The Market Price of Credit Risk in Stocks, Bonds and CDSs: Theory and Evidence

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Abstract

In this paper a procedure for computing homogenous measures of the market price of credit risk for stocks, bonds and CDSs is presented. The measures are based on bond spreads (CS), CDS spreads (CDS) and implied stock market credit spreads (ICS). We compute these measures for a sample of North American and European firms and find that in most cases the stock market leads the credit risk price discovery process with respect to bond and CDS markets.

Keywords: Credit risk, credit spreads, structural models, price discovery.
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Introduction

There are many economic agents who dedicate time and effort to estimating company credit risk. A few examples being: corporate bond holders, large investment banks ready to cover the risk that bondholders could experience through the sale of bond derivatives, such as Credit Default Swaps (CDSs), or shareholders worried about the interests that their company might have to face when the credit rating deteriorates.[1] Each of these assets, bonds, CDSs and shares, are traded in markets that differ in terms of organization (greater weight of organized markets in the case of shares, less weight in the bond market, and a clear domination of OTC markets for CDSs), liquidity (the stock market will generally be the most liquid, followed by the bond market and the CDS market) and traders (the stock market has probably a greater number of least professional traders, followed by the bond market, and with the CDS market populated by professional brokers and traders); Three characteristics which are possibly not independent. Given that credit risk affects all these assets, information available about credit risk will eventually show in their prices. However, given the structural differences mentioned between the markets, it may be possible that such information appears into some prices with greater speed than in others. In this essay we develop a methodology that allows the evaluation of which of these prices, that is, which of these markets, incorporates this information first. We also apply this methodology to a sample of North American and European companies.

When it comes to comparing the speed with which different markets incorporate new information in relation to credit risk, it is advisable to follow the following steps: Firstly, to formally define what is understood by the term ‘credit risk’. Secondly, to propose a quantitative variable that measures the perception that a certain market has of the risk in accordance with the given definition. Thirdly, to

[1] We could of course include central banks, whose objective is to ensure the health of the financial system.

develop procedures and techniques which construct the chosen variable given the available information in each market; and finally, to define a methodology to analyse the price discovery process.

We may define credit risk as “risk created by loss associated with the default of the borrower, or the event of credit rating deterioration”. Given that loss due to credit rating deterioration (downgrading) is a loss that stems from an increase in risk due to losses associated with the failure to pay, the key element is the possibility of failure to pay (default). It seems therefore that a reasonable measure of the credit risk perceived by a certain market for a specific case of a particular company would be the premium that agents in that market would claim for the debt with a possibility of failure, in relation to a debt of the same nature but without a possibility of failure. We could therefore name the premium of a certain market the market price of credit risk. Although it may not be reasonable to expect that different markets assign very different prices of credit risk to the same company on a permanent basis (as it would induce arbitrage opportunities), it is possible that such differences may appear in the short term due to the structural differences between the markets described previously.

Of the three markets mentioned, the market in which the definition of the variable market price of credit risk is more intuitive is perhaps the bond market. In principle, it would be enough to subtract from the bond return of a certain company, the return of an equivalent debt instrument without default risk, or the equivalent rate. This in fact completely corresponds to the measurement that we wish to estimate. The problem is that such an equivalent rate simply does not exist. Traditionally, a Government Bond or Bill rate has been used. However, the differential between a corporate bond return and the Government Bonds rate is explained only in part by the fact that the Government Bond rate is seen as free from credit risk and corporate bonds are not. On one hand certain legal requirements induce the demand for Government Bonds (Hull, Predescu and White, 2003), which tends to put its profitability below the ideal equivalent rate. During recent years this factor has had greater relevance due to shocks in the bond supply (Reinhart and Sack, 2001). It can be gathered that Government Bonds are generally more liquid than corporate bonds (Longstaff, Mithal and Neis, 2003, and Chen, Lesmond and Wei, 2004) and have better tax treatment (Elton, Gruber, Agrawal and Mann, 2001), which also reduces their return in comparison to our hypothetical equivalent rate. As a result, using Government Bonds as an approximation would mean that the price assigned to credit risk in that market would be overestimated.

An alternative which seems to provide better results is to use the interest rate swap, or fixed rate which is received as compensation for providing a floating rate, adjusted to the Libor (Reinhart and Sack, 2001). Hull, Predescu and White (2003), Longstaff, Mithal and Neis (2003), Howeling and Vorst (2003), and Blanco, Brennan and Marsh (2003) show that deducting the swap rate from the corporate bonds returns instead of the Government Bond rate, gives premiums closer to the CDSs spreads. As the spreads of the CDSs 'essentially' represent the price assigned to credit risk in this market, and it being unreasonable to expect systematic differences in the price given to such risk in different markets, we can conclude that the use of the swap rate aids (at least to some extent) to extract the credit risk component of the bond returns. Two additional reasons can explain this result: Firstly, the swap rate is not affected by legal requirements and secondly, unlike Government Bonds the swap rate is lacking in any special taxation (Hull, Predescu and White, 2003). Despite these advantages, the corporate bonds will still have on average a greater liquidity component than the swap rate (Reinhart and Sack, 2001) and therefore generally, the equivalent rate will be above it. One way to minimise this discrepancy is to select the most recently issued bonds. These being the most traded, their equivalent rate will have a lesser liquidity part and will come closer to the swap rate. Given this information, we understand that by subtracting the corresponding swap rate from the most recently issued corporate bonds; a more reasonable measure is obtained of the price assigned to the credit risk in the bond market, than if the Government Bond rate were used.

On the other hand we have the relatively new CDSs Market. A standard CDS is basically an insurance contract through which an agent, the insured, makes periodical payments to another agent, the insurer, until the time that either the contract expires or the bond in reference in the contract fails, whichever happens first. In the event that the contract expires without the bond failing, the insurer does not make any payment to the insured. In the event that the bond fails before the contract expires, the insurer compensates the insured for the difference between the face value and the bond market value after the failure and the contract is liquidated. The premium of the CDS (spread), that is, the constant return λ on the face value of the bond paid by the insured to the insurer as a quota for the protection, directly gives us a measure quite close to the credit risk price estimated by the traders in this market. In effect, an equivalent definition for the variable that we have termed market price of credit risk in relation to a certain company, would be the premium that agents in that market would be ready to pay when they have a debt with that company, to convert such a debt into a debt of the same nature, but without the possibility of default, which is what λ precisely represents.

There are however various reasons for which λ can differ from the price that we wish to estimate. For example, let's suppose that the bond in reference has a face value of 100. The insured then possesses a put option on the bond, with 'strike' equal to 100 and which is executable in the event of default. If a bond market value below 100 is justified only by its credit quality, then the CDS premium will be equal to the market price of credit risk in this market. However, within what we have generically termed 'default', possible restructurings are included in which not all debt instruments are necessarily liquidated. If there are reasons that have nothing to do with credit risk, but that justify that the bond value be below 100 (liquidity problems, long maturity, special clauses such as a conversion clause), then the CDS gives the insured, in the case of restructuring, the option to sell a bond that may be worth 80, for 100. This can happen even though a default has not been strictly produced and although the price is not justified by the credit quality of the bond in question. Logically, the CDS premium will be superior to the price that would be fixed solely by the credit risk. Furthermore, the CDSs do not generally establish a bond, but a portfolio of reference bonds, generating by this means a 'cheapest-to-deliver option'. However, the entirety of deliverable assets has been limited since May 2001 for American CDSs (Blanco, Brennan and Marsh, 2003), tending to eliminate from the portfolio those bonds that, due to their special nature, could be traded with a substantial discount with regards to their face value, and to reconcile the CDSs premium with the premium that strictly corresponds to the credit risk price of this market.

Other considerations, which can also deviate the CDS premium with regards to the premium which would be established solely by credit risk, have to do with the possibility that the contract fixes a final premium payment in the event of failure, prior to the exchange of bonds, and that the said exchange is carried out at a price that does or does not include the accrued interest as well as the face value. These elements however seem to have a marginal effect on the CDSs premiums.[2]

So finally, it may be that the CDS premium is not exactly the market price of credit risk in this market, but we can assume that in the majority of cases it is a reasonable approximation.

Our last market is the stock market. In this case, the price that traders give to credit risk is not exactly explicit. It is necessary to use a theoretical model that allows, based on stock market values and other financial data, to derive the price that is implicitly being assigned to company credit risk.

[2] See Hull, Predescu and White (2003).

Merton (1974) was the first to establish a relationship between the market value of bonds and shares based on the theory of option pricing. His idea of a zero coupon bond as the only debt instrument of the company opened the door to more complex models, the so-called structural models. A brief list of those that are worth more attention include of course Merton (1974), but also Black and Cox (1976), Geske (1977), Leland (1994), Longstaff and Schwartz (1995) and Leland and Toft (1996). The natural method to validate a structural model is to verify whether it is capable of generating theoretical premiums which are consistent or not, with those traditionally observed in the bond market. This procedure presents some difficulties, since in order to replicate the observed premiums there would be a need to introduce all of those elements that help to explain such premiums, including for example liquidity risk (as we do not generally observe only the most liquid bonds) and even a demand for Government Bonds amplified by legal requirements in the event that these are used as a reference for a risk-free bond rate. For this reason Huang and Huang (2003) adopt a different approach to test several structural models in which the only variable relevant to explain the bond premium is the credit risk. They try to directly replicate the observed rates of default. They conclude that structural models are capable of replicating the said rates of failure for reasonable parameter values, but that those same parameters imply premiums that are typically below the bond spreads, spreads that in turn have been calculated taking the Government Bond rate as a reference for a risk-free rate. This would be consistent with the fact that the credit risk premiums represent only a part of the differential between the return on corporate bonds and the return on Government Bonds.[3] It is tempting therefore to conclude that the premiums generated in this way are those that are really attributable to credit risk. However, the idea that replicate observed default rates through a structural model directly leads to the replicating of the credit risk price unobserved in

[3] They likewise show that the proportion of the total premium represented by the credit risk premium is greater when the swap rate is used instead of the Government Bond rate as a measure of the risk-free rate. Eom, Helwege and Huang (2003) find on the other hand, that structural models do not suffer a problem of premium *under-prediction*, but of precision.

the stock market, and by extension in the bond market, must be taken with caution. The risk of default (a probability of failure strictly greater than zero) is a necessary element for credit risk to exist, but it is not the only element that affects the final price. The recovery risk, for example, assumes a fundamental part of the credit risk price and however, may depend at least partially on parameters that are relatively independent from those that lead to the replication of default rates.

