (and vice versa). The reported F-statistics actually refers to the null hypothesis that all of the lagged coefficients are jointly equal to 0[12]. The results of the Granger causality test performed on the remaining sub-sample of 77 companies are presented in *Table 9*. The null hypothesis that changes in ICS do not Granger-cause changes in CDS is rejected at the 5% significance level for 47 companies (61.04% of the sub-sample). In contrast, null hypothesis that changes in CDS do not Granger-cause changes in ICS is rejected for just 16 companies (20.78% of the sub-sample). More rigorously, the one-way influence, of the stock market (ΔICS do Granger-cause ΔCDS, but ΔCDS do not Granger-cause ΔICS) is detected for 36 companies while the opposite is true just for 5. It seems that the lagged changes in ICS are important in the explanation of current changes in CDS more often than other way around which might suggests the dominance of the stock market in price discovery process over the entire 2002-2004 sampling period. These results are not surprising. Literature has already uncovered similar patterns when considering stock returns. For instance, Norden and Weber (2005) on the basis of the lead-lag relationship in the VAR model found that that stock returns on average lead CDS and bond spread changes.

<Table 9 about here>

[12] For example, the null hypothesis "ΔICS do not Granger-cause ΔCDS" corresponds to testing $\beta_{11}=\beta_{12}=....=\beta_{1p}=0$ by the means of Wald test.

In order to investigate whether the observed findings are stable over time we perform the same analysis with the natural half-yearly periods. Likewise, the null hypothesis "ΔICS do not Granger-cause ΔCDS" is rejected more frequently than vice versa (see *Table 10*). But, interestingly, and in line with the previous sub-section, the informational precedence of the stock market appears to diminish over time measured by the proportion of the corresponding null hypothesis rejections in the total number of examined companies. In addition, it is important to note that for a considerable number of companies, from both static and time-dynamic perspective, no clear influence could be determined. At the bottom, this shows that both markets play important role in incorporating information on credit risk.

<Table 10 about here>

## III FACTORS UNDERLYING THE CREDIT RISK DISCOVERY

In this section we extend previous analysis of the relative importance of the stock and CDS market to price discovery by investigating underlying factors that might influence the contribution of each particular market. As it has already been shown, information content of the stock and CDS market when pricing credit risk differs not only between companies but within the same company across different time periods. Therefore, in order to reveal the driving forces of the information content of credit risk indicators we depart from the obtained half-yearly observations, thus allowing for cross-sectional differentiation through the prism of time. As previous studies have pointed out, a number of factors play a role in price formation. Hence, following current literature we consider: liquidity of the stock and CDS market, credit quality of the reference entity and its progress over time, as well as the eventual presence of significant negative shocks as the potential variables that might influence the relative domination of one market over another in price discovery.

- ***CDS percentage bid-ask spread.*** Liquidity is an obscure concept and there is no one, universally accepted liquidity measure. So far, literature has uncovered many of them with the percentage bid-ask spread being one of the most commonly used. In the context of CDS market, higher percentage bid-ask spread would indicate lower liquidity of the credit derivative and vice versa. Although, we would expect a negative relationship between the CDS percentage bid-ask spread and CDS market leadership in price discovery process it is important to note that the high liquidity issuers have on average higher credit risk. This argument is supported by Chen, Cheng and Wu (2005). For a single half-yearly observation we use the average percentage bid-ask spread (calculated relative to the mid quote) over the corresponding half-yearly period.
- ***Stock turnover ratio.*** The turnover ratio shows how actively the stock is being traded. It is defined as the number of shares traded adjusted by the number of shares outstanding i.e. the turnover volume over the market capitalization. This proxy for market activity and liquidity seems suitable for our international sample as it is a unitless measure that allows direct comparison over time and over different geographical regions. Following the intuition that the more actively the stock is being traded the more information revelation should occur in the stock market, we expect a positive relationship between the stock turnover ratio and stock market leadership in terms of price discovery. For a single half-yearly observation we use the average daily turnover ratio over the corresponding half-yearly period.

- ***Relative frequency of adverse shocks.*** Acharya and Johnson (2007) have showed that information revelation in CDS market is asymmetric, consisting exclusively of bad news. In line with this study we use the relative frequency of adverse shocks as the measure of the credit deterioration severity where adverse shocks in the CDS market are defined as one-day increase in CDS level of more than 50 bp. Accordingly, we expect that the presence of negative and severe credit events will be positively related with the information share of the CDS market.
- ***Credit condition.*** This variable aims to reflect the overall credit quality of the underlying reference entity. In order to achieve higher robustness of the results we separately perform the analysis using: rating, credit spread level and a dummy variable which takes the value 1 if CDS level overpass 100bp during the sampling period. The credit rating corresponds to the 30 June 2003,[13] which is exactly the middle of the sampling period. Credit ratings are defined numerically, in line with Odders-White and Ready (2006) where the numerical values range from 35 for AAA issuers to 23 for BB issuers. For a single half-yearly observation we use the average credit spread level over the corresponding half-yearly period.
- ***Trend of the level of CDS premiums*** over the covered period. This variable is included in the analysis in order to track the general trend, i.e. increase, or decrease in the CDS levels. It is defined as the slope of the characteristic line over the observed half-yearly period. The positive sign of the slope indicates increase in the general CDS level and vice versa.
- ***Time effect.*** The considered time period covers year 2002, characterized with sizeable movements in credit spreads due to the observable changes in credit conditions for many of the considered entities. In addition, it captures rapid

[13] So there is no time-variation in this instance.

expansion of CDS market in terms of regulation, liquidity and size especially from the year 2003. We control for the substantial time effect through the introduction of the dummy variable that equals one if the half-yearly observation falls into the corresponding time interval and 0 otherwise[14]. In that way, we differentiate between the early stage of CDS market and the more developed one.

The correlation matrix between the relevant variables: CDS bid-ask spread, CDS percentage bid-ask spread, stock turnover ratio, frequency of adverse shocks, rating, average CDS spread level and dummy variable for the CDS level exceeding 100bp, is shown in *Table 11*.

<Table 11 about here>

The first stage of the analysis of the factors underlying price discovery takes into account only companies for which cointegration relationship between ICS and CDS series has been detected. Allowing for the change in the factor loadings on a half-yearly basis while imposing the cointegration equation of the entire sample we obtain in total 92 half-yearly observations of the price discovery measures. Although both measures (GG and Hasbrouck) are commonly used in the literature (for example, Blanco at al, 2005) GG measures might be below 0 or above 1 and are completely determined only by the estimated factor loadings. Hasbrouck measures are by definition always in 0-1 range and in addition account for the variance-covariance of residuals in the VECM specification, consequently containing more information. In the reminder we will focus, following Baillie et al. (2002), only on the mean of the

[14] Standard errors clustered by firm are in the level of White standard errors therefore we just control for the time-effect through the introduction of time dummy variables.

upper and lower Hasbrouck bound (HM) as the dependent variable. *Table 12* depicts obtained Mid Hasbrouck information shares in terms of stock market contribution to price discovery that will be used as the dependent variable in the following regression analysis.

<Table 12 about here>

The results of the OLS regression with White heteroskedasticity robust standard errors are summarized in *Table 13*. According to the obtained results it seems that even one simple econometric framework is capable to reveal significant determinants of the information shares. To be precise, the employed parsimonious set of factors explains around 30% (average $R^2$=0.31 and average adjusted $R^2$=0.25) of the Hasbrouck's information shares variation in a time-varying context. The information share of the stock market is statistically significantly influenced by the stock turnover ratio, credit condition of the underlying reference entity and relative frequency of negative shocks. The increase in the stock turnover ratio as the proxy of the increase in the liquidity of the stock market has a positive influence on the information share of the stock market. Rating, expressed numerically (i.e. a higher quality credit rating corresponds to a higher numerical score), seems to have a negative effect on the stock market information share. This finding is supported by statistically significant positive relation between the average credit spread level and information share of the stock market. Finally, consistent with initial hypothesis, the presence of credit deterioration shocks of 50bp or more, positively influence the information share in terms of price discovery of the CDS market. The coefficients for the remaining regressors are not statistically significant.

