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A Model to Test the Price Discovery of Sovereign Credit Risk in the Eurozone

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Abstract

This paper investigates the price discovery process of credit risk of Eurozone countries from 2008 to 2014 within the two interconnected Bond and Credit Default Swap markets. Subject of the analysis are the short-term and long-term dynamic relationships between the two time-series of credit spreads obtained from the Bond and Credit Default Swap markets. The analysis allows determining which credit spread anticipates the other in pricing a certain Sovereign entity, because it is more efficient and timely to incorporate new credit information. The empirical evidence obtained in periods characterized by different levels of credit risk, and then associated to different volatility and liquidity conditions, suggests implications for practitioners who want to take advantage of potential market inefficiencies and for policymakers interested in maintaining the stability of financial systems through timely and correct responses to possible price shocks.

Keywords: credit risk, Eurozone countries, price discovery, CDS, bond spreads
JEL classification: G01, G12, G14, G20

I. Introduction and Objectives

The object of this work is to study the relationships established over time between the market of credit default swaps (CDS) and that of bonds. The analysis of these relationships allows us to investigate the dynamic effects of the process by which the pricing of credit risk is determined in Eurozone countries. This kind of risk is in fact, incorporated in the credit spreads, or rather in a series of indicators suited to quantify the investor's return for assuming the credit risk that is intrinsic in a bond.

The most commonly used indicators are

- the bond spread (BS), or the difference between the bond return and the risk-free rate (AAA rating) or between the bond return and the interest rate swap (IRS) rate, which synthesises the conditions of the interbank market (AA rating);
- the CDS spread (CDSS), whose quotation depends on the probability of default of the underlying entity of the CDS contract.

Under normal conditions, whether in the long or short term, the prices of the BS and CDSS for the same period and referencing entity are sufficiently related and thus leave no way for arbitrage opportunities. This relation is not true, especially in the short term, under conditions of financial instability such as those that have been prevalent in the market in the last few years. This observation, in the context of the sovereign market of the Eurozone, offers us a way to verify whether, in the adjustment process between the various spreads, a *leading* market and possible *following* markets emerges. This should be the case the practical implications are obvious. Knowledge of the mechanism and timing of any adjustment process between the markets should in fact, be particularly interesting for market operators, policy makers and academics.

For operators, the phenomenon of mean reversion over the long term offers the opportunity for arbitrages or margins to make profits taking on zero or low risks. For policy makers, a

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deeper familiarity with the dynamics by which the markets evolve creates a starting point for planning timely and calibrated monetary policies. For academics, analysing the dynamics between the prices of a given asset traded in several different markets is fundamental to improve the study of the microstructure and efficiency of the financial markets.

A critical step to understand fully the objectives of this work is to understand that, if the "asset" credit risk were traded in a single market, then the whole process of price discovery would be concentrated in that market. In reality, the asset in question is traded in more than one market, CDS and bond, and the complex flow of information is fragmented. From this, the importance emerges of determining which market has the greater informative power, or which market succeeds in incorporating new information into its own price first.

For this aim, the work sets out two intermediate objectives and one final objective. The intermediate objectives aim to test whether:

1. the action of the market forces reduces or annuls the divergences observed in the short term between the CDSSs and BSs, such that those spreads converge towards an equilibrium in the long term;
2. between the bond market and the CDS market it is possible to identify a market that is more efficient than the other, in terms of speed with which it absorbs new credit risk information into its prices.

Verifying the intermediate objectives represent the methodological premise for realising the final objective of this study, that is, adequately represented by the changes in the actual dynamics of price discovery in the following three periods:

1. from the second half of September 2008 to the first half of September 2010, approximately equivalent to the period of greatest intensity of the financial crisis;
2. from the second half of September 2010 to the first half of September 2012, approximately equivalent to the period of greatest intensity of the sovereign debt crisis;
3. from the second half of September 2012 to the first half of September 2014, approximately equivalent to the period marked by a trend of progressive downsizing of credit risk in the Eurozone[1].

The final objective will be reached by verifying the intermediate objectives for each Eurozone country and for each of the three above mentioned time periods. The results will be synthesised by period, both at the country level and the aggregate level, distinguished into the group of core countries (Austria, Belgium, Finland, France and Holland) and the group of peripheral countries (Greece, Ireland, Italy, Portugal and Spain) of the Eurozone.

The paper is organised as follows. Section II discusses in detail the related literature. Section III describes the dataset. Section IV introduces the econometric methodology to be used and develops in such a way that the reader will have at their disposal a conceptual map that will facilitate comprehension of the empirical results, which are reported in Section V. In that section the results are presented in three tables that refer to the three time periods examined. With the aim to offering greater consistency for the reader, the results in each table are configured in such a way as to show the succession of the methodological phases, distinguishing between the core and peripheral countries. Section VI, summarises and

[1] The second period of analysis finishes with the start of the programme of Outright Monetary Transactions (OMT) that has successfully limited the credit spreads of the Eurozone countries.

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interprets the results of this work. Section VII, concludes the paper and practical implications of the findings are presented in section VIII.

II. Review of the Literature

This work positions itself within the more generic thread of study that examines the relationship of theoretical parity between CDSS and BS, considered inviolable prior to the crisis. Specifically, it relates to a series of scientific works that empirically investigate the propositions of Duffie (1999). That author was the first to argue that, theoretically, there is a perfect correspondence, or no probability of arbitrage, between a risky obligation, a risk-free security and a CDS contract with equivalent maturity on a notional of equal nominal value. In truth, a portfolio composed of a risky bond and a CDS on the same security should replicate synthetically a position on a risk-free security. The difference between the BS and the CDS spread is referred to the CDS-Bond Basis (or Basis), both by market operators and academics. Its theoretical value is equal to zero, but in practice, even under normal market conditions, because of multiple technical factors and other variables, the basis takes positive values, although close to zero (Choudhry 2006). In phases of market turbulence, the basis can take values that are negative or even highly positive. These configurations of the basis offer, therefore, opportunities to apply arbitrage strategies, or operations that are theoretically risk free but produce positive returns and do not absorb capital (Amadei et al, 2011)[2].

These considerations have driven academics to investigate the link, at times contradictory, between the theoretical efficiency of the microstructure of the markets and the above described evidence. The key research interests can be divided into two threads.