There is not therefore a procedure that can be considered unquestionable when it comes to validating a structural model. Even if the only desired thing is to verify its capacity to predict the probability of default, this probability is also unobservable. As an approximation, we could consider the case of a 'representative' company in a given credit rating level in relation to leverage, volatility, etc., and check whether it can generate a probability of failure for this 'typical' company equal to the failure rate of the reference rating. The limitation stems from the fact that within the same rating there may be heterogeneous companies with regards to leverage, volatility and even, credit risk.[4]

To try to solve this problem, in this paper we present a modified version of the Leland and Toft model (1996) (referred to as LT from here on). As in the original case, the debt premium will have as its only determinant the company's credit risk, and therefore the model will directly provide the credit risk price in the stock market. The method of validation consists of verifying whether the model is capable or not of generating prices that are consistent with the prices obtained in the bond market and in the CDS market for reasonable values of the parameters. It is evident that such verification will be more reliable the greater our trust is with regards to the information obtained in those markets. Because of this, more than just selecting the most recently issued debt instrument and using the swap rate as a risk-free rate in the case of the bond market, we will begin the analysis

[4] See Kealhofer, Kwok and Weng (1998).

by focusing on the specific case of Ford Motor Credit Company. The Ford Motor Company bonds represent around 10% of the North American bond market (Chen, Lesmond and Wei, 2004), which leads us to believe that they are among the most liquid bonds, and that specially the CDSs that have these bonds as reference are among the most liquid of the CDS market. Once the model is validated, we will extend the procedure to the rest of our sample and will use the premiums generated as a measure of the estimated credit risk price in the stock market.

Other essays have compared the speed with which different markets incorporate new information about the companies' credit risk. Blanco, Brennan and Marsh (2003) analyse a sample of 33 companies and conclude that the CDS market heads the bond market in terms of the incorporation of new information. Although the effect of specific variables on the stock market is studied, the essay does not formally include the stock market as a third market in the analysis of price discovery. With regards to the methodology, they assume that the observed prices in both markets (bonds and CDSs) are co-integrated, which allows them to carry out the analysis using a vector error correction model (VECM). Certainly, such an approach could be interesting, but rests on the idea that the price in each market follows a non-stationary process, an assumption difficult to verify if the time series have relatively short span, like in this case (approximately a year and a half). For this reason and due to a lack of a longer series with which to verify the non-stationary hypothesis, it may be preferable to apply a more conservative methodology. The alternative would be based on the procedure used by Longstaff, Mithal and Neis (2003) who suggest a vector auto-regressive model (VAR) for the increases in bond spreads, increases in CDSs spreads and the returns in the stock market, in order to later compare the possible dependencies of the current changes in each market to the past changes in the other two markets. Using a sample of 68 firms, they conclude that the stock market as well as the CDS market head the bonds market with respect to the incorporation of new information.

Although the work presents the interesting novelty of explicitly incorporating the stock market, it appears somewhat limited because the comparison of information of the different markets is based on heterogeneous measures. In effect, whilst the use of the CDSs premiums provides a rather close measure of the credit risk price, the choice of the Government Bond rate as a reference rate in the bond market means the premium obtained is probably a biased measure of the credit risk price in that market. Being this point important, the major limitation arises however in the measurement of changes of perception of the credit risk in the stock market through the observed returns. The procedure that we propose in this paper offers the advantage of considering a homogenous measure of credit risk for all the markets.

The rest of the paper is organised as follows: Section 2 establishes the methodology with which the variables in each market will be created and with which the price discovery analysis will be made. Section 3 describes the sample of companies. Section 4 analyses the specific case of Ford Motor Credit Co., whilst Section 5 extends the methodology to the full sample. Lastly, Section 6 offers some conclusions and proposes future lines of investigation.

Methodology

Construction of Variables

The CDS Market

Let us begin with the CDSs market, as usually the available data regarding this market will condition the methodology to apply in the other two markets.

A CDS establishes an annual premium λ, in the form of basis points on the nominal value of the insured debt as payment for the protection, as well as certain maturity. Although this maturity may be between just a few months and more than 10 years, the development of the market has tended to adopt the 5 years contract. Let us therefore assume that we have a series of daily CDS-5y premiums for a certain company on their bonds designated in local currency. In accordance with the arguments in the introduction, we will consider this annual premium the measure of the credit risk price in the CDS market. Therefore

$$CDS_t = \lambda_t(5); \quad t = 1, ..., T \tag{1}$$

where $\lambda_t(5)$ is the CDS-5y premium for day t.

The Bond Market

It is evident that the credit risk price will depend on the maturity of the debt to which we are referring. In other terms, a particular market's agents will not claim the same premium for bearing the credit risk of a company for a month as they would for bearing the credit risk for 10 years. We have assumed that in the CDSs market the price we have is what the traders assign to bear the credit risk for 5 years, and therefore in order for our comparison to make sense, we must obtain the corresponding price in the bond market. However, although the daily swap rate for 5 years is readily available, we will rarely observe returns in corporate bonds that have exactly the same maturity. It is therefore necessary to create an estimation of this constant return for 5 years based upon the available bond returns.

Following the ideas of Blanco et al. (2003) we will look for two bonds, which have the following characteristics:

1. Designated in local currency.
2. Without special clauses, such as a buyback clause.
3. One of the bonds throughout the period of reference (the period for which we have information of CDSs) has a maturity of less

than 5 years but more than 1 year, whilst the other has a maturity of more than 5 years for the whole period.

4. Given the above characteristics, they are the most recently issued bonds and those that have maturity closer to 5 years.

Then carrying out a linear interpolation between the return of the two bonds it is possible to obtain an estimated series of returns for 5 years.

It is appropriate to restrict the bond to a maturity of less than 5 years and at the same time greater than 1 year, since as the maturity is closer to zero the return of the bond can remain constant, tend toward zero, or increase substantially depending on its credit rating, which would make the linear interpolation particularly inappropriate if we were to work with bonds that would expire very quickly. With the same objective of minimising the effects of the linear interpolation, we will select those bonds that have maturity closer to 5 years. Finally, as mentioned in the introduction, we will select the most recently issued bonds, as they are generally the most liquid. If $y_t(5)$ is the return for 5 years obtained for day t, and $r_t^s(5)$ is the corresponding swap rate (5 years and in local currency), the series of prices assigned to the credit risk in the bond market will be shown as

$$CS_t = y_t(5) - r_t^s(5); \quad t = 1, ..., T \tag{2}$$

The Stock Market

Modifying LT Model

In the case of the Stock Market, as already mentioned, we will consider a modified version of Leland and Toft (1996). Following the LT model, we will assume that the value of the company's assets evolves in accordance with the diffusion process, expressed as

$$dV = (\mu - \delta)Vdt + \sigma Vdz \tag{3}$$

where μ is the expected assets return, δ is the constant fraction of the assets value dedicated to payment to investors, σ is the constant volatility of the assets return, and z is a standard Brownian motion process. If failure occurs on V reaching a specific critical point V_B, then the results obtained by LT imply that at any t the value of a bond with maturity τ, principal $p(\tau)$, coupon $c(\tau)$, and which receives a fraction $\rho(\tau)$ of the value of the company's assets in the event of default, will be expressed as

$$d(V,\tau,t)=\frac{c(\tau)}{r}+e^{-r\tau}\left[p(\tau)-\frac{c(\tau)}{r}\right][1-F(\tau)]+\left[\rho(\tau)V_B-\frac{c(\tau)}{r}\right]G(\tau) \qquad (4)$$

where r represents the risk-free rate, and

$$F(\tau)=N[h_1(\tau)]+\left(\frac{V}{V_B}\right)^{-2a}N[h_2(\tau)] \qquad (5)$$

$$G(\tau)=\left(\frac{V}{V_B}\right)^{-a+z}N[q_1(\tau)]+\left(\frac{V}{V_B}\right)^{-a-z}N[q_2(\tau)] \qquad (6)$$

with

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

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

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

In the original model, LT find a closed expression for V_B as an endogenous result. It is specifically the assets value that the stockholders consider to be the optimum value to declare a company in bankruptcy, and to leave it in the hands of the creditors. It may be preferable not to use this expression for various reasons: Firstly, because it is based on the hypothesis that the company will issue debt always with the same principal, coupon and maturity, which can be an overly restrictive hypothesis. Secondly, because one of the arguments is the tax rate, which can be difficult to estimate as it depends on the representative investor. An alternative is to express the point of bankruptcy as a fraction β of the nominal value of the total debt issued P.[5] Therefore, the term $\rho(\tau)V_B$ in (4) will be expressed as $\rho(\tau)\beta P$.

Let us assume that all the bonds have the same priority and therefore, in the event of bankruptcy, each creditor receives (after taking into account the possible costs of liquidation) the part that reflects their participation in the company's total debt. If liquidation costs, or bankruptcy costs, represent a fraction $\alpha \in [0,1]$ of the assets value, then

$$\rho(\tau) = (1-\alpha)\frac{p(\tau)}{P} \tag{7}$$

and therefore, what each creditor will finally receive in the event of bankruptcy will be

$$\rho(\tau)\beta P = (1-\alpha)\beta p(\tau) \tag{8}$$

now leaving formula (4) as

$$d(V,\tau,t) = \frac{c(\tau)}{r} + e^{-r\tau}\left[p(\tau) - \frac{c(\tau)}{r}\right][1 - F(\tau)] + \left[(1-\alpha)\beta p(\tau) - \frac{c(\tau)}{r}\right]G(\tau) \tag{9}$$

and with $V_B = \beta P$ in formulas (5) and (6). Please note that the recovery rate will be $(1-\alpha)\beta$.

[5] Leland (2002) demonstrates that in default prediction terms, it is equivalent to use the expression obtained in LT or to use the term βP for an adequate value of β.

The total value of the debt will be the value of all the company's bonds. Let us suppose that the company has N issued bonds, being τ_i the maturity of the i–th bond for $i = 1,...,N$. Then

$$D(V,t) = \sum_{i=1}^{N} d(V,\tau_i,t) \tag{10}$$

where $d(V,\tau_i,t)$ corresponds to equation (9).