<Table 13 about here>

For the remaining sub-sample of companies for which unit roots are not simultaneously detected in ICS and CDS series or for which cointegration relationship is not suggested by the Johansen Cointegration Test we replicate the aforementioned analysis in the ordered probit framework. Results of the Granger causality test actually allow us to define discrete dependent variable, and make distinction between three naturally ordered states:

- ***-1*** *if the strict price leadership of CDS market is suggested by the Granger causality test (i.e. changes in CDS Granger cause changes in ICS but not the other way around);*
- ***0*** *if there is unclear interpretation;*
- ***+1*** *if the strict price leadership of stock market is suggested by the Granger causality test (i.e. changes in ICS Granger cause changes in CDS but not the other way around).*

The estimates from the ordered probit regression performed on the basis of 388 half-yearly observations are presented in *Table 14*. As results show, the likelihood ratio statistics (LR) which tests the null hypothesis that all slope coefficients are simultaneously equal to zero is highly significant while Pseudo-$R^2$ takes the value from 0.056 to 0.08. Although, at first glance it might appear low, it should be noted, that in discrete models, this measure is of secondary importance. We are primarily interested in the statistical and economical significance of the regression coefficients. The ordered probit estimates confirm that the stock market is more likely to lead in credit risk discovery for the higher levels of credit risk. This finding is actually corroborated through several variables. Namely, not only that the average CDS spread level shows positive relation with the probability of stock market leadership, but also CDS level trend points out in the same direction. In addition, the CDS percentage bid-ask spread is negatively related with the probability of the stock market leadership. Although at first glance this might seem puzzling it happens that higher liquidity, measured by the percentage bid-ask spread, is associated with higher levels of CDS spreads. On the other hand, and in accordance with the results of the OLS regression, the CDS market is more likely to lead credit risk discovery for the firms that experience strong credit downturns. At last, it turns out that the probability of stock market leadership is highly associated with the year 2002.

<Table 14 about here>

Although the signs of the obtained coefficients can be immediately interpreted in terms of the effect the explanatory variables have on the extreme cases (i.e. 1 and -1) the marginal effect on the probabilities of each particular state asks for additional calculation. In our case we are mainly concerned with the marginal effects on the probability of the strict CDS market leadership (-1) and the strict stock market leadership (1). Marginal effects, calculated at the mean of the explanatory variables or for the discrete change of dummy variable from 0 to 1, reveal high economical impact of the year 2002 (see *Table 15*). Nevertheless, this finding leaves us with ambiguity to a certain degree. Year 2002 is characterized with general upward trend and sizeable upward movements in credit spreads for many of the examined entities reflecting the notable turbulence of the CDS market. At the same time the positive sign of the coefficient for the 2002 dummy variable might be the clear reflection of the CDS market development in the subsequent period. Further examination of the economical significance suggests that one standard deviation increase in the credit spread level increases the probability of stock market leadership by 0.12, while one standard deviation increase in the frequency of adverse shocks decreases this probability by 0.09 on average.

<Table 15 about here>

In order to enhance the analysis we apply the ordered probit framework on the whole sample of 480 half-year observations. Namely, we merge two approaches that on a complementary basis indicate the relative informational dominance of the particular market and basically, at the bottom, lead to three possible mutually exclusive situations: a) the clear stock market leadership in the price discovery process; b) the clear CDS market leadership; and c) the situation in which no clear interpretation can be made. Consequently, we introduce three dummy variables that take the value:

- ***-1*** *if the price leadership of CDS market is suggested by the VECM or Granger causality test, whichever is appropriate. In the case when the ICS and CDS series are cointegrated, this value will be associated to the situations in which loading factor* $\lambda_1$ *is significantly negative but not the other way around (i.e. only ICS spreads adjust to eliminate pricing errors); and, in the case when the ICS and CDS series are not cointegrated to the situations in which changes in CDS Granger cause changes in ICS but not the other way around;*
- ***0*** *if there is unclear interpretation;*

- ***+1*** *if the price leadership of stock market is suggested by the VECM or Granger causality test, whichever is appropriate. In the case when the ICS and CDS series are cointegrated, this value will be associated to the situations in which loading factor* $\lambda_2$ *is significantly positive but not the other way around (i.e. only CDS spreads adjust to eliminate pricing errors); and, in the case when the ICS and CDS series are not cointegrated to the situations in which changes in ICS Granger cause changes in CDS but not the other way around.*

In line with previous findings, estimated coefficients corresponding to the CDS percentage bid-ask spread, stock turnover-ratio, relative frequency of adverse shocks, average CDS spread level, dummy variable for CDS level exceeding 100bp, CDS level trend and the dummy variable for the year 2002 are found to be statistically highly significant with expected signs. Ordered probit estimation results for complete sample, as well as, the corresponding marginal effects are reported in *Table 16* and *Table 17*, respectively.

<Table 16 about here>

<Table 17 about here>

Finally, in order to ensure the robustness of the results we perform probit analysis directly confronting two extreme cases. Therefore, we introduce the dummy variable that will take just two values, 1 for strict stock market leadership and 0 for strict CDS market leadership consequently obtaining the total sample of 151 half-yearly observations. The results of such probit analysis are completely consistent with previous findings. In addition, as illustrated in *Table 18*, apart from the highly significant LR statistics, Pseudo-$R^2$ is considerably higher with values ranging from 0.16 to 0.19. Reflecting economical significance through marginal effects on the likelihood of stock market dominance reveals as before high positive impact of the year 2002 (0.17 on average for the discrete change of dummy variable from 0 to 1), stock turnover ratio (0.13 for one standard deviation increase), credit spread level (0.12 for one standard deviation increase) and negative impact of the frequency of adverse shocks (-0.11 for one standard deviation increase). This confirms the initial hypothesis of the impact of these variables to price discovery.

<Table 18 about here>

**IV CONCLUSIONS**

This paper investigates the dynamic relationship between CDS spreads and stock market implied credit spreads (ICS) for a large international sample of the 94 US, European and Japanese companies, tracked over the 2002-2004 period. Departing from the relative informational dominance of the stock and CDS market in credit risk discovery this paper goes beyond the existing studies by investigating the underlying factors in a time-variant context. Price formation is based on the information revelation and it is important to know which market in which situations responds more quickly to the changes in credit conditions. When answering the above question this study conducts the credit risk discovery analysis on the basis of the observed CDS spreads and the credit spreads generated from the stock market following the Forte and Peña (2007) methodology.

Our results allow for several conclusions. First, we find the relationship between CDS and ICS to be stronger at the higher levels of the credit risk. Second, we document that stock market leads credit risk discovery more times than CDS market, while in the same its leading role tends to diminish over the considered period. Third, the relative informational dominance of the stock market is statistically significantly influenced by overall credit condition of the underlying reference entity. Namely, the probability of the stock market leading increases with the credit risk level. Forth, and consistent with the argument of insider trading in credit derivatives, we find a positive relation between the relative frequency of the severe credit deterioration shocks and the probability of the CDS market leading price discovery.

**APPENDIX: The Forte and Peña (2007) Methodology**

The market value of total assets $(V)$ is assumed to evolve according to the continuous diffusion process of the following form:

$$dV = (\mu - \delta)Vdt + \sigma V dz\,, \qquad \text{(A.1)}$$

where $\mu$ is the expected rate of return on asset value, $\delta$ is the fraction of the asset value paid out to investors, $\sigma$ is the asset return volatility, and $z$ is a standard Brownian motion. The default occurs when $V$ reaches specific critical point $V_B$ defined in this case as the fraction $\beta$ of the nominal value of the total debt $P$. With this modification of the original Leland and Toft (1996) model, at any $t$, the value of the bond with maturity $\tau$, principal $p(\tau)$, coupon $c(\tau)$, will be expressed as:

$$d(V,\tau,t) = \frac{c(\tau)}{r} + e^{-r\tau}\left[p(\tau) - \frac{c(\tau)}{r}\right]\left[1 - F(\tau)\right] + \left[(1-\alpha)\beta p(\tau) - \frac{c(\tau)}{r}\right]G(\tau) \qquad \text{(A.2)}$$

where $r$ represents the risk-free rate, $\alpha \in [0,1]$ bankruptcy costs, and

$$F(\tau) = N[h_1(\tau)] + \left(\frac{V}{V_B}\right)^{-2a} N[h_2(\tau)]$$

$$G(\tau) = \left(\frac{V}{V_B}\right)^{-a+z} N[q_1(\tau)] + \left(\frac{V}{V_B}\right)^{-a-z} N[q_2(\tau)]$$

with

$$q_1(\tau)=\frac{-b-z\sigma^2\tau}{\sigma\sqrt{\tau}}; \qquad q_2(\tau)=\frac{-b+z\sigma^2\tau}{\sigma\sqrt{\tau}};$$

$$h_1(\tau)=\frac{-b-a\sigma^2\tau}{\sigma\sqrt{\tau}}; \qquad h_2(\tau)=\frac{-b+a\sigma^2\tau}{\sigma\sqrt{\tau}};$$

$$a=\frac{r-\delta-\sigma^2/2}{\sigma^2}; \qquad b=\ln\left(\frac{V}{V_B}\right); \qquad z=\frac{\left[\left(a\sigma^2\right)^2+2r\sigma^2\right]^{1/2}}{\sigma^2}.$$

The total value of the debt $D(V,t)$ will equal the sum of the values of all individual bonds. Accordingly, for *N* issued bonds, with $\tau_i$ being the maturity of the *i*–th bond, the total value of debt will be:

$$D(V,t)=\sum_{i=1}^{N} d(V,\tau_i,t), \tag{A.3}$$

Finally, the total market value of the equity $S(V,t)$ will be expressed as:

$$S(V,t)=V(t)-D(V,t\,|\,\alpha=0) \tag{A.4}$$

where $D(V,t\,|\,\alpha=0)$ is the value of the total debt when bankruptcy costs equal zero. This expression follows the reasoning that $\alpha$ affects only creditors in the event of bankruptcy.