The first thread aimed to determine the Basis drivers that cause the theory of the absence of arbitrage opportunities between BSs and CDSSs to be violated. Bai & Dufresne (2013) and Fontana (2011) provide evidence that, during periods of financial turbulence, deviations from the parity of the Basis do not allow for profitable arbitrage. This happens because of multiple factors that can be attributable to a rise in the cost of liquidity and in the return, to frictions implicit in the functioning of the markets, or the availability of counterparties and quality standards for the necessary guarantees.

The other thread of research, within which the current work sits, is directed towards investigating the dynamic relations established over time between the bond and CDS

[2] From among the first authors who dealt with the topic of arbitrage limits, we cite Shleifer and Vishny (1997). In principle, and from the theoretical viewpoint, arbitrage does not require capital and is not risky. In reality, however, the majority of arbitrage opportunities do require capital and are risky. Along these lines, Amadei et al (2011) hold that there exists counterparty risk tied to the use of CDS that prevents the arbitrage from being perfectly risk free. More generally, it has been observed that arbitrage strategies are not always attractive to intermediaries or professional market operators. Especially in extreme market conditions (such as those examined in this work), it could be difficult to find resources and allocate them in a timely manner to the most opportune strategies, with inevitable consequences for the economic effectiveness of the strategies themselves. Because of possible frictions in the functioning of markets, there is, moreover, the risk of having to close out positions before their natural maturity and, therefore, of incurring penalties on the implemented strategies. Li, Zhang and Kim (2013), following on from Shleifer and Vishny (1997), reach similar conclusions about the limits of arbitrage. In their 2013 work, they argue that a non-zero Basis, although from a theoretical point of view represents the operating assumption for setting up an arbitrage, in fact creates a wide range of risks. In the first place, a non-zero Basis could have been caused by differences in contract types between bonds and CDSs and might not necessarily represent the theoretical premise for realizing an arbitrage strategy. Secondly, arbitrageurs could lose even in potentially profitable exchanges. They could, for example, incur liquidity risks relating to both the bond market and the CDS market, just as they could incur deleveraging risks from other investors. Therefore Li, Zhang & Kim (2013) argue that a non-zero Basis in fact exposes operators and arbitrageurs to risky activity. In the European sovereign context, the main cause of obstacles to the realization of arbitrage has been the difficulty of short selling government bonds, in turn due to the elevated costs and the difficulty of finding bonds to borrow.

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markets. More precisely, the focus of this second thread is the analysis of the *price discovery* of credit risk, defined by Lehman (2002) as "the efficient and timely incorporation of the information implicit in investor trading into market prices".

The fact that the price discovery process for credit risk does not occur within a single market has led academics to pose two important research questions:

1. Does the divergence in the short term between CDSS and BS present a return to the equilibrium in the long term?
2. Between the bond market and the CDS market, does one anticipate the other in pricing credit risk? In other words, which is the leading market and which the lagging market?

In the face of these questions, the first contribution is the study of Blanco et al (2005) that analyses a sample of 33 US and European investment-grade companies. Blanco et al. (2005), for 26 of the 33 entities examined, show the presence of a stable cointegrating relationship, or the tendency for the deviations in the short term between the CDSSs and BSs to return to equilibrium in the long term. Other important works that investigate the corporate sector in the pre-crisis period are those of Zhu (2006) and Norden & Weber (2009). The two verify the presence of cointegration for 14 out of 24 and 36 out of 58 entities analysed respectively. These studies show that in the corporate sector the Basis is usually positive and narrow and that, in most of cases and predominantly for the US companies, the CDS market anticipates the bond market. The authors attribute this evidence to the greater liquidity of the CDS market and to the different types of intermediaries that operate in it.

Among the more recent contributions examining the impact of the financial crisis on the price discovery of credit risk, we find Giannikos et al (2013). In this study, the authors, using a sample of 10 US financial companies, investigate the short-term and long-term dynamic relationships between the stock, bond and CDS markets. In the quest to identify the possible existence of a leading market, this work offers an important contribution by showing how the role of the stock market changes with the start of the financial crisis. Specifically, the authors observe that before the financial crisis the stock market played a dominant role in price discovery. Then, with the beginning of the crisis, its informative power decreased and the CDSSs assumed a dominant role. Within this thread of research, Avino et al (2013) provide a wider examination of price discovery in the corporate market, taking into account a sample of 30 non-financial European and US companies. The empirical evidence shows that the leading role was taken by both the CDS market and the stock market before the default of Lehman Brothers (2006-2007) and during the sovereign debt crisis (2009-2012). In contrast, during the period of the sub-prime crisis (2007-2009), and only in the European sample, the BSs took leadership of the price discovery process. In contrast, for the US sample, during the sub-prime crisis, the CDSSs took on the dominant role, as also evidenced in Giannikos et al. (2013). From the evidence that can be inferred from the literature, it is not however possible to draw unequivocal conclusions because the process of price discovery among credit spreads changes significantly depending on the periods, geographical areas and specific reference entities examined.

The studies on price discovery are concentrated predominantly on the corporate sector. Little attention has been given to the sovereign sector. However, the recent European sovereign debt crisis has offered further opportunities to study the dynamics of price discovery in relation to European government entities, and possibly to compare the results to those obtained for the corporate sector.

The first authors who study the price discovery of credit risk in the Eurozone countries are Fontana and Sheicher (2010), who investigate the relationship between CDSSs and BSs in 10 European countries from 2006 to 2010. These authors show, before the financial crisis, a general absence of cointegration between the two credit spreads, as a result of the lack of trading in CDS contracts. Then, from the default of Lehman Brothers onwards, all countries prove to be cointegrated. This fact allows an investigation of the dynamics in the adjustment process of the two series of spreads towards equilibrium in the long term. For Germany, France, Holland, Austria and Belgium, the bond market guides the price discovery. In contrast, for Italy, Ireland, Spain, Portugal and Greece, the CDS market moves first.

The most recent contributions on the price discovery of sovereign credit risk are those from Coudert and Gex (2013) and Alper et al. (2013). Coudert and Gex (2013) analyse the links between CDSSs and BSs in order to determine which market is the leader in the price discovery process. The analysis is carried out on a sample made up of CDSSs and BSs for 18 government entities, for the period 2007-2010. The authors show significant differences between the peripheral and core countries of the euro area. Specifically, for countries with high credit ratings, the bond market leads the CDS market. For the countries with low ratings, the CDS market leads the bond market. Moreover, the CDS prices see their informative role increase in the period with the highest perception of credit risk. Similar conclusions are reached by Alper et al (2013), using a sample of 10 advanced countries, limited to the period 2008-2010.

