Universidad de Navarra

Facultad de Ciencias Económicas y Empresariales

Working Paper nº 22/12

Credit-Risk Valuation in the Sovereign CDS and Bonds Markets: Evidence from the Euro Area Crisis

Óscar Arce
Bank of Spain

Sergio Mayordomo
University of Navarra

Juan Ignacio Peña
Universidad Carlos III de Madrid

Credit-Risk Valuation in the Sovereign CDS and Bonds Markets: Evidence from the Euro Area Crisis

Oscar Arce, Sergio Mayordomo, Juan Ignacio Peña

Working Paper No.22/12
December 2012

ABSTRACT

We analyse the extent to which prices in the sovereign credit default swap (CDS) and bond markets reflect the same information on credit risk in the context of the current crisis of the European Monetary Union (EMU). We first document that deviations between CDS and bond spreads are related to counterparty risk, common volatility in EMU equity markets, market illiquidity, funding costs, flight-to-quality, and the volume of debt purchases by the European Central Bank (ECB) in the secondary market. Based on this we conduct a state-dependent price-discovery analysis that reveals that the levels of the counterparty risk and the common volatility in EMU equity markets, and the banks' agreements to accept losses on their holdings of Greek bonds impair the ability of the CDS market to lead the price discovery process. On the other hand, the funding costs, the flight-to-quality indicator and the volume of debt purchases by the ECB worsen the efficiency of the bond market.

Óscar Arce
Directorate General Economics, Statistics and Research
Bank of Spain
o.arce@bde.es

Sergio Mayordomo
School of Economics and Business Administration
University of Navarra
smayordomo@unav.es

Juan Ignacio Peña
Department of Business Administration
Universidad Carlos III de Madrid
ypenya@eco.uc3m.es

Credit-Risk Valuation in the Sovereign CDS and Bonds Markets: Evidence from the Euro Area Crisis*

Oscar Arce
Bank of Spain

Sergio Mayordomo**
University of Navarra

Juan Ignacio Peña
Universidad Carlos III de Madrid

Abstract

We analyse the extent to which prices in the sovereign credit default swap (CDS) and bond markets reflect the same information on credit risk in the context of the current crisis of the European Monetary Union (EMU). We first document that deviations between CDS and bond spreads are related to counterparty risk, common volatility in EMU equity markets, market illiquidity, funding costs, flight-to-quality, and the volume of debt purchases by the European Central Bank (ECB) in the secondary market. Based on this we conduct a state-dependent price-discovery analysis that reveals that the levels of the counterparty risk and the common volatility in EMU equity markets, and the banks' agreements to accept losses on their holdings of Greek bonds impair the ability of the CDS market to lead the price discovery process. On the other hand, the funding costs, the flight-to-quality indicator and the volume of debt purchases by the ECB worsen the efficiency of the bond market.

Keywords: sovereign credit default swaps, sovereign bonds, credit spreads, price discovery.

JEL Codes: G10, G14, G15.

* Oscar Arce is at the Directorate General Economics, Statistics and Research of the Bank of Spain, Calle Alcalá 48, 28014 Madrid, o.arce@bde.es. Sergio Mayordomo is at the School of Economics and Business Administration, University of Navarra, Edificio Amigos, 31009 Pamplona, smayordomo@unav.es, Phone: +34 948 42 56 00 Ext. 802435. Juan Ignacio Peña is at the Department of Business Administration, Universidad Carlos III de Madrid, c/o Madrid 126, 28903 Getafe (Madrid, Spain), ypenya@eco.uc3m.es. The authors acknowledge Aquiles Rocha da Farias, Francisco Rodriguez-Fernandez, Gerald Dwyer, Richard Braun, Dante Amengual, Stefano Puddu, Jose Olmo, Stefanie Kleimeier, and seminar participants at CNMV, VI Seminar on Risk, Financial Stability, and Banking of the Banco Central do Brasil, XIX Finance Forum (Granada, 2011), Federal Reserve Bank of Atlanta Conference on Sovereign Debt and Default after the Financial Crisis of 2007-08, XXXV Symposium of Economic Analysis (Malaga, 2011), VIII Workshop in Public Policy Design: Financial System Perspectives and the Crisis (Girona, 2012), FMA Europe Annual Meeting (Istanbul, 2012). A previous version of this paper circulated under the title "Do Sovereign CDS and Bond Markets Share the Same Information to Price Credit Risk? An Empirical Application to the European Monetary Union Case". The opinions in this article are the sole responsibility of the authors and they do not necessarily coincide with those of the Bank of Spain.

** Corresponding author: Sergio Mayordomo

1. Introduction

In recent years many studies have analysed the relationship between credit default swaps (CDS) and bond spreads for corporate as well as for emerging sovereign reference entities.[1] However, the relation between sovereign CDS and bond markets in developed countries has not attracted much interest until very recently, mainly for two reasons. First, sovereign CDS and bond spreads in developed countries have been typically very low and stable given the perceived high credit quality of most issuers (see Table 1). Second, trading activity in this segment of the CDS market was typically low.

However, the global financial crisis that followed the collapse of Lehman Brothers in September 2008 triggered an unprecedented deterioration in public finances of the world's major advanced economies in a peacetime period. Since 2010, some countries in the euro area, including Greece, Ireland, Portugal, Spain and Italy, have faced some episodes of heightened turbulence in their sovereign debt markets. Against this context, the levels of perceived credit risk and the volume of trading activity in the sovereign CDS markets in many advanced economies have increased.

The existing literature on credit risk has paid some attention to investigating the relationship between the corporate bond market and the corporate CDS markets, but only a few papers have studied whether the empirical regularities identified in the corporate markets, including those related to price discovery, are also found in the case of sovereign reference entities. The aim of this paper is to shed light on these latter issues within the context of the recent episodes of sovereign-debt crises in several countries in the European Monetary Union (EMU).

Specifically, we analyse the theoretical equivalence relation between the sovereign bond yield spread (with respect to a risk-free benchmark) and the corresponding CDS

[1] We discuss the related literature in Section 2.

spread.[2] Abstracting from market frictions and other contractual clauses, both spreads should reflect the same information on the credit risk of a given reference entity and therefore should be equal. In other words, the *basis*, defined as the difference between the CDS spread and the corresponding bond spread, should be zero. If the basis differs from zero, the differences should be purely random and unrelated to any systematic factor. Moreover, in such a frictionless scenario, both spreads should incorporate the credit-risk information in a similar way, i.e., both markets should be equally efficient in terms of the process of credit-risk price discovery.

The current European sovereign debt crisis poses a particularly interesting scenario to test for the previous hypotheses. In particular, we analyse the differences in the informational content of the EMU sovereign bond and CDS spreads. First, we study the possible causes of the deviations between the bonds and the CDS spreads. We find that the counterparty risk indicator has a negative and significant effect on the basis, especially after September 2008, when some of the most active protection sellers began to face financial difficulties. Funding costs have a negative effect on the basis due to their stronger effect on the demand for bonds relative to the demand for CDS, as the latter require less funding to take on the same risk position. A higher degree of liquidity in the bonds market relative to the CDS market has a positive effect on the basis given that *ceteris paribus* a more liquid bond implies a lower bond yield and spread. The effect of the common volatility in the EMU equity markets, proxied by the series corresponding to the first common component of the volatility of the EMU countries stock market indexes that is obtained from a principal component analysis (PCA), affects the basis positively and significantly. This suggests that the CDS market reacts

[2] The results are obtained using the German bond as a proxy of the risk-free asset, as in, e.g., Geyer et al. (2004), Bernoth et al. (2006), Delis and Mylonidis (2010), Favero et al. (2010), Foley-Fisher (2010), and Palladini and Portes (2011), among others.

more to changes in the EMU stock markets' volatility than bond market does. The demand of safer assets instead of risky assets (flight-to-quality), proxied by the product of the decreases in the correlations between the returns of risky and safe assets and the volatility for the European stock market, has a negative effect on the basis. This effect is due to the increase in the bond spreads that is motivated by the lower yields of the German bonds and the lower demand of riskier bonds. The volume of debt purchased by the European Central Bank (ECB) in the secondary market that has taken place since May 2010 increases the basis significantly. These purchases exert a negative effect on bond spreads. The fact that such an effect is not present (or is weaker) in the case of the CDS spreads may indicate that ECB interventions affect other components of bond prices other than default risk (e.g., through a fall in the bond's liquidity premium) or, simply, induce some overpricing effect in the bond market for a given level of default risk. Finally, the effect of the lagged basis suggests a high degree of persistence and, hence, a relatively low speed of adjustment of the basis.

Second, we address the question of which market leads the credit-risk price-discovery process. To this aim, we follow a dynamic price-discovery approach based on Gonzalo and Granger (1995). Our analysis reveals that the price-discovery process is state-dependent. Specifically, the levels of the counterparty risk and the common volatility in EMU equity markets, and the successive agreements of private banks to accept losses on their holdings of Greek bonds impair the ability of the CDS market to lead the price-discovery process. The effect of counterparty risk is due to the perception of a lower quality of protection sold in the CDS market when this risk is high. The effect of the EMU equity markets volatility could be due to the fact that the information contained in bond spreads is more reliable during periods of high global risk. The agreements of private banks to accept losses on their holdings of Greek bonds could have caused a lack of confidence among investors in the CDS market after such agreements. On the other hand, the level of funding costs, the preference of the investors for the safest financial assets (flight-to-quality), and the volume of sovereign debt purchased by the ECB worsens the efficiency of the bond market in the price-discovery process. Funding costs affect bond buyers more than they do CDS buyers, as the CDS market allows for more leveraged positions. The investors' preferences for investing in the safest assets could have diminished the demand of most of the EMU countries' debt, especially debt issued by the peripheral economies, in favour of debt issued by countries with high credit quality (Germany, United States or United Kingdom) or safe assets (gold). The operations of the ECB seem to impair the informational content of bond prices as they relate to the actual credit risk of these assets.

