

Has the CDS market influenced the borrowing cost of European countries during the sovereign crisis?

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Abstract

In this paper, we assess the impact of the CDS market on the borrowing cost of Western Europe sovereigns on the post-Lehman Brothers' bankruptcy period. We challenge the belief that the relatively small CDS market cannot influence bond spreads in countries with long-established and large sovereign debt markets. To do so, we relax the linearity assumption in a model of the price discovery process across the CDS premium and the bond spread for a panel of Euro-zone member countries between September 2008 and July 2010. We find that: 1) linearity tests clearly reject the null hypothesis of a linear relationship between the bond spread and the CDS premium; 2) market distress alters the mutual influence exercised by each market; 3) the higher the distress, the more the CDS premia influence the bond spreads in the core European countries.

JEL Classification: C33; G01; G15.

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1 Introduction

The recent European sovereign debt crisis of 2010 has raised concerns regarding the use of credit default swaps (CDS). It has been suspected that a few hedge funds drove up the prices of the CDS market, a fact that may have influenced the sovereign bonds spreads. This is a key debate because, whether hedging or speculative motives drove the activity, the outcome was the same: the CDS premia of Greece, Spain, Portugal and other European countries have reached record highs (see Fig. A.1 in the appendix). Have these dynamics influenced the sovereign bond cash market during the financial crisis? If this were the case, then it would be the case that derivatives spurred financial instability rather than reducing risk (Stulz, 2010). Whether the CDS market has amplified the European debt crisis is therefore a crucial issue that deserves special attention.

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Credit default swaps, the most commonly traded credit derivatives, are bilateral contracts between a buyer and seller under which the seller sells protection against the credit risk of the reference entity. The buyer pays a periodic premium to the seller. This premium, also called a spread, is the CDS quote. When the budget balance of a state deteriorates, the risk increases along with the insurance cost, priced in the sovereign CDS premium. In sum, there is a theoretical relationship equating credit default swap prices and bonds spreads. Intuitively, one expects that bond spreads lead the price discovery process.

Yet, previous studies on the price discovery process in the corporate market have evidenced the inverse causality. These studies find that the CDS premium plays a more dominant role in price discovery than does the bond spread (Blanco, Brennan and Marsh (2005) and Norden and Weber (2004)). There are few empirical studies on sovereign CDS premia and even fewer on sovereign CDS premia of developed countries, because of their recent emergence. As the volume of sovereign CDS premia of developed countries is dramatically small relative to the underlying government bonds, one expects that the price of CDS premia does not affect the bond spread. Coudert and Gex (2010) confirm this result for low-yield European countries but finds that the sovereign CDS market has had a lead over the bond market in emerging countries (Bowe, Klimavicienne and Taylor (2009) found the same pattern).

However, a limit of the existing literature is that a continuous and constant price discovery process (PDP in the following) is implicitly assumed. Yet, the presence of heterogenous agents makes this assumption unrealistic. The expanding literature on heterogenous agent models has documented that financial markets are *complex adaptive systems* implying that the interaction of heterogenous agents with "bounded rationality" produces highly nonlinear systems (Hommes and Wagener (2009)). In fact, when they price sovereign credit risk, traders under uncertainty use rules of thumb for their decisions and they may switch between different strategies, a fact that would imply nonlinear PDP. To verify this assumption and to determine the determinants of nonlinearity are precisely the objectives of this paper.

The above-mentioned result of Coudert and Gex (2010) states that CDS leads the bond market in high-yield countries only, but not in low-yield countries. This result suggests that the perceived risk level may have an influence on which market is dominant in price discovery. This would be the case if a proportion of traders changed their strategy when they reached a critical value of market uncertainty. If the linear PDP assumption can be relaxed, then we could test whether or not the lead reverses above a certain (high) level of spread. Market liquidity may play a role in the reversion mechanism as well because differences in market practices can give market participants an incentive to trade on the CDS market rather than on the cash market. In sum, our proposition is that the direction is neither continuous nor constant. Rather, the market where the price is primarily discovered may depend on economic factors.

To address this issue, we adopt a nonlinear approach by introducing threshold effects in a linear error correction model of the price discovery process. More precisely, we rely on a panel smooth transition model for the adjustment process, initially proposed by González, Teräsvirta and van Dijk (2005). This modeling strategy allows us to relax the restricting hypothesis of a constant adjustment toward equilibrium. On the contrary, in our model, the adjustment speed smoothly changes as a function of economic variables. This is the first

contribution of our paper: we explicitly test whether certain market conditions influence the price discovery process. A distinguishing feature of our model is that, according to the value of a transition variable, we can precisely identify the periods of the price discovery process reversion. Our second main contribution is that our analysis focuses on European countries and covers the recent sovereign debt crisis. In fact, in the aftermath of Lehman Brother's bankruptcy, most sovereign countries have considerably increased their public deficit in order to offset the effects of the financial shock due to the subprime market crisis. We thus focus our analysis on the post-Lehman period (2008-2010) precisely to examine the specific dynamics due to this radical change in fiscal stance.

This remainder of this paper is organized as follows. The next section presents an overview of the sovereign CDS market and the issue of the price discovery process in the literature. Section 3 presents our methodology and Section 4 the data set. Section 5 presents the results of the nonlinear model test. Finally, Section 6 concludes the paper.

2 Sovereign CDS Market and the Price Discovery Process: An Overview of the Market

The emergence of the activity on developed sovereign CDS is relatively recent phenomenon. Initially, the majority of the protection traded through CDSs regarded corporate reference entities. Prior to the crisis, participants had little incentives to negotiate CDS on developed countries, as sovereign risk was considered as insignificant for highly-rated countries. The level of CDS premia was very low, ranging between a few basis points to around ten basis points, as well as the liquidity of the market. Yet, the modification of the perception of sovereign risk, following the set up of massive rescue plans and the deterioration of public balance, has led to an increasing activity on this segment of the CDS market. Notional amounts outstanding of sovereign CDSs increased by 76% between December 2006 and December 2009, while corporate CDSs posted a rise of 19%, according to the BIS semiannual Over-The-Counter (OTC) market derivatives statistics (Bank for International Settlements (2010)). This increase in volumes came along with skyrocketing CDS premia, suggesting that a significant part of the activity could be explained more by trading than hedging purposes. However the sovereign CDS market, with notional amounts outstanding of 1.9 trillion USD, is still dwarfed by the size of the underlying market, amounting 36.4 trillion USD in December 2009 (BIS, 2010)¹. In spite of the strong activity on sovereign CDSs², the ratio of gross notional amounts of CDSs to outstanding amounts of underlying debt ranged between 3% and 33% for eurozone countries end-2009, far from the levels observed for corporate, exceeding 100% in most cases.