LT make on the other hand a distinction between the market value of the company's assets and the market value of the same assets with leverage. As Goldstein, Ju and Leland (2002) state, such a distinction presents various difficulties, some as obvious as assuming that the equity capital value is an increasing function of the tax rate. We therefore prefer to use the alternative approach of the last authors. The idea is that the value of the company's assets, indebted or not, should reflect the present value of all future cash flows that the company could generate, and that these cash flows are not affected by leverage. On the contrary, the only thing this leverage does is to modify how these flows, and so the company value, is distributed between those agents who have rights to the cash flows. In this way, a company without debt is shared between shareholders and the Government, where the Government acquires rights to the cash flows in the form of taxes. If the company issues debt, then there will be four agents that have rights to the cash flows: The shareholders, the creditors, the Government and the 'lawyers', who will receive part of the company's income in the event of bankruptcy. In order to simplify things let us assume there are no taxes. Then, and in accordance with the previous arguments, the following relation for any t will have to be met:

$$V(t) = S(V,t) + D(V,t) + BC(V,t) \tag{11}$$

where $S(V,t)$ and $BC(V,t)$ represent the market value of the equity capital and of the lawyer's fees in the case of default, or simply bankruptcy costs, respectively.[6] Continuing with our line of reasoning that the indebtedness does not alter the value of the company but only its distribution, the existence of bankruptcy costs will have the sole effect of transferring value from the creditors to the lawyers, who, to the detriment of the creditors, will receive part of the company's actions in the event of bankruptcy.[7] Therefore,

$$BC(V,t) = D(V,t \mid \alpha = 0) - D(V,t) = \sum_{i=1}^{N} \alpha\beta p(\tau_i) G(\tau_i) \tag{12}$$

Finally, we can use the formulas (11) and (12) to express $S(V,t)$ as

$$S(V,t) = V(t) - D(V,t \mid \alpha = 0) \tag{13}$$

Model Calibration

The price given to credit risk in the stock market at time t, could be obtained from equation (9) as the resulting premium from issuing at par value a hypothetical bond with maturity equal to 5 years. This bond should pay a coupon such that the following equation holds

$$d(V,5,t | p) = p \tag{14.a}$$

Noting this coupon as $c_t(5,p)$, the bond return would be

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[6] Of course identifying all the bankruptcy costs with lawyer's fees is quite restrictive, but seems a useful way to think of such costs. It is interesting on the other hand to verify that when there are no taxes there is no 'formal' contradiction between the approach of LT and that of Goldstein, Ju and Leland (2001). If we identify the sum of the equity capital and the debt as the *market value* of the company, this will be expressed as $v(V,t) = S(V,t) + D(V,t) = V(t) - BC(V,t)$, which is in line with the results of LT in the absence of taxes. However, now $V(t)$ will not be interpreted as the market value of the company's assets that are not indebted, but instead as *the economic value* of the company, or the present value of all the cash flows that the company can generate.

[7] At the time of issuing debt, the existence of bankruptcy costs will make the creditors claim a greater interest rate, implying an indirect loss for the shareholders.

$$y_t^E(5) = \frac{c_t(5,p)}{p} \tag{14.b}$$

and the market price of credit risk in the stock market would be then the difference between the return of this hypothetical bond and the risk-free rate

$$ICS_t = y_t^E(5) - r \tag{14.c}$$

Such a procedure requires however in each t moment availability of information regarding

I.1. Company value V.
I.2. Nominal value of total debt P.
I.3. Risk-free rate r.
I.4. Pay-out rate δ.
I.5. Asset volatility σ.
I.6. Bankruptcy costs α.
I.7. The indicator of default point β.

parameters and variables that in the majority of cases are not observable, and that should be therefore calibrated.

Adapting a theoretical model to real data is usually a complex exercise, and this case is not an exception. As an example let us consider the risk-free rate. In the original model this rate is constant. We could calculate the average of the swap rate for the whole period,[8] but not this, nor any other procedure that intends to provide a constant rate, would be free from criticism. On the other hand, using for each t the observed rate in that period leads to the paradox of assuming that the agents modify the reference rate each day, and at the same time that they assume that there will be no more changes in the future. The

[8] We will use the swap rate as an approximation of the risk-free rate with the objective of being consistent with the bond market.

problem is even worse if we consider that the model assumes a completely flat interest rate curve.

Taking into account these limitations, we will assume that the only constants are the bankruptcy costs, the volatility of the assets and the default point indicator,[9] allowing the rest of the inputs to depend on t.

With the objective of compiling the information described in points I.1. – I.7, we will begin by obtaining the following:

- D.1. Daily information on stock market capitalization.
- D.2. Accounting data referring to:
    - D.2.1. Short term liabilities (STL).
    - D.2.2. Long term liabilities (LTL).
    - D.2.3. Interest Expenses (IE).
    - D.2.4. Cash Dividends (CD).

Given that accounting data cannot be obtained with daily frequency, it will be necessary to carry out an interpolation between the available observations (normally on a quarterly, semester or annual basis), with the objective of collecting the evolution of these variables throughout the time.

The total liabilities (TL) will be the sum of short term liabilities and the long term liabilities. We can therefore approximate P_t as

$$P_t = TL_t; \quad t = 1, ..., T \tag{15}$$

[9] It is possible that to some readers the hypothesis of constant volatility appears particularly controversial. There is a need to remember however that σ represents the volatility of the company's total assets, not of the equity capital, and that the hypothesis of constant assets' volatility is compatible with the stochastic volatility of the equity capital given that the company maintains debt between its financial sources. On the other hand, although we consider β as a constant in the sense that it does not vary in daily terms, it may be useful as we will see, to allow its value to be readjusted in monthly, trimester, semester or annual terms.

At the same time, we may express δ_t as a function of the total value of assets at t, as well as the payment of dividends and interests

$$\delta_t = \frac{CD_t + IE_t}{V_t}; \quad t = 1, ..., T \tag{16}$$

To estimate the series of assets' value V_t, as well as the volatility σ, we will make use of formula (13). It is worth noting now that that such a formula includes the total value of the debt without bankruptcy costs, and that the formula that expresses this is constructed from the characteristics of the company's individual bonds. It is therefore necessary to interpret the available information about the debt (short and long term liabilities, as well as interest payments) in terms of individual bonds.

One possibility would be to assume that the debt consists of two bonds, one with the nominal value of the short term liabilities, and one with the nominal value of the long term liabilities. However, considering the collection of the whole debt in just two instalments can also cause the results to largely depend on the choice of these. Our alternative is to assume that in each instant t there are 10 company's bonds in the market: One with a maturity of 1 year and a principal equal to the short term liabilities STL_t, and nine with a maturity between 2 and 10 years, each with a principal that is a 1/9 of the long term liabilities LTL_t. Stohs and Mauer (1996) consider a wide sample of companies and find that 95% of the total debt has a maturity of less than 10 years. The proposed procedure offers the advantage of assuming that the debt repayment is made in a relatively homogenous way, and throughout a period that reasonably corresponds to the literature.

The next step will be to assign to each of those bonds an annual coupon that represents a fraction of IE_t, proportional to the weight of its nominal value to the nominal value of the total debt. Under this idea, the total value of the debt without bankruptcy costs will be given in each moment t by (10) under the restriction $\alpha = 0$, where $N = 10$. Furthermore, we will need to collect the following information:

D.3. Daily data of the swap rate for years 1 to 10, that is, $r_t^s(\tau); \tau = 1, ..., 10$.

This in turn provides us with the rate to apply in (14):

$$r_t = r_t^s(5); \quad t = 1, ..., T \tag{17}$$

Following this we should determine the parameters α, σ and β, as well as the series V_t. Let us assume that for now we have the value of α and of β. In this case we are left to calibrate the series V_t and σ, which applying the following algorithm could do:

1. Propose an initial value for σ, σ_0.[10]
2. Evaluate the series of V_t, such as (13) is fulfilled for all t.
3. Estimate the volatility of V_t, σ_1, from the series obtained in 2.
4. Conclude if $\sigma_1 = \sigma_0$. Otherwise, propose σ_1 at step 1 and repeat until convergence.

This procedure generates (for a value of β), a value for σ and a series V_t, which are consistent with the observed stock market capitalisation. In brief,

$$(V_t, \sigma; t = 1,...,T) \equiv (V_t, \sigma; t = 1,...,T) \big| \ \textit{Is the solution of the algorithm} \tag{18}$$

[10] Vassalou and Xing (2004) establish a similar procedure to calibrate the volatility in the Merton model (1974), using the volatility of the equity capital as an initial proposal to derive the volatility of the company's assets. This is a reasonable way to proceed although not necessarily the most efficient: The volatility of the equity capital will be greater than the company's assets volatility anyway. Therefore, this procedure starts the search with a biased estimation of the volatility that we wish to estimate. In our case we start from the value of 0.2, which is used in many calibration exercises. We have checked that, in any case, the result obtained is robust with regards to the initial proposed value.

We could therefore obtain the implicit credit premiums in accordance with (14), although this still requires us to specify α and β. We proceed by setting a value for α, specifically,

$$\alpha = 0.3 \tag{19}$$

which seems reasonably in accordance with the literature.[11] β Will therefore be everything that is missing to solve (14).

It seems reasonable to believe that the higher the price level, the greater the discrepancy between the prices provided in the different markets.[12] The relationship between the price in the stock market and the price in the CDSs market could be therefore given by the expression

$$ICS_t = CDS_t \times e^{\varepsilon_t} \tag{20}$$

where ε_t are error terms i.i.d. with $E[\varepsilon_t] = 0$ and $Var(\varepsilon_t) = \sigma_\varepsilon$. An adequate measure of the discrepancy between these series will therefore be The Mean Squared Error:

$$MSE = \frac{1}{T}\sum_{t=1}^{T} \log\left(\frac{ICS_t}{CDS_t}\right)^2 \tag{21}$$

Given that we have already said it is not reasonable to expect significant differences between the prices assigned to credit risk in distinct markets, we can define β as the value of the indicator of the default point, which minimises this measure of discrepancy between the series, that is[13]

$$\beta \equiv \underset{\beta}{\operatorname{argmin}}\left(MSE\right) \tag{22}$$

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[11] See Leland (2002).

[12] See for example Bruche (2004).

[13] Obviously the series CS_t can also be taken as reference in the calculation of β.