The remainder of the paper is organised as follows: Section 2 discusses the related literature. Section 3 describes the data. Section 4 analyses the determinants of the basis. Section 5 presents the results of the dynamic price-discovery test. Section 6 contains several robustness checks of the main results. Section 7 contains some final remarks.

2. Related literature

In this section we focus on the branch of literature on CDS and bond spreads that is related to the two questions approached in this paper: determinants of the deviations between CDS and bond spreads, and the price-discovery process in bonds and CDS markets.

There is extensive literature addressing the determinants of corporate bond and CDS spreads.[3] Although this type of analysis is less frequent in the case of sovereign

[3] See, for instance, Elton et al. (2001), Collin-Dufresne et al. (2001), Chen et al. (2007), among others studying the determinants of the corporate bond spread. The studies analysing the determinants of the corporate CDS spreads include Longstaff et al. (2005), and Ericsson et al. (2009).

references, this topic is attracting increasing attention in recent times.[4] Our aim, however, is not to study the determinants of the CDS or the bond spread *per se,* but, rather, a number of factors that may affect the basis with the aim of testing whether both markets reflect different information and, if not, of shedding light on the determinants of such differences in market informational efficiency. Although the analysis of the determinants of the basis is less frequent than the analysis of the individual credit spreads, there are some earlier contributions in the literature on sovereign credit markets. For instance, Fontana and Scheicher (2010) employ weekly data from 2006 to 2010 to find that the sovereign bases are significantly linked to the cost of short-selling bonds and to country-specific and global risk factors. In his analysis of CDS–bond parity, Levy (2009) finds that the frictionless parity relation does not hold for emerging markets' sovereign debt, but he argues that an important part of the deviations can be attributed to liquidity effects. Küçük (2010) relates the CDS–bond basis for 21 emerging market countries between 2004 and 2008 to factors capturing bond liquidity, speculation in CDS market, liquidity, equity market performance, and global macroeconomic variables. Foley-Fisher (2010) studies the relation between bond and CDS spreads for ten EMU countries on the basis of a theoretical model of heterogeneous investors' expectations. He shows that a non-zero basis is consistent with a relatively small dispersion in the beliefs of investors on the probability that certain European countries would default.[5]

We share some of the objectives pursued by these previous papers but in contrast with previous analyses, our study of the determinants of the sovereign basis is carried out using daily data (instead of weekly) that covers the recent European Monetary Union

[4] See, e.g., Codogno et al. (2003), Geyer et al. (2004), Bernoth et al. (2006), Favero et al. (2010), Beber et al. (2009), and Mayordomo et al. (2012).
[5] Analyses of the basis in the corporate credit market include Trapp (2009), Nashikkar et al. (2008), and Bai and Collin-Dufresne (2009), among others.

sovereign debt crisis (May 2010– February 2012). This scenario enables us to evaluate the differential effect on government debt and CDS market of several factors not addressed in the aforementioned previous studies, including the effect of the purchases of sovereign debt by the ECB, the counterparty risk, the financing costs, the flight-to-quality phenomena, and the several haircuts on the banks' holdings of Greek bonds agreed within that period. There is also a methodological departure in our paper that deserves some attention. Specifically, the previous papers typically considered the level of the basis as the dependent variable in the regressions run to analyze the effect of its potential determinants. In our sample period the basis in levels is not stationary and for this reason, we use the relative basis to avoid problems derived from non-stationarity. In general, our study differs from these previous papers because we exploit methodological tools and data that allow us to offer a more detailed explanation of the deviations from the zero-basis benchmark during the European sovereign debt crisis.

Finally, the most frequent analysis of the CDS–bond relation in corporate and sovereign credit markets is based on the concept of price discovery. Most recent papers study price discovery based on either Hasbrouck's (1995) or Gonzalo and Granger's (1995) methodologies. Both approaches build upon a test based on a Vector Auto Regression (VAR) with an Error Correction Term (ECT). For the period before the subprime crisis a recurrent empirical finding is that the CDS market reflects the information more accurately and quickly than the bond market in the corporate sector (see Blanco et al., 2005; or Zhu, 2006, among others). Most of the analyses of price discovery in sovereign markets have been applied to emerging markets. For instance, Ammer and Cai (2007) find that bond spreads lead CDS premia more often than what had been found for investment-grade corporate credits. Using data from eight emerging market countries for the period 2003–2006, Bowe et al. (2009) find that the CDS market does not, in general, lead price discovery, which appears to be country-dependent.

The recent crisis has renewed interest in this question in the context of the European sovereign debt markets. For instance, Fontana and Scheicher (2010) find that since the outset of the crisis, the bond market has had a predominant role in price discovery in Germany, France, the Netherlands, Austria, and Belgium, while the CDS market is playing a major role in Italy, Ireland, Spain, Greece, and Portugal. Palladini and Portes (2011) use data on six euro-area countries (Austria, Belgium, Greece, Ireland, Italy, and Portugal) over the period 2004–2011. They find that the CDS market moves ahead of the bond market in terms of price discovery for all the countries in the sample except for Greece. Delatte et al. (2012) examine a sample of 11 European countries, both high and low-yield countries during the period 2008-2010 and find evidence that the relation between CDS premiums and bond spreads is not linear. The authors find that in periods of turbulence the CDS could drive up the bond interest rates of sovereign nations, even when the CDS market is relatively smaller than bond market. All these analyses have been carried out based on measures of price discovery that are obtained using the information for the entire sample period analysed at once. However, as argued by Longstaff (2010), the price-discovery process in financial markets may well be state-dependent. Thus, Delis and Mylonidis (2010) study the dynamic interrelation between bond and CDS spreads of several peripheral countries (Greece, Italy, Portugal, and Spain) during the period July 2004 to May 2010 on the basis of a Granger causality test. They find bidirectional causality during periods of financial distress.

In the spirit of Longstaff's (2010) conjecture and Delatte et al.'s (2011) findings, we perform a state-dependent price-discovery analysis. Our paper estimates for the first time Gonzalo and Granger's (1995) price-discovery metrics over time. The use of this test allows us to overcome the bidirectional causality issue, which is commonly found by using the Granger causality test (see Delis and Mylonidis, 2010). We find methodological questions of the utmost importance given that determining which market leads at every period is essential to shed light on the factors that may influence the quality of a given market in terms of its power to contribute to the price-formation process. Our study offers, in our view, an interesting contribution because most pre-crisis evidence supported the leading role of the CDS market in most cases. However, our results here suggest that during the collapses of Bear Stearns (February, 2008) and of Lehman-AIG (September, 2008), as well as during acute periods of stress in the Eurozone related to the episodes of Greece's debt rescheduling (June-August, 2011) the bond market led the price-discovery process. A similar reflection to the one that reinforces the contribution of this paper in the analysis of the determinants of the basis applies also in relation to the sample and the battery of variables employed in the section of the price discovery analysis performed in this paper. Thus, another important difference between our approach and the one followed in some previous contributions is that we offer a separate analysis of the factors driving the price discovery metrics over time.

3. Data

The data consists of daily 5-year sovereign bond yields and CDS spreads for eleven EMU countries (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, The Netherlands, Portugal, and Spain) from January 2004 to February 2012. Bond yields are obtained from Reuters and CDS spreads from Credit Market Analysis (CMA), which reports data (bid, ask, and mid) sourced from 30 buy-side firms, including major global investment banks, hedge funds, and asset managers.

Table 1 reports the main properties of the data. As evident from this table, average CDS rates vary substantially across countries and periods. For the period 2004–2008, the lowest average CDS spread was 5 basis points (bp) for Germany and the highest one was 23 bp points for Greece. For the same period, the lowest average bond spread was 4 bp for both France and The Netherlands, and the highest average was 25 bp for Greece. For the period 2009–2012, the lowest annual average CDS spread was 31 bp for Finland in 2010 and the highest annual average was 4,013 bp for Greece in period that comprises 2011 and two months of 2012 (being the maximum daily CDS spread at 21,162 bp on February 28th, 2012). The lowest annual average bond spread was -6 bp for Finland in 2010 and the highest was 2,548 bp for Greece in 2011-2012.[6] We observe an increase in both the average and the volatility of CDS and bond spreads over the subsequent years (from 2009 on) in most of the countries and especially in the peripheral ones (Greece, Ireland, Portugal, Spain, and Italy). We note that CDS spreads are on average higher than bond spreads in most of the countries, that is, the basis is positive (some of the most significant exceptions are Ireland and Portugal in 2011-2012 and Greece in 2009 and 2010). Figure 1 shows the evolution of the CDS-bond basis for the peripheral and core countries. We observe frequent deviations between CDS and bond spreads being such deviations more intense after the end of 2008 due to the effect of the global financial crisis that emerged after Lehman Brothers collapse in September 2008. These deviations are observed for both the countries less affected by the crisis and the ones with a weak fiscal position.