In any case, it is necessary to interpret the results with due caution, given that all the mentioned studies are based on rather short intervals and none take into consideration the period of instability identified by the sovereign debt crisis in the Eurozone. While the current paper is based on a sufficiently long period of time. The chosen extension of the time period allows us to represent particularly accurately the actual dynamics of the price discovery of credit risk in market contexts characterised by different levels of volatility and liquidity.

III. Dataset

To carry out the present study, a dataset was extracted from the Bloomberg platform. The dataset includes, for the time period 2008-2014, daily quotations, from the close of trading, of the CDSSs and rates of return of government bonds with five-year maturities from 10 euro-zone countries[3].

For each country, the series of BS is calculated as the difference between the bond rate of return for that country and the rate of return on a five-year German government bond. The choice to use German government bonds is justified for at least three reasons. First, for the interval considered, the rate of return on German government bonds was recognised by the market as a valid proxy for the risk-free rate. Second, with this approach, in contrast to that using interest rate swaps (IRS) as a proxy for the risk-free rate, we obtain bond spreads that are always positive[4]. The third reason is directly linked to the second. Having only positive

[3] In detail, the countries subjected to the analysis are Austria, Belgium, Finland, France, Greece, Ireland, Italy, Holland, Portugal and Spain. Germany is not included, as it is used as the reference country for the calculation of the BSs. The selection of the time period and countries is based on data availability. The choice of a five-year maturity is based on the greater liquidity at this maturity for the financial instruments considered. It is scarcely necessary to note that there is little interest in investigating the period preceding the financial crisis for two reasons: i) the CDSs and BSs for sovereign entities were particularly contained and stable at that time, since, for the majority of issuers, creditworthiness was perceived to be high; ii) the orders on government CDS showed trading volumes particularly contained.

[4] This approach avoids incurring negative credit risk quotations, implicit in the bond market, for those government entities with high creditworthiness. Precisely, the IRS rate synthesises the conditions of the interbank market and is typically associated with an AA rating. Using this rate as a proxy for the risk-free rate produces negative bond spreads for countries to

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bond spreads allows us to run our analysis on the logarithms of the two series of credit spreads.

The data sample is divided into three periods: (1) 2008-2010, (2) 2010-2012 and (3) 2012-2014.

IV. Econometric Methodologies

In order to verify the changes from one period to another of the country-dependent dynamics of the price discovery process in the Eurozone, a specific econometric model is developed, based on the methodology proposed by Gonzalo and Granger (1995) that is widely used throughout the literature on this subject. In detail, the price discovery analysis is divided into two phases. This division is justified by the fact that the first and second phases are aimed at addressing, respectively, the two intermediate objectives of this work.

In the first phase, in order to verify whether the short-term deviations in the CDSSs and BSs converge, following the action of market forces, towards parity in the long term (first intermediate objective), the concept of "cointegration" is used. Testing of the presence of cointegration between the CDSS and BS series offers an adequate response to the first research question. Two series are said to be cointegrated if, despite deviating from each other in the short term, they exhibit a process of adjustment towards equilibrium in the long term. In other words, and in technical terms, when a linear combination of two historical non-stationary series generates a stationary process, we can say that the two series are cointegrated.

Initially, the hypothesis of non-stationary (or unit root) of the CDSS and BS series is verified using the Augmented Dickey-Fuller (ADF) test, for each of the 11 Eurozone countries. Next, using Johansen's (1988) trace statistic, the existence of a cointegrating relationship between the CDSSs and BSs, or of a stationary linear combination of the two non-stationary series, is verified. This econometric technique allows us to test the null hypothesis of the absence of cointegration between the CDSSs and BSs for each of the countries studied.

The results of this first step of the analysis serve as preparation for the second phase of the research[5]. In this phase, in order to check whether a leading and a following market exist, or something in between, the lead-lag relationship between the BSs and CDSSs is analysed. In other words, we analyse the adjustment process of the short-term deviation between the two series towards the long-term equilibrium that was confirmed by the test of cointegration (in the first phase). An econometric model that allows us to investigate this adjustment process is the Vector Error Correction Model (VECM) proposed by Engle and Granger (1987). The VECM is a vector autoregressive (VAR) model with an error correction term (ECT). The model is specified in this paper by the following equations:

$$\Delta CDS_t = \alpha_1 + \lambda_1 Z_{t-1} + \sum_{i=1}^{p} \beta_{1i} \Delta CDS_{t-i} + \sum_{i=1}^{p} \gamma_{1i} \Delta BOND_{t-i} + \varepsilon_{1t} \qquad (1)$$

$$\Delta BOND_t = \alpha_2 + \lambda_2 Z_{t-1} + \sum_{i=1}^{p} \beta_{2i} \Delta CDS_{t-i} + \sum_{i=1}^{p} \gamma_{2i} \Delta BOND_{t-i} + \varepsilon_{2t} \qquad (2)$$

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which the market attributes creditworthiness superior to the interbank creditworthiness. Since, during the period of analysis, Germany benefited from an interest rate on debt that was lower than those for all other Eurozone countries, using this rate of return as a proxy for the risk-free rate allows us to obtain positive BSs for all of the countries under study.

[5] See Section 1 (Introduction), 2nd intermediate objective.

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Where:

a) ΔCDS_t and $\Delta BOND_t$ are the CDSS and BS series expressed in first differences and represent, respectively, the dependent variables in equations 1 and 2;
b) ΔCDS_{t-i} and $\Delta BOND_{t-i}$ are the lagged first differences of the CDSS and BS series; they are included, in equations 1 and 2, as model regressors that explain the deviations in the short term in the first differences of the CDSSs and BSs;
c) p=the number of lags in the regressors;
d) ε_{1t} and ε_{2t} are error terms;
e) $Z_{t-1} = CDS_{t-1} - c - \beta_0 BOND_{t-1}$ (the ECT) describes the deviations of the CDSSs and BSs, lagged by one day, from their theoretical relationship of parity in the long term[6].
f) λ_1 and λ_2 are termed "adjustment coefficients" in view of the fact that they correct the deviations in the CDS and bond spreads towards equilibrium in the long term, as verified by the cointegration analysis.