It is important at this point to note that: Firstly, the choice of β fitting the criteria described does not guarantee a perfect adjustment between the ICSs series on one hand and the CDSs series on the other, in the same way that carrying out a linear regression does not guarantee an R-squared adjustment of 100%. Therefore, to apply such an adjustment does not prevent us from extracting conclusions about the validity of the model with regards to its capacity to generate ICSs series, which are consistent with the CDSs series whenever the obtained value of β is reasonable. Secondly, β modifies the general level of the ICSs, but not the sign of the changes in that variable. This is important since it implies that the results of the price discovery analysis will generally be robust faced with a moderate bias of the estimation of β.

In summary, the price attributed to credit risk is obtained starting with formula (14). The arguments in this (described in points I.1 – I.7.) can be estimated from the data mentioned in D.1. – D.3. and the formulae (14) - (22).

Analysis of Price Discovery

Once the CS, CDS and ICS series are constructed, we can establish the following VAR model for changes in the price of credit risk in the three markets:

$$\Delta CS_t = a_1 + \sum_{z_1=1}^{Z_1} b_{1z_1} \Delta CS_{t-z_1} + \sum_{z_1=1}^{Z_1} c_{1z_1} \Delta CDS_{t-z_1} + \sum_{z_1=1}^{Z_1} d_{1z_1} \Delta ICS_{t-z_1} + e_{1t} \qquad (23.a)$$

$$\Delta CDS_t = a_2 + \sum_{z_2=1}^{Z_2} b_{2z_2} \Delta CS_{t-z_2} + \sum_{z_2=1}^{Z_2} c_{2z_2} \Delta CDS_{t-z_2} + \sum_{z_2=1}^{Z_2} d_{2z_2} \Delta ICS_{t-z_2} + e_{2t} \qquad (23.b)$$

$$\Delta ICS_t = a_3 + \sum_{z_3=1}^{Z_3} b_{3z_3} \Delta CS_{t-z_3} + \sum_{z_3=1}^{Z_3} c_{3z_3} \Delta CDS_{t-z_3} + \sum_{z_3=1}^{Z_3} d_{3z_3} \Delta ICS_{t-z_3} + e_{3t} \quad (23.c)$$

where the errors e_{it} are i.i.d., and where Z_i for $i = 1, 2, 3$ can be defined according to the Schwarz Criterion. The price discovery analysis is made testing the null hypothesis that present changes in one given market are independent of past changes in another market. For example, if using the Wald Test, the null hypothesis $c_{11} = c_{12} = ... = c_{1Z_1} = 0$ is rejected, but we cannot reject the null hypothesis that $b_{21} = b_{22} = ... = b_{2Z_2} = 0$, then we will have evidence that the CDS market incorporates new information about company credit risk faster than the bond market. Repeating this analysis for all possible cases we will finally obtain general conclusions about the price discovery in the three markets. Additionally, we will carry out the Granger Causality Test for each couple of series. To do this we will consider one of the three possible couples of series and we will establish the VAR model excluding the remaining series. We will then obtain the number of optimum lags according to the Schwarz Criterion for the VAR model, and will carry out the Causality Test. We will repeat this procedure for the three possible couples of series.

Data Description

The CDSs Market

Our initial sample of CDSs contains daily data about 5 years premiums for 52 North American and European non-financial companies. This information has been provided by Banco Santander and is taken from the period between the 12th of September 2001 and the 25th of June 2003. We exclude those firms located in European countries that do not belong to the single currency zone, as the available CDSs for these companies are those designated in euros.

The Bond Market

In this case corporate bond returns that satisfy the described conditions in Section 2.1.2., as well as the 5-year swap rate, both in dollars and euros, are collected from DataStream. One company has been excluded for generating negative premiums.

The Stock Market

For this last market, stock market capitalization and accounting data have been obtained from Standard & Poor's for the inclusive period between the 2nd of January 2001 and the 30th of June 2003. For some companies the accounting data has been completed using the available information from DataStream. The swap rate, as for the bond market, has been taken from DataStream, although this time for a maturity of 1 to 10 years.

Implementation and Additional Limitations

The general procedure to estimate the ICSs from the stock market series described in section 2.1.3., is implemented in our case following the next steps:

I. The accounting data in each moment t is determined through the linear interpolation between the data on the 2nd of January 2001 and the 30th of June 2003.

II. We divide the sample period into natural semesters with the objective of allowing parameter β to be adjusted for each of those semesters. We therefore have a maximum of 4 sub-periods for each company, that is, 01/2 (with observations only starting from the 12th of September), 02/1, 02/2 and 03/1 (with observations only until the 25th of June). Those companies for which there is no information for at least 3 consecutive semesters have been eliminated, and no semester is included if it does not have at least 50 observations. These additional limitations leave us with a final sample of 21 companies. The total number of price discovery tests to be performed is 65.

III. Once the companies that form our sample and the semesters that will be included for each one are defined, we will make a first estimation of β, β_{01-03}, assuming that it is constant throughout the whole period.

At this point it is important to realize that a change in β has two contrary effects over the mean level of the ICS series that we pretend, somehow, to adjust to the mean level of the CDS series. On one hand there is a default probability effect (DPE), that consists in that a higher β implies a higher default point and therefore, a higher default probability and a higher mean level for the ICS series. On the other hand there is a recovery rate effect (RRE), that follows from the fact that a higher β implies a higher recovery rate and a lower mean level for the series. To see which effect dominates the other, and when, let us start by considering the limit case of $\beta = 0$. For this value of β the recovery rate in case of default is cero, but because there is a null probability for this event (as the barrier is also at cero), all the points of the ICS series will be equal to cero. An increase in β will generate positive credit risk premiums, that is, for small values of β, the DPE will dominate the RRE. As β increases the RRE will tend to be higher, and eventually will dominate de DPE. In the other limit case of $\beta = 1/(1-\alpha)$, the default probability will be 'very high', but as the recovery rate is equal to 1 there is no credit risk, so all the points of the ICS series will be again equal to cero.

In brief, the mean level of the ICS series will be a concave function of β that takes value cero for $\beta = 0$ and $\beta = 1/(1-\alpha)$. The result is that in searching the value of β according to (22), we may fall into two quite different solutions depending on the starting value for the search: Either a small β that implies a small default probability, but with a recovery rate $(1-\alpha)\beta$ that is also small, or a large β, that implies a high default probability but, in the event of this occurring, also a large recovery rate. This large β is typically above 1, which is not rational from the point of view of the shareholders.[14] For this reason we will apply the following procedure with the objective of ensuring that we find the more reasonable first solution (in which the DPE dominates the RRE):

- III.1. We choose an initial value that is sufficiently small for β_{01-03}, β_0 (specifically 0.3), and define $\beta_1 = \beta_0 + 0.05$.
- III.2. We evaluate $MSE_0 = MSE(\beta_0)$ and $MSE_1 = MSE(\beta_1)$.
- III.3. If $MSE_1 < MSE_0$, then we define again β_0 as $\beta_0 = \beta_1$ and go back to step III.1.

[14] A value of β greater than 1 implies that the total assets value is greater than the total nominal value of the debt in the event of failure. In this case the stockholders could simply sell the assets, liquidate the debt, and be left with the surplus instead of leaving all assets in the hands of creditors and lawyers.

III.4. If $MSE_1 \geq MSE_0$, then we look for the value of β that minimizes the MSE in the interval $(\beta_0 - 0.05, \beta_0 + 0.05)$.

It must be highlighted that each proposal for β implies a new estimation of the volatility of V_t, $\sigma(\beta)$, which is in keeping with the algorithm described in Section 2.1.3. For this estimation we make use of all the available information, that is, the stock market capitalization series and the accounting data from the 2nd of January 2001 to the last date for which we simultaneously have available CS and CDS data. This means making the assumption that this value of β is also applicable to the period for which we have data from the stock market but not from the other markets.

IV. Once β_{01-03} is estimated, we can use this as an initial value for the estimation of the vector $\beta_s = \{\beta_{01/2}, \beta_{02/1}, \beta_{02/2}, \beta_{03/1}\}$. Again, each proposal of a vector β_s implies a new estimation of the volatility.[15] For those periods in which we only have information about the stock market we apply the closest (on time) value for β.

The Ford Motor Credit Co. Case

We begin with this company because, as mentioned, we expect their bonds, and especially the CDSs on those bonds, to be among the most liquid in the market.

Figure 1 shows the CS, CDS and ICS time series for Ford Motor Credit Co.[16] Panel A of Table 1 shows the value of the estimated parameters in this case, as well as the resulting MSE adjustment of the ICS and CDS series. The constant β is 0.93 and the asset volatility is

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[15] In this case we omit the leaps between semesters to prevent a bias in the estimations of σ.

[16] The data for the stock market has been taken from Ford Motor Company.

around 5%. In the case of a constant β the recovery rate $(1-\alpha)\beta$ is also constant and equal in this occasion to 0.65.

Panel B shows descriptive statistics of these series whilst in Panel C we collect the measures of discrepancy usually considered in the literature: The average basis (avb), the percentage average basis (avb(%)), the average absolute basis (avab) and the percentage average absolute basis (avab(%)). The data confirms what is evident at first glance in the graph, which is a good adjustment between the different series. Particularly notable is the consistency between the estimated price for the stock market and the estimated price obtained for the other two markets, which obtains through reasonable values of the unobserved parameters (Panel A).

Panel D shows the results of a first analysis of the Price Discovery procedure for each semester. The number of optimum lags for each equation of the model varies between 1 and 2 according to the Schwarz Criterion. Likewise, the t-statistic or the F-statistic is shown, resulting from the Wald Test for the null hypothesis from which the coefficients of the explanatory variables are equal to zero. The Panel also shows the F-statistic that summarizes the overall significance of each equation. The main conclusion from this Panel is that, in the case of Ford Motor Credit Co., and for the considered period, the stock market clearly headed the other markets in the incorporation of new information about company credit risk, without a clear leader pattern between the bond market and the CDSs market. These results are confirmed in Panel E where Granger Causality Tests for the distinct couples of time series are shown. The number of optimum lags for each VAR model varies as well between 1 and 2. (dngc = does not Granger causes).

Results for the Full Sample

We now extend the analysis to a total sample of 21 companies. Table 2 contains descriptive statistics, whilst Table 3 shows the distinct measures of discrepancy between the series. The total number of pieces of information for the 21 companies in the three markets is 25371 daily data points.