< Insert Table 1 here>

< Insert Figure 1 here>

[6] The negative sign for the bond spread in Finland in 2010 is due to the fact that the average yield of the Finnish bond was lower than for the German bond during the second half of year 2010.

As for the rest of the data used in the subsequent estimations, the information for the measure of common volatility in the EMU stock markets indexes is obtained from Reuters. To capture funding costs we use the difference between the 90-day US AA-rated commercial paper interest rates for financial companies and the 90-day US T-bill, both from Datastream. We employ liquidity measures for the sovereign CDS and bonds, which are obtained from the bond and CDS bid–ask spreads. Bond bid–ask prices are obtained from Reuters, while CDS bid–ask spreads come from CMA. To proxy for the counterparty risk on the side of CDS dealers, we employ the CDS spreads of the 14 banks most active as dealers in the CDS market. These CDS spreads are obtained from CMA. The information regarding the European Central Bank (ECB) bond purchases, which took place after May 2010, was obtained from the ECB webpage. To compute the flight-to-quality indicator we use information on the prices for safe and risky assets. The prices for the safe assets refer to the benchmark 10-year Government bonds of Germany, United Kingdom and United States, which are obtained from Datastream; and the Thomson Reuters contributed spot gold multi-contributor index (commodity cash) which is obtained from Reuters. The prices for the risky assets refer to the Bank of America Merrill Lynch global high yield and emerging markets, and the broad corporate BBB bond indexes which are obtained from Datastream; and the MSCI World Index also from Datastream.

4. The determinants of the basis

Suppose that an investor buys a bond at its par value with a maturity equal to T years and a given yield-to-maturity equal to ytm. Also, assume that at the same time the investor buys protection on such reference entity for T years in the CDS market and the premium of such contract is s. The investor has eliminated the default risk associated with the underlying bond and the investor's net annual return is equal to $ytm - s$. Absent any friction, arbitrage forces would imply that the net return should be equal to the *T*-year risk-free rate, which we denote by *r*. Hence, in equilibrium, $ytm - r = s$ where $ytm - r$ is the bond spread and *s* is the CDS spread. The fact that recurrent non-zero bases seem to be common during the crisis period (see Figure 1) may be symptomatic of the presence of other restrictions and frictions that prevent a perfect timeless alignment between the CDS and the bond spreads. In this section we test whether the differences between the CDS and bond spreads are purely random or, alternatively, whether they are related to any market-specific or global factors. Due to observations corresponding to the last months of 2010, the year 2011, and the months of 2012 included in the sample; the basis behaves like a non-stationary variable. For this reason, instead of analysing the determinants of the basis we study the determinants of the relative basis, defined as the difference between the CDS and bond spreads relative to the CDS spread.[7] We consider the following potential explanatory factors:

a. Counterparty Risk. In principle, the higher the counterparty risk of the seller of a CDS, the lower the CDS price should be as a result of the lower quality of protection. We test for this effect by using the first principal component obtained from the CDS spreads of the main 14 banks that act as dealers in that market.[8] The first principal component series should reflect the common default probability and, hence, it is akin to an aggregate measure of counterparty risk.[9] Actually, the first principal component for the series of CDS spreads of this set of dealers explains 86% of the total variance of the

[7] We use the CDS spread instead of the average credit spread (simple mean of the CDS and the bond spreads) in the denominator of the relative basis because the bond spread takes negative values and zero values for some of the observations in the sample.

[8] The 14 main dealers are: Bank of America, Barclays, BNP Paribas, Citigroup, Credit Suisse, Deutsche Bank, Goldman Sachs, HSBC, JP Morgan, Morgan Stanley, Royal Bank of Scotland, Societé Generale, UBS, and Wachovia/Wells Fargo. These dealers are the most active global derivatives dealers and are known as the G14 (see, for instance, ISDA Research Notes (2010) on the Concentration of OTC Derivatives among Major Dealers).

[9] The use of the dealers' CDS spreads as a proxy of counterparty risk is based on the Arora et al. (2009) study, which analyses the existence of counterparty risk in the corporate CDS market.

observed variables. We use the counterparty risk variable lagged one period to avoid problems of endogeneity derived from the potential contemporaneous effects of the banks' activity on sovereign credit spreads.[10]

b. Liquidity. In theory, one would expect that higher liquidity in the bond market relative to the CDS market would go hand in hand with a higher basis, since a more liquid bond implies a lower spread in that market. To test for relative liquidity effects, we construct a ratio of relative liquidity between the CDS and the bond. Specifically, the degree of liquidity in the CDS market is proxied by the bid–ask spread of the CDS premium. The higher this spread is, the lower the degree of liquidity in the CDS market. A similar measure of liquidity is computed for the bond market. The ratio between both measures is taken as indicative of the relative liquidity in the CDS market vis-à-vis the bond market. As this ratio rises, liquidity in the CDS market relative to the bond market falls. Therefore the basis would, in principle, increase.

c. Financing Costs. One would expect that higher financing costs would lower the demand for bonds and could lead to a decrease in prices, and therefore to higher bond spreads. The effect of funding costs on CDS spreads should be weaker given that in this case the required amount of funding to get the same (gross) risk position is lower (i.e., risk–leverage is higher in the case of the CDS investment). For this reason, in principle, an increase in financing costs would have a negative effect on the basis. Due to the difficulty in obtaining data on institution-level funding constraints, we use the spread between financial commercial paper and T-bill rates as a common proxy for the funding constraints faced by financial global intermediaries, as in Acharya et al. (2007). Specifically, we use the spread between the 90-day US AA-rated commercial paper interest rates for the financial companies and the 90-day US T-bill.

[10] We have used the counterparty risk variable lagged one week and the average level of counterparty risk one month before each date and find similar results.

d. Common volatility in European Monetary Union equity markets: As an additional potential explanatory variable for the basis, we consider a measure of the EMU volatility index or EMU risk premium. If both the CDS and bond spreads are prices for the same credit risk, the effect of this measure on the basis should not significantly differ from zero. However, a significant non-zero effect would suggest that one of the markets reacts more to common changes in the volatility of the EMU stock markets. To control for the fact that volatility could be priced differently in the two markets, we use the previous risk factor as an additional explanatory variables. The volatility of the EMU stock markets is proxied by the first principal component obtained from the squared of the stock indexes' returns of the 11 countries that form the sample of this study. The first principal component series should reflect the common volatility in the euro zone and explains 72% of the total variance in the observed variables.

e. Flight-to-quality indicator: a flight-to-quality episode can be defined as an event in which there is a decrease in the correlation of the safe and risky assets in response to a high level of market turbulences or market downturns. We construct the flight-to-quality indicator from the relation between the prices of safe assets (Government bonds of Germany, United Kingdom and United States; and gold) and risky assets (global high yield and emerging markets and broad corporate BBB bond indexes; and a global stock market index such as the MSCI World Index). We first express the indexes in the same scale by assigning value 100 to the observations corresponding to the 1st of January 2004 (the beginning of the sample period) and then take the averages for similar groups of assets.[11] We define the flight-to-quality indicator as the product of the decreases in the correlations between the returns of risky and safe assets, which are estimated by

[11] We construct an indexed price for the three countries' Government bond indexes and another index for the global high yield plus emerging markets and broad corporate BBB indexes. Then, we obtain the average value of the index for each category of assets (safe and risky assets) by calculating the average of the high quality sovereign bonds and gold indexed prices on the one hand, and the global high yield bond and the MSCI Index standardized prices on the other hand.

means of a dynamic conditional correlation (DCC) GARCH model of Engle (2002), and the volatility for the European stock market, which is measured by means of the VSTOXX implied volatility index.[12] We assign value zero to the observations corresponding to dates when the correlations are increasing instead of decreasing and to the observations before the 5th of November 2009.[13] The demand for safer assets in detriment of other risky assets observed in periods of financial distress (flight-to-quality) should have a negative effect on the basis due to the decrease of bond prices or equivalently, the increase in the bond spreads; especially the ones of the peripheral countries. This increase may occur for two reasons, on the one hand the flight-to-quality would lead to lower yields of the German bonds, which are the ones used as the benchmark to compute the bond spreads. On the other hand, the demand of riskier bonds would diminish in favour of the safest assets (i.e. German, U.K., or U.S. Government bonds or gold).

f. Volume of Debt Purchased by the European Central Bank: We use as an additional explanatory variable the amount of sovereign debt purchased by the ECB in the secondary market from May 2010 onwards. This information is available only on a weekly basis, and so the effect of the ECB debt purchases is proxied by the amount of debt that was purchased the week before the current date. These purchases are supposed to decrease both CDS and bond spreads, but in principle it is natural to think that they would have a more direct effect on bond prices. Thus, following these

[12] The VSTOXX Index is based on EURO STOXX 50 real time options prices and is designed to reflect the market expectations of near-term up to long-term volatility by measuring the square root of the implied variance across all options of a given time to expiration. The VSTOXX information is obtained from Datastream.