Theoretically, in the absence of arbitrage opportunity, the CDS premium should be equal to the bond spread for the same borrower and maturity (Duffie (1999), Hull, Predescu and White (2004) and Hull and White (2000)). In reality, bond and CDS spreads are never equal for several reasons, such as accrued interest, the cheapest-to-deliver option and counterparty risk. This justifies the existence of the basis, defined as the difference between the CDS

¹This is contrary to corporate CDSs notional amounts, which have nearly outsized the bond market.

²End-2009, the 6 most traded reference entities in terms of gross notional were sovereigns, including Italy and Spain, with notional of respectively 223 billion USD and 94 billion USD, according to DTCC.

premium and the bond spread and raises the issue of the price discovery process on the credit markets³. Where does it take place? On the bonds market, as one could intuitively expect, or rather on the CDS market? This has constituted a key issue in the recent literature on CDS.

Corporate CDSs, which are less encumbered by covenants and guarantees than corporate bonds, as pointed out by Longstaff, Pan, Pedersen and Singleton (forthcoming), are often considered as a better source of information on the price of credit risk than the cash bond market. In particular, short positions are difficult and costly to take on the bond market. This reduces the efficiency of the bond market because agents are prevented to trade to express belief (Diamond and Verrecchia (1987)), prompting agents to trade CDSs rather than bonds if they expect the borrower to default. Moreover, the lack of liquidity of underlying bonds justifies that corporate CDSs, which can be sold in arbitrarily large amounts, are much less affected by liquidity effects⁴. Longstaff et al. (2005) Cossin and Lu (2005), Crouch and Marsh (2005) and Zhu (2006) among others, have empirically evidenced that corporate CDS premia incorporate a lower liquidity premium than underlying bonds. This suggests a lead of the CDS market over the bond market, which is confirmed by empirical studies. Indeed, a leading role of the CDS market is clearly detected by Blanco et al. (2005), European Central Bank (2004) and Zhu (2006)), for instance, on various samples of European and American corporate CDS and by Baba and Inada (2007) who reach a similar conclusion on a sample of Japanese banks. However, crisis periods tend to mitigate this leading position of the CDS market (Coudert and Gex (forthcoming)).

In the sovereign case, the size of the CDS market compared to the amounts of public debt securities suggest diverging results. So far, empirical studies on sovereign CDS have focused on emerging countries because it was where the CDS were originally traded. In these markets, in spite of the relative size of the CDS and the underlying bond market just mentionned, evidence mostly converge towards a lead of the CDS market. On a sample of 8 emerging countries, Bowe et al. (2009) conclude to the lead of the CDS market. Ammer and Cai (2007), on a different sample of 7 emerging countries, find that the price discovery process occurs on the CDS when underlying bonds are relatively illiquid. To our knowledge, few articles have focused on CDS of developed countries, due to their recent emergence. Some exceptions include Coudert and Gex (2010) who worked on a sample of countries from the Euro zone and found that in the low-yield countries, the price discovery process takes place in the bond market, as expected. But they also found that the direction changes in high-yield countries, where the CDS market is found to lead the price discovery process. Alternatively Boone, Fransolet and Willemann (2010) argue that the development of the CDS market in the developed countries should have influenced the dynamics of the sovereign trading.

In sum, results are therefore less clear cut for sovereign reference entities. Assessing the potential influence of the growing CDS market on the underlying bond market is thus a pivotal issue. Indeed, the level of CDS premia witnessed during distressed periods has raised concerns (Andritzky and Singh (2005)) as overreactions of the CDS market could impact the financing conditions of the states. In the following Section we present the methodology of our paper.

³For a review of the factors impacting the basis, see O’Kane and McAddie (2001), or Coudert and Gex (forthcoming)

⁴See Longstaff, Mithal and Neis (2005)

3 Methodology

We first present the empirical strategy employed by existing studies to examine this issue and second we introduce the nonlinear model that overcomes the limits of the linear specifications.

3.1 The linear specification

Existing studies accurately use a vector error correction model (VECM) to examine the individual adjustment processes toward the long-term cointegration relationship. In fact, suppose that the efficient price is primarily discovered in a market, the price in the other market tends to converge to the price in the primary market, and thus the adjustment of the main market price is slower than the other price. This mechanism can be described by a VECM where the intensities of the price adjustments are measured by the error correction coefficients.

In theory, arbitrage activities imply that CDS and bond spreads should co-move together. Thus, the CDS and bond spreads for the same sovereign and maturity should have a long-run relationship (i.e. they are cointegrated). Following the previous considerations and in a panel data framework, this relationship can be expressed as follows:

$$CDS_{it} = \mu_i + \alpha_1 Bond_{it} + z_{it} \quad (1)$$

where i denotes the country ($i = 1, \dots, N$), t the time dimension ($t = 1, \dots, T$), $Bond$ is a sovereign bond spread, CDS is the premium of the CDS contract on the subordinated bond with same maturity, μ_i denotes the country-specific intercepts, and $z_{i,t}$ is the vector of errors. In theory, $\alpha_1 = 1$, i.e. CDS and bond spreads should be proportional, at the exception of institutional factors such as the difference in transaction costs, represented by a constant individual fixed effects, μ_i .