Of the 21 companies one stands out for the apparent excessive size of the MSE (1.2619). This company is the Spanish Petroleum Company, Repsol YPF SA. Figure 2 shows the CS, CDS and ICS series for this company. It is evident that the general level of the ICS series is systematically below the other two, which maintains a close relationship between them. A detailed study of the circumstances of the company reveals an interesting situation: As Standard & Poor's report of the 26 of March 2002 indicates, part of Repsol YPF SA's debt (8.000 million Euros) was (at least at that time) subject to a clause that allowed the creditors to declare the debt in default if the Argentinean subsidiary company YPF SA failed to pay its debt by an amount superior to 20 million dollars. This clause has the incentive effect on Repsol YPF SA to financially support YPF SA. Standard and Poor's remarked moreover on the individual nature of this clause between the European debt issuers. The effect that this clause can have on the bond spreads of Repsol YPF SA and on the CDSs traded on these bonds is evident (as much as if they are directly affected by the said clause as if not). We have decided therefore to eliminate this company from our sample.

The company with the next largest MSE (0.1464) is Telecom Italia SPA. Although this MSE is not as in the previous case substantially greater than for the rest of the companies, it is relevant that this company, together with Repsol YPF SA, is the only company to have a percentage average basis of two digits (-20%). It must be highlighted that this company merged with Olivetti just a few months after our sample period, news about the merger going back to 2001. Figure 3 shows the CDS of Telecom Italia SPA as well as the CDS of Olivetti. It is clear that as the merger came closer a convergence of the CDSs of the two companies was produced. It seems reasonable to assume that the risk of the company that would end in the merger was being represented more and more by the CDSs of Telecom Italia SPA throughout our sample period, and the CDSs represented less of the associated risk particular to the company's own financial situation. As in the case of Repsol YPF SA, the CDS market reflects in its premiums information that, being relevant in order to evaluate the credit risk of the company, is not completely included in the evolution of the stock market capitalization nor in its accounts. In both cases the credit risk of the company is not completely reflected in the financial information of the company, but it depends to some extent on the financial information of another company. We have decided therefore to also eliminate Telecom Italia SPA from the sample.

The last company that we will eliminate is Royal Ahold. Figure 4 shows the three series of premiums for this company. The leap that is produced at the end of February 2003 is due to the information about accounting irregularities in its American subsidiary Foodservice. Although it is clear that the three markets react jointly to this information, it is not possible to reliably determine which is the new credit risk price estimated by the stock market. The reason is that although the model incorporates the correction of the equity capital value, the same does not occur with the correction of the total debt, which could have been discounted in the markets following the detection of fraud.

Tables 2 and 3 therefore show the averages for the 21 original companies, as well as the averages that come from eliminating the three companies mentioned. Table 4 contains the resulting parameters of the estimation of the ICS series where we no longer include the three companies excluded from our original sample of 21. Looking at Panel A, which reflects the results of the first stage of the estimate in which a constant [illegible] is assumed, it highlights on one hand that the average recovery rate is 0.55, very much in line with the historical average. On the other hand, the close relationship shown in Graph 5 between the default point indicator and the volatility stands out. Carrying out a linear regression in which the independent variable is $\sigma(\beta_{01-03})$ and the dependent variable is β_{01-03}, the slope is significant at 1%, and with a negative sign as the structural models with an endogenous bankruptcy point normally predict. This variable explains by itself 85% of the variability of β_{01-03}.

For two companies, Endesa and Fiat, we observe a value of β_{01-03} slightly greater than 1. Despite not being in line with the hypothesis of shareholders' rationality, a β_{01-03} estimated slightly greater than 1 can be justified by some bankruptcy costs greater that the 30% assumed. Note that some larger bankruptcy costs imply, for a given β_{01-03}, a lower recovery rate and a higher level for the ICS series. The mean level of the CDS series will be then explained by a β_{01-03} value greater than the original one (under the assumption that the DPE still dominates the RRE for the new value of α). At least in the case of Fiat the reason seems however to be something else: As Blanco, Brennan and Marsh (2001) state, the CDSs on Fiat for our sample period had a large cheapest-to-deliver option component. This fact probably has the effect of generating a β_{01-03} greater than what would be produced in the absence of this option.

Table 5 contains the results of the price discovery analysis. Panel A shows the rejections of the different null hypotheses, in terms of the total number of companies and semesters in our sample. For example, Column A1 indicates that for 40 cases over 65 (62%), the null hypothesis that past changes in the CSs are not important to the explanation of current changes in the CSs is rejected at the 95% level of significance. From Panel A it can be seen that, for our sample, the most predictable market is the bond market (50 rejections of the null hypothesis of no significance of the model), followed by the CDSs market (35) and lastly the stock market being the least predictable (7 rejections). On 25 occasions past changes in the CDSs are important for explaining current changes in the CSs, and on 18 occasions past changes in the CSs are important for explaining current changes in the CDSs. This lack of clear leadership in the bond and CDSs markets is confirmed by carrying out the Granger Causality Test.

This test is in Panel B. For instance in Column B1, excluding the stock market, for 25 cases the null hypothesis that changes in the CSs do not cause, in Granger's sense, changes in the CDSs, is rejected. The contrary hypothesis is rejected for exactly the same number of cases. For ICSs we may see that only in 8 (5) cases the hypothesis that CS (CDS) does not Granger-causes ICS is rejected. Similarly we may see that in 22 (29) cases the hypothesis that ICS does not Granger-causes CS (CDS) is rejected. The overall impression is that stock market is leading the other two markets in most cases, which is confirmed through the Granger Causality Test.

Conclusions

Credit risk is a fundamental element in bond, CDSs and stock prices. These assets are traded in markets that differ greatly in terms of organization, liquidity and traders, which can give rise to new information about credit risk being incorporated into the price of some assets more quickly than in others. This paper establishes a methodology that allows the analysis of which markets incorporate the said information first, and applies the methodology to a sample of North American and European companies.

We begin with a formal definition of credit risk: Risk due to losses associated with the event of failure to pay of the borrower, or the event of deterioration of its credit rating. We then propose a measurement of this risk in accordance with the definition given: The market price of credit risk, or premium that the agents of a certain market would claim for the debt with a possibility of default of a certain company, in relation to a debt of the same nature, but without a possibility of default. As a next step we define the form in which such a variable can be estimated for each market based on the available information in that market. More specifically, we establish that the price attributed to credit risk in the bond market will be measured by the differential between the return on the bonds and the corresponding swap rate, by the CDSs premiums in the market in which these CDSs are traded, and in the case of the stock market, by the theoretical premium generated by a modified version of the Leland and Toft (1996) model. Here the distinction between the value of the leveraged assets and the non-leveraged assets of a company is avoided and the default point is determined based on the available information in the other markets. That allows us for the first time in the literature as far as we know to present homogeneous measures of the market price of credit risk.

From the application of our methodology to the sample it is deduced that the proposed modification of the Leland and Toft (2001) model allows implied credit spreads to be generated for the stock market that are consistent with the observed spreads in the other markets. On carrying out a linear regression in which the default point indicator acts as a dependent variable and the asset volatility acts as an independent variable, we find a negative and significant relationship in line with what was established by the structural models with an endogenous default point. The volatility also explains by itself 85% of the variability of the estimated indicator point of bankruptcy.

The price discovery analysis is carried out by means of a VAR model for the daily increases in prices in each of the three markets. This analysis reveals that in most cases the stock market clearly headed the other two markets. However, there is not a clear pattern of leadership between the bond market and the CDSs market.

Future work should verify the results obtained here using a larger sample of companies and time periods. This would allow a validation of the proposed structural model as well as the calibration procedure employed. It must be remembered that although the calibration is based on the stock market capitalization and accounting information, we estimate the parameters of the model with the objective of the price in the stock market being consistent with the price in the CDSs market, or alternatively in the bond market. In many cases however, the information about the price in these last two markets is not available, is not easy to find, or simply is unreliable, and it will be precisely in these circumstances when the information about the price in the stock market is the most valuable. It would be suitable therefore to study, based on companies for which sufficient information exists about other markets, whether a functional relationship can be established between the stock market capitalization and the accounting data of a company on one hand, and the parameters of the model on the other, in a way that the market price of credit risk in the stock market can be derived even in the absence of information about the price in the other markets. Recent studies have demonstrated the potential of the maximum likelihood estimation for the non-observed parameters in the structural models. Some examples would be the works of Duan, Gauthier, Simonato, and Zaanoun (2003), Duan, Gauthier, and Simonato (2004), Ericsson and Reneby (2004a, 2004b), and Bruche (2004). It would be interesting to study the possible application of the said method of estimation to the proposed model in this paper. This is left for future research.

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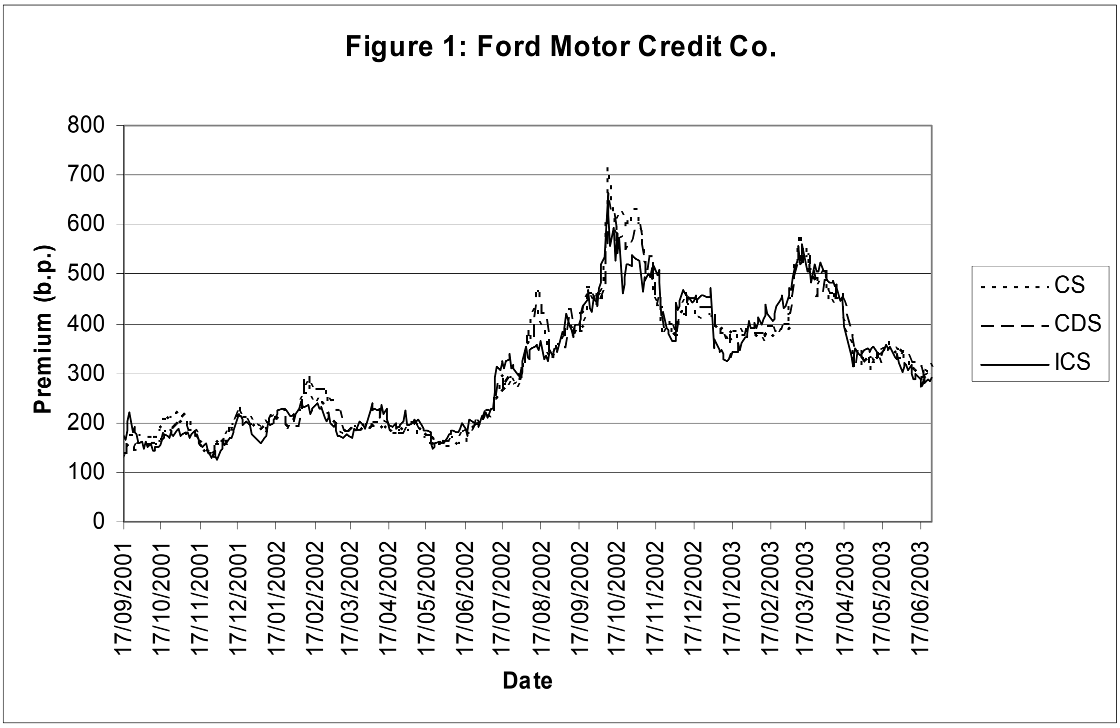