[13] At this date Greece revealed that its real budget deficit was 12.7% of GDP (more than twice the previous disclosed) and it is generally considered as the beginning of the European sovereign debt crisis. As the flight-to-quality refers to the demand of sovereign debt we avoid including in the indicator potential episodes of flight-to-quality in which the bond spreads for the core and peripheral countries were very low and of a similar magnitude.

interventions, the bond spread would decrease more than the decrease in the CDS spread, thus affecting the basis positively.

g. Dummy for the Private Banks' Agreements to Accept Losses on Their Holdings of Greek Bonds: The proposal launched in July 2011, and restated in October 2011, for an agreement among banks to accept a voluntary haircut on their holdings of Greek bonds, which could come without the activation of the CDS contracts, could have generated a lack of confidence among institutional investors in the CDS market. This last effect may lead to a lower quality of the protection sold, which should imply lower CDS spreads and a lower basis. For this reason, we use as additional regressors two dummy variables that are equal to 1 after the banks agreed on the 21st of July 2011 and the 27th of October 2011 to accept 21% and 50% losses on their holdings of Greek bonds, respectively; and zero before that date.

h. Lagged Basis: The lag of the basis should absorb any past information transmitted into the current observation. We expect a positive sign for this variable. The larger the coefficient, the more persistent the deviation between CDS and bond spreads.

We estimate the coefficients for the above factors for the period spanning January 2004 to February 2012 using a fixed-effects estimation procedure that is robust to heteroskedasticity.[14] We use the bootstrap methodology to correct for any potential bias in the standard errors due to the use of generated regressors. The results are reported in Column 1 of Table 2. Column 2 of that table reports the standardised coefficients (i.e., the regression coefficient as in Column 1 multiplied by one standard deviation of the corresponding explanatory variable). Most of the variables, including the dependent variable, are expressed on a per unit basis with some exceptions. The volume of bonds purchased by the ECB in a given week is defined in billions of euros. The common

[14] We have checked the order of integration of the above factors and find that they are stationary.

volatility in the EMU is obtained from the squared returns of the stock market indexes which are defined on a per unit basis. The flight-to-quality indicator is obtained by multiplying two variables (correlation between safe and risky assets returns and VSTOXX implied volatility index) which are expressed on a per unit basis.

The counterparty risk proxy has a negative and significant effect, as expected, which confirms its relevance on the levels of the CDS spreads. Funding costs have a negative effect due to their stronger effect on the demand for bonds relative to the demand for CDS that requires a lower amount of funding. A low degree of liquidity in the CDS market relative to the bond market has a positive effect given that a more liquid bond implies a lower bond spread. The proxy for the EMU volatility seems to be priced differently in both markets. The positive and significant effect could be explained by the fact that the CDS spread reacts more to the variation in aggregate or macro factors, such as the common volatility of the EMU stock market indexes, than the bond spreads. This feature has been documented by Alexopoulou et al. (2009) and Mayordomo and Peña (2011). As expected, the flight to quality indicator has a negative and significant effect on the basis suggesting an increase in the bond spreads. The dummies for the banks' willingness to accept losses on their holdings of Greek bonds have negative signs, as expected, but they are not significant at any standard significance level. In line with the results of the previous section, we find a high level of persistency in the relative basis. That is, there is a relatively low speed of adjustment towards the long-run bond–CDS equivalence relation. Finally, the constant term reflects whether the relative basis differs, on average, from zero and the magnitude of such deviation. We observe that the relative basis is on average significantly positive, suggesting that the bond–CDS equivalence relation does not hold even when we take into account the market frictions described above and the costs that are needed to trade the basis. Nevertheless, its magnitude is low relative to the average relative basis during the period 2004–2012 (2.7% relative to 38.2%). Thus, when we take into account the determinants of the basis, the magnitude of the average relative deviation is close to zero and is reduced by 93%. This result confirms the strong influence on these determinants to guarantee the bond–CDS equivalence relation.

The relatively high R-square of this regression is mainly due to the effect of the lagged basis. However, it should be noted that the explanatory variables retain a relatively high explanatory power even when we ignore the lagged basis, in which case the R-square is 0.28. Actually, this is of a similar magnitude to the one reported by Trapp (2009) on a daily basis for corporates using firm fixed effects but ignoring the effect of the lagged basis.

< Insert Table 2 here >

5. Price-Discovery Analysis

An efficient price-discovery process is characterised by a quick adjustment of market prices from the old to the new equilibrium as new information arrives (see, e.g., Yan and Zivot, 2007). In the analysis that follows, we show that the price-discovery process in the markets for sovereign credit risk in the euro area shows a time-variant pattern (Section 5.1). We then try to identify the effect of several potential explanatory variables of the dynamic pattern followed by the price-discovery metrics obtained in the previous step (Section 5.2).

5.1. A Dynamic Price-Discovery Metric

To estimate a time-variant price-discovery metric we extend Gonzalo and Granger's (1995) price-discovery analysis using rolling windows. Gonzalo and Granger's model of price discovery is based on the following vector error correction model (VECM) specification:

$$\begin{pmatrix} \Delta BSpr_t \\ \Delta CDSSpr_t \end{pmatrix} = \alpha(BSpr_{t-1} - \beta_2 - \beta_3 CDSSpr_{t-1}) + \begin{pmatrix} \sum_{i=1}^{p} \lambda_{1,i} \Delta BSpr_{t-i} \\ \sum_{i=1}^{p} \lambda_{2,i} \Delta BSSpr_{t-i} \end{pmatrix} + \begin{pmatrix} \sum_{i=1}^{p} \delta_{1,i} \Delta CDSpr_{t-i} \\ \sum_{i=1}^{p} \delta_{2,i} \Delta CDSSpr_{t-i} \end{pmatrix} + \begin{pmatrix} u_{1,t} \\ u_{2,t} \end{pmatrix} \quad (3).$$

The above empirical model is a vector autoregressive (VAR) system formed by two equations defined from the vector, which includes the bond and CDS spreads of the same underlying country, denoted by $BSpr_t$ and $CDSSpr_t$, respectively, and an error correction term (ECT) defined by the expression $\alpha(BSpr_{t-1} - \beta_2 - \beta_3 CDSSpr_{t-1})$, where β_2 and β_3 are estimated in an auxiliary cointegration regression and the parameter vector $\alpha' = (\alpha_1, \alpha_2)$ contains the error-correction coefficients measuring each price's expected speed of adjustment. The estimation of the VECM specification is restricted to the existence of a cointegration relation between the bond and CDS spreads. This cointegration relation appears in the ECT as $(BSpr_{t-1} - \beta_2 - \beta_3 CDSSpr_{t-1})$. The parameters $\lambda_{1,i}$, $\lambda_{2,i}$, $\delta_{1,i}$, and $\delta_{2,i}$ for $i = 1,..p$, with p indicating the total number of lags, contain the coefficients of the VAR system that measure the effect of the lagged first difference in the CDS and bond spreads on the first difference of such spreads at time t.[15] Finally, u_t denotes a white noise vector.

The price-discovery metric for the bond and CDS markets, denoted by GG_{bond} and GG_{CDS}, respectively, can then be constructed from the elements of the vector α', which contains the coefficients that determine each market's contribution to price discovery:

$$GG_{Bond} = \frac{\alpha_2}{-\alpha_1 + \alpha_2}; \qquad GG_{CDS} = \frac{-\alpha_1}{-\alpha_1 + \alpha_2} \quad . \qquad (4)$$

[15]The optimal number of lags is determined by the Schwarz information criteria.

Given that $GG_{Bond} + GG_{CDS} = 1$, we would conclude that the bond (CDS) market leads the price-discovery process whenever GG_{Bond} is higher (lower) than 0.5. The intuition for this is the faster the speed in eliminating the price difference from the long-term equilibrium attributable to a given market, the higher the corresponding α according to (3), and the higher the price-discovery metric.

In order to apply the methodology outline above to a dynamic metric of price-discovery leadership in the two markets at stake, we estimate the system in equation (3) using rolling windows with different lengths: 500, 750, and 1,000 days. To do so, we first need to check for the order of integration of the CDS and bond spreads and then for the existence of a cointegration relation. An interesting feature is that, on average, the estimated metrics do not seem to be very sensitive to the window length. Based on this, in the remainder of the paper we focus on 1,000-day windows.[16] Using rolling windows with a length of 1,000 observations, we find that both CDS and bond spreads are non-stationary in all the countries and dates.[17] We next apply the cointegration test to a total of 1,089 1,000-day windows for each of the ten countries to find cointegration between both spreads in 6,989 cases (64% of the total). The country with the lowest (highest) percentage of cointegration relations is Belgium (Austria) with cointegration in 36% (87.5%) of the windows. As we increase the window length from 500 to 750 and to 1,000 observations, we find a higher number of unit roots and cointegration relations.

[16] On the one hand, the 500-day windows enable us to update the influence of the new observations quicker than the 1,000-day windows and to estimate the price-discovery metrics for the years 2006 and 2007. On the other hand, the 1,000-day windows enable us to consider a higher number of price-discovery metrics per day and country after 2007 due to the existence of a higher percentage of cointegration relations for these windows. Actually, the years 2006 and 2007 present the lowest number of days with cointegration relations per year.

[17] The number of lags employed in the unit root test is chosen according to the Schwarz information criterion.

Figure 2 shows the estimated price-discovery metric for the 1,000-day windows for two groups of countries in the sample, peripheral and central.[18] In particular, we report a 30-day moving average of the mean price-discovery metrics, which is obtained as an equally weighted mean across the ten euro-area countries. An important message in Figure 2 is that the price-discovery metrics are not static but rather evolve over time, with the relative leadership of the CDS market in the process of price discovery being more pronounced around specific dates.