**Credit Spread Estimation**

The theoretical credit spread at time *t* is determined as the premium from issuing at par value a hypothetical bond with maturity that corresponds to the maturity of CDS contract, in this case 5 years. This bond is assumed to pay a coupon $c_t(5, p)$, so that the following equation holds:

$$d(V,5,t|p) = p \tag{A.5.a}$$

Accordingly, the bond yield is

$$y_t^E(5) = \frac{c_t(5,p)}{p}, \tag{A.5.b}$$

and, as a result, the theoretical credit spread is determined as the difference between the yield of the hypothetical bond and the risk-free rate:

$$ICS_t = y_t^E(5) - r_t \tag{A.5.c}$$

In order to perform all necessary calculations at each point $t$ we need the information on: firm asset value $V_t$, nominal value of total debt $P_t$, risk-free rate $r_t$, pay-out rate $\delta_t$, volatility $\sigma_t$, bankruptcy costs $\alpha_t$ and default point indicator $\beta_t$. Volatility, bankruptcy costs and the default point indicator are assumed to be constant. The nominal value of total debt $P_t$ is approximated with the sum of short-term $STL_t$ and long-term $LTL_t$ liabilities:

$$P_t = STL_t + LTL_t; \quad t = 1, ..., T \tag{A.6}$$

The pay-out rate, $\delta_t$, is expressed as the proportion of interest and dividend payments in the total asset value at $t$,

$$\delta_t = \frac{IE_t + CD_t}{V_t}; \quad t = 1, ..., T \tag{A.7}$$

In order to determine $D(V,t \mid \alpha = 0)$ it is assumed that at each point $t$ the company has 10 bonds: one with a maturity of one year with face value equal to $STL_t$, and nine with maturity from 2 to 10 years, with face value equal to 1/9 of $LTL_t$ each. Corresponding coupons are determined as the fraction of $IE_t$ proportional to the share of the individual bond face value in the face value of total debt. Risk-free rate for each bond is fixed according to the swap rate for the corresponding maturity.

For an assumed initial arbitrary value of $\beta$, constant volatility $\sigma$ and the series of the total value of assets $V_t$ are simultaneously estimated on the basis of the following algorithm:

1) Proposing an initial value for $\sigma$, $\sigma_0$;
2) Estimating $V_t$ series using the information on the stock market capitalization $S_t$, so that (4) holds for all $t$;
3) Estimating new volatility $\sigma_1$ from the obtained $V_t$ series;
4) End of the process if $\sigma_1 = \sigma_0$. Otherwise, $\sigma_1$ is proposed at step 1 and the process is repeated until the convergence is achieved.

Following Leland (2004), bankruptcy costs are assumed to be constant and equal to $\alpha = 0.3$. Finally, ICS series are generated on the basis of equation (5) where the default point indicator $\beta$ is determined following the assumed relationship between ICS and CDS series and the corresponding natural measure of discrepancy, the Mean Squared Error (MSE):

$$ICS_t = CDS_t \times e^{\varepsilon_t}, \tag{A.8}$$

where $\varepsilon_t$ are *i.i.d.* error terms with $E[\varepsilon_t] = 0$ and $Var(\varepsilon_t) = \sigma_\varepsilon$.

$$MSE = \frac{1}{T}\sum_{t=1}^{T}\left[\log\left(\frac{ICS_t}{CDS_t}\right)\right]^2 \tag{A.9}$$

The default point indicator $\beta$ is determined so that the divergence between credit spreads is minimized:

$$\beta \equiv \underset{\beta}{argmin}(MSE) \tag{A.10}$$

In Alonso, Forte and Marqués (2006) bankruptcy costs are calibrated in such a way that the expected recovery rate, $(1-\alpha)\beta$, matches the historical mean by sector.

**Table 1.** *Descriptive Statistics*

This table provides general descriptive statistics for the credit default swap spreads (CDS) and stock market implied credit spreads (ICS) averaged over the period 2002-2004, region and rating.

| Period / Region / Rating | CDS | | | | | ICS | | |
|---|---|---|---|---|---|---|---|---|
| | N firms | Mean | Median | SD | Bid-Ask | Mean | Median | SD |
| 2002 | 53 | 109.52 | 100.51 | 37.86 | 20.33 | 85.33 | 72.79 | 45.73 |
| 2003 | 94 | 74.70 | 69.29 | 23.58 | 14.30 | 106.93 | 100.38 | 38.97 |
| 2004 | 94 | 51.75 | 52.81 | 10.68 | 8.66 | 62.85 | 61.80 | 16.13 |
| 02/1 | 52 | 84.81 | 82.34 | 17.01 | 16.70 | 51.99 | 47.75 | 15.49 |
| 02/2 | 53 | 131.93 | 134.73 | 30.64 | 23.73 | 115.94 | 114.22 | 36.40 |
| 03/1 | 93 | 92.08 | 91.59 | 18.47 | 17.62 | 135.36 | 132.42 | 28.73 |
| 03/2 | 94 | 58.76 | 58.37 | 10.41 | 11.33 | 80.85 | 79.40 | 17.91 |
| 04/1 | 94 | 54.51 | 54.74 | 6.64 | 9.44 | 59.65 | 58.86 | 11.18 |
| 04/2 | 94 | 49.22 | 47.92 | 8.63 | 7.94 | 65.88 | 65.42 | 11.31 |
| Europe | 40 | 66.12 | 55.52 | 31.59 | 8.85 | 77.05 | 62.15 | 49.95 |
| US | 32 | 101.06 | 89.21 | 41.34 | 20.76 | 116.82 | 109.89 | 52.69 |
| Japan | 22 | 40.45 | 33.64 | 20.50 | 10.48 | 45.08 | 34.33 | 28.60 |
| AAA-AA | 14 | 22.00 | 19.84 | 9.35 | 6.83 | 24.92 | 21.18 | 14.12 |
| A | 41 | 51.39 | 44.07 | 23.51 | 10.84 | 60.99 | 52.41 | 33.82 |
| BBB | 35 | 107.02 | 90.01 | 48.45 | 17.63 | 121.12 | 107.78 | 63.46 |
| BB | 4 | 151.95 | 145.06 | 61.75 | 23.03 | 180.86 | 135.04 | 127.13 |
| All | 94 | 72.00 | 61.87 | 32.31 | 13.29 | 83.11 | 71.89 | 45.89 |

**Table 2.** *Credit spread differentials between two series*

This table provides mean and median values of the standard measures of credit spread differentials between CDS and ICS series: the average basis – *avb*, and the average absolute basis – *avab*. Measures of discrepancy are reported by period, region and rating.

| Period / Region / Rating | | Mean | | Median | |
|---|---|---|---|---|---|
| | N firms | avb | avab | avb | avab |
| 2002 | 53 | -24.20 | 46.79 | -15.91 | 32.40 |
| 2003 | 94 | 32.23 | 39.60 | 21.62 | 24.37 |
| 2004 | 94 | 11.11 | 23.32 | 2.43 | 12.03 |
| 02/1 | 52 | -32.91 | 42.35 | -30.21 | 32.61 |
| 02/2 | 53 | -15.99 | 51.07 | -8.14 | 38.05 |
| 03/1 | 93 | 42.97 | 50.87 | 29.85 | 32.94 |
| 03/2 | 94 | 22.09 | 28.86 | 9.64 | 13.59 |
| 04/1 | 94 | 5.14 | 20.05 | -0.21 | 11.36 |
| 04/2 | 94 | 16.65 | 26.40 | 7.73 | 12.77 |
| Europe | 40 | 10.94 | 30.99 | 5.09 | 22.61 |
| US | 32 | 15.76 | 45.92 | 5.94 | 26.00 |
| Japan | 22 | 4.63 | 17.20 | 2.33 | 12.83 |
| AAA-AA | 14 | 2.92 | 10.57 | 2.33 | 9.64 |
| A | 41 | 9.60 | 25.40 | 3.27 | 20.87 |
| BBB | 35 | 14.10 | 46.11 | 8.18 | 33.02 |
| BB | 4 | 28.91 | 71.11 | 23.82 | 51.61 |
| All | 94 | 11.10 | 32.85 | 4.38 | 23.00 |

**Table 3.** *Adjusted $R^2$ for (A), (B), (C) and (D) model specifications*

This table provides the average adjusted $R^2$ statistics from individual regressions for (A), (B), (C) and (D) model specifications over the period 2002-2004.

| Period | N firms | adjusted $R^2$ | | | |
|---|---|---|---|---|---|
| | | (A) | (B) | (C) | (D) |
| 2002-2004 | 94 | 0.081 | 0.072 | 0.073 | 0.068 |

**Table 4.** *Explanatory power and credit risk level*

This table provides adjusted $R^2$ statistics for model (A) over the period 2002-2004 and over different rating categories together with the corresponding mean and median levels of CDS spreads.