In practice, equations 1 and 2 express the deviations in the short term between the BSs and CDSSs in first differences, with the respective addition of "$\lambda_1 Z_{t-1}$" and "$\lambda_2 Z_{t-1}$" that capture the relationships between the two spreads in the long term.

For the purpose of our analysis, the significance and the signs of the adjustment coefficients (λ_1 and λ_2) allow us to verify the degree of informative power of one market with respect to the other. Specifically, we can consider three cases:

1. If λ_1 is negative and significant, the bond market incorporates new information more quickly than the CDS market, and consequently the latter moves in the direction of restoring some kind of equilibrium in the long run.
2. If λ_2 is positive and significant, the CDS market incorporates new information more quickly than the bond market, and consequently the latter moves in the direction of restoring some kind of equilibrium in the long run[7].

[6] In theory, the parameters and should be equal to 0 and -1 respectively, but this condition is not imposed because, as noted earlier, equality between CDSSs and BSs, for equal maturities and reference entities, occurs only approximately, due to technical and market factors (Choudhry, 2006). In other words, if the quotations of the two credit spreads were exactly equal in the long term, they would be cointegrated with a vector (1, -1, 0), while in this study the vector (1,-b,c) is used, in line with the relevant literature. These two parameters are estimated in the first phase of the analysis using Johansen's method.

[7] A more detailed explanation of the theoretical interpretation of the adjustment coefficients (λ_1 and λ_2) is the following. If, in equation 1 the ECT of the equilibrium relationship in the long term predicts significant changes in the CDSSs, then that signifies that the BSs generally move first and the CDSSs conform to them afterwards. Precisely, if the ECT is positive (negative), it signifies that the CDSS is greater (smaller) in numerical terms than the BS and is outside of the long-term equilibrium verified by the cointegration test. In other words, it is higher (lower) than the theoretical value expected in equilibrium, which signifies that one would expect a readjustment downwards (upwards). In order to find such a dynamic empirically, λ_1 should take a negative sign. If, in equation 2 the ECT of the equilibrium relationship in the long term predicts significant changes in the BSs, then that signifies that the CDSSs generally move first and the BSs conform to them afterwards. Precisely, if the ECT is positive (negative), it signifies that the BS is smaller (greater), in numerical terms, than the CDSS and is outside of the long-term equilibrium verified by the cointegration test. In other words, it is lower (higher) than the theoretical value expected in equilibrium, which signifies that one would expect a readjustment upwards (downwards). In order to find such a dynamic empirically, λ_2 should take a positive sign. In other terms, the lower is the speed of adjustment (the smaller is λ) of a certain market (dependent variable), the greater is its contribution to price discovery. Ultimately, if a market (dependent variable) is more efficient then it incorporates new information (λ decreases) more quickly and it has a more informative power in the price discovery process.

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3. When both coefficients are significant and have the correct sign (λ_1 negative and λ_2 positive), both markets participate in the adjustment process towards equilibrium in the long term.

In the first two cases, when only one of the coefficients is statistically different from zero (significant) and has the correct sign (negative for λ_1 and positive for λ_2), a single market contributes to the price discovery (*Market Share* = 100%). This is termed the leading or dominant market. In the third case, when both coefficients are significant, in order to determine how much each market contributes to the price discovery, the following formula of Gonzalo and Granger (1995) is applied:

$$\textit{Market Share}: \frac{\lambda_2}{\lambda_2 - \lambda_1} \qquad (3)$$

If the CDS market is dominant, *Market Share* will be close to 1. On the other hand, if the bond market is dominant, it will be close to 0. If the two markets contribute similar amounts to the price discovery, the ratio will be close to 0.5.

When the CDSSs and BSs turn out not to be cointegrated, the VECM is not valid. In this case, in order to study the lead-lag relationship between the historical series, it is necessary to apply the Granger (1969) causality test, in line with Forte (2009). In detail, given two series X and Y, one says that X "Granger causes" Y if the past values of X contain useful information, other than that contained in the past values of Y, for explaining the current value of Y.

In order to determine whether, in the price discovery process, there exists a leading market between the CDS and bond markets, or whether both play a significant role, Granger's causality test, as just described, is applied to the following regressions 4 and 5, in which the terminology is the same as that in equations 1 and 2:

$$\Delta CDS_t = \alpha_1 + \sum_{i=1}^{p} \beta_{1i} \Delta CDS_{t-i} + \sum_{i=1}^{p} \gamma_{1i} \Delta BOND_{t-i} + \varepsilon_{1t} \qquad (4)$$

$$\Delta BOND_t = \alpha_2 + \sum_{i=1}^{p} \beta_{2i} \Delta CDS_{t-i} + \sum_{i=1}^{p} \gamma_{2i} \Delta BOND_{t-i} + \varepsilon_{2t} \qquad (5)$$

In detail, equations 4 and 5 represent a VAR model without ECT and are obtained by eliminating from equations 1 and 2 the terms "$\lambda_1 Z_{t-1}$" and "$\lambda_2 Z_{t-1}$" due to the absence of cointegration. Specifically, the Granger causality test of the coefficients of the VAR model considers the following three cases[8]:

1. If, in equation 4, the null hypothesis that the BSs do not Granger cause the CDSSs, that is $\gamma_{1i} = 0$ for i=1,...,p, is rejected, we may conclude that the bond market contributes to the price discovery.

[8] It is appropriate to underline some limitations of the Granger causality test when applied in this context. If the variables are linked by a cointegrating relationship, the omission of the ECT, or the process of adjustment towards the long-term equilibrium, will produce a specification error in the model that could distort the estimations of the coefficients and of the statistical test in an unpredictable direction. At the same time, it is not possible to include the ECT in cases where the hypothesis of cointegration has been rejected. The results should therefore be interpreted with caution. However, given that the interest of this study lies predominantly in investigating the lead-lag relationship and not the magnitude of the parameters, the test utilised provides sufficiently robust empirical evidence. See Forte (2009).