Specifically, before the Lehman Brothers collapse the CDS market led sovereign risk price discovery. This finding is consistent with the results reported by, for example, Blanco et al. (2005) or Zhu (2006) in the context of the corporate debt markets. The first noticeable rise in the relative leadership of the bond market took place around February 2008, around the collapse of Bear Stearns. Afterwards, in September 2008, coinciding with the fall of Lehman Brothers and AIG, the bond price-discovery metric again jumped reaching its highest value at the end of 2008. This pattern suggests that during these two specific episodes, the collapse of Bear Stearns and Lehman-AIG, the bond spread led, by a small margin, the price-discovery process. The price-discovery metrics show the last significant rebound around the end of June 2011, some days before the proposal for an agreement among some private banks in July 2011 to accept a loss of 21% on their Greek bonds under the implicit presumption that such a voluntary deal would not trigger a credit event that would call for the activation of CDS protection. Following this, in August 2011 the bond market became the leader in terms of price discovery, confirming the role of this market during the most recent phase of the crisis

[18] The peripheral group includes Ireland, Italy, Greece, Portugal, and Spain. The core group includes Austria, Belgium, Finland, France, and The Netherlands. The window length in all cases is 1,000 days.

as the fairest source of information on credit risk.[19] The bond market remains as the leader in the peripheral countries but losses its informational advantage after December 2011 in favour of the CDS market in the core countries.

From a different perspective, we observe a decoupling of the price-discovery measure for the core and peripheral countries from the end of 2008 until mid-2011. Starting at the end of 2008, it is worth noting that for most of the time the relative efficiency of the CDS market in the peripheral countries is significantly higher than for the core countries, where the bond market indeed led the price-discovery process for most of 2009. The difference between the estimated price-discovery metric for both groups of countries widened further during 2010. This pattern, which is mainly motivated by a sharp increase in the relative efficiency of the CDS market, may reflect the ECB policy of buying sovereign debt issued by peripheral countries.

This core-peripheral countries decoupling persisted until May 2011 when we observed a similar trend in both groups of countries of improving the power of the bond market to lead price discovery. In particular, after July 2011 the bond market moved ahead of the CDS market. This result could be due to the increase of overall risk perception, but it also could be due to a lack of confidence of institutional investors in the CDS market after the aforementioned proposal for an agreement among the banks to accept a voluntary haircut on their Greek bonds without activating the CDS contracts. This explanation would fit well with the fact that the price-discovery metric for Greece jumps from a value near zero in April 2011 to 1 in July 2011. The price discovery metric for Greece remains at its maximum level up to the end of November 2011 and then decreases slightly but still supporting a better informational efficiency of the bond market until the end of the sample. We observe a new decoupling between the core and

[19] This result is in line with the role of the bond market as an appropriate credit-risk measure in crisis periods found by Mayordomo et al. (2011b) for the corporate case.

peripheral countries which is more pronounced after November 2011. While the bond market remains as a fair indicator of credit risk in the peripheral countries, the CDS market moved ahead of the bond market in the core countries after that date.

< Insert Figure 2 here >

Figure 3 shows the estimated price-discovery metrics for the 1,000-day windows for the same two groups of countries (peripheral and core), but it shows the number of countries for which we can implement the Gonzalo and Granger methodology (i.e., unit roots in both the CDS and bond spreads series are found and both spreads are cointegrated). The darker the line is, the higher the number of countries for which the analysis can be implemented. We observe that for most of the time, the analysis can be implemented in four or more countries. Actually, it can be implemented in eight or more countries for long windows of time from the beginning of 2008 to the end of 2009.

< Insert Figure 3 here >

5.2. An Analysis of the Determinants of Market Leadership in Price Discovery

In this section we aim to shed some light on the dynamic pattern of the price-discovery metrics estimated before by regressing them on potential explanatory factors. Specifically, for each country we construct a dummy variable that takes a value of 1 when the bond market reflects information more efficiently than the CDS market and zero otherwise. This dummy is constructed on the basis of a rolling window estimation using 1,000 observations,[20] and then it is used as the dependent variable in a Logit

[20] When faced with missing values (due to a lack of cointegration relation between the CDS and the bond spreads), the value of the dummy is imputed according to the Granger-causality analysis performed earlier. For the remaining missing values, the value of the dummy is imputed whenever there is another observed value within the next ten days that coincides with the previous price discovery value observed and persists at least in the next ten observations. If after a given date there are not cointegration relations up to the end of the sample we do not impute any value. For sake of the robustness of this procedure, we use the 1,000-observation estimation. Thus, we do not employ the price-discovery metric directly, which is a concrete value between 0 and 1, but instead assign a value of one or zero to such metrics, thus softening such a strong assumption. We impute 12% of the total observations.

regression that includes as regressors the same used in the regression contained in Table 2, with the exception of the lagged basis. We consider these regressors because they have been found to have a significant effect on the deviations from a zero basis.[21] Hence, as this shows that the effect of such regressors is not reflected in the same way in the two markets, it seems natural to consider that one market captures better than the other the effect of each determinant of the basis.

The results are reported in Table 3. Column 1 reports the results obtained when we use daily price discovery metrics for the period spanning December 2007– February 2012. Column 2 contains the marginal effects of the coefficients reported in Column 1. The marginal effects of the dummy variables are obtained as the discrete change (from 0 to 1) in the corresponding variable. All the explanatory variables, including the dependent variable, are expressed in percentages with the exception of the bonds purchased by the ECB in a given week, defined in billions of euros, and the two dummy haircut agreements by banks, which are equal to 1 after the 21st of July 2011 and the 27th of October 2011, respectively; and zero before then. The common volatility in the EMU is obtained from the squared returns of the stock market indexes which are defined on a per unit basis. The flight-to-quality indicator is obtained by multiplying two variables (correlation between safe and risky assets returns and VSTOXX implied volatility index) which are expressed on a per unit basis.

One might expect that the higher the counterparty risk, the lower the power of the CDS market to adequately reflect the credit risk due to the lower quality of the protection sold in this market and, perhaps, the uncertainty around such quality. The sign is the expected (positive) and significant. An increase equal to one percentage point in the

[21] Although the dummies for the haircut agreements by banks are not significant determinants of the basis, we use them to test whether they affect the relative efficiency of the CDS market in the price discovery process.

counterparty risk measure would increase the contribution of the bond market to the leadership of the price discovery process by 5.1%.

As argued before, funding costs affect the bond market more negatively relative to the CDS, as the CDS market allows for higher-leveraged positions. This could explain why the funding costs negatively affect the ability of the bond market to anticipate the price of credit risk relative to the CDS market. Specifically, we find that an increase of 1% in financing cost would decrease the estimated price-discovery metric by 22.3%.

Surprisingly, the degree of liquidity in the CDS market relative to the bond market does not significantly affect the price-discovery metric but, as expected, has a positive effect on the dependent variable. Our interpretation of this finding is the following. Under the special features of the period under study (financial stress and limited access to funding), it seems natural to think that a major determinant of the degree of investors' participation in the bond market (and, hence, of much of the information contained in the prices determined therein) is the availability of funding and its cost, rather than the magnitude of the bid-ask gap. Furthermore, the relative importance of the bid/ask gap in this respect could be of second order if there are some big players in the market, like the ECB, buying bonds without any regard to the ongoing bid-ask spreads. Hence, this could render the liquidity variable non-significant.

In line with the results obtained by Mayordomo et al. (2011b) for corporate bonds and CDS, the bond spreads tend to reflect credit risk more efficiently than CDS spreads during periods of high global risk (high values of the common volatility in EMU equity markets). In this sense, the intensification of the Euro area sovereign debt crisis in 2011 favored the leading role of the sovereign bond market in the price discovery process. In particular, according to the estimates above, an increase in the level of the common volatility in the EMU stock markets of 1% would cause a fall of 4.8% in the contribution of the CDS market to the price-discovery process.

The investors' preferences for investing in the safest assets would diminish the demand of most of the EMU countries' debt, especially the debt issued by the peripheral economies, in favour of the debt issued by countries with high credit quality or other safe assets such as the gold. For this reason, we find that an increase in the level of the flight-to-quality indicator of 1% would cause a fall of 1.1% in the contribution of the bond market to the price-discovery process.

If the ECB's demand for debt is relatively inelastic with respect to its price then the information embedded in the prices formed in that market could reveal less about the fundamental value of the corresponding bonds. This hypothesis is confirmed by the significant and negative sign of the variable representing the total amount of sovereign debt purchased by the ECB.[22] An increase of €1 bn in the total amount of debt purchased by the ECB leads to a decrease of 0.4% in the ability of the bond market in terms of price discovery. For instance, the 16.5 billion euros spent during the first week of the ECB's initial foray into Greek markets through the Securities Markets Program in May 2010 could have contributed to a 6.6% fall in the estimated price-discovery metric. The total amount purchased by the ECB at the end of the sample period (February 2012) was €219.5 bn.

The proposal for an agreement among private banks in July 2011, and the restatement of the agreement in October 11, to accept voluntary losses on their holdings of Greek bonds seemed to favour the relative efficiency of the bond markets, according to the positive and significant effect of the corresponding dummy variables. Specifically, after

[22] Given that we are using historical information on bond and CDS spreads to construct the price-discovery metric, we now use the stock of debt purchased by the ECB instead of the flow corresponding to the previous week.