Equation (1) represents the efficient price following a random walk process with equilibrium, given by $z_{it} = 0$. Theory predicts that, if the CDS and bond spreads are cointegrated, at least one of the spreads adjusts back to equilibrium in case of short-run deviations, or misalignments in the relationship (Engle and Granger (1987)). Hence disequilibrium is given by:

$$z_{it} = CDS_{it} - \hat{\alpha}_1 Bond_{it} - \hat{\mu}_{it} \quad (2)$$

The contribution of price discovery can be assessed through the adjustment process of both spreads. Indeed the market where the price is primarily discovered leads the other. It implies that the market that follows the other adjusts more rapidly to target. In this sense, in order to investigate the adjustment speed towards the equilibrium, linear studies rely on the following panel VECM of market prices:

$$\Delta CDS_{it} = \lambda_1(CDS_{it-1} - \alpha_1 Bond_{it-1} - \mu_{i,t-1}) + \beta_{1j} \sum_{j=1}^p \Delta X_{it-j} + \varepsilon_{1it} \quad (3)$$

$$\Delta Bond_{it} = \lambda_2(CDS_{it-1} - \alpha_1 Bond_{it-1} - \mu_{i,t-1}) + \beta_{2j} \sum_{j=1}^p \Delta X_{it-j} + \varepsilon_{2it} \quad (4)$$

where λ_1 and λ_2 are the error correction coefficients of the CDS premium and bonds spread, respectively, $X_{it} = [Bond_{it}, CDS_{it}]$, such that $\hat{\beta}_{1j}$ and $\hat{\beta}_{2j}$ stand for the estimated short-term effects and ε_{1it} and ε_{2it} are i.i.d shocks.

The contribution of price discovery depends on the relative values of λ_1 and λ_2 . If the bond market contributes significantly to the discovery of the price of credit risk, then λ_1 will be negative and statistically significant as the CDS market adjusts to incorporate this information. If the CDS market is important for price discovery, then λ_2 will be positive and statistically significant. If both coefficients are significant, then both markets contribute to price discovery. The dominant market in the price discovery process has the lower adjustment speed. In other words, if the adjustment speed of the bonds is lower than of the CDSs ($\lambda_2 < \lambda_1$), the bonds has a dominant role in price discovery and thus it leads the CDS premia.

As an alternative way to identify where the price discovery takes place, Baba and Inada (2007), among others, use the price discovery measure of Gonzalo and Granger (GG), calculated as follows:

$$GG = \frac{\lambda_2}{\lambda_2 - \lambda_1} \quad (5)$$

Based on (4), the CDS (bonds) market has a dominant role in price discovery when GG is larger (smaller) than 0.5.

3.2 Introducing threshold effects: the nonlinear model

As mentioned before, a drawback of the previous specification is that it implicitly assumes that the speed of adjustment is continuous and of constant speed. In other words, the reversion is independent of the characteristics of the market. A way to overcome this restriction is to relax the linearity hypothesis by allowing λ_1 and λ_2 to vary according to market conditions.

To address this issue, and based on González et al. (2005), we introduce threshold effects in the linear error correction model presented in Equations (3) and (4). These models have several interesting features that make them suitable for our purposes. First, the error correction coefficient is allowed to vary according to observable economic variables. More precisely, the observations in the panel are divided into a small number of homogenous groups or “regimes”, with different coefficients depending on the regimes. Second, regression coefficients are allowed to change gradually when moving from one group to another: the PSTR is a regime-switching model where the transition from one regime to the other is smooth rather than discrete. Finally, individuals are allowed to change between groups over time according to changes in the “threshold variable”.

Following Béreau, López-Villavicencio and Mignon (2010), the Panel Smooth Transition Error Correction Model can be specified as follows:

$$\Delta CDS_{it} = \lambda_1(z_{i,t-1}) + \lambda_1^* z_{i,t-1} * g(s_{it}; \gamma, c) + \beta_{1j} \sum_{j=1}^p \Delta X_{it-j} + \varepsilon_{1it} \quad (6)$$

$$\Delta Bond_{it} = \lambda_2(z_{i,t-1}) + \lambda_2^* z_{i,t-1} * g(s_{it}; \gamma, c) + \beta_{2j} \sum_{j=1}^p \Delta X_{it-j} + \varepsilon_{2it} \quad (7)$$

with $z_{i,t-1}$ representing the last's period deviation from equilibrium (i.e $z_{it} = CDS_{it} - \hat{\alpha}_1 Bond_{it} - \hat{\mu}_{it}$). In Equations (6) and (7), $g(s_{i,t}; \gamma, c)$ is the transition function defined by:

$$g(s_{i,t}; \gamma, c) = \left[1 + \exp \left(-\gamma \prod_{j=1}^m (s_{i,t} - c_j) \right) \right]^{-1} \quad (8)$$

This function is continuous, normalized and bounded between 0 and 1, γ is the speed of transition, and c denotes the threshold parameter ($c_1 \leq c_2 \leq \dots \leq c_m$). Depending on the realization of the transition variable $s_{i,t}$, the cointegration relationship between the CDS and the Bond will be specified by a continuum of parameters, namely λ_i in Regime 1 (when $g(\cdot) = 0$), and $\lambda_i + \lambda_i^*$ in Regime 2, when $g(\cdot) = 1$. In eq. (8), g can be either a first-order logistic function (when $m=1$), in which case the two regimes are associated with small and large values of the transition variable relative to the threshold or an exponential function (when $m=2$) which, contrary to the logistic model, is characterized by symmetric dynamics in the two extreme regimes.

In other words, this model allows us to investigate if non-linearity in the reversion towards equilibrium could be associated with changes in the transition variable. Indeed, whereas the error correction coefficient in a linear model is constant and equal to λ_1 et λ_2 in Equations (3) and (4), in the PSTR model these coefficients vary between countries and time according to the value of the transition function. In particular, the error correction coefficients (ECC) for the i^{th} country at time t is defined as a weighted average of the parameters λ_1 and λ_1^* for the CDS and λ_2 and λ_2^* for the Bond:

$$ECC = \lambda_i + \lambda_i^* g(s_{it}; \gamma, c) \quad (9)$$

The nonlinear specification allows the speed of adjustment to vary according to the value of the transition variable. In this paper, we assume that four candidates may influence the price discovery process: $s_{it} \in Q = \{CDS_{it}, Bonds_{it}, z_{it}, l_{it}\}$ with l_{it} the market liquidity of country i at time t . Firstly, as mentioned in the introduction, existing linear results suggest that the level of the spread has an influence on which market leads the other (Coudert and Gex (2010)). Thus we use both CDS_{it} and $Bond_{it}$ as possible transition variables. By doing so, we expect that the adjustment speed will vary with the value of both premium and spread, such that when any of them is sufficiently high (i.e. exceeds a certain limit), the direction of the price discovery process changes. Since, the magnitude of the spreads matters in this case, we use a logistic function to model this transition dynamics.