| Period / Rating | N firms | Model (A) adj $R^2$ | Mean CDS level | Median CDS level |
|---|---|---|---|---|
| 2002 | 53 | 0.121 | 109.52 | 100.51 |
| 2003 | 94 | 0.076 | 74.70 | 69.29 |
| 2004 | 94 | 0.044 | 51.75 | 52.81 |
| 02/1 | 52 | 0.100 | 84.81 | 82.34 |
| 02/2 | 53 | 0.111 | 131.93 | 134.73 |
| 03/1 | 93 | 0.075 | 92.08 | 91.59 |
| 03/2 | 94 | 0.049 | 58.76 | 58.37 |
| 04/1 | 94 | 0.047 | 54.51 | 54.74 |
| 04/2 | 94 | 0.032 | 49.22 | 47.92 |
| AAA-AA | 14 | 0.042 | 22.00 | 19.84 |
| A | 41 | 0.089 | 51.39 | 44.07 |
| BBB | 35 | 0.094 | 107.02 | 90.01 |
| BB | 4 | 0.036 | 151.95 | 145.06 |
| All | 94 | 0.081 | 72.00 | 61.87 |

**Table 5.** *Augmented Dickey-Fuller (ADF) test*

The ADF unit root test is performed for the three possible alternatives: without constant and trend in the series, with constant and without trend, and with constant and trend. Reported ADF test statistics correspond to the model with the lowest Schwartz criterion where the number of lags is determined according to the Akaike information criterion. *** indicates significance at 1% level, ** indicates significance at 5% level, and * indicates significance at 10% level, with the corresponding null hypothesis of nonstationarity. Panel A lists the companies for which the presence of unit roots is rejected at the 95% level for at least one series. Panel B lists the companies for which ADF test show I(1) for both series simultaneously.

Panel A

| Company ID | Company_Name | CDS | | ICS | |
|---|---|---|---|---|---|
| | | t-stat | p-val | t-stat | p-val |
| 3 | BASF AG | -3.750 | 0.020 ** | -0.980 | 0.293 |
| 6 | BOUYGUES SA | -3.187 | 0.002 *** | -3.779 | 0.018 ** |
| 8 | DAIMLERCHRYSLER AG | -4.110 | 0.006 *** | -0.500 | 0.499 |
| 11 | ELECTRICIDADE DE PORTUGAL SA | -2.431 | 0.015 ** | -1.529 | 0.119 |
| 18 | KONINKLIJKE KPN NV | -1.480 | 0.130 | -2.017 | 0.042 ** |
| 26 | SAINT GOBAIN | -3.976 | 0.000 *** | -2.854 | 0.004 *** |
| 28 | STMICROELECTRONICS NV | -3.335 | 0.001 *** | -0.467 | 0.513 |
| 32 | THALES SA | -3.618 | 0.000 *** | -0.898 | 0.327 |
| 33 | THYSSENKRUPP AG | -5.210 | 0.000 *** | -1.018 | 0.278 |
| 36 | VALEO SA | -3.021 | 0.034 ** | -2.719 | 0.229 |
| 45 | CENTEX CORP | -2.971 | 0.039 ** | -1.373 | 0.158 |
| 61 | NORTHROP GRUMMAN CORP | -1.020 | 0.277 | -2.352 | 0.018 ** |
| 62 | OMNICOM GROUP | -2.763 | 0.006 *** | -0.961 | 0.301 |
| 68 | TOYS R US INC | -3.521 | 0.038 ** | -2.419 | 0.137 |
| 72 | WALT DISNEY CO, THE | -2.368 | 0.017 ** | -4.361 | 0.000 *** |
| 74 | CANON INC | -2.666 | 0.008 *** | -1.581 | 0.107 |
| 78 | HITACHI LTD (JPY) | -1.963 | 0.048 ** | -1.869 | 0.347 |
| 79 | HONDA MOTOR CO LTD | -27.033 | 0.000 *** | 0.000 | 0.683 |
| 81 | JAPAN TOBACCO INC | -3.859 | 0.015 ** | -4.046 | 0.008 *** |
| 83 | MATSUSHITA ELECTRIC INDUSTRIAL CO LTD (JPY) | -2.635 | 0.008 *** | -1.157 | 0.226 |
| 84 | MITSUBISHI CORP (JPY) | -2.952 | 0.003 *** | -2.096 | 0.035 ** |
| 85 | MITSUI AND CO LTD (JPY) | -3.343 | 0.014 ** | -2.753 | 0.006 *** |
| 86 | NEC CORP | -3.941 | 0.000 *** | -2.358 | 0.018 ** |
| 87 | NIPPON STEEL CORP (JPY) | -3.587 | 0.000 *** | -2.389 | 0.017 ** |
| 88 | NIPPON TELEGRAPH AND TELEPHONE CORP (JPY) | -3.741 | 0.000 *** | -1.569 | 0.110 |
| 89 | NTT DOCOMO INC (JPY) | -4.128 | 0.000 *** | -0.416 | 0.533 |
| 92 | SUMITOMO CORP | -4.670 | 0.000 *** | -2.049 | 0.039 ** |
| 94 | TOSHIBA CORP (JPY) | -2.049 | 0.039 ** | -1.111 | 0.242 |

Panel B

| Company ID | Company_Name | CDS | | | ICS | | |
|---|---|---|---|---|---|---|---|
| | | t-stat | p-val | | t-stat | p-val | |
| 1 | AKZO NOBEL NV | -0.734 | 0.398 | | -0.830 | 0.356 | |
| 2 | ARCELOR | -1.154 | 0.227 | | -0.929 | 0.314 | |
| 4 | BAYER AG | -1.317 | 0.174 | | -1.313 | 0.175 | |
| 5 | BMW AG | -0.721 | 0.405 | | -0.316 | 0.572 | |
| 7 | CARREFOUR SA | -0.788 | 0.375 | | -0.178 | 0.622 | |
| 9 | DEUTSCHE LUFTHANSA AG | -1.300 | 0.179 | | -0.590 | 0.462 | |
| 10 | E.ON AG | -0.646 | 0.437 | | -0.643 | 0.439 | |
| 12 | ENDESA (SPAIN) | -1.187 | 0.216 | | -1.127 | 0.237 | |
| 13 | ENEL SPA | -0.715 | 0.407 | | -0.695 | 0.416 | |
| 14 | ENI SPA | -1.128 | 0.236 | | -0.860 | 0.343 | |
| 15 | FINMECCANICA SPA | -0.551 | 0.478 | | -2.677 | 0.079 | * |
| 16 | FRANCE TELECOM | -0.809 | 0.366 | | -0.952 | 0.304 | |
| 17 | HEIDELBERGCEMENT AG | -0.599 | 0.458 | | -1.042 | 0.268 | |
| 19 | KONINKLIJKE PHILIPS ELECTRONICS NV | -1.032 | 0.272 | | -0.546 | 0.481 | |
| 20 | L AIR LIQUIDE SA | -0.977 | 0.294 | | 1.229 | 0.944 | |
| 21 | METRO AG | -0.814 | 0.363 | | -1.355 | 0.163 | |
| 22 | NOKIA OYJ | -0.819 | 0.361 | | -0.267 | 0.590 | |
| 23 | PEUGEOT SA | -2.986 | 0.137 | | -0.475 | 0.510 | |
| 24 | RENAULT SA | -1.506 | 0.124 | | -1.395 | 0.152 | |
| 25 | RWE AG | -0.774 | 0.381 | | -0.985 | 0.291 | |
| 27 | SIEMENS AG | -0.826 | 0.358 | | -1.124 | 0.238 | |
| 29 | STORA ENSO OYJ | -1.022 | 0.276 | | -2.810 | 0.057 | * |
| 30 | SUEZ SA | -0.817 | 0.362 | | -1.084 | 0.253 | |
| 31 | TELEFONICA SA | -1.009 | 0.281 | | -1.142 | 0.231 | |
| 34 | TOTALFINAELF SA | -1.031 | 0.273 | | -0.488 | 0.505 | |
| 35 | UPM-KYMMENE OYJ | -0.798 | 0.370 | | -2.060 | 0.261 | |
| 37 | VEOLIA ENVIRONNEMENT | -1.693 | 0.086 | * | -1.849 | 0.062 | * |
| 38 | VNU NV | -1.290 | 0.182 | | -0.891 | 0.330 | |
| 39 | VOLKSWAGEN AG | -2.851 | 0.052 | * | 0.668 | 0.860 | |
| 40 | WOLTERS KLUWER NV | -1.027 | 0.274 | | -0.883 | 0.334 | |
| 41 | ALBERTSONS INC | -1.286 | 0.183 | | -0.702 | 0.412 | |
| 42 | BELLSOUTH CORPORATION | -1.213 | 0.207 | | -0.672 | 0.426 | |
| 43 | BOEING CO | -1.085 | 0.252 | | -0.705 | 0.411 | |
| 44 | CATERPILLAR INC | -1.885 | 0.057 | * | -1.209 | 0.208 | |
| 46 | CVS CORP | -1.669 | 0.090 | * | -1.744 | 0.409 | |
| 47 | DEERE AND CO | -1.370 | 0.159 | | -0.986 | 0.291 | |
| 48 | DELL COMPUTER CORP | -1.535 | 0.117 | | -0.347 | 0.560 | |
| 49 | DELPHI CORP | -0.332 | 0.566 | | 0.117 | 0.719 | |
| 50 | DOW CHEMICAL CO, THE | -1.006 | 0.283 | | -0.790 | 0.374 | |
| 51 | EASTMAN KODAK CO | -1.292 | 0.182 | | -0.924 | 0.316 | |
| 52 | ELECTRONIC DATA SYSTEMS CORP | -1.037 | 0.270 | | -0.944 | 0.307 | |
| 53 | FEDERATED DEPARTMENT STORES INC | -1.202 | 0.211 | | -0.863 | 0.342 | |
| 54 | FORD MOTOR CREDIT CO | -0.711 | 0.409 | | -1.747 | 0.407 | |
| 55 | GENERAL ELECTRIC CAPITAL CORP | -0.621 | 0.448 | | -0.503 | 0.499 | |
| 56 | GENERAL MOTORS ACCEPTANCE CORP | -2.315 | 0.168 | | 0.392 | 0.797 | |
| 57 | MAY DEPARTMENT STORES CO | -2.761 | 0.065 | * | -1.492 | 0.127 | |
| 58 | MAYTAG CORP | 0.836 | 0.891 | | -0.329 | 0.567 | |
| 59 | NORDSTROM INC | -1.563 | 0.111 | | -1.770 | 0.073 | * |
| 60 | NORFOLK SOUTHERN CORP | -1.072 | 0.257 | | -1.005 | 0.283 | |
| 63 | SBC COMMUNICATIONS INC | -1.196 | 0.213 | | -3.138 | 0.098 | * |
| 64 | SOUTHWEST AIRLINES CO | -1.124 | 0.237 | | -0.327 | 0.568 | |
| 65 | SPRINT CORP | -1.002 | 0.284 | | -0.911 | 0.322 | |
| 66 | SUN MICROSYSTEMS INC | -0.948 | 0.306 | | -2.585 | 0.097 | * |
| 67 | TARGET CORP | -0.772 | 0.382 | | -0.707 | 0.411 | |
| 69 | VERIZON GLOBAL FUNDING CORP | -1.279 | 0.186 | | -0.884 | 0.333 | |
| 70 | VIACOM INC | -1.574 | 0.109 | | -0.459 | 0.516 | |
| 71 | VISTEON CORP | -2.546 | 0.105 | | -0.446 | 0.521 | |
| 73 | ALL NIPPON AIRWAYS CO LTD | -1.255 | 0.193 | | -1.769 | 0.073 | * |
| 75 | CHUBU ELECTRIC POWER CO INC | -1.591 | 0.105 | | -1.342 | 0.167 | |
| 76 | DAIWA SECURITIES GROUP INC | -1.529 | 0.119 | | -0.905 | 0.324 | |
| 77 | FUJITSU LTD (JPY) | -1.123 | 0.238 | | -0.595 | 0.459 | |
| 80 | JAPAN AIRLINES SYSTEM CORP | -1.318 | 0.622 | | -1.158 | 0.225 | |
| 82 | KANSAI ELECTRIC POWER CO INC | -1.339 | 0.168 | | -1.244 | 0.197 | |
| 90 | SHARP CORP (JPY) | -3.166 | 0.092 | * | -0.744 | 0.394 | |
| 91 | SONY CORP (JPY) | -1.644 | 0.095 | * | -0.258 | 0.593 | |
| 93 | TOKYO ELECTRIC POWER CO INC | -1.088 | 0.251 | | -0.785 | 0.376 | |