July 21st, 2011, we find a fall of 28% in the contribution of the CDS market to the price-discovery process. The fall in the contribution of the CDS market after October 27th, 2011 was 43%. The stronger effect of the October agreement could be explained by the increase in the magnitude of the voluntary losses to be accepted by the banks (the new haircut was 50% instead of the 21% agreed in July 2011).

< Insert Table 3 here >

6. Robustness checks

6.1 Determinants of the basis

To discard any bias due to potential collinearity problems, we report the correlation matrix for all the factors employed in our analysis (see Table 4). The correlations therein are obtained as a weighted average of the correlations between the variables for each country in the sample. The strongest correlation (0.71) is the one between the two dummies capturing the agreed haircuts on Greek debt. Besides that, the remaining correlations are lower than 0.7. In view of this and the low level of the multi-collinearity condition number (4.19), i.e. well below the critical value (30), we consider that collinearity is unlikely to be a source of concern in our sample.

< Insert Table 4 here>

In our baseline estimation, we have included the gap between U.S. commercial paper and T-Bills to approximate a measure of global funding costs, under the assumption that participants in sovereign CDS and bond markets could be global, in particular, including the largest US financial institutions. Nevertheless, we also consider the 3-month Euribor-OIS spread as another proxy for financing costs. We first notice that the 3-month Euribor-OIS spread is highly correlated (0.76) with the indicator of counterparty risk as it has been documented earlier (see e.g. Rodriguez-Moreno and

Peña, 2012). Thus, we orthogonalize the two variables by excluding from the Euribor-OIS gap the part that is due to counterparty risk.[23] The results obtained using this last variable, which are shown in Column 2 of Table 5, do not change materially with respect to the estimations obtained using the U.S.-based proxy (baseline specification) that are reported in Column 1 of Table 5.[24] Regarding the standardised coefficients, the strongest effect is the one corresponding to the lagged relative basis, as expected. Among the rest of the variables, the strongest effects are the ones coming from the financing costs. An increase equal to one standard deviation in this last variable would reduce the relative basis by 1%.

We also address the cross-sectional differences in the relative effects of the explanatory variables for the peripheral and core countries by adding interaction terms between the variables and two dummies (peripheral-countries dummy and sovereign debt crisis dummy). The first dummy takes value one for the peripheral countries and zero for the core countries while the second dummy takes value one after November 2009, which we consider as the approximate beginning of the European sovereign debt crisis following the first news on misreporting of fiscal data in Greece, and zero before. Instead of exploiting all the interaction variables at the same time, we introduce them one by one to check whether they produce any significant distinctive effect in the peripheral countries vis-à-vis the core ones during the crisis. This strategy allows us to discard any potential bias due to collinearity, given that the correlations between some of these interaction variables are high (in some case above 0.8).

[23] Specifically, we regress the Euribor-OIS gap on the counterparty risk variable and a constant term and use the residuals plus the constant as the new funding cost variable.
[24] A similar conclusion is obtained in the analysis of the drivers of the price discovery metrics when we use the 3-month Euribor-OIS as the proxy for financing costs. The coefficient for the new variable (-1.57) is also significantly different from zero and non-significantly different to the one obtained for the baseline financing costs proxy (-1.55). The sign and coefficients of the remaining variables are also similar to the ones in Column 1 of Table 3.

Interestingly, we do not find any significant effect from any of the variables when they are introduced individually. They only interaction variable with a significant effect is the purchases of public debt in the secondary market by the ECB when interacted with the subset of peripheral countries that had benefited from fully-fledged multilateral program of financial support by the end of the sample period, that is, Greece, Ireland, and Portugal. The debt purchases by the ECB had a significant effect on the prices of the sovereign debt issued by these last three countries, but not a differential effect on Spain and Italy, with respect to the core countries. Our interpretation of this result is based on the conjecture that the ECB purchases of debt under its Securities Markets Program on the previous subset of "program countries" relative to their total amount of debt outstanding was much larger than the corresponding ratio of the ECB purchased debt relative to the total debt of Italy and Spain.[25] Detailed results of this estimation are reported in Column 3 of Table 5.

< Insert Table 5 here >

6.2 Price-Discovery Analysis

To confirm that our results are not influenced by potential non-linearities in the price discovery process as documented in Delatte et al. (2012), we use an alternative estimation methodology. In particular, to make this alternative estimation strategy consistent and comparable to the one followed in our paper we have to: (1) estimate dynamically a non-linear model of price discovery using rolling windows; (2) avoid using information on the drivers of price discovery to determine the regime or state given that these variables will be used to identify their contribution to price discovery; and (3) apply this procedure country by country.

[25] See the estimations of Barclays Capital in the report "ECB SMP: Marking to Market news" by January 2012.

Based on the previous requirements, we use a threshold VECM-model for each country to check whether the results change due to the non-linearities in the price discovery process. The marginal effects of the drivers of price discovery under the new specification are in Column 2 of Table 6. Column 1 of Table 6 reports the baseline marginal results obtained with the linear dynamic price discovery analysis.

We observe that the marginal effect of counterparty risk, financing costs, common volatility, and ECB debt purchases are of a similar magnitude and degree of significance. The marginal effects of the two dummies, although also significant, are of a lower magnitude. The flight-to-quality indicator is non-significant now. The liquidity variable is not significant at 5% level and its marginal effect is negligible in line with the baseline result.

Finally, we note that the use of daily price-discovery metrics obtained with 1,000-day rolling windows implies that the new information added in a given day is small relative to the information of the other 999 days, which persists from one estimation to the next. Faced with this, we check whether the results hold independently or whether we use daily or monthly linear price-discovery metrics. The marginal effects of the explanatory variables that are obtained using monthly information are reported in Column 3 of Table 6. The comparison of the results reported in Column 1 confirms that the results are robust regarding daily or monthly metrics in terms of the magnitudes and levels of significance of the explanatory variables.

< Insert Table 6 here >

7. Conclusions

This paper analyses the extent to which the sovereign CDS and bond markets reflect the same information on their prices in the context of the European Monetary Union. In approaching this question, we follow a two-stage approach, whose main insights are summarized below.

We first analyse the role of some potential determinants of the basis, including several sources of risk (counterparty risk and the volatility of the EMU stock market indexes) and other market frictions. In particular, we find that the counterparty risk indicator has a negative and significant effect on the basis. Funding costs have a negative effect on the basis, while a high liquidity in the bond market relative to the CDS market has a positive effect. The EMU risk premium measured by means of the series corresponding to the common component of the volatility of the EMU countries stock market indexes affects the basis positively and significantly. A "flight-to-quality" indicator has a negative effect on the basis. The European Central Bank's purchases of sovereign debt in the secondary market in May 2010 were found to positively and significantly affect the basis.

We then conduct a dynamic analysis of market leadership in the price-discovery process. An important result here is that the price-discovery process is clearly state-dependent. To shed some light on the determinants of such a state-contingent pattern of relative market informational efficiency we relate our measure of price-discovery to the set of factors identified in the previous stage as potential determinants of the bond-CDS basis. Specifically, the levels of the counterparty risk and the common volatility in EMU equity markets, and the banks' agreements to accept losses on their holdings of Greek bonds impair the ability of the CDS market to lead the price discovery process. On the other hand, the funding costs, the flight-to-quality indicator and the volume of debt purchases by the ECB worsen the efficiency of the bond market.

References

Acharya, V., S. Schaefer, S. and Zhang, Y. (2007), Liquidity risk and correlation risk: A clinical study of the General Motors and Ford Downgrade of May 2005, Working Paper, SSRN.

Alexopoulou, I., Andersson, M., and Georgescu, O. M. (2009), An empirical study on the decoupling movements between corporate bond and CDS spreads, European Central Bank, Working Paper 1085.

Ammer, J. and Cai, F. (2007), Sovereign CDS and Bond Pricing Dynamics in Emerging Markets: Does the Cheapest-to-Deliver Option Matter?, Journal of International Financial Markets, Institutions and Money 21, 369-387.

Arora, N., Gandhi, P., and Longstaff, F. (2009), Counterparty Credit Risk and the Credit Default Swap Market, Journal of Financial Economics 103, 280-293.

Bai, J., and Collin-Dufresne, P. (2009), The Determinants of the CDS-Bond Basis during the Financial Crisis of 2007-2009. Working Paper.

Barclays Capital (2012), ECB SMP: Marking to Market news, January 2012.

Bernoth, K., von Hagen J. and Schuknecht, L. (2006), Sovereign Risk Premiums in the European Government Bond Market. GESY Discussion paper 151.

Beber, A., Brandt, M.W. and Kavajecz, K.A. (2009), Flight-to-quality or flight-to-liquidity? Evidence from the Euro-area bond market, Review of Financial Studies 22, 925-957.

Blanco, R., Brennan, S., Marsh, I. W. (2005), An Empirical Analysis of the Dynamic Relationship between Investment Grade Bonds and Credit Default Swaps, Journal of Finance 60, 2255-2281.

Bowe, M., Klimaviciene, A., and Taylor, A. P. (2009), Information Transmission and Price Discovery in Emerging Sovereign Credit Risk Markets, Working Paper.

Chen, L., Lesmond, D.A. and Wei, J. (2007), Corporate Yield Spreads and Bond Liquidity, Journal of Finance 62, 119-149.

Collin-Dufresne, P., Goldstein, R., and Martin, J.S. (2001), The Determinants of Credit Spread Changes, Journal of Finance 56, 1926-1957.