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2. If, in equation 5, the null hypothesis that the CDSSs do not Granger cause the BSs, that is $\beta_{2i} = 0$ for i=1,...,p, is rejected, we may conclude that the CDS market contributes to the price discovery.
3. If the tests reject the null hypothesis in both directions of causality, we may conclude that the price discovery is manifested in both markets.

In the first two cases, when only one of the two directions of causality is significant, a single market contributes (*Market Share* = 100%) to the price discovery. This is known as the leading market, in the same way as in the approach adopted in the VECM. It should be observed that, in the third case, or when both directions of causality are significant, it is not possible to apply the *Market Share* formula, unlike in the case of the VECM.

In a nutshell, the first phase of the analysis verifies the possible presence of cointegration between the CDSSs and BSs. The second phase of the analysis investigates the lead-lag relationship between the two markets using either the VECM or the VAR, depending on whether there is a presence or lack of cointegration[9]. The two methodological phases are repeated for each Eurozone country and for each of the three periods indicated earlier.

V. Data Analysis

The empirical results of this paper are presented in the following Tables 1, 2 and 3, in each of which the core countries of the Eurozone are grouped on the left, and the peripheral ones on the right. The tables refer respectively to the following time periods:

- the period of the financial crisis (15/9/2008-14/9/2010), Table 1;
- the period of the sovereign debt crisis (15/9/2010-14/9/2012), Table 2;
- the period of contraction of credit spread quotations (15/9/2012-14/9/2014), Table 3.

In the tables, each column, for each country, repeats the methodological process to identify the dominant market in the credit risk price discovery process. This market is explicitly indicated, for each country and for each of the three intervals studied, in the penultimate row of each table.

As shown by the tables, the price discovery analysis can be summarised as follows:

- In the first phase, the results of the unit root tests on the levels and on the first differences of the two series of credit spreads are presented, and then the estimates of the trace statistics, to verify the presence or lack of cointegration.
- In the second phase, the estimates of the VECM or VAR model are presented. The VECM is used when the two series are cointegrated (trace test). The VAR model is used in one of two cases:
  - o when the unit root test has rejected the hypothesis of non-stationary on the levels for at least one of the two series, such that it is not possible to estimate the trace statistic, or
  - o when the trace statistic has led to the acceptance of the hypothesis of the absence of cointegration.
- In the penultimate row, the conclusions about price discovery are indicated, inferred from the estimates of the VECM or VAR model. The last row contains, where

[9] One resorts to the VAR model in two cases: (1) if the Johansen trace test accepts the null hypothesis of an absence of cointegration; (2) if the ADF test for a unit root rejects the hypothesis of non-stationary on the levels for at least one of the two series of credit spreads, as a consequence of which it is not possible to carry out the trace test of cointegration.

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identifiable, the proportion of informative power (*Market Share*) of the dominant market in the process of price discovery.

VI. Discussion of Data Analysis

In Table 1 (15/9/2008-14/9/2010, Core Countries), the estimates from the first phase of analysis show that the CDSSs and BSs for Belgium and France follow a process of returning to equilibrium in the long term. This emerges from the trace statistic that rejects the hypothesis of the absence of cointegration. For Austria, Finland and Holland, the rejection of the preliminary hypothesis of non-stationary in the levels of one of the two series of credit spreads prevented us from using the trace statistic. In detail, for the Austrian and Dutch CDSSs and the Finnish BSs the hypothesis of non-stationary was rejected. This evidence explicitly obliged us to apply the second phase of the analysis using the VECM for Belgium and France, and the VAR model for the other core countries. The results underline that, for Belgium and France, the only market that contributes to price discovery is the CDS market, given that only coefficient of adjustment λ_2 is significant. The Granger causality test applied to the VAR models for Austria and Finland confirms that even in these cases only the CDS market contributes significantly to the price discovery. In contrast, for Holland, the Granger causality test shows that the process is sustained entirely by the bond market.

In Table 1 (15/9/2008-14/9/2010, Peripheral Countries), the estimates from the first phase of analysis show that the CDSSs and BSs from all the peripheral countries, except for Slovakia, follow a cointegrated process. The results of the second phase of analysis show that, for Greece, Ireland and Spain, only the CDS market contributes to the price discovery, given that only λ_2 (coefficient of adjustment) is significant. For Slovakia the same result is achieved, but from the Granger causality test that is applied to the VAR model. In Italy, the significance levels of both coefficients of adjustment, λ_1 and λ_2, show that both the CDS and the bond market contribute to the process of price discovery. For the Italian market, the significance levels of both coefficients (λ_1 and λ_2) allow us to calculate *Market Share*, from which we learn that the informative power of the CDS market is equal to 66.7%.

In Table 2 (15/9/2010-14/9/2012, Core Countries) the estimates from the first phase of analysis show that the CDSSs and BSs of Austria, Finland and France follow a cointegrating process. For Belgium the hypothesis of the absence of cointegration can be accepted. For Holland, the rejection of the preliminary hypothesis of non-stationary of the levels of the BSs meant that it was not possible to run the trace statistic. The results of the second phase of analysis show that, for Belgium, Finland and Holland, the CDS market alone contributes to the price discovery. In Austria and France, both the CDS and the bond market contribute. However, for both countries, the calculation of *Market Share* reveals that the CDS market has more informative power, at 69% and 71.3% respectively.

In Table 2 (15/9/2010-14/9/2012, Peripheral Countries) the estimation of the first phase of analysis shows that the CDSSs and BSs of Greece, Italy, Portugal and Slovakia follow a cointegrating process. For Spain, the hypothesis of the absence of cointegration can be accepted. For Ireland, the rejection of the preliminary hypothesis of non-stationary of the levels of the BSs and CDSSs meant that it was not possible to run the trace statistic. The results of the second phase show that for Greece, Italy and Portugal only the bond market contributes to the price discovery, in view of the fact that only λ_1 (adjustment coefficient) is significant. It is hardly necessary to underline that, for Greece, the effect of the adjustment of

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the CDSSs towards the BSs is more intense (λ_1=0.14). In Slovakia, both the CDS and the bond market contribute to the price discovery process. However, the calculation of *Market Share* reveals that the bond market has greater informative power, at 66.1%. For Ireland and Spain, the Granger causality test applied to the VAR model shows that both the CDS and bond markets contribute significantly to the price discovery.