**Table 6.** *Johansen Cointegration Test*

The Johansen Cointegration Test is performed for the 66 pairs of non-stationary ICS –CDS series. A constant is allowed in the cointegration equation and in the VAR component of the VECM while the corresponding number of lags is determined according to the Schwartz criterion. Reported Trace statistics correspond to the number of cointegration relationships between ICS and CDS series. *** indicates significance at 1% level, ** indicates significance at 5% level, and * indicates significance at 10% level.

| Company_ID | Company_Name | None | At most 1 |
|---|---|---|---|
| | | Trace stat | Trace stat |
| 1 | AKZO NOBEL NV | 10.565 | 1.227 |
| 2 | ARCELOR | 13.059 | 0.787 |
| 4 | BAYER AG | 19.517 ** | 2.863 * |
| 5 | BMW AG | 9.889 | 3.134 * |
| 7 | CARREFOUR SA | 12.749 | 3.197 * |
| 9 | DEUTSCHE LUFTHANSA AG | 9.380 | 2.507 |
| 10 | E.ON AG | 12.661 | 1.910 |
| 12 | ENDESA (SPAIN) | 37.630 *** | 2.801 * |
| 13 | ENEL SPA | 11.535 | 2.000 |
| 14 | ENI SPA | 7.904 | 3.206 * |
| 15 | FINMECCANICA SPA | 10.035 | 2.126 |
| 16 | FRANCE TELECOM | 11.353 | 0.863 |
| 17 | HEIDELBERGCEMENT AG | 9.551 | 1.333 |
| 19 | KONINKLIJKE PHILIPS ELECTRONICS NV | 9.112 | 1.267 |
| 20 | L AIR LIQUIDE SA | 5.494 | 0.051 |
| 21 | METRO AG | 23.970 *** | 3.623 * |
| 22 | NOKIA OYJ | 7.498 | 0.671 |
| 23 | PEUGEOT SA | 10.220 | 3.731 * |
| 24 | RENAULT SA | 10.154 | 2.699 |
| 25 | RWE AG | 10.522 | 3.321 * |
| 27 | SIEMENS AG | 8.464 | 1.683 |
| 29 | STORA ENSO OYJ | 16.789 ** | 1.764 |
| 30 | SUEZ SA | 8.879 | 2.927 * |
| 31 | TELEFONICA SA | 21.642 *** | 1.779 |
| 34 | TOTALFINAELF SA | 9.729 | 2.926 * |
| 35 | UPM-KYMMENE OYJ | 8.397 | 1.632 |
| 37 | VEOLIA ENVIRONNEMENT | 9.554 | 0.784 |
| 38 | VNU NV | 31.924 *** | 3.260 * |
| 39 | VOLKSWAGEN AG | 12.748 | 2.220 |
| 40 | WOLTERS KLUWER NV | 8.071 | 3.701 * |
| 41 | ALBERTSONS INC | 7.761 | 1.542 |
| 42 | BELLSOUTH CORPORATION | 21.997 *** | 2.505 |
| 43 | BOEING CO | 13.081 | 1.780 |
| 44 | CATERPILLAR INC | 23.051 *** | 2.018 |
| 46 | CVS CORP | 10.796 * | 2.804 |
| 47 | DEERE AND CO | 7.211 | 2.170 |
| 48 | DELL COMPUTER CORP | 10.386 | 2.957 * |
| 49 | DELPHI CORP | 10.705 | 2.370 |
| 50 | DOW CHEMICAL CO, THE | 22.571 *** | 0.821 |
| 51 | EASTMAN KODAK CO | 14.312 * | 1.007 |
| 52 | ELECTRONIC DATA SYSTEMS CORP | 18.991 ** | 1.055 |
| 53 | FEDERATED DEPARTMENT STORES INC | 7.517 | 2.210 |
| 54 | FORD MOTOR CREDIT CO | 14.186 * | 2.659 |
| 55 | GENERAL ELECTRIC CAPITAL CORP | 10.191 | 1.779 |
| 56 | GENERAL MOTORS ACCEPTANCE CORP | 8.773 | 2.793 * |
| 57 | MAY DEPARTMENT STORES CO | 17.984 ** | 1.039 |
| 58 | MAYTAG CORP | 11.085 | 0.372 |
| 59 | NORDSTROM INC | 14.425 * | 1.960 |
| 60 | NORFOLK SOUTHERN CORP | 5.497 | 0.658 |
| 63 | SBC COMMUNICATIONS INC | 15.497 * | 0.633 |
| 64 | SOUTHWEST AIRLINES CO | 8.779 | 3.697 * |
| 65 | SPRINT CORP | 19.822 ** | 1.238 |
| 66 | SUN MICROSYSTEMS INC | 12.356 | 2.672 |
| 67 | TARGET CORP | 14.410 * | 2.454 |
| 69 | VERIZON GLOBAL FUNDING CORP | 12.842 | 1.886 |
| 70 | VIACOM INC | 9.587 | 2.640 |
| 71 | VISTEON CORP | 39.264 *** | 2.557 |
| 73 | ALL NIPPON AIRWAYS CO LTD | 13.284 | 1.884 |
| 75 | CHUBU ELECTRIC POWER CO INC | 11.626 | 0.308 |
| 76 | DAIWA SECURITIES GROUP INC | 6.587 | 0.652 |
| 77 | FUJITSU LTD (JPY) | 17.922 ** | 1.125 |
| 80 | JAPAN AIRLINES SYSTEM CORP | 11.895 | 1.243 |
| 82 | KANSAI ELECTRIC POWER CO INC | 19.272 ** | 0.352 |
| 90 | SHARP CORP (JPY) | 10.296 | 2.389 |
| 91 | SONY CORP (JPY) | 16.284 ** | 3.203 * |
| 93 | TOKYO ELECTRIC POWER CO INC | 15.892 ** | 1.310 |