Secondly, we would like to confirm that market conditions influence the lead direction using another observable variable than premium and spread. To do so, we include z_{it} , the short-run deviations from the long-run relationship, as a proxy for market confusion. As deviations can be either positive (when the CDS is higher than the bond) or negative (when the bond is higher than the CDS), in this case, we use an exponential function to model the transition dynamics. By doing so, we consider symmetry for high deviations from equilibrium, independently on whether they are positive or negative.

Finally, existing studies suggest that market liquidity, l_{it} , determines which market leads the other (Chakravarty, Gulen and Mayhew (2004)). Therefore, we use the bid-ask spread of

the CDS market to proxy liquidity, expecting that as the liquidity of one market increases, it takes the lead on the other market.

As in the previous linear specification, the GG measure can be used in order to identify where the price discovery takes place. An advantage of the nonlinear specification is that GG can take a continuum of values depending on the transition function as follows:

$$GG = \frac{\lambda_2 + \lambda_2^*g(s_{it}; \gamma, c)}{[\lambda_2 + \lambda_2^*g(s_{it}; \gamma, c)] - [\lambda_1 + \lambda_1^*g(s_{it}; \gamma, c)]} \quad (10)$$

In sum, this specification takes into account the non-constancy of the adjustment process towards equilibrium. This is because we allow the ECC to depend on economic variables. To our knowledge, this econometric procedure is novel in its application to the price discovery process in the CDS market. The following Section presents our data set.

4 Data description

The aim of our investigation is to examine reversion conditions during the latest period of tension in the European sovereign debt markets. Our sample starts from Lehman Brother's bankruptcy (15 September 2008). After this event, the CDS market's liquidity has significantly increased, as well as CDS premia and bond spreads. This is especially true for sovereign CDSs, as the serious deterioration of the fiscal situation in European sovereign has motivated a larger activity on the CDS market of these countries. The sample ends on 27 July 2010. We exclude the pre-crisis period such that if there is any evidence of nonlinear reversion this is not due to structural changes but rather to specific conditions in the market.

To investigate the relationship between the CDS and the bonds markets, we need data of the same maturity. We use the 5-year CDS premia because this maturity is the most traded in the CDS market. As the CDS market for developed countries has recently developed, we concentrate on a cylindrical panel of 11 countries where the CDS market has been liquid enough to produce reliable prices data. We also need to compute bond spreads, defined as the difference between the bond yield and the risk free rate of the same maturity. To do so, for each country in the sample, we use the 5-year German yield, which is the benchmark risk free rate for the euro area, and the 5-year government yield of this country⁵. We end up with 11 pairs of CDS and bonds spreads of the same maturity. Data of the bond yields and the 5-year senior CDS premia are taken from Bloomberg and Datastream respectively.

In addition, we split the countries into two sub samples according to their risk category. The "core Euro-area" group, which includes six European countries (Austria, Belgium, Denmark, Finland, France, Netherlands), is characterized by an average CDS spread below 50 bp over the whole period. In the second group including "peripheral" European countries (Greece, Ireland, Italy, Spain, Portugal), the spread of bonds and the CDS premia are considerably higher. The descriptive statistics in table 1 show a significant heterogeneity across them. In fact, volatility (as measured by the standard deviation) in the the "core euro" is

⁵We provide details on our choice for this risk-free rate in the Data Appendix.

Table 1: **Descriptive statistics**

| | Mean | Std. Error | Minimum | Maximum |
|-----------------------|---------|------------|---------|----------|
| Full panel | | | | |
| CDS | 107.256 | 106.600 | 11.300 | 1125.810 |
| Bond | 87.198 | 111.869 | -7.300 | 1293.800 |
| Liquidity | 0.0847 | 0.0497 | 0.0156 | 0.3270 |
| Core Euro | | | | |
| CDS | 58.964 | 36.324 | 11.300 | 273.000 |
| Bond | 42.118 | 27.451 | -7.300 | 151.300 |
| Liquidity | 0.1085 | 0.0506 | 0.0251 | 0.3270 |
| High-yiel Euro | | | | |
| CDS | 165.208 | 131.388 | 31.200 | 1125.810 |
| Bond | 141.293 | 145.832 | 26.000 | 1293.800 |
| Liquidity | 0.0562 | 0.0297 | 0.0156 | 0.2201 |

significantly lower. Last, table 1 reports a liquidity measure of the CDS market, calculated as the bid-ask spread of the CDS premia. Notice that liquidity is higher in the high-yields European countries, due to an longer existence of the CDS market in these countries. In total, given than heterogenous panels yield poorly relevant and statistically less robust results, we estimate the model on the whole sample as well as these two sub-samples.

5 Results

This Section presents the results of our estimation based on a PST-EC model. For comparative purposes, we first present the results of the benchmark linear model before proceeding to the estimation of the nonlinear model.

5.1 The benchmark estimation

Building on the existing studies, we first estimate the long run coefficients in Equation (1) by the Fully Modified-OLS (FMOLS) estimator for panel data. Based on this estimation, we derived z_{it} , the deviation from equilibrium, as expressed in Equation (2)⁶. We then estimate the linear VECM model as defined in Equations (3) and (4). We use this estimation as a benchmark to check whether the coefficients are consistent with the literature⁷. Table 2 below reports the estimates of the error correction coefficient in our linear specifications for the whole panel as well as the two sub-groups of countries.

⁶Our results indicate higher deviations from the equilibrium in the case of the high-yield European countries, which again suggests higher volatility.

⁷Both the Bond spread and the CDS premium are found to be integrated and cointegrated according to several panel unit root and cointegration tests. To this end, we consider various usual first and second generation unit root tests that rely both on the assumption of cross-section and co-movements of the individuals in the panel. In order to test for the existence of cointegration, we relied on Pedroni's and Kao's cointegrations tests. All the results are available upon request to the authors.