Figure 1: Ford Motor Credit Co.
800
700
600
500
400
300
200
100
0
Premium (b.p.)
17/09/2001
17/10/2001
17/11/2001
17/12/2001
17/01/2002
17/02/2002
17/03/2002
17/04/2002
17/05/2002
17/06/2002
17/07/2002
17/08/2002
17/09/2002
17/10/2002
17/11/2002
17/12/2002
17/01/2003
17/02/2003
17/03/2003
17/04/2003
17/05/2003
17/06/2003
Date
CS
CDS
ICS

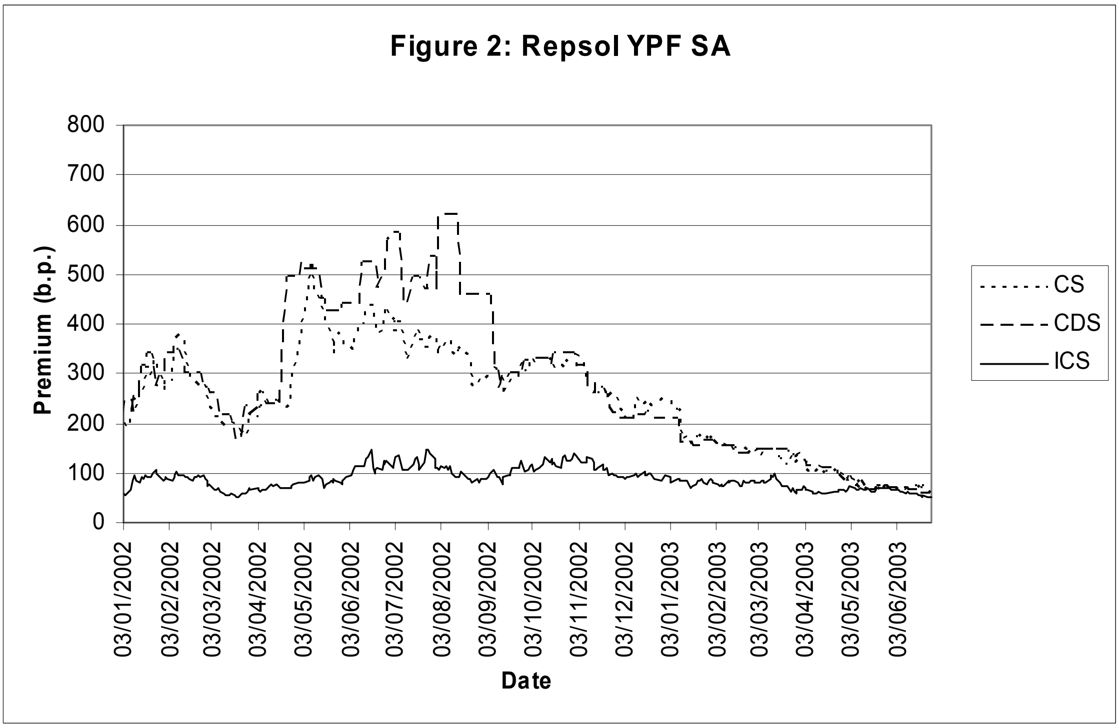

Figure 2: Repsol YPF SA
800
700
600
500
400
300
200
100
0
Premium (b.p.)
03/01/2002
03/02/2002
03/03/2002
03/04/2002
03/05/2002
03/06/2002
03/07/2002
03/08/2002
03/09/2002
03/10/2002
03/11/2002
03/12/2002
03/01/2003
03/02/2003
03/03/2003
03/04/2003
03/05/2003
03/06/2003
Date
CS
CDS
ICS

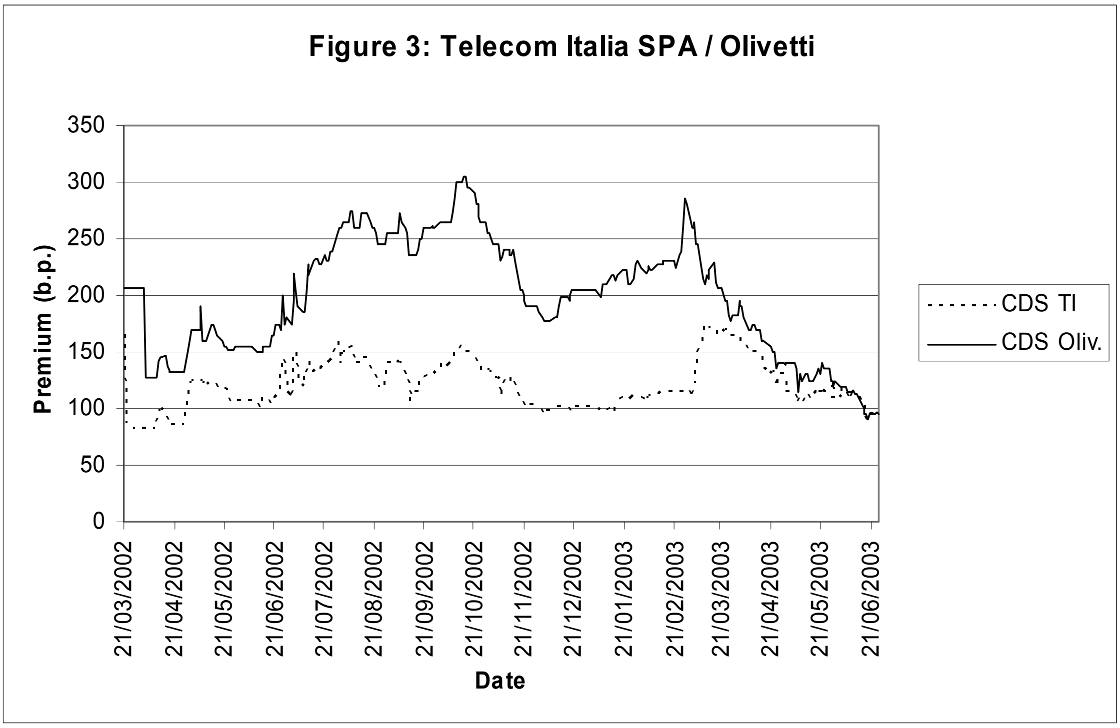
Figure 3: Telecom Italia SPA / Olivetti
Premium (b.p.)
0
50
100
150
200
250
300
350
21/03/2002
21/04/2002
21/05/2002
21/06/2002
21/07/2002
21/08/2002
21/09/2002
21/10/2002
21/11/2002
21/12/2002
21/01/2003
21/02/2003
21/03/2003
21/04/2003
21/05/2003
21/06/2003
Date
CDS TI
CDS Oliv.

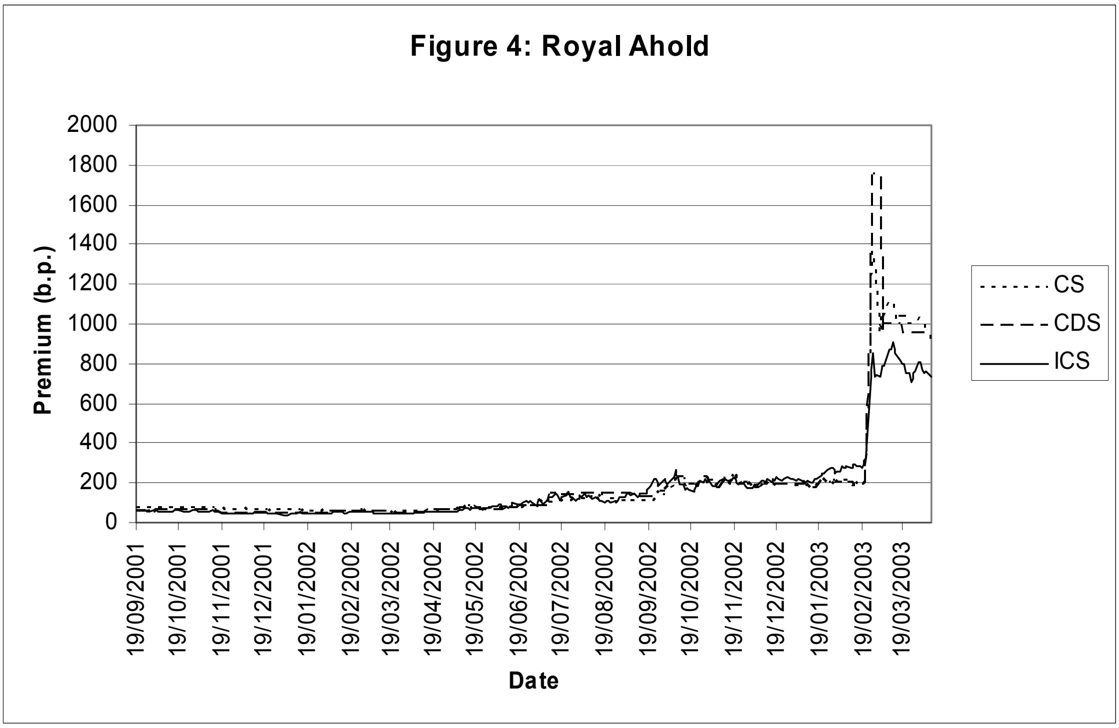
Figure 4: Royal Ahold
Premium (b.p.)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
19/09/2001
19/10/2001
19/11/2001
19/12/2001
19/01/2002
19/02/2002
19/03/2002
19/04/2002
19/05/2002
19/06/2002
19/07/2002
19/08/2002
19/09/2002
19/10/2002
19/11/2002
19/12/2002
19/01/2003
19/02/2003
19/03/2003
Date
CS
CDS
ICS