**Table 7.** *Measures of contribution to price discovery process*

This table reports various measures of the stock and CDS market contribution to price discovery process ($\lambda_1$, $\lambda_2$, GG and Hasbrouck measures) for the companies for which the cointegration relationship has been detected by the Johansen Cointegration Test. Estimated $\lambda_1$ and $\lambda_2$ coefficients are presented together with the corresponding t-values where *** indicates significance at 1% level, ** indicates significance at 5% level, and * indicates significance at 10% level.

| Company Name | $\lambda_1$ | t-stat | $\lambda_2$ | t-stat | GG | Hasbrouck | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Lower | Upper | Mid |
| BAYER AG | 0.013 | 0.600 | 0.078 | 4.061 *** | 1.20 | 0.98 | 0.99 | 0.98 |
| ENDESA | -0.041 | -3.379 *** | 0.032 | 4.257 *** | 0.43 | 0.51 | 0.68 | 0.59 |
| METRO AG | 0.002 | 0.157 | 0.018 | 4.400 *** | 1.11 | 0.95 | 1.00 | 0.97 |
| STORA ENSO OYJ | -0.016 | -2.261 ** | 0.007 | 2.039 ** | 0.30 | 0.39 | 0.52 | 0.46 |
| TELEFONICA SA | -0.022 | -1.984 ** | 0.021 | 2.894 *** | 0.49 | 0.42 | 0.80 | 0.61 |
| VNU NV | -0.040 | -3.167 *** | 0.009 | 0.773 | 0.18 | 0.05 | 0.20 | 0.12 |
| BELLSOUTH CORPORATION | -0.046 | -3.684 *** | -0.015 | -2.595 *** | -0.46 | 0.31 | 0.34 | 0.33 |
| CATERPILLAR INC | -0.007 | -1.359 * | 0.009 | 3.514 *** | 0.57 | 0.77 | 0.89 | 0.83 |
| DOW CHEMICAL CO | -0.038 | -2.936 *** | 0.034 | 3.245 *** | 0.48 | 0.48 | 0.61 | 0.54 |
| ELECTRONIC DATA SYSTEMS CORP | -0.004 | -0.402 | 0.041 | 4.085 *** | 0.92 | 0.92 | 0.99 | 0.96 |
| MAY DEPARTMENT STORES CO | -0.014 | -1.947 * | 0.010 | 2.904 *** | 0.41 | 0.69 | 0.69 | 0.69 |
| SPRINT CORP | -0.044 | -3.280 *** | 0.019 | 0.829 | 0.29 | 0.04 | 0.43 | 0.23 |
| VISTEON CORP | -0.002 | -0.158 | 0.053 | 6.094 *** | 0.97 | 0.98 | 1.00 | 0.99 |
| FUJITSU LTD | -0.009 | -2.489 ** | 0.029 | 3.093 *** | 0.76 | 0.57 | 0.63 | 0.60 |
| KANSAI ELECTRIC POWER CO INC | -0.038 | -3.975 *** | 0.009 | 1.859 * | 0.18 | 0.17 | 0.18 | 0.18 |
| SONY CORP | -0.018 | -3.357 *** | -0.005 | -1.748 * | -0.40 | 0.14 | 0.23 | 0.19 |
| TOKYO ELECTRIC POWER CO INC | -0.029 | -3.780 *** | 0.003 | 0.464 | 0.10 | 0.01 | 0.02 | 0.02 |
| Average | | | | | 0.44 | 0.49 | 0.60 | 0.55 |

**Table 8.** *Measures of contribution to price discovery process over half-year periods*

This table reports GG and Hasbrouck measures of the stock and CDS market contribution to price discovery process over the corresponding half-year periods. For the sake of brevity, the table reports only the mean level of the individual values estimated for the companies for which the cointegration relationship has been detected by the Johansen Cointegration Test over the entire sample period. Half-year coefficients are estimated by imposing the entire sample cointegration equation to the half-year VECM.

| Period | N firms | GG | Hasbrouck | | |
|---|---|---|---|---|---|
| | | | Lower | Upper | Mid |
| 02/1 | 12 | 0.63 | 0.61 | 0.72 | 0.67 |
| 02/2 | 12 | 0.49 | 0.44 | 0.63 | 0.54 |
| 03/1 | 17 | 0.41 | 0.43 | 0.56 | 0.50 |
| 03/2 | 17 | 0.43 | 0.43 | 0.51 | 0.47 |
| 04/1 | 17 | 0.43 | 0.52 | 0.59 | 0.56 |
| 04/2 | 17 | 0.37 | 0.44 | 0.50 | 0.46 |
| All | 92 | 0.46 | 0.48 | 0.59 | 0.53 |

**Table 9.** *Granger causality test*

The table reports pairwise Granger causality test statistics (dngc = does not Granger cause) for the sub-sample of 77 companies that either do not have unit roots or for which the cointegration relationship is not distinctly suggested by the Johansen Cointegration Test. The number of lags is selected according to the Schwartz information criterion. *** indicates significance at 1% level, ** indicates significance at 5% level, and * indicates significance at 10% level.

| Company_Name | ΔICS dngc ΔCDS | | ΔCDS dngc ΔICS | |
|---|---|---|---|---|
| | F-statistic | | F-statistic | |
| AKZO NOBEL NV | 7.564 | *** | 0.180 | |
| ARCELOR | 4.215 | ** | 1.725 | |
| BMW AG | 4.119 | ** | 10.870 | *** |
| CARREFOUR SA | 18.914 | *** | 1.431 | |
| DAIMLERCHRYSLER AG | 25.560 | *** | 0.473 | |
| DEUTSCHE LUFTHANSA AG | 30.926 | *** | 3.454 | * |
| E.ON AG | 14.411 | *** | 0.884 | |
| ELECTRICIDADE DE PORTUGAL SA | 6.580 | ** | 0.176 | |
| FINMECCANICA SPA | 15.223 | *** | 0.153 | |
| FRANCE TELECOM | 23.229 | *** | 2.849 | * |
| HEIDELBERGCEMENT AG | 3.944 | ** | 0.931 | |
| KONINKLIJKE KPN NV | 25.340 | *** | 4.818 | ** |
| KONINKLIJKE PHILIPS ELECTRONICS NV | 5.600 | ** | 2.824 | * |
| L AIR LIQUIDE SA | 0.700 | | 5.373 | ** |
| NOKIA OYJ | 10.546 | *** | 1.314 | |
| PEUGEOT SA | 21.850 | *** | 1.920 | |
| RENAULT SA | 11.141 | *** | 0.210 | |
| RWE AG | 28.656 | *** | 0.445 | |
| SAINT GOBAIN | 4.115 | *** | 6.067 | *** |
| SIEMENS AG | 46.190 | *** | 0.000 | |
| STMICROELECTRONICS NV | 4.446 | ** | 1.022 | |
| SUEZ SA | 18.314 | *** | 0.359 | |
| THALES SA | 5.326 | ** | 0.461 | |
| THYSSENKRUPP AG | 1.471 | | 21.046 | *** |
| VALEO SA | 9.868 | *** | 19.096 | *** |
| VOLKSWAGEN AG | 36.913 | *** | 1.107 | |
| BOEING CO | 19.885 | *** | 10.075 | *** |
| DEERE AND CO | 4.075 | ** | 4.092 | ** |
| EASTMAN KODAK CO | 62.310 | *** | 0.002 | |
| FEDERATED DEPARTMENT STORES INC | 37.829 | *** | 0.004 | |
| FORD MOTOR CREDIT CO | 95.236 | *** | 0.362 | |
| GENERAL ELECTRIC CAPITAL CORP | 15.567 | *** | 0.532 | |
| GENERAL MOTORS ACCEPTANCE CORP | 25.942 | *** | 0.045 | |
| MAYTAG CORP | 10.853 | *** | 5.288 | ** |
| NORDSTROM INC | 4.201 | ** | 0.319 | |
| NORFOLK SOUTHERN CORP | 6.805 | *** | 1.693 | |
| NORTHROP GRUMMAN CORP | 1.659 | | 3.002 | *** |
| SBC COMMUNICATIONS INC | 10.280 | *** | 3.357 | * |
| SUN MICROSYSTEMS INC | 19.407 | *** | 0.023 | |
| TARGET CORP | 28.335 | *** | 5.073 | ** |
| TOYS R US INC | 7.346 | *** | 1.614 | |
| VERIZON GLOBAL FUNDING CORP | 22.789 | *** | 5.586 | *** |
| WALT DISNEY CO, THE | 10.619 | *** | 0.035 | |
| DAIWA SECURITIES GROUP INC | 4.552 | ** | 4.773 | ** |
| HITACHI LTD | 5.745 | *** | 0.300 | |
| JAPAN AIRLINES SYSTEM CORP | 1.982 | * | 3.754 | *** |
| MATSUSHITA ELECTRIC INDUSTRIAL CO LTD | 8.039 | *** | 2.747 | * |
| NIPPON STEEL CORP | 1.002 | | 2.788 | ** |
| NIPPON TELEGRAPH AND TELEPHONE CORP | 8.625 | *** | 2.423 | |
| NTT DOCOMO INC | 2.830 | ** | 2.390 | * |
| SHARP CORP | 6.235 | ** | 4.975 | ** |
| TOSHIBA CORP | 6.521 | ** | 2.464 | |