Table 2: **Linear error correction model**

| Variable | Full panel | | Core Euro | | High-yield Euro | |
|-------------|------------|--------|-----------|--------|-----------------|--------|
| | Coef. | t-stat | Coef. | t-stat | Coef. | t-stat |
| λ_1 | -0.0120 | -4.10 | -0.0315 | -6.07 | -0.0020 | -0.58 |
| λ_2 | 0.0163 | 3.80 | 0.0166 | 1.92 | 0.0197 | 4.92 |

Notes: (1) The corresponding cointegration vector is equal to $CDS_{it} = \mu_i + Bond_{it} + z_{it}$; (2) λ_1 and λ_2 correspond to the estimated coefficients in equations (3) and (4), respectively

Results in table 2 indicate that in the full panel and the Core Euro-area panels that λ_1 (λ_2) is statistically significant and negative (positive) implying that both CDSs and bonds prices contribute to the price discovery process. However, this is not the case in the high-yield European countries, where the estimated coefficient for λ_1 is not significant, meaning that the CDS is not driven by mean-reverting dynamics. In turn, a significant λ_2 implies that bonds adjust to CDS.

In the full sample, bonds adjust more rapidly than CDS, implying that the CDS market has a dominant role in the price discovery process (i.e $\lambda_2 > |\lambda_1|$) in Equations (3) and (4). Yet, when focusing on the sub-samples, one observes that this result is not homogenous across the regions. On the contrary, in the core-Euro group, the bonds market has a dominant role in the price discovery process ($|\lambda_1| > \lambda_2$). In the high-yield countries, the bonds market adjusts to the CDS market and not the other way round.

The previous results confirm earlier findings based on linear VECM, on an earlier period (Bowe et al. (2009), Coudert and Gex (2010)). The fact that the bonds market has a dominant role in the core-euro area is consistent with the large size and liquidity of the sovereign bonds market as compared with the market of CDSs, still under development in this area. Coudert and Gex (2010) also find that in high-yield countries, the CDS market generally leads the bonds market.

While giving a relevant global insight regarding the links between spreads, the linear VECM implies that the price discovery always takes place in the same market. In the following we present the results of our nonlinear estimation.

5.2 The nonlinear results

In order to estimate the nonlinear models presented above, the first step is to test the null hypothesis of homogeneity against the PSTR alternative. Given the difference in size, maturity and historical yields of both sub samples (see table 1), we estimate the PSTR model on the two samples in order to allow a different threshold value and a different adjustment process. If the null is rejected, we then proceed to the estimation of a threshold model with the different transition functions. Following Gonzalez et al. (2005) in the time series context, we consider a variable as a possible transition variable if it rejects the null hypothesis of linearity. Then, we establish a statistical "ranking" of the threshold variables which corresponds to the variable

that leads to the strongest rejection of the linearity hypothesis.

First, our linearity tests results (presented in table A.2 in the appendix for the two sub-groups of countries) show, that linearity is strongly rejected in the three first models. This first result confirms the relevance of adopting a non-linear approach to model the discovery process of sovereign credit price. More precisely, in the core Euro, the adjustment speed of the CDS towards equilibrium is non-linear but it is linear in the bond market. The contrary patterns are found in high-yield countries. The fact that linearity is rejected with the variables which proxy market distress (CDS_{it} , $Bonds_{it}$ and z_{it}) strongly supports the novel hypothesis of an influence of adverse market conditions on the price discovery process. Second, the strongest rejection of the null hypothesis of linearity is obtained in the model using the misalignment as a threshold variable (i.e. it rejects linearity with the lowest p-value). This variable is thus statistically better suited than the rest in accounting for non-linearity in the price discovery process. Finally, our results indicate that linearity is not rejected at the 5% with the market liquidity, l , as a transition variable, which suggests that it is not a satisfying determinant of the nonlinear characteristic of the model.

Since the hypothesis of linearity is rejected in certain markets, we estimate the corresponding panel smooth transition regression models for our two sub-samples. We focus our comments on model 1 because it yields the highest linearity rejection and similar values to models 2 and 3⁸. Table (3) reports the estimated value of the main parameters of interest in the first model: the location parameter, c and the error correction coefficients in the extreme regimes (λ_i and $\lambda_i + \lambda_i^*$). Notice, however, that in case linearity is not rejected, the coefficients λ_1 and λ_2 correspond to the linear estimated values presented in table (2).

Table 3: **PSTR error correction models. Model (1)**

| Dependent variable | λ_i | t-stat | λ_i^* | t-stat | $\lambda_i + \lambda_i^*$ | \hat{c} |
|--|-------------|--------|---------------|---------|---------------------------|-------------|
| Core Euro | | | | | | |
| $\Delta CDS_{it} (\Rightarrow \lambda_1)$ | -1.403 | -12.95 | 1.383 | 12.68 | -0.020 | -0.30;-0.30 |
| $\Delta Bond_{it} (\Rightarrow \lambda_2)$ | 0.017 | 1.92 | | | | |
| High-yield Euro | | | | | | |
| $\Delta CDS_{it} (\Rightarrow \lambda_1)$ | -0.002 | -0.58 | | | | |
| $\Delta Bond_{it} (\Rightarrow \lambda_2)$ | 0.391 | 11.570 | -0.386 | -11.050 | 0.005 | -3.64;-3.64 |

Notes: (1) λ_i correspond to the error correction terms in Equations (6) and (7); (2) z , the transition variable in model (1), represents misalignment as expressed in Equation (2)

Several important conclusions can be drawn from our estimated models. Let us first comment the case of the Core European Countries. First, in this group, the speed of adjustment is

⁸The results for model 2 and 3 are presented in the appendix. We notice that the three models yield very similar estimator values, suggesting that our results are robust to the different transition variables.

linear in the bonds market only. The results show that the higher the misalignments, the lower the adjustment speed of the CDS market ($|\lambda_1|$). The threshold estimate value \hat{c} is equal to -0.3 implying that the transition dynamics is V-shaped⁹. More precisely, when the deviation from equilibrium is small (around \hat{c}), the CDS market adjusts at a much higher speed than the bonds market (when $g(q_{it}; \gamma, c) = 0$, $|\lambda_1| = 1.4$ and $\lambda_2 = 0.017$). As the deviation increases, the CDS adjustment speed falls to reach $|\lambda_1 + \lambda_1^*| = 0.020$ in the second regime. Between these two extreme regimes, the error correction term takes a continuum of values depending on the realization of the nonlinear transition function. In sum both the CDS and the bond markets adjust at a similar speed when the market becomes confused.