In Table 3 (15/9/2012-14/9/2014, Core Countries) the estimates from the first phase of analysis show that only for France do the CDSSs and BSs follow a cointegrating process. For Belgium and Holland, the hypothesis of the absence of cointegration is accepted. For Austria, the rejection of the preliminary hypothesis of non-stationary of the levels of the BSs meant that it was not possible to run the trace statistic. The results of the second phase show that, for France, only the CDS market contributes to the price discovery, given that λ_2 (adjustment coefficient) is significant. For Austria and Holland, the Granger causality test applied to the VAR model evidences a significant contribution to the price discovery from the bond market alone. For Belgium and Finland, neither the CDS nor the bond market turns out to be significant for price discovery.

In Table 3 (15/9/2012-14/9/2014, Peripheral Countries) the estimations of the first phase of analysis evidence that the CDSSs and BSs of Ireland, Italy and Portugal follow a cointegrating process. For Slovakia and Spain, the hypothesis of the absence of cointegration can be accepted. It is scarcely necessary to note that, for Greece, the small number of observations makes it inadvisable to run the analysis[10]. The results of the second phase of analysis show that, for Italy and Portugal, only the bond market contributes to the price discovery. The only coefficient of adjustment that is significant is λ_1, in fact. In Ireland, both the CDS and the bond market contribute to determine the price. However, the *Market Share* calculation shows that the bond market has slightly more informative power, at 58.5%. The Granger causality test applied in the case of Spain demonstrates that only the bond market provides a significant contribution. For Slovakia, both markets contribute significantly to the price discovery.

In the light of what has emerged from the above detailed evaluation of the results, it can be confirmed that during the financial crisis the CDSSs dominate price discovery. In the second period the CDS market's share of informative power decreases and the bond market assumes greater relevance. In the third period, price discovery is dominated by the BSs. This pattern is more marked for the high-yield (peripheral) countries and more restrained for the low-yield (core) countries.

The robustness of the theory and the correct application of the econometric model is inferable from the discord in the signs of the adjustment coefficients. For the countries that exhibit cointegrated CDSSs and BSs, the estimated values of λ_1 are negative, and those of λ_2 positive. In other words, the signs of the coefficients are consistent with mean reversion of the CDS-bond basis in the long term. This evidence confirms the theoretical expectation of a diffuse pattern of adjustment in the long term between the CDS and bond markets. It is hardly necessary to observe that the levels of significance and speed of adjustment of the

[10] This is due to the lack of issuance of Greek government bonds for three or four years.

coefficients, even if generalizable to the aggregate level, assume specific connotations at the level of the single country and with reference to each of the three time periods investigated[11].

VII. Conclusions

This study has analysed the dynamics of the relationships between BSs and CDSSs in the price discovery process of credit risk in the core and peripheral countries of the Eurozone, from 2008 to 2014. In order to fulfil the two intermediate objectives, the analysis of price discovery was carried out in two phases. In the first phase it was investigated whether the misalignments of the CDSSs and BSs exhibited a mean-reverting effect, or a return towards the equilibrium in the long term. In the second phase a lead-lag analysis was carried out, looking at which market anticipated the other in pricing credit risk. Both methodological phases were carried out in three time periods: 2008-2010, 2010-2012 and 2012-2014.
This methodological approach has allowed us to present the changes in the actual price discovery dynamics, for every country in the Eurozone.

From the first phase of analysis, the following can be observed:

- During the periods with greater volatility (2008-2010 and 2010-2012), it is possible to verify the existence of an equilibrium relationship in the long term between the two credit spreads.
- During the period with less financial turbulence (2012-2014), the two series turn out to be less strongly related in the long term[12].

These results can be interpreted as follows:
The action of the market forces is able to close the divergence between the two credit spreads towards an equilibrium in the long term, more frequently in periods of high volatility. From the operating point of view, that is equivalent to a situation in which the market forces come

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[11] An approach that allows the reader to comprehend the above mentioned specific connotations at the level of the country and the time period is to analyse the results in Tables 1, 2 and 3 according to two interpretations:

a) the heterogeneity between the 11 countries within the same time period (in terms of level of significance and speed of adjustment coefficients);
b) the heterogeneity between the 3 time periods for each single country (in terms of the level of significance and speed of adjustment coefficients).

For example, regarding the heterogeneity between countries, during the sovereign debt crisis (second period), in France, Austria and Slovakia, the p-values (or t-statistics) and the signs of the coefficients of adjustment (λ_1 and λ_2) reveal that the CDS market contributes just as significantly as the bond market to the phenomenon of adjustment towards equilibrium). On the contrary, again in the second period, in Italy, Greece and Finland, even though the signs of both coefficients of adjustment are consistent with the phenomenon of mean reversion of the CDS-bond basis, the process of adjustment is realized significantly (p-values below 10%) in just a single market: in Finland in the bond market, in Italy and Greece in the CDS market, with significance levels of 1%, 10% and 1% respectively. As well as the significance level, the speed of adjustment varies according to the country considered. For example, again in the second period, the Greek CDSSs exhibit a speed of adjustment (0.145) towards the bond market far greater than the Italian CDS market (0.0029), signifying that during the sovereign debt crisis the bond market had greater informative power in Greece than in Italy.
Similar findings emerge for the case of heterogeneity between time periods. For example, in France, during the financial crisis and the sovereign debt crisis (first and second periods), the CDSSs were more efficient than the BSs in the price discovery process. However, from the observation of the significance levels and speeds of adjustment of the adjustment coefficients there emerge differences between the first and second periods. The CDS *Market Share* goes from 100% in the first period to 71.26% in the second. This change reflects the lack of significance of λ_1 in the first period and its significance (at 5%) in the second. In other words, only in the second period there is significant adjustment towards equilibrium from the CDS market as well, and therefore statistically significant informative power for the bond market (28.74%), albeit inferior to that of the CDS market. The process of adjustment towards equilibrium on the part of the bond market is marked, in the two periods of analysis, by the same level of significance of λ_2 (5%) but different speeds of adjustment (0.028 in the first period and 0.059 in the second).

[12] The low presence of cointegration in the period of low volatility is in line with Fontana and Sheicher (2010), who find an absence of cointegration for the Eurozone countries in the period preceding the financial crisis.

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into play when the misalignment between the two credit spreads is sufficiently wide for strategies to be implemented that are profitable net of transaction costs.