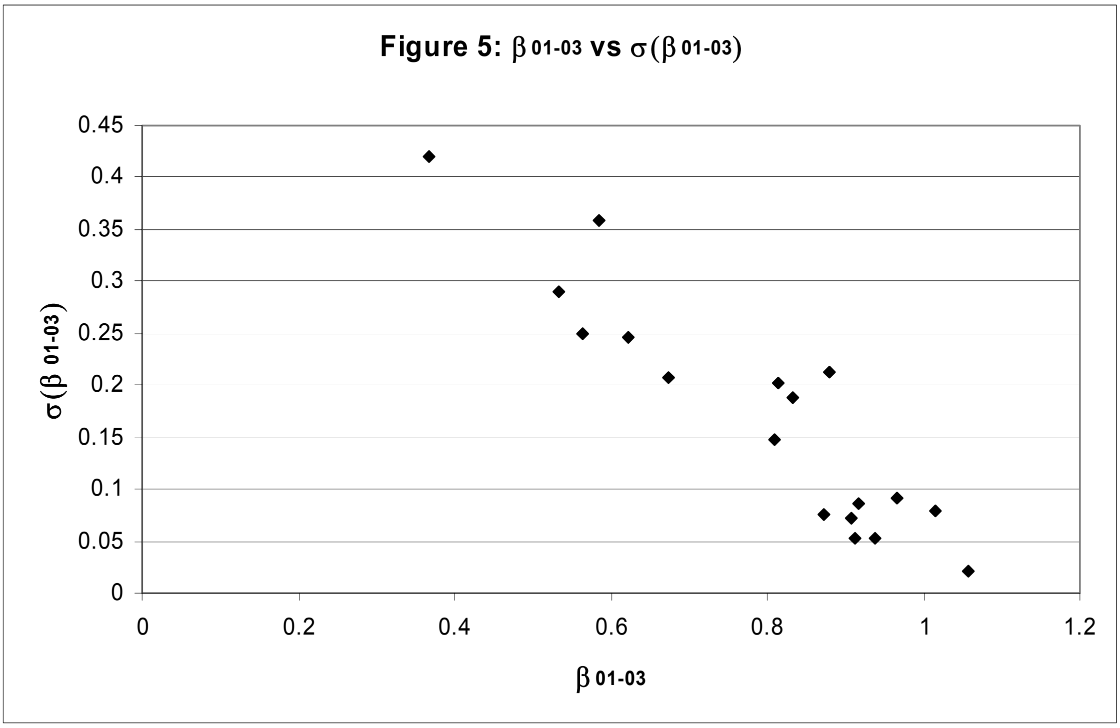
Figure 5: β 01-03 vs σ(β 01-03)
σ(β 01-03)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.2
0.4
0.6
0.8
1
1.2
β 01-03

TABLE 1: FORD MOTOR CREDIT CO.

A: CALIBRATION PARAMETRES

		$\beta_{01/2}$	0,9419
β_{01-03}	0,9375	$\beta_{02/1}$	0,9407
$(1-\alpha)\beta_{01-03}$	0,6563	$\beta_{02/2}$	0,9424
$\sigma(\beta_{01-03})$	0,0520	$\beta_{03/1}$	0,9279
		$\sigma(\beta_{01/2}-\beta_{03/1})$	0,0518
		MSE	0,0104

B: DESCRIPTIVE STATISTICS

CS				CDS				ICS			
Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.
129,5	713,6	309,4	129,8	125,0	650,0	310,6	127,9	126,3	662,7	309,7	126,2

C: BASIS

CS vs CDS				ICS vs CS				ICS vs CDS			
avb	avb(%)	avab	avab (%)	avb	avb(%)	avab	avab (%)	avb	avb(%)	avab	avab (%)
-1,15	-0,13	15,36	5,34	0,31	0,82	25,43	8,56	-0,84	0,42	24,47	8,07

Table 1: This table has five panels. In panel A it contains the calibration parameters used in computing the ICS for Ford Motor Credit Co.. In Panel B the descriptive statistics for three measures (CS,CDS and ICS) of the market price of credit risk are shown. Panel C shows the basis for the three series. Panel D contains the results of the price discovery exercice using Wald test. Panel E contains the results of the Granger causality test. *** Indicates significance at the 1% level, ** indicates significance at the 5% level and * indicates significance at the 10% level.

TABLE 1: FORD MOTOR CREDIT CO. (Cont.)

D: PRICE DISCOVERY - WALD TEST

	ΔCS				ΔCDS				ΔICS			
	ΔCS-L	ΔCDS-L	ΔICS-L	MODEL	ΔCS-L	ΔCDS-L	ΔICS-L	MODEL	ΔCS-L	ΔCDS-L	ΔICS-L	MODEL
01/2	-1.48	2.34**	2.41**	5.99***	0.04	-0.24	2.22**	1.81	0.96	-0.59	-0.86	0.66
02/1	-1.11	3.31***	2.17**	5.48***	18.21***	7.70***	2.92*	8.57***	1.16	-0.14	-1.49	1.11
02/2	3.52***	-0.59	5.62***	21.57***	6.30***	-3.52***	1.69*	17.44***	0.09	-0.24	-2.04**	1.57
03/1	-1.86*	1.77*	7.53***	20.65***	23.54***	2.90*	14.27***	17.89***	-0.33	2.10**	-0.30	1.49

E: PRICE DISCOVERY - GRANGER CAUSALITY TEST

	VAR (ΔCS,ΔCDS) MODEL		VAR (ΔCS,ΔICS) MODEL		VAR (ΔCDS,ΔICS) MODEL	
01/2	CS dngc CDS	0.00	CS dngc ICS	0,59	CDS dngc ICS	0,01
	CDS dngc CS	11.14***	ICS dngc CS	11.52***	ICS dngc CDS	5.01**
02/1	CS dngc CDS	20.99***	CS dngc ICS	1,40	CDS dngc ICS	0,05
	CDS dngc CS	4.52**	ICS dngc CS	5.04**	ICS dngc CDS	4.33**
02/2	CS dngc CDS	30.49***	CS dngc ICS	0,00	CDS dngc ICS	0,05
	CDS dngc CS	2.88*	ICS dngc CS	31.72***	ICS dngc CDS	9.57***
03/1	CS dngc CDS	27.51***	CS dngc ICS	0,06	CDS dngc ICS	4.38**
	CDS dngc CS	2.80*	ICS dngc CS	57.10***	ICS dngc CDS	28.65***

Table 1 (cont.): This table has five panels. In panel A it contains the calibration parameters used in computing the ICS for Ford Motor Credit Co.. In Panel B the descriptive statistics for three measures (CS, CDS and ICS) of the market price of credit risk are shown. Panel C shows the basis for the three series. Panel D contains the results of the price discovery exercice using Wald test. Panel E contains the results of the Granger causality test. *** Indicates significance at the 1% level, ** indicates significance at the 5% level and * indicates significance at the 10% level.

TABLE 2: DESCRIPTIVE STATISTICS

				A: CS				B: CDS				C: ICS			
	Sector	Obs.	Rating	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.
ALCATEL	Equip.	398	Baa1/Baa2/Ba1/B1	130,8	1655,7	567,1	378,9	202,0	1750,0	648,1	418,9	176,7	1932,0	636,9	394,2
BMW AG	Autos	367	A1	10,7	39,0	24,9	4,9	20,0	52,0	32,6	7,4	14,5	84,7	34,4	12,8
CARREFOUR SA	Retail	443	A1	15,1	54,2	31,7	9,0	19,0	75,0	34,7	11,6	16,5	78,3	35,1	12,5
DAIMLERCHRYSLER AG	Autos	444	A3	62,7	185,9	97,5	24,5	87,0	215,0	137,9	23,8	66,6	322,0	139,7	45,6
DEUTSCHE TELEKOM AG	Telec.	341	A3/Baa1/Baa3	44,1	214,3	150,5	35,2	87,0	405,0	218,8	65,5	113,7	384,3	218,1	63,9
ENDESA	Utilit.	439	Aa3/A2/Baa1	38,3	152,6	69,1	28,5	25,0	205,0	73,1	45,3	24,4	226,1	74,0	47,2
FIAT SPA	Autos	370	Baa2/Baa3/Ba1	118,5	710,6	352,4	156,5	167,0	1100,0	573,6	242,7	115,6	1001,8	565,6	261,3
FORD MOTOR CREDIT CO	Autos	432	A2/A3	129,5	713,6	309,4	129,8	125,0	650,0	310,6	127,9	126,3	662,7	309,7	126,2
FRANCE TELECOM	Telec.	448	A3/Baa1/Baa3	65,6	429,5	172,8	54,5	90,0	660,0	270,9	119,1	99,9	905,7	274,2	134,4
GENERAL MOTORS ACCEPTANCE CORP	Autos	432	A2/A3	92,9	436,4	211,4	80,5	100,0	430,0	217,3	76,6	93,2	396,4	218,1	77,9
KONINKLIJKE KPN NV	Telec.	452	Baa3/Baa2/Baa1	44,9	826,1	210,6	182,0	60,0	875,0	243,6	187,4	81,9	868,1	237,5	169,4
KONINKLIJKE PHILIPS ELECTRONICS NV	Equip.	418	A3/Baa1	43,7	130,1	78,9	21,7	54,0	170,0	101,1	30,2	56,6	211,3	102,5	34,3
PORTUGAL TELECOM SGPS SA	Telec.	311	A3	39,7	172,6	79,5	32,0	38,0	175,0	76,6	31,0	39,0	191,0	76,3	28,9
REPSOL YPF SA	Energ.	365	Baa1/Baa2	65,2	529,9	245,6	107,3	55,0	620,0	267,5	159,2	51,3	147,6	88,5	21,6
ROYAL AHOLD	Retail	391	Baa1/Baa3/B1	49,1	1370,5	187,8	262,7	43,0	1750,0	189,1	279,3	37,4	909,7	172,8	197,6
RWE AG	Utilit.	445	Aa3/A1	7,9	74,5	37,8	13,6	17,0	103,0	58,8	23,4	12,3	165,8	56,0	31,2
SIEMENS AG	Equip.	443	Aa3	0,8	54,6	22,0	9,6	31,0	90,0	50,4	13,1	21,1	126,3	52,4	19,4
TELECOM ITALIA SPA	Telec.	436	Baa1	81,0	168,1	109,1	18,2	82,0	175,0	119,0	21,0	40,6	210,4	95,1	29,5
TELEFONICA SA	Telec.	366	A2/A3	48,5	203,4	90,6	32,6	38,0	275,0	105,3	56,4	46,0	231,9	103,5	48,5
VEOLIA ENVIRONNEMENT	Utilit.	370	A3/Baa1	54,7	260,0	98,6	27,7	50,0	195,0	100,2	34,5	38,1	251,7	102,4	39,2
VOLKSWAGEN AG	Autos	346	A1	24,7	63,2	44,1	8,8	25,0	90,0	56,0	16,2	17,6	123,9	58,7	23,7
Mean/21				55,63	402,12	151,96	77,07	67,38	479,05	185,01	94,79	61,39	449,12	173,88	86,63
S.D./21				37,59	440,49	133,38	97,49	49,48	509,90	165,68	108,48	44,75	454,81	163,43	97,91
Mean/18				54,06	354,23	147,15	68,35	68,61	417,50	183,86	85,06	64,44	453,54	183,06	87,25
S.D./18				40,18	408,05	142,15	93,89	53,13	447,49	177,86	105,72	47,76	471,33	174,75	100,57

Table 2: Descriptive statistics for the three measures of the market price of credit risk.