Codogno, L., Favero, C. and Missale, A. (2003), Government bond spreads, Economic Policy 18, 504-532.

Delatte, A. L., Gex, M., and Lopez-Villavicencio, A. (2010), Has the CDS market influenced the borrowing cost of European countries during the sovereign crisis?, Journal of International Money and Finance 31 (2012) 481–497.

Delis, M. D., and Mylonidis, N. (2010), The Chicken or the Egg? A Note on the Dynamic Interrelation between Government Bond Spreads and Credit Default Swaps, Finance Research Letters 8, 163-170.

Engle, R. F. (2002), Dynamic Conditional Correlation - A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models, Journal of Business and Economic Statistics 20, 339-350.

Elton, E. J., Gruber, M. J., and Agrawal, D. (2001), Explaining the Rate Spread on Corporate Bonds, Journal of Finance 56, 247-278.

Ericsson, J., Jacobs, K. and Oviedo-Helfenberger, R. A. (2009), The Determinants of Credit Default Swap Premia, Journal of Financial and Quantitative Analysis 44, 109-132.

European Central Bank (2009), Credit Default Swaps and Counterparty Risk, August.

Favero, C., Pagano, M. and Von Thadden E.-L. (2010), How Does Liquidity Affect Government Bond Yields?, Journal of Financial and Quantitative Analysis 45, 107-134.

Foley-Fisher, N. (2010), Explaining Sovereign Bond-CDS Arbitrage Violations during the Financial Crisis 2008-09, Working Paper.

Fontana, A., and Scheicher, M. (2010), An Analysis of Euro Area Sovereign CDS and their Relation with Government Bonds, European Central Bank Working Paper.

Geyer, A. Kossmeier, S. and Pichler, S. (2004), Measuring Systematic Risk in EMU Government Yield Spreads, Review of Finance 8, 171–197.

Hasbrouck, J. (1995), One security, many markets: Determining the contributions to price discovery, Journal of Finance 50, 1175-1199.

ISDA Research Notes (2010), Concentration of OTC Derivatives among Major Dealers.

Küçük, U. N. (2010), Non-Default Component of Sovereign Emerging Market Yield Spreads and its Determinants: Evidence from Credit Default Swap Market, Journal of Fixed Income 19, 44-66.

Levy, A. (2009), The CDS Bond Basis Spread in Emerging Markets: Liquidity and Counterparty Risk, Working Paper.

Longstaff, F. A. (2010), The Subprime Credit Crisis and Contagion in Financial Markets, Journal of Financial Economic 97, 436-450.

Longstaff, F.A., Mithal, S. and Neis, E. (2005), Corporate Yield Spreads: Default Risk or Liquidity? New Evidence from the Credit Default Swap Market, Journal of Finance 60 2213-2253.

Mayordomo, S., and Peña, J. I. (2011), An Empirical Analysis of the Dynamic Dependencies in the European Corporate Credit Markets, Working Paper SSRN.

Mayordomo, S., Peña, J. I. and Romo, J. (2011a), A New Test of Statistical Arbitrage with Applications to Credit Derivatives Markets, Working Paper SSRN.

Mayordomo S., Peña, J. I., and Romo J. (2011b), The Effect of Liquidity on the Price Discovery Process in Credit Derivatives Markets in Times of Financial Distress, European Journal of Finance 17, 851 – 881.

Mayordomo, S., Peña, J. I., and Schwartz, E. S. (2012), Towards a Common European Monetary Union Risk Free Rate, Working Paper UCLA.

Nashikkar, A., Subrahmanyam, M., and Mahanti, S. (2008), Limited Arbitrage and Liquidity in the Market for Credit Risk, Working Paper New York University.

Palladini, G., and Portes, R. (2011), The Information Content of Euro-area Sovereign CDS Spreads, Working Paper.

Politis, D. N., Romano, J. P., and Wolf, M., (1997), Subsampling for heteroskedastic time series, Journal of Econometrics 81, 281-317.

Politis, D. N., Romano, J. P., and Wolf, M. (1999), Subsampling intervals in autoregressive models with linear time trend, Econometrica 69, 1283-1314.

Rodriguez-Moreno, M., and Peña, J. I. (2012), Systemic risk measures: the simpler the better? Journal of Banking and Finance, forthcoming.

Schonbucher, P. J. (2003). Credit derivatives pricing models: Models, pricing, implementation. Wiley Finance, New York.

Trapp, M. (2009), Trading the bond-CDS Basis – The Role of Credit Risk and Liquidity, Centre for Financial Research – Working Paper No. 09-16.

Yan, B. and Zivot, E. (2007), The Dynamics of Price Discovery, University of Washington Working Paper Series.

Zhu, H. (2006), An Empirical Comparison of Credit Spreads between the Bond Market and the Credit Default Swap Market, Journal of Financial Services Research 29, 211-235.

Table 1: CDS and Bond Spreads Descriptive Statistics

Table 1 reports the CDS and bond spreads main descriptive statistics (mean and standard deviation) for different time periods (2004–2008, 2009, 2010, and 2011-2012). We group years 2011 and 2012 because there are only two months of observation for 2012. The bond spreads are obtained as the difference between country A's yield and the German yield.

			Bond	CDS
Austria	2004-2008	Mean	7	8
		Std.Dev.	12	21
	2009	Mean	52	104
		Std.Dev.	25	49
	2010	Mean	42	79
		Std.Dev.	12	13
	2011	Mean	59	90
		Std.Dev.	14	33
Belgium	2004-2008	Mean	9	8
		Std.Dev.	17	14
	2009	Mean	49	63
		Std.Dev.	29	33
	2010	Mean	57	110
		Std.Dev.	27	43
	2011	Mean	136	187
		Std.Dev.	47	51
Finland	2004-2008	Mean	5	6
		Std.Dev.	12	9
	2009	Mean	34	37
		Std.Dev.	21	19
	2010	Mean	-6	31
		Std.Dev.	13	3
	2011	Mean	18	44
		Std.Dev.	26	18
France	2004-2008	Mean	4	6
		Std.Dev.	9	9
	2009	Mean	23	40
		Std.Dev.	12	20
	2010	Mean	24	70
		Std.Dev.	8	18
	2011	Mean	41	107
		Std.Dev.	18	39
Germany	2004-2008	Mean		5
		Std.Dev.		7
	2009	Mean		36
		Std.Dev.		18
	2010	Mean		40
		Std.Dev.		8
	2011	Mean		58
		Std.Dev.		20

Table 1 (Cont.): CDS and Bond Spreads Descriptive Statistics

Greece	2004-2008	Mean	25	23
		Std.Dev.	36	36
	2009	Mean	166	165
		Std.Dev.	78	54
	2010	Mean	779	682
		Std.Dev.	290	242
	2011	Mean	1644	2075
		Std.Dev.	506	1452
The Netherlands	2004-2008	Mean	4	6
		Std.Dev.	8	12
	2009	Mean	30	53
		Std.Dev.	18	30
	2010	Mean	19	45
		Std.Dev.	7	8
	2011	Mean	24	55
		Std.Dev.	16	22
Ireland	2004-2008	Mean	9	13
		Std.Dev.	20	31
	2009	Mean	151	190
		Std.Dev.	56	62
	2010	Mean	262	302
		Std.Dev.	164	154
	2011	Mean	821	730
		Std.Dev.	235	145
Italy	2004-2008	Mean	19	19
		Std.Dev.	25	27
	2009	Mean	74	103
		Std.Dev.	32	39
	2010	Mean	109	165
		Std.Dev.	40	42
	2011	Mean	218	246
		Std.Dev.	101	115
Portugal	2004-2008	Mean	13	14
		Std.Dev.	20	19
	2009	Mean	71	76
		Std.Dev.	37	27
	2010	Mean	251	293
		Std.Dev.	111	116
	2011	Mean	918	767
		Std.Dev.	366	273
Spain	2004-2008	Mean	8	12
		Std.Dev.	15	20
	2009	Mean	54	89
		Std.Dev.	30	26
	2010	Mean	152	205
		Std.Dev.	74	67
	2011	Mean	257	295
		Std.Dev.	66	64

Table 2: Determinants of the Basis

This table reports the effect of the potential determinants of the basis based on a fixed-effects regression robust to heteroskedasticity. Column (1) reports the effect of such determinants for the period spanning January 2004– February 2012. This column contains the explanatory variables' coefficients and the standard errors between brackets. *** (** and *) indicates whether the coefficients are significant at a significance level of 1% (5% and 10%). The bootstrap methodology is employed to correct any potential bias in the standard errors. Column 2 reports the standardised coefficient (i.e., the regression coefficient as in Column 1 multiplied by the standard deviation of the corresponding explanatory variable).