- The effect of mean reversion in the long term is less evident for the low-yield (core) countries in all three periods.

This result can be interpreted as follows:
Especially in periods of turbulence, market participants look to rebalance their positions by investing in those bond markets that are considered risk free, such as those of the core countries. This generates, for the low-yield countries, an increasing volume of trading in the bond market and lower liquidity in the CDS market. This causes the absence of a stable relationship between the two credit spreads in the long term.

From the second phase of analysis, the following can be observed:

- During the financial crisis (2008-2010), the CDS market assumes the dominant role in the price discovery of credit risk in the core and peripheral countries.

This result can be interpreted as follows:
The period of financial crisis triggers a strong demand for protection and consequently CDS are more convenient and simpler instruments for trading credit risk. The principal reasons for positions on credit risk being taken up through the CDS market rather than the bond market are the following:

- *the greater ease of buying and selling large quantities of credit risk with CDS, given the unfounded nature of CDS and the funded nature of bonds;*
- *the difficulty of short selling bonds for those who wish to engage the protection of the bond market, in particular in periods of stress and high default risk.*

These circumstances shift the liquidity towards the CDS market, making this market de facto more efficient at pricing credit risk.

- During the period of the sovereign debt crisis (2010-2012), both the CDS and the bond market contribute to the price discovery of credit risk. As a consequence, relative to the preceding period, the share of informative power of the CDS market falls in favour of the bond market. This tendency is sharply more evident for the peripheral countries, particularly Greece, in comparison to the core countries. It is hardly necessary to underline that this result is particularly interesting in view of the related works that have investigated the 2008-2010 period of financial crisis. Such works conclude that, during the periods of greatest perception of credit risk in the Eurozone , the CDS market dominated price discovery for the high-yield countries. In contrast, the present work demonstrates the significant role played by the bond market in the peripheral countries, during the sovereign debt crisis.

This result can be interpreted as follows:
Following the downgrading of sovereign debt by the rating agencies, there is a more objective evaluation of credit risk with respect to the period of 2008-2010. The investors begin to differentiate their positions within the European market between core and peripheral countries. The speculation about the disintegration of the euro area triggers market tensions concerning the peripheral bonds. This causes large volumes of capital to be moved towards the bond market, increasing the informative power of the bond spreads.

- During the period marked by a progressive downsizing of credit risk in the Eurozone (2012-2014), the informative power of the bond market grows still further with respect to that of the CDS market.

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This result can be interpreted as follows:
The lower trading activity in the CDS market and the greater liquidity in the bond market contribute towards the bond spreads' active role in price discovery.
Clearly, the concepts of volatility and liquidity assume a key role in the interpretation of the results of this study. Volatility represents the fundamental premise for market forces having adequate margins to exploit the misalignment between the bond and CDS spreads. Liquidity represents the fundamental requirement of the leading market in terms of price discovery, which occurs in the market that is more informed and liquid.

VIII. Practical Implications

The results that emerge from the empirical analysis support the scientific studies that investigate the microstructure of the financial markets. Meanwhile, they are particularly useful for market operators and policy makers, too. For market operators, the ability to identify the leading and following instruments of price discovery offers them the opportunity to profit from the implementation of strategies that exploit the process of adjustment between the two markets. For policy makers, in their capacity as guarantors of price stability and in their function as controllers of any systemic crises, it would seem appropriate for them to have a deep knowledge of the dynamics of price discovery. The identification of leading instruments, related to specific phases of the market (of volatility, liquidity, credit risk etc.), in fact facilitates the assessment of adequate and efficient monetary and fiscal policies. Nevertheless, the policy makers should take due notices of the fact that their own manoeuvres will in turn affect the future dynamics of price discovery.

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Table 1: Price Discovery of Credit risk in Eurozone - First Period: 15/9/2008-14/9/2010 - Core Countries (Austria, Belgium, Finland, France, Netherlands) and Peripheral Countries (Greece, Ireland, Italy, Portugal, Slovakia, Spain).

		CORE COUNTRIES					PERIPHERAL COUNTRIES					
	FIRST PERIOD	AUSTRIA	BELGIUM	FINLAND	FRANCE	NETHERLANDS	GREECE	IRELAND	ITALY	PORTUGAL	SLOVAKIA	SPAIN
I PHASE	**UNIT ROOT Analysis**											
	CDS Level	-4.64***	-2.02	-2.34	-2.25	-2.85*	-1.23	-1.48	-2.46	-1.19	-1.46	-1.83
	BOND Level	-2.35	-2.18	-3.26**	-2.31	-2.55	-0.73	-1.09	-1.87	-1.34	-1.63	-1.69
	CDS Difference	-6.60***	-13.00***	-26.53***	-20.85***	-20.17***	-20.53***	-11.84***	-18.68***	-18.71***	-15.47***	-13.36***
	BOND Difference	-18.94***	-19.97***	-11.18***	-22.11***	-21.33***	-19.42***	-12.18***	-16.78***	-18.33***	-15.96***	-15.72***
	COINTEGRATION Analysis											
	TRACE Test	-	13.54*	-	15.37*	-	14.99*	16.61**	21.80***	16.25**	11.40	16.76**
II PHASE	**VECM Analysis**											
	Lambda 1	-	-0.012436	-	-0.004474	-	-0.021992	-0.015	-0.019365	-0.012656	-	-0.022454
	[t-stat]	-	-1.44	-	-0.73	-	-1.38	-0.68	-1.83*	-0.91	-	-1.54
	Lambda 2	-	0.017017	-	0.028639	-	0.027807	0.092	0.038743	0.046238	-	0.039072
	[t-stat]	-	1.98**	-	2.56**	-	1.94*	3.36***	2.63***	2.84***	-	2.26**
	VAR Granger casuality											
	BOND	2.53	-	2.94	-	7.89**	-	-	-	-	2.12	-
	CDS	8.66**	-	9.05**	-	0.06	-	-	-	-	6.41**	-
	PRICE DISCOVERY	CDS	CDS	CDS	CDS	BOND	CDS	CDS	CDS>BOND	CDS	CDS	CDS
	Market Share	100%	100%	100%	100%	100%	100%	100%	66.7%	100%	100%	100%

***,** and * denote:

- in UNIT ROOT Analysis, rejection at the 1%, 5% and 10% levels, respectively, of the null hypothesis of non-stationarity;
- in COINTEGRATION Analysis, rejection at the 1%, 5% and 10% levels, respectively of the null hypothesis of absence of cointegration;
- in VECM Analysis, significance of adjustment coefficients at the 1%, 5% and 10% levels, respectively;
- in VAR Analysis, significance of Granger causality at the 1%, 5% and 10% levels, respectively.