TABLE 3: BASIS

	A: CS vs CDS				B: ICS vs CS				C: ICS vs CDS				
	avb	avb(%)	avab	avab (%)	avb	avb(%)	avab	avab (%)	avb	avb(%)	avab	avab (%)	MSE
ALCATEL	-81,02	-13,58	119,33	19,68	69,75	21,60	94,48	24,74	-11,26	2,08	108,21	16,41	0,0402
BMW AG	-7,78	-22,47	8,03	23,41	9,58	38,67	10,74	42,78	1,80	6,74	8,81	26,90	0,1001
CARREFOUR SA	-3,01	-0,42	10,69	30,95	3,44	17,71	11,69	40,59	0,43	2,41	5,69	15,99	0,0378
DAIMLERCHRYSLER AG	-40,38	-29,52	40,41	29,54	42,25	44,99	44,33	46,77	1,87	2,57	32,67	23,97	0,0873
DEUTSCHE TELEKOM AG	-68,35	-29,17	68,55	29,35	67,57	48,12	68,81	48,90	-0,78	1,98	30,01	14,74	0,0356
ENDESA	-4,07	9,97	16,65	27,46	4,92	-0,29	18,60	26,70	0,85	2,38	12,60	15,03	0,0356
FIAT SPA	-221,24	-37,47	221,24	37,47	213,19	59,57	215,52	60,23	-8,05	-2,54	91,39	16,22	0,0521
FORD MOTOR CREDIT CO	-1,15	-0,13	15,36	5,34	0,31	0,82	25,43	8,56	-0,84	0,42	24,47	8,07	0,0104
FRANCE TELECOM	-98,04	-31,87	98,12	31,93	101,39	54,05	101,73	54,31	3,35	1,79	44,42	15,72	0,0344
GENERAL MOTORS ACCEPTANCE CORP	-5,90	-3,47	14,16	6,88	6,67	5,01	23,08	11,73	0,77	1,19	25,38	12,16	0,0211
KONINKLIJKE KPN NV	-33,01	-16,10	37,77	17,24	26,94	22,27	44,99	25,68	-6,07	2,04	36,60	16,05	0,0389
KONINKLIJKE PHILIPS ELECTRONICS NV	-22,16	-19,77	23,15	21,19	23,61	32,35	25,08	33,87	1,44	3,63	18,94	18,25	0,0594
PORTUGAL TELECOM SGPS SA	2,94	4,49	7,25	10,38	-3,23	-0,21	16,37	19,57	-0,29	3,99	17,37	23,19	0,0670
REPSOL YPF SA	-34,97	-6,67	44,62	12,23	-157,09	-56,84	157,14	56,91	-192,06	-58,70	192,11	58,77	1,2619
ROYAL AHOLD	-1,36	5,69	21,06	13,29	-14,98	-1,53	38,96	17,94	-16,34	2,13	38,91	14,58	0,0358
RWE AG	-15,08	-22,06	17,50	31,55	18,22	49,56	21,80	59,20	3,14	5,80	12,09	23,48	0,0854
SIEMENS AG	-28,40	-54,87	28,42	54,92	30,44	192,53	30,64	193,14	2,04	5,19	12,13	23,83	0,0797
TELECOM ITALIA SPA	-9,92	-7,73	12,19	10,23	-13,97	-11,91	25,76	24,22	-23,90	-20,00	29,39	24,93	0,1464
TELEFONICA SA	-19,15	-13,66	19,57	14,42	17,39	19,67	21,76	24,69	-1,76	2,64	18,87	18,09	0,0452
VEOLIA ENVIRONNEMENT	-1,57	1,48	10,65	11,00	4,13	6,09	27,29	27,97	2,56	6,46	26,37	26,40	0,1102
VOLKSWAGEN AG	-11,86	-16,86	13,69	22,65	14,54	32,50	19,85	44,41	2,69	4,79	13,29	23,68	0,0828
Mean/21	-33,59	-14,49	40,40	21,96	22,15	27,37	49,72	42,52	-11,45	-1,10	38,08	20,78	0,1175
S.D./21	51,14	16,30	51,07	12,03	65,19	46,53	52,50	37,89	41,99	14,27	43,51	10,10	0,2643
Mean/18	-36,62	-16,42	42,81	23,63	36,17	35,83	45,68	44,10	-0,45	2,98	29,96	18,79	0,0568
S.D./18	54,52	16,69	54,70	12,22	52,38	43,75	50,05	40,23	4,05	2,29	27,52	5,25	0,0284

Table 3: Statistics for the basis between the three measures of the market price of credit risk.

TABLE 4: CALIBRATION PARAMETERS

	A			B				
	β_{01-03}	$(1-\alpha)\beta_{01-03}$	$\sigma(\beta_{01-03})$	$\beta_{01/2}$	$\beta_{02/1}$	$\beta_{02/2}$	$\beta_{03/1}$	$\sigma(\beta_{01/2}-\beta_{03/1})$
ALCATEL	0,5852	0,4096	0,3594	0,5314	0,6122	0,6263	0,5208	0,3593
BMW AG	0,8083	0,5658	0,1474	-	0,9007	0,8064	0,6932	0,1469
CARREFOUR SA	0,8336	0,5835	0,1884	0,8962	0,8519	0,8555	0,7398	0,1883
DAIMLERCHRYSLER AG	0,9670	0,6769	0,0920	1,0010	1,0661	0,9951	0,9063	0,0864
DEUTSCHE TELEKOM AG	0,5333	0,3733	0,2893	-	0,5601	0,5462	0,4719	0,2905
ENDESA	1,0155	0,7109	0,0799	1,0279	1,0329	0,9972	0,9530	0,0811
FIAT SPA	1,0574	0,7402	0,0210	-	1,0542	1,1011	1,0398	0,0219
FORD MOTOR CREDIT CO	0,9375	0,6563	0,0520	0,9419	0,9407	0,9424	0,9279	0,0518
FRANCE TELECOM	0,6734	0,4714	0,2067	0,7524	0,7390	0,6370	0,6181	0,2049
GENERAL MOTORS ACCEPTANCE CORP	0,9133	0,6393	0,0529	0,9171	0,9226	0,9148	0,8980	0,0528
KONINKLIJKE KPN NV	0,6226	0,4358	0,2455	0,6038	0,6168	0,6821	0,6098	0,2433
KONINKLIJKE PHILIPS ELECTRONICS NV	0,3681	0,2577	0,4198	0,4379	0,4271	0,3529	0,2561	0,4192
PORTUGAL TELECOM SGPS SA	0,8135	0,5694	0,2028	-	0,9107	0,8558	0,7332	0,2023
RWE AG	0,8716	0,6101	0,0751	0,9067	0,9033	0,8604	0,8018	0,0747
SIEMENS AG	0,5631	0,3942	0,2490	0,5745	0,6498	0,5571	0,4632	0,2489
TELEFONICA SA	0,8800	0,6160	0,2132	-	0,9425	1,0335	0,7724	0,2113
VEOLIA ENVIRONNEMENT	0,9169	0,6418	0,0868	-	1,0548	1,0068	0,8929	0,0827
VOLKSWAGEN AG	0,9079	0,6355	0,0714	-	0,9546	0,9115	0,8671	0,0696
Mean	0,7927	0,5549	0,1696	0,7810	0,8411	0,8157	0,7314	0,1687
S.D.	0,1905	0,1334	0,1136	0,2092	0,1926	0,2044	0,2074	0,1138
REGRESSION: $\beta_{01-03} = a + b\sigma(\beta_{01-03})$	a	1.0559***						
	b	-1.5521***						
	Adj. R-Sq.	0,8471						

Table 4: Calibration parameters obtained using equations (18) and (22). *** Indicates significance at the 1% level.

TABLE 5: PRICE DISCOVERY

A: WALD TEST

Period	N	A1: ΔCS				A2: ΔCDS				A3: ΔICS			
		ΔCS-L	ΔCDS-L	ΔICS-L	MODEL	ΔCS-L	ΔCDS-L	ΔICS-L	MODEL	ΔCS-L	ΔCDS-L	ΔICS-L	MODEL
01/2	11	6	4	3	6	1	1	3	3	0	1	0	1
02/1	18	10	7	4	14	7	8	7	14	3	2	1	3
02/2	18	11	9	6	13	6	3	6	7	3	0	4	2
03/1	18	13	5	6	17	4	6	8	11	2	2	2	1
All	65	40	25	19	50	18	18	24	35	8	5	7	7

B: GRANGER CAUSALITY TEST

Period	N	B1: VAR (ΔCS,ΔCDS) MODEL		B2: VAR (ΔCS,ΔICS) MODEL		B3: VAR (ΔCDS,ΔICS) MODEL	
		CS dngc CDS	CDS dngc CS	CS dngc ICS	ICS dngc CS	CDS dngc ICS	ICS dngc CDS
01/2	11	2	4	0	3	1	4
02/1	18	10	7	2	4	2	8
02/2	18	7	9	4	9	0	9
03/1	18	6	5	2	6	2	8
All	65	25	25	8	22	5	29

Table 5: This table has two panels. Panel A contains the results of the price discovery exercice using Wald test for each semester. Panel B contains the results of the Granger causality test. In both cases the numbers shown are the rejections at the 5% level of significance of the null hypotheses of no relation.