Table 4: **The GG price discovery measure. Model (1)**

| sub-panel | Transition variable | F=0 | F=1 |
|-----------------------|---------------------|------|------|
| Core Euro | z | 0.01 | 0.47 |
| High-yiel Euro | z | 0.99 | 0.73 |

Notes: (1) F=0 (F=1) represents the linear (nonlinear) regime in Equations (6) and (7) (i.e the extreme regimes); (2) We judge that market 1 (CDS) has a dominant role in price discovery when this GG measure for market 1 is larger than 0.5; (3) z represents misalignment as expressed in Equation (2)

The GG measure reported in table 4 thus smoothly changes from 0.01 (when F=0) to get closed to 0.5 (when F=1) as the deviations from equilibrium get higher. Figure 1 shows the evolution of the GG measure for a selection of countries of our sample. Note that the GG presents large fluctuations which confirms that the price discovery process is strongly non-linear. Second, the GG measure has been more often closed to its upper limit (closed to 0.5) during the period. It suggests that CDS have played a significant role in pricing sovereign credit risk in the core European countries since the beginning of the global crisis. In sum the activity on the CDS market has indeed influenced the borrowing cost of core European States. Last but not least, after a relative calm period during the last term 2009, the GG measures have been particularly volatile in every countries in 2010, switching from one regime to another. It fits with the beginning of the sovereign crisis which suggests again difficulties to price credit risk and uncertainties about the responses of national and European authorities to address the crisis.

In other words, during periods of relatively low distress, the bond market unambiguously leads the price discovery process. But as distress increases, market participants tend to consider the CDS market as an advanced indicator of risk. The price discovery process changes and the sovereign bond market loses its dominant role. When the market becomes confused, market participants focus on the CDS spread to retrieve information. This observation is very important because, contrary to previous findings based on linear specifications, we find that the CDS market becomes an important forum during confused times, even in low-yield

⁹As we use an exponential function, the transition dynamics has an U-shape if c takes two different values and a V-shape if there is only one threshold value.

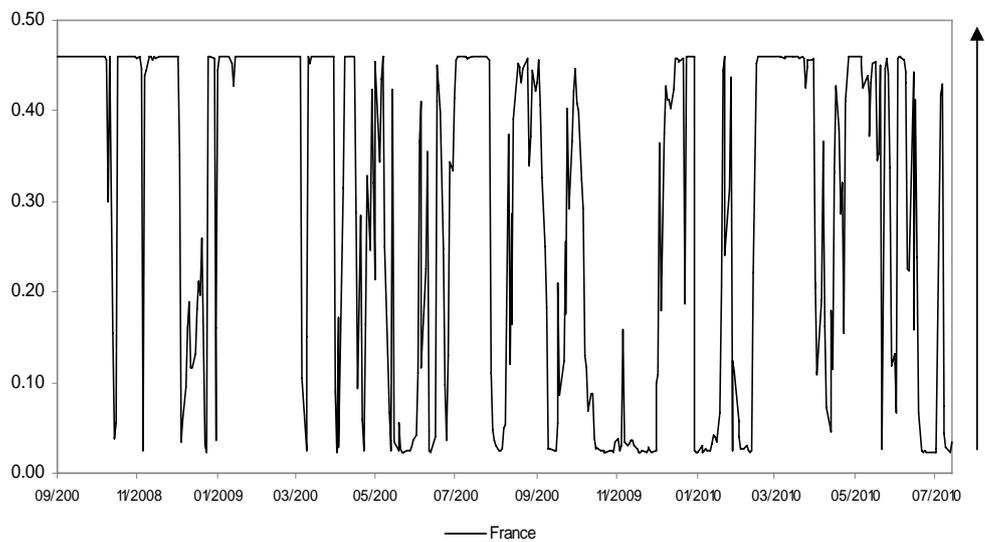
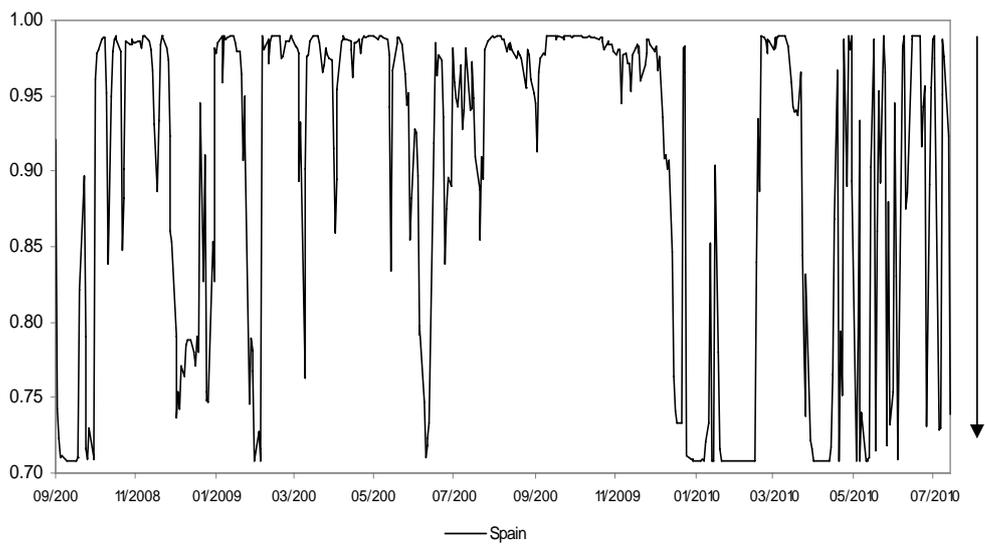
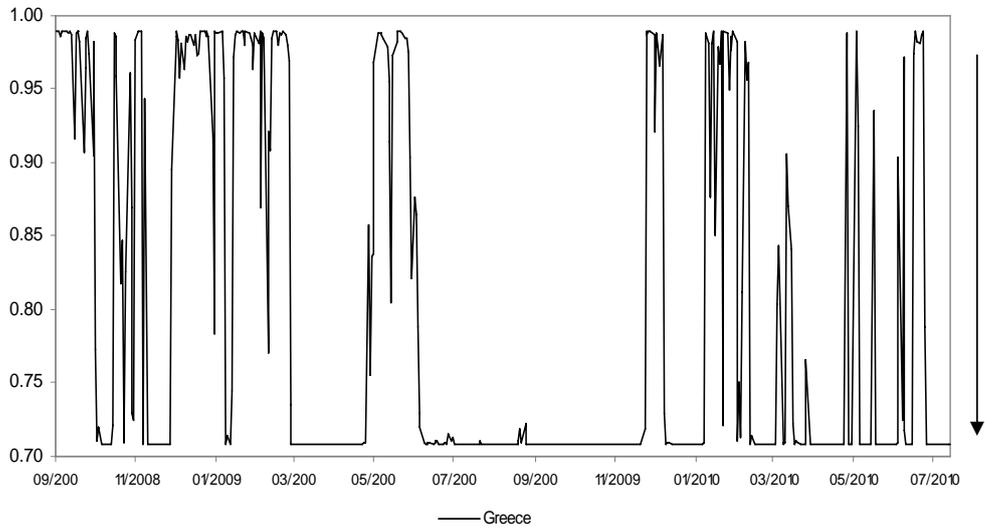
countries with long-established sovereign bond markets. During these precise periods characterized by deteriorating liquidity levels in the secondary bond market, a bearish investor eager to take a short position will naturally turn to the CDS market through naked positions. This is probably one reason why that, during financial turmoil, as agents turn more pessimistic, the CDS market takes the lead over the bond market. This suggests that speculation may strongly motivate investors' strategies and generate larger volume on the CDS market. This result is probably not surprising for a market practitioner who observes that financial news on CDS occupies a larger space in the press when market uncertainty increases. In total, we find that the argument about size and liquidity in the sovereign bond markets in the core European countries does not hold during periods of distress.