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Table 2: Price Discovery of Credit risk in Eurozone - Second Period: 15/9/2010-14/9/2012 - Core Countries (Austria, Belgium, Finland, France, Netherlands) and Peripheral Countries (Greece, Ireland, Italy, Portugal, Slovakia, Spain).

		CORE COUNTRIES					PERIPHERAL COUNTRIES					
	SECOND PERIOD	AUSTRIA	BELGIUM	FINLAND	FRANCE	NETHERLANDS	GREECE	IRELAND	ITALY	PORTUGAL	SLOVAKIA	SPAIN
I PHASE	**UNIT ROOT Analysis**											
	CDS Level	-0.87	-1.59	-1.58	-1.46	-1.47	-0.41	-6.34***	-1.25	-1.71	-1.46	-1.99
	BOND Level	-1.63	-1.35	-2.29	-1.73	-2.63*	0.53	-6.63***	-1.55	-1.67	-2.30	-1.96
	CDS Difference	-18.83***	-17.73***	-29.62***	-19.75***	-17.65***	-18.82***	-19.57***	-15.96***	-17.73***	-17.55***	-16.36***
	BOND Difference	-22.58***	-19.45***	-21.14***	-22.27***	-23.49***	-13.05***	-21.77***	-19.15***	-17.23***	-20.75***	-18.63***
	COINTEGRATION Analysis											
	Trace test	14.64*	11.72	17.41**	21.11***	-	22.01***	-	13.47*	13.69*	16.33**	12.86
II PHASE	**VECM Analysis**											
	Lambda 1	-0.010069	-	-0.013251	-0.024135	-	-0.145080	-	-0.029933	-0.043162	-0.012495	-
	[t-stat]	-2.00**	-	-1.59	-2.41**	-	-3.82***	-	-1.93*	-3.05***	-1.85*	-
	Lambda 2	0.022462	-	0.049295	0.059852	-	0.013849	-	0.006809	-0.013976	0.024399	-
	[t-stat]	1.97**	-	3.27***	2.39**	-	0.50	-	0.34	-0.84	2.42**	-
	VAR Granger casuality											
	BOND	-	3.12	-	-	2.97	-	39.77***	-	-	-	6.30**
	CDS	-	10.91***	-	-	5.02*	-	30.93***	-	-	-	4.78*
	PRICE DISCOVERY	CDS>BOND	CDS	CDS	CDS>BOND	CDS	BOND	CDS&BOND	BOND	BOND	CDS>BOND	CDS&BOND
	Market Share	69%	100%	100%	71.26%	100%	100%	n.d.	100%	100%	66.1%	n.d.

***,** and * denote:

- in UNIT ROOT Analysis, rejection at the 1%, 5% and 10% levels, respectively, of the null hypothesis of non-stationarity;
- in COINTEGRATION Analysis, rejection at the 1%, 5% and 10% levels, respectively of the null hypothesis of absence of cointegration;
- in VECM Analysis, significance of adjustment coefficients at the 1%, 5% and 10% levels, respectively;
- in VAR Analysis, significance of Granger causality at the 1%, 5% and 10% levels, respectively.

Table 3: Price Discovery of Credit risk in Eurozone - Third Period: 15/9/2012-14/9/2014 - Core Countries (Austria, Belgium, Finland, France, Netherlands) and Peripheral Countries (Ireland, Italy, Portugal, Slovakia, Spain).

		CORE COUNTRIES					PERIPHERAL COUNTRIES				
	THIRD PERIOD	AUSTRIA	BELGIUM	FINLAND	FRANCE	NETHERLANDS	IRELAND	ITALY	PORTUGAL	SLOVAKIA	SPAIN
I PHASE	**UNIT ROOT Analysis**										
	CDS Level	-2.44	-2.09	-2.35	-1.24	-0.80	-0.55	-0.48	-0.45	-0.89	0.26
	BOND Level	-3.90***	-1.77	-3.25**	-2.12	-1.14	-0.02	-0.41	-0.21	-1.13	-0.33
	CDS Difference	-24.61***	-34.27***	-20.80***	-10.88***	-10.79***	-21.40***	-19.77***	-20.08***	-18.56***	-12.57
	BOND Difference	-13.92***	-18.82***	-12.24***	-20.65***	-21.60***	-19.48***	-20.84***	-19.36***	-22.31***	-22.43
	COINTEGRATION Analysis										
	Trace test	-	12.42	-	14.55*	7.14	14.28*	14.21*	13.59*	10.62	11.00
II PHASE	**VECM Analysis**										
	Lambda 1	-	-	-	-0.002848	-	-0.020964	-0.031318	-0.048154	-	-
	[t-stat]	-	-	-	-0.74	-	-2.34**	-1.71*	-2.26**	-	-
	Lambda 2	-	-	-	-0.036981	-	0.029577	0.022988	0.016346	-	-
	[t-stat]	-	-	-	3.18***	-	1.93*	1.07	0.73	-	-
	VAR Granger casuality										
	BOND	6.15**	3.46	0.38	-	5.70*	-	-	-	8.76**	21.47***
	CDS	4.28	0.69	0.15	-	1.16	-	-	-	6.39**	0.24
	PRICE DISCOVERY	BOND	n.d.	n.d.	CDS	BOND	CDS>BOND	BOND	BOND	CDS&BOND	BOND
	Market Share	100%	n.d.	n.d.	100%	100%	58.5%	100%	100%	n.d.	100%

***,** and * denote:

- in UNIT ROOT Analysis, rejection at the 1%, 5% and 10% levels, respectively, of the null hypothesis of non-stationarity;
- in COINTEGRATION Analysis, rejection at the 1%, 5% and 10% levels, respectively of the null hypothesis of absence of cointegration;
- in VECM Analysis, significance of adjustment coefficients at the 1%, 5% and 10% levels, respectively;
- in VAR Analysis, significance of Granger causality at the 1%, 5% and 10% levels, respectively.