**Table 10.** *Granger causality test over half year periods*

The table reports the number and percentage of firms for which the corresponding Granger causality test statistics is significant at 5% level, over each of the considered half-year periods.

| Period | N firms | ∆ICS dgc ∆CDS | | ∆CDS dgc ∆ICS | |
|---|---|---|---|---|---|
| | | N firms | % | N firms | % |
| 02/1 | 40 | 13 | 32.50 | 3 | 7.50 |
| 02/2 | 41 | 18 | 43.90 | 1 | 2.44 |
| 03/1 | 76 | 20 | 26.32 | 10 | 13.16 |
| 03/2 | 77 | 14 | 18.18 | 7 | 9.09 |
| 04/1 | 77 | 14 | 18.18 | 5 | 6.49 |
| 04/2 | 77 | 12 | 15.58 | 7 | 9.09 |
| All | 388 | 91 | 23.45 | 33 | 8.5 |

**Table 11.** *The correlation matrix*

This table shows the correlation matrix between relevant variables.

| Variable | CDS bid-ask spread | % CDS bid-ask spread | Stock turnover ratio | Frequency of adverse shocks | Credit rating | Average CDS level | CDS>100 |
|---|---|---|---|---|---|---|---|
| CDS bid-ask spread | 1.000 | | | | | | |
| % CDS bid-ask spread | -0.028 | 1.000 | | | | | |
| Stock turnover ratio | 0.193 | -0.193 | 1.000 | | | | |
| Frequency of adverse shocks | 0.541 | -0.088 | 0.203 | 1.000 | | | |
| Credit rating | -0.351 | 0.426 | -0.189 | -0.178 | 1.000 | | |
| Average CDS level | 0.847 | -0.359 | 0.247 | 0.569 | -0.486 | 1.000 | |
| CDS>100 | 0.562 | -0.312 | 0.213 | 0.355 | -0.461 | 0.761 | 1.000 |

**Table 12.** *Mid Hasbrouck information shares over the half year periods*

This table reports Mid Hasbrouck (HM) information shares in terms of stock market contribution to price discovery process over the half-year periods for the companies for which the cointegration relationship has been detected by the Johansen Cointegration Test over the entire sample period. Half-year information shares are estimated by imposing the entire sample cointegration equation to the half-year VECM.

| Company | Period | | | | | |
|---|---|---|---|---|---|---|
| | 02/1 | 02/2 | 03/1 | 03/2 | 04/1 | 04/2 |
| BAYER AG | | | 0.93 | 0.40 | 0.04 | 0.16 |
| ENDESA | 0.78 | 0.82 | 0.30 | 0.82 | 0.46 | 0.89 |
| METRO AG | 0.67 | 0.64 | 0.11 | 0.97 | 0.76 | 0.99 |
| STORA ENSO OYJ | 0.98 | 0.77 | 0.11 | 0.62 | 0.84 | 0.55 |
| TELEFONICA SA | 0.92 | 0.51 | 0.16 | 0.25 | 0.40 | 0.14 |
| VNU NV | 0.70 | 0.26 | 0.83 | 0.17 | 0.10 | 0.30 |
| BELLSOUTH CORPORATION | | | 0.32 | 0.10 | 0.22 | 0.19 |
| CATERPILLAR INC | 0.99 | 0.84 | 0.63 | 0.14 | 0.95 | 0.95 |
| DOW CHEMICAL CO | 0.31 | 0.56 | 0.91 | 0.65 | 0.90 | 0.29 |
| ELECTRONIC DATA SYSTEMS CORP | | | 0.95 | 0.94 | 0.72 | 0.95 |
| MAY DEPARTMENT STORES CO | | | 0.99 | 0.82 | 0.75 | 0.44 |
| SPRINT CORP | 0.43 | 0.59 | 0.07 | 0.04 | 0.09 | 0.00 |
| VISTEON CORP | | | 0.97 | 0.97 | 1.00 | 0.97 |
| FUJITSU LTD | 0.96 | 0.96 | 0.87 | 0.99 | 0.99 | 0.59 |
| KANSAI ELECTRIC POWER CO INC | 0.56 | 0.02 | 0.06 | 0.04 | 0.59 | 0.44 |
| SONY CORP | 0.66 | 0.36 | 0.02 | 0.01 | 0.61 | 0.03 |
| TOKYO ELECTRIC POWER CO INC | 0.06 | 0.11 | 0.18 | 0.01 | 0.01 | 0.01 |
| All | 0.67 | 0.54 | 0.50 | 0.47 | 0.56 | 0.46 |

**Table 13.** *Regression estimation results*

This table summarizes estimates from the OLS regression where t-statistics correspond to the White heteroskedasticity robust standard errors. *** indicates significance at 1% level, ** indicates significance at 5% level, and * indicates significance at 10% level.

| Explanatory variables | OLS estimates | | | | | |
|---|---|---|---|---|---|---|
| | *coef* | *t-stat* | *coef* | *t-stat* | *coef* | *t-stat* |
| c | 2.042 ** | 2.555 | 0.193 | 1.267 | 0.186 | 1.243 |
| CDS % bid-ask spread | 0.002 | 0.593 | -0.002 | -0.611 | -0.002 | -0.648 |
| Stock turnover ratio | 0.731 *** | 3.698 | 0.716 *** | 3.316 | 0.789 *** | 3.665 |
| Frequency of adverse shocks | -0.109 *** | -2.979 | -0.151 *** | -4.759 | -0.104 *** | -3.709 |
| Credit condition | | | | | | |
| Credit rating | -0.066 ** | -2.297 | | | | |
| Average CDS level | | | 0.001 *** | 3.485 | | |
| CDS>100 | | | | | 0.173 * | 1.965 |
| CDS level trend | -0.006 | -0.142 | 0.063 | 1.332 | -0.019 | -0.470 |
| Dummy variables | | | | | | |
| 2002 | 0.060 | 0.777 | 0.019 | 0.246 | 0.049 | 0.593 |
| 2004 | 0.082 | 0.965 | 0.075 | 0.887 | 0.109 | 1.329 |
| $R^2$ | 0.330 | | 0.310 | | 0.294 | |
| adj $R^2$ | 0.273 | | 0.251 | | 0.234 | |
| F-statistic | 5.836 | | 5.316 | | 4.929 | |
| Prob(F-statistic) | 0.000 | | 0.000 | | 0.000 | |

**Table 14.** *Ordered probit estimation results for the sub-sample of 77 companies*

This table reports the ordered probit estimation results for the sub-sample of 77 companies that either do not have unit roots or for which the cointegration relationship is not distinctly suggested by the Johansen Cointegration Test. The dependent variable takes the value of -1 for the clear CDS market leadership, the value of 0 for the situation in which no clear interpretation can be made and the value of +1 for the clear stock market leadership in the price discovery process. *** indicates significance at 1% level, ** indicates significance at 5% level, and * indicates significance at 10% level.

| Explanatory variables | Ordered probit estimates | | | | | |
|---|---|---|---|---|---|---|
| | *coef* | *z-stat* | *coef* | *z-stat* | *coef* | *z-stat* |
| % CDS bid-ask spread | -0.017 *** | -3.017 | -0.007 | -1.221 | -0.013 ** | -2.496 |
| Stock turnover ratio | 0.353 | 1.528 | 0.273 | 1.177 | 0.312 | 1.357 |
| Frequency of adverse shocks | -0.389 ** | -1.973 | -1.033 *** | -4.018 | -0.525 ** | -2.507 |
| Credit condition | | | | | | |
| Credit rating | -0.007 | -0.211 | | | | |
| Average CDS level | | | 0.006 *** | 3.940 | | |
| CDS>100 | | | | | 0.346 * | 1.830 |
| CDS level trend | 0.192 | 1.101 | 0.507 *** | 2.645 | 0.277 | 1.548 |
| Dummy variables | | | | | | |
| 2002+ | 0.547 *** | 3.035 | 0.474 *** | 2.626 | 0.487 *** | 2.709 |
| 2004+ | -0.092 | -0.615 | -0.058 | -0.387 | -0.105 | -0.705 |
| Log likelihood | -264.889 | | -260.292 | | -266.574 | |
| Pseudo $R^2$ | 0.056 | | 0.080 | | 0.058 | |
| LR stat - $\chi^2_7$ | 31.212 | | 45.408 | | 32.844 | |
| Prob(LR stat) | 0.000 | | 0.000 | | 0.000 | |