Second, and contrary to the core-euro panel, in the high-yield European countries, the speed of adjustment is constant in the CDS market whereas linearity in the bonds market is rejected in all models. In this case, the higher the misalignments, the lower the adjustment speed of the bonds market. However, we find that $|\lambda_1| < \lambda_2 + \lambda_2^*$ whatever the value of the transition variable, implying that the CDS market always leads the bonds market. When the deviation from equilibrium is small (around c), the bonds market adjusts at a much higher speed than the CDS market (when $g(q_{it}; \gamma, c) = 0$, $|\lambda_1| = 0.002$ and $\lambda_2 = 0.39$). Once the deviation gets far from this threshold, the bonds adjustment speed falls to reach $|\lambda_2 + \lambda_2^*| = 0.005$ in the second regime. That is, both markets adjust at a similar speed when the market gets confused. The GG measures reported in table 4 thus decreases from 1 to 0.72, which implies that the CDS market keeps a dominant role over all regimes. However, this decrease suggests that the price discovery process changes and the bonds market becomes an important forum during confused times.

Last but not least, the GG measure of Greece is particularly interesting because it reflects the huge impact of the sovereign debt crisis on this country. We observe that this is the only country in which market tensions last for such a long period which is illustrated by a GG measure at its lowest limit between June and December 2009. It means that the bond market has gained influence in the price discovery process very early. This result shows that specific fears about the refinancing conditions of Greece, such as a possible close of the primary market and a drying-up liquidity on the secondary market have started early in 2009.

In total, the diverging results across samples are not surprising if one considers the probability of default in each sub-sample. In the core European countries, even during a period of distress, the sovereign default probability has remained very low so far. Market participants who want to take short positions while remaining on the market take naked positions on the CDS market. On the contrary, in the peripheral countries, where default probabilities are much higher, market participants turn to the underlying market to sell bonds and exit the market. It probably justifies our diverging results.

Figure 1: **The GG measure: selected countries.** The arrows indicate increase in the tensions



6 Conclusions

In this paper, we assess the role, the CDS market plays in the borrowing cost of sovereign countries using a panel of European countries during the post-Lehman Brothers' bankruptcy period. We challenge the belief that the relatively small CDS market cannot influence bond spreads in countries with long-established and large sovereign debt markets. To respond to this challenge, we relaxed the linearity assumption in a model of the price discovery process across the CDS premium and the bond spread for a panel of Euro-zone member countries between September 2008 and July 2010.

By relying on a nonlinear vector error correction model, we find evidence that the adjustment process to the equilibrium relationship between CDS premia and bond spreads is not linear and, far from being constant, it is strongly sensitive to certain conditions or thresholds that can cause distress in the markets. In particular, these conditions are the high levels of CDS premium or bonds spreads, as well as the deviations to the long-run equilibrium that exists among them. These distress thresholds vary across different groups of countries, with higher thresholds in the higher risk category.

We note that our period sample covers only the crisis, although we are able to distinguish two extreme dynamics. The bond markets play a dominant role in the price discovery process only in the core European countries and it is below the estimated threshold. Yet, when the threshold is crossed, the CDS gains a large influence on the sovereign borrowing costs. In sum, CDS spreads are perceived as a better advanced indicator of default probability when the market is under distress. In the high-yield countries, the CDS market is ahead of the bond market in the two regimes but the bond market regains influence during financial turmoil.

The lack of data on the CDS market, especially on market participants' exposure, impedes further analysis of investors' motivations to use CDS, either for hedging or speculative motives. Nevertheless, the main observation of the paper – that the activity on the CDS market has influenced the borrowing cost of core European States since the beginning of the global crisis – strengthens the legitimacy of ongoing regulation reforms on OTC derivatives.

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Appendix

Figure A.1 Sovereign Bonds spreads and CDS (in basis points)