**Table 15.** *Marginal effects for the sub-sample of 77 companies*

The marginal effects of the explanatory variables on the probability of stock market leadership are presented in column *d(1)/dx,* while the marginal effects on the probability of CDS market leadership are presented in column *d(-1)/dx.*

| Explanatory variables | Ordered probit estimates - marginal effects | | | | | |
|---|---|---|---|---|---|---|
| | *d(1)/dx* | *d(-1)/dx* | *d(1)/dx* | *d(-1)/dx* | *d(1)/dx* | *d(-1)/dx* |
| % CDS bid-ask spread | -0.005 | 0.002 *** | -0.002 | 0.001 | -0.004 | 0.002 ** |
| Stock turnover ratio | 0.097 | -0.035 | 0.079 | -0.028 | 0.091 | -0.033 |
| Frequency of adverse shocks | -0.108 | 0.039 ** | -0.278 | 0.099 *** | -0.146 | 0.053 ** |
| Credit condition | | | | | | |
| Credit rating | -0.002 | 0.001 | | | | |
| Average CDS level | | | 0.002 | -0.001 *** | | |
| CDS>100 | | | | | 0.101 | -0.029 * |
| CDS level trend | 0.052 | -0.019 | 0.135 | -0.048 *** | 0.075 | -0.028 |
| Dummy variables | | | | | | |
| 2002+ | 0.170 | -0.043 *** | 0.149 | -0.038 *** | 0.155 | -0.040 *** |
| 2004+ | -0.025 | 0.009 | -0.011 | 0.004 | -0.024 | 0.009 |

* dy/dx is for discrete change of dummy variable from 0 to 1

**Table 16.** *Ordered probit estimation results*

This table presents the ordered probit estimation results where the dependent variable takes the value of -1 for the clear CDS market leadership, the value of 0 for the situation in which no clear interpretation can be made and the value of +1 for the clear stock market leadership in the price discovery process. *** indicates significance at 1% level, ** indicates significance at 5% level, and * indicates significance at 10% level.

| Explanatory variables | Ordered probit estimates | | | | | |
|---|---|---|---|---|---|---|
| | *coef* | *z-stat* | *coef* | *z-stat* | *coef* | *z-stat* |
| CDS % bid-ask spread | -0.012 ** | -2.361 | -0.006 | -1.194 | -0.011 ** | -2.261 |
| Stock turnover ratio | 0.478 ** | 2.234 | 0.428 ** | 1.992 | 0.470 ** | 2.207 |
| Frequency of adverse shocks | -0.249 ** | -2.224 | -0.643 *** | -4.354 | -0.320 *** | -2.729 |
| Credit condition | | | | | | |
| Credit rating | -0.030 | -1.034 | | | | |
| Average CDS level | | | 0.005 *** | 4.339 | | |
| CDS>100 | | | | | 0.365 ** | 2.294 |
| CDS level trend | 0.223 * | 1.777 | 0.516 *** | 3.472 | 0.270 ** | 2.118 |
| Dummy variables | | | | | | |
| 2002 | 0.429 *** | 2.798 | 0.334 ** | 2.167 | 0.376 ** | 2.460 |
| 2004 | -0.039 | -0.299 | 0.002 | 0.013 | -0.015 | -0.112 |
| Log likelihood | -367.399 | | -358.172 | | -365.285 | |
| Pseudo $R^2$ | 0.045 | | 0.069 | | 0.051 | |
| LR stat - $\chi^2_7$ | 34.773 | | 53.227 | | 39.001 | |
| Prob(LR stat) | 0.000 | | 0.000 | | 0.000 | |

**Table 17.** *Marginal effects from the ordered probit analysis*

The marginal effects of the explanatory variables on the probability of stock market leadership are presented in column *d(1)/dx,* while the marginal effects on the probability of CDS market leadership are presented in column *d(-1)/dx.*

| Explanatory variables | Ordered probit estimates - marginal effects | | | | | |
|---|---|---|---|---|---|---|
| | *d(1)/dx* | *d(-1)/dx* | *d(1)/dx* | *d(-1)/dx* | *d(1)/dx* | *d(-1)/dx* |
| CDS % bid-ask spread | -0.003 | 0.002 ** | -0.001 | 0.001 | -0.003 | 0.001 ** |
| Stock turnover ratio | 0.142 | -0.065 ** | 0.118 | -0.051 ** | 0.130 | -0.058 ** |
| Frequency of adverse shocks | -0.075 | 0.034 ** | -0.194 | 0.085 *** | -0.098 | 0.044 *** |
| Credit condition | | | | | | |
| Credit rating | -0.009 | 0.004 | | | | |
| Average CDS level | | | 0.001 | -0.001 *** | | |
| CDS>100 | | | | | 0.120 | -0.043 ** |
| CDS level trend | 0.067 | -0.030 * | 0.156 | -0.068 *** | 0.084 | -0.037 ** |
| Dummy variables | | | | | | |
| 2002+ | 0.139 | -0.049 *** | 0.114 | -0.040 ** | 0.129 | -0.045 ** |
| 2004+ | -0.012 | 0.005 | -0.004 | 0.002 | -0.009 | 0.004 |

+ dy/dx is for discrete change of dummy variable from 0 to 1

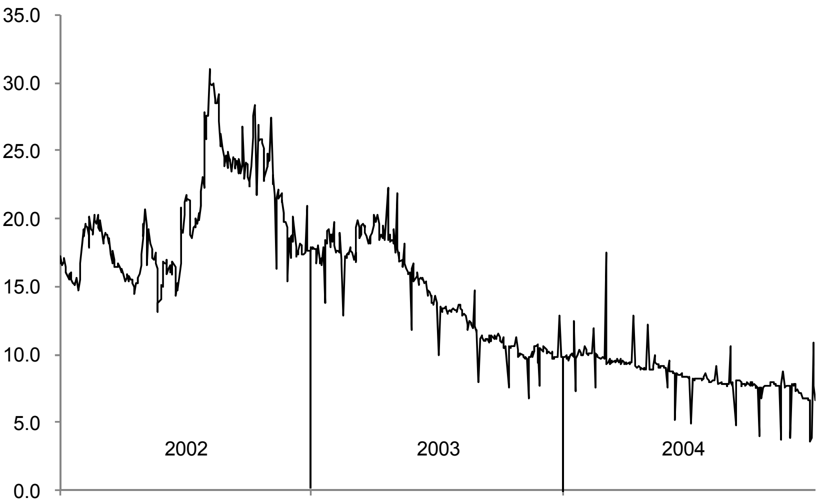
**Table 18.** *Probit estimation results*

This table presents the probit estimation results where the dependent variable takes the value of 1 for the clear stock market leadership and the value 0 for the clear CDS market leadership in the credit risk discovery process. *** indicates significance at 1% level, ** indicates significance at 5% level, and * indicates significance at 10% level.

| Explanatory variables | Probit estimates | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *coef* | | *z-stat* | *d(1)/dx* | *coef* | | *z-stat* | *d(1)/d(x)* | *coef* | | *z-stat* | *d(1)/dx* |
| c | 1.657 | | 0.891 | | -0.059 | | -0.115 | | 0.345 | | 0.767 | |
| CDS % bid-ask spread | -0.019 | | -1.510 | -0.005 | -0.011 | | -1.032 | -0.003 | -0.017 | | -1.549 | -0.005 |
| Stock turnover ratio | 1.869 | *** | 2.794 | 0.539 | 1.611 | ** | 2.176 | 0.442 | 1.706 | *** | 2.604 | 0.484 |
| Frequency of adverse shocks | -0.519 | * | -1.894 | -0.153 | -1.050 | ** | -2.498 | -0.293 | -0.626 | ** | -2.211 | -0.181 |
| Credit condition | | | | | | | | | | | | |
| Credit rating | -0.047 | | -0.684 | -0.014 | | | | | | | | |
| Average CDS level | | | | | 0.006 | ** | 2.206 | 0.002 | | | | |
| CDS>100 | | | | | | | | | 0.346 | | 1.102 | 0.094 |
| CDS level trend | 0.622 | ** | 2.123 | 0.180 | 0.971 | ** | 2.219 | 0.268 | 0.696 | ** | 2.328 | 0.199 |
| Dummy variables | | | | | | | | | | | | |
| 2002+ | 0.689 | ** | 2.158 | 0.175 | 0.646 | * | 1.894 | 0.157 | 0.662 | ** | 2.133 | 0.167 |
| 2004+ | 0.040 | | 0.136 | 0.011 | 0.045 | | 0.154 | 0.012 | 0.011 | | 0.037 | 0.003 |
| Log likelihood | -71.820 | | | | -70.724 | | | | -73.041 | | | |
| Pseudo $R^2$ | 0.167 | | | | 0.188 | | | | 0.162 | | | |
| LR stat - $\chi^2_7$ | 28.877 | | | | 32.840 | | | | 28.208 | | | |
| Prob(LR stat) | 0.000 | | | | 0.000 | | | | 0.000 | | | |

+ dy/dx is for discrete change of dummy variable from 0 to 1

**Graph 1.** *Bid-Ask spread development over the period 2002-2004*



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