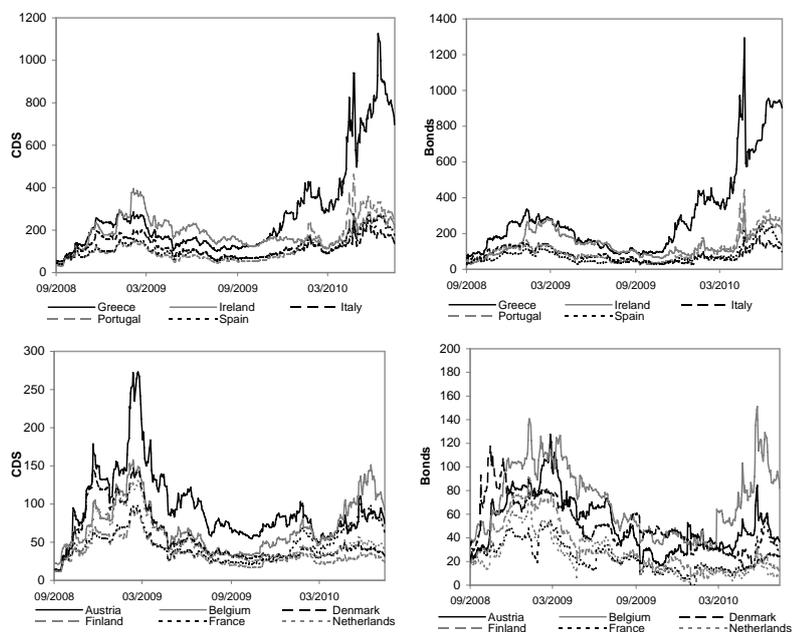


Table A.2 LM linearity tests, p-values

| Dependent variable | Transition variable | Core Euro | High-yield Euro |
|---------------------|---------------------|-----------|-----------------|
| ΔCDS_{it} | Bonds | 0.0084** | 0.6689 |
| | CDS | 0.0084** | 0.6689 |
| | z | 0.0009** | 0.5966 |
| | Liquidity | 0.9999 | 0.5457 |
| $\Delta Bonds_{it}$ | Bonds | 0.3328 | 0.0040** |
| | CDS | 0.4670 | 0.0019** |
| | z | 0.1230 | 0.0002** |
| | Liquidity | 0.0975* | 0.0956* |

Notes: (1) **(*) Indicates rejection of the null hypothesis of linearity at the 5 (10)%; (2) z represents misalignment as expressed in Equation 2

Table A.3 PSTR error correction models. Models (2) and (3)

| Dependent variable | Transition variable | λ_i | t-stat | λ_i^* | t-stat | $\lambda_i + \lambda_i^*$ | \hat{c} |
|-----------------------|---------------------|-------------|--------|---------------|--------|---------------------------|-----------|
| Core Euro | | | | | | | |
| Model (2) | | | | | | | |
| ΔCDS_{it} | CDSs | -0.115 | -5.74 | 0.092 | 4.39 | -0.023 | 25.50 |
| $\Delta Bond_{it}$ | CDSs | 0.017 | 1.92 | | | | |
| Model (3) | | | | | | | |
| ΔCDS_{it} | Bonds | -0.060 | -6.58 | 0.042 | 3.8 | -0.018 | 39.53 |
| $\Delta Bond_{it}$ | Bonds | 0.017 | 1.92 | | | | |
| High-yiel Euro | | | | | | | |
| Model (2) | | | | | | | |
| ΔCDS_{it} | CDSs | -0.002 | -0.58 | | | | |
| $\Delta Bond_{it}$ | CDSs | -0.069 | -2.87 | 0.092 | 3.75 | 0.022 | 51.09 |
| Model (3) | | | | | | | |
| ΔCDS_{it} | Bonds | -0.002 | -0.58 | | | | |
| $\Delta Bond_{it}$ | Bonds | 0.027 | 4.56 | -0.013 | -1.61 | 0.014 | 232.83 |

Notes: (1) λ_i correspond to the error correction terms in Equations (6) and (7); (2) z represents misalignment as expressed in Equation (2)

Table A.4 The GG measure

| Model | Transition variable | F=0 | F=1 |
|-----------------------|---------------------|------------|------|
| Core Euro | | | |
| Model (2) | CDSs | 0.13 | 0.43 |
| Model (3) | Bonds | 0.22 | 0.49 |
| High-yiel Euro | | | |
| Model (2) | CDSs | $\simeq 1$ | 0.91 |
| Model (3) | Bonds | $\simeq 1$ | 0.90 |

Notes: (1) F=0 (F=1) represents the linear (nonlinear) regime in Equations (6) and (7) (i.e the extreme regimes); (2) We judge that market 1 (CDS) has a dominant role in price discovery when this GG measure for market 1 is larger than 0.5; (3) z represents misalignment as expressed in Equation (2)

A.5 Data definition

In order to study the relationship between the CDS market and the underlying market, we need to gather CDS premia and bond spreads. Obtaining CDS premia is straightforward, as these premia are actually CDS quotes. We opt for CDSs on a five year maturity, which is the most traded compared to other maturities.

However, the calculation of bond spreads, defined as the difference between the bond yield of a given issuance and a risk free rate, raises the issue of the choice of the risk free rate. For corporate entities, several studies use the yield of the U.S. Treasuries (for instance, Longstaff et al. (2005)). Other studies use the swap rate on the same maturity (for instance, Blanco et al. (2005)). Choosing a swap rate as a risk free rate can be justified by market practices. Indeed, traders on derivative markets working for major financial institutions use the swap rate as a benchmark for their pricing models, the swap rate being close to their opportunity cost of capital (Hull et al. (2004)). Empirically, Houweling and Vorst (2005) and Hull et al. (2004) show that swap rates are closer to the risk free rate used by markets than Treasuries yields.

As regards sovereign issuances of developed countries, using a swap rate leads to negative bond spreads in most cases. This reflects the low risk of these issuances (theoretically risk free). Literature on emerging markets provides an alternative approach. In order to assess emerging sovereign spreads' dynamics, several studies which investigate emerging sovereign spreads (see McGuire and Schilvers (2003), Sy (2001), Sy (2003), Hartelius and Kodres (2008) and Hilscher and Nosbruch (2010)) or the relationship between emerging sovereign CDS premia and underlying bonds (Chan-Lau and Kim (2004), Andriksy and Singh (2006) and Powell and Martinez (2008)), rely on EMBI spreads. These spreads, provided by J.P. Morgan, are calculated from benchmark sovereign issuances of a given geographical area, i.e. U.S. Treasuries or a Western Europe benchmark bond (generally the German Bund). Alternately, Ammer and Cai (2007) use sovereign bond spreads calculated by Bloomberg with a similar way.

It is therefore consistent for developed countries to choose, as a risk free rate, the bond yield of the country considered the less risky of a given area. We thus compute, for each country in the sample, a bond spread as the difference between the government yield of this country and the German yield, which is the benchmark for the euro area. We calculate these spreads for the same maturity than the maturity of the CDSs, i.e. 5 years.

5-year CDS premia are extracted from Datastream. Among the CDSs of Euro area countries, 11 are selected after filtering (exclusion of series than begin after our starting date and series with missing values): Austria, Belgium, Denmark, Finland, France, Greece, Ireland, Italy, Netherlands, Portugal and Spain. Corresponding bond yields are generic 5-year yields taken from Bloomberg. These generic series display, at each date, the yield of the bond considered by the market as the benchmark bond on a 5 year maturity.

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