	(1)	(2)
Counterparty risk	-0.150***	-0.005
	(0.06)	
Ratio CDS/bond liquidity	0.003**	0.002
	(0.00)	
Financing costs	-2.011***	-0.010
	(0.30)	
Common volatilty of EMU countries' stock index returns	3.184***	0.006
	(0.71)	
Bonds purchased by ECB	0.0005***	0.001
	(0.00)	
Dummy haircut agreement by banks (July 11)	0.001	0.000
	(0.00)	
Dummy haircut agreement by banks (October 11)	-0.003	-0.001
	(0.00)	
Flight-to-quality indicator	-0.461***	-0.002
	(0.12)	
Lagged relative basis	0.933***	0.558
	(0.01)	
Constant	0.028***	
	(0.00)	
Number of observations	17,057	
Wald Chi2 statistic	49,206	
Prob>Wald Chi2	0	
Adjusted R-squared	0.906	

Table 3: Determinants of the Price-Discovery Metrics

This table reports the effect of the potential determinants of the price-discovery metrics using a panel fixed-effects logistic regression robust to heteroskedasticity. The price-discovery metrics are obtained from Gonzalo and Granger's (1995) methodology using rolling windows of 1,000 observations. The dependent variable takes a value of 1 when the bond spread reflects the information more efficiently than the CDS spread, while a value equal to 0 indicates that the CDS spread leads the price discovery process. The bond spread is defined as the difference between country A's yield and the German yield. Column (1) reports the results obtained when we use daily price-discovery metrics for the period spanning December 2007– February 2012. Column (2) includes the marginal effects of the coefficients in Column (1). The sample length is due to the use of the first 1,000 observations to estimate the price-discovery metric. The table contains the explanatory variables' coefficients and the standard errors between brackets. *** (** and *) indicates whether the coefficients or effects are significant at 1% (5% and 10%) level.

	(1)	(2)
Counterparty risk	0.354***	0.051***
	(0.02)	
Ratio CDS/bond liquidity	0.000	0.000
	(0.00)	
Financing costs	-1.549***	-0.223***
	(0.08)	
Common volatilty of EMU countries' stock index returns	33.144**	0.048**
	(14.48)	
Bonds purchased by ECB	-0.028***	-0.004***
	(0.00)	
Dummy haircut agreement by banks (July 11)	1.974***	0.284***
	(0.18)	
Dummy haircut agreement by banks (October 11)	2.983***	0.429***
	(0.24)	
Flight-to-quality indicator	-7.816**	-0.011**
	(3.91)	
Constant	-2.392***	
	(0.14)	
Number of observations	8817	8817
Wald Chi2 statistic	1723	1723
Prob>Wald Chi2	0	0
Log pseudolikelihood	-3393	-3393
Pseudo R2	0.346	0.346

Table 4: Correlation Matrix

This table reports the correlation among the factors employed as the determinants of the basis and the price discovery metrics. The correlations are obtained as a weighted average of the correlations between the variables for each country in the sample (excluding Germany).

	Counterparty risk	Ratio CDS/Bond liquidity	Financing costs	Common volatility EMU stock indexes	Bonds purchased by ECB	Dummy haircut July 11	Dummy haircut October 11	Flight-to-quality	Lagged relative basis
Counterparty risk									
Ratio CDS/Bond liquidity	0.16								
Financing costs	0.08	0.22							
Common volatility EMU	0.33	0.14	0.35						
Bonds purchased by ECB	0.39	-0.09	-0.12	0.08					
Dummy haircut July 11	0.56	-0.08	-0.16	0.09	0.52				
Dummy haircut October 11	0.44	-0.04	-0.12	0.02	0.22	0.71			
Flight-to-quality	0.13	-0.06	-0.11	0.02	0.07	0.16	0.07		
Lagged relative basis	-0.09	0.01	-0.31	-0.04	0.03	-0.02	-0.03	0.00	

Table 5: Robustness Checks for the Determinants of the Basis

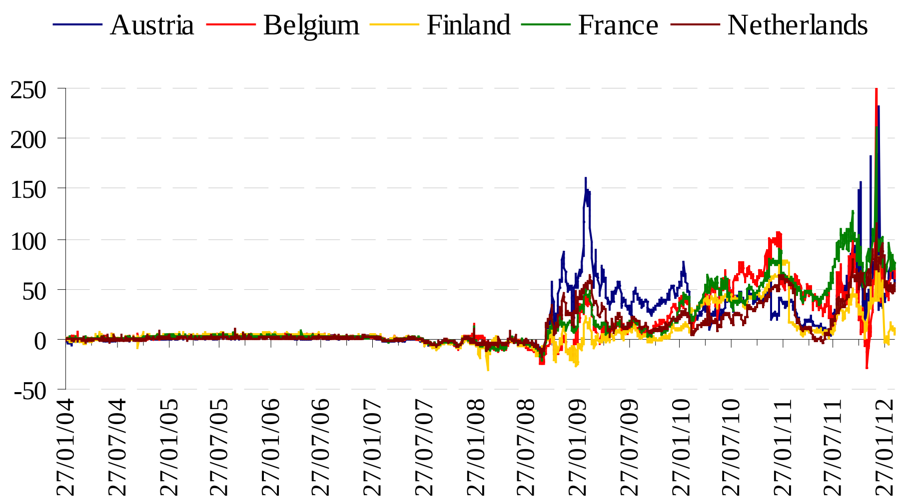
This table reports the effect of the potential determinants of the daily basis based on a fixed-effects regression robust to heteroskedasticity. Column (1) reports the baseline effect of such determinants for the period spanning January 2004– February 2012 (the same effects reported Column 1 of Table 2). Column 2 reports the results obtained when the financing costs measure is proxied by means of the 3-month Euribor-OIS spread instead of the gap between U.S. commercial paper and T-Bills. Due to the high correlation between Euribor-OIS and the indicator of counterpart risk we orthogonalize the Euribor-OIS gap with respect to the counterparty risk variable. Column 3 reports the results obtained when we add as an additional explanatory variable the purchases of public debt in the secondary market by the ECB interacted with a dummy variable for the subset of peripheral countries that had benefited from fully-fledged multilateral program of financial support by the end of the sample period (Greece, Ireland, and Portugal). This table contains the explanatory variables' coefficients and the standard errors between brackets. *** (** and *) indicates whether the coefficients are significant at a significance level of 1% (5% and 10%). The bootstrap methodology is employed to correct any potential bias in the standard errors.

	(1)	(2)	(3)
Counterparty risk	-0.150***	-0.207***	-0.151***
	(0.06)	(0.07)	(0.06)
Ratio CDS/bond liquidity	0.003**	0.004***	0.003**
	(0.00)	(0.00)	(0.00)
Financing costs (U.S. commercial paper-Tbills)	-2.011***		-2.014***
	(0.30)		(0.28)
Financing costs (3-month Euribor-OIS)		-3.319***	
		(0.50)	
Common volatilty of EMU countries' stock index returns	3.184***	2.433***	3.184***
	(0.71)	(0.68)	(0.66)
Bonds purchased by ECB	0.0005***	0.0006**	0.0002
	(0.00)	(0.00)	(0.00)
Bonds purchased by ECB interacted with a dummy for the countries that received financial assistance (Gre, Ire, Por)			0.0009**
			(0.00)
Dummy haircut agreement by banks (July 11)	0.001	0.005	0.001
	(0.00)	(0.00)	(0.00)
Dummy haircut agreement by banks (October 11)	-0.003	0.001	-0.003
	(0.00)	(0.00)	(0.00)
Flight-to-quality indicator	-0.461***	-0.475***	-0.461***
	(0.12)	(0.12)	(0.13)
Lagged relative basis	0.933***	0.936***	0.933***
	(0.01)	(0.01)	(0.01)
Constant	0.028***	0.022***	0.028***
	(0.00)	(0.00)	(0.00)
Number of observations	17,057	17,057	17,057
Adjusted R-squared	0.906	0.906	0.906

Table 6: Robustness Checks for the Determinants of the Price-Discovery Metrics

This table reports the marginal effect of the potential determinants of the price-discovery metrics using a panel fixed-effects logistic regression robust to heteroskedasticity. The price-discovery metrics are obtained from Gonzalo and Granger's (1995) methodology using rolling windows. The dependent variable takes a value of 1 when the bond spread reflects the information more efficiently than the CDS spread, while a value equal to 0 indicates that the CDS spread leads the price discovery process. The bond spread is defined as the difference between country A's yield and the German yield. Column (1) reports the marginal effects obtained when we use linear daily price-discovery metrics for the period spanning December 2007–February 2012 (the same effects reported Column 2 of Table 3). Column (2) reports the marginal effects of the drivers of price discovery obtained when we use non-linear price discovery metrics that are obtained from a threshold VECM-model instead of the standard VECM model. Column (3) reports the marginal effects obtained when we use monthly linear price-discovery metrics (instead of daily as in Column 1) for the same period. The sample length is due to the use of the first 1,000 observations to estimate the price-discovery metric. The table contains the explanatory variables' coefficients and the standard errors between brackets. *** (** and *) indicates whether the coefficients or effects are significant at 1% (5% and 10%) level.

	(1)	(2)	(3)
Counterparty risk	0.051***	0.046***	0.027**
Ratio CDS/bond liquidity	0.000	0.000*	0.000
Financing costs	-0.223***	-0.195***	-0.348***
Common volatilty of EMU countries' stock index returns	0.048**	0.044**	0.006**
Bonds purchased by ECB	-0.004***	-0.002***	-0.004***
Dummy haircut agreement by banks (July 11)	0.284***	0.191***	0.405***
Dummy haircut agreement by banks (October 11)	0.429***	0.100***	0.318**
Flight-to-quality indicator	-0.011**	0.008	-0.002**
Number of observations	8817	8811	432
Wald Chi2 statistic	1723	1729	113
Prob>Wald Chi2	0	0	0
Log pseudolikelihood	-3393	-4289	-144
Pseudo R2	0.346	0.207	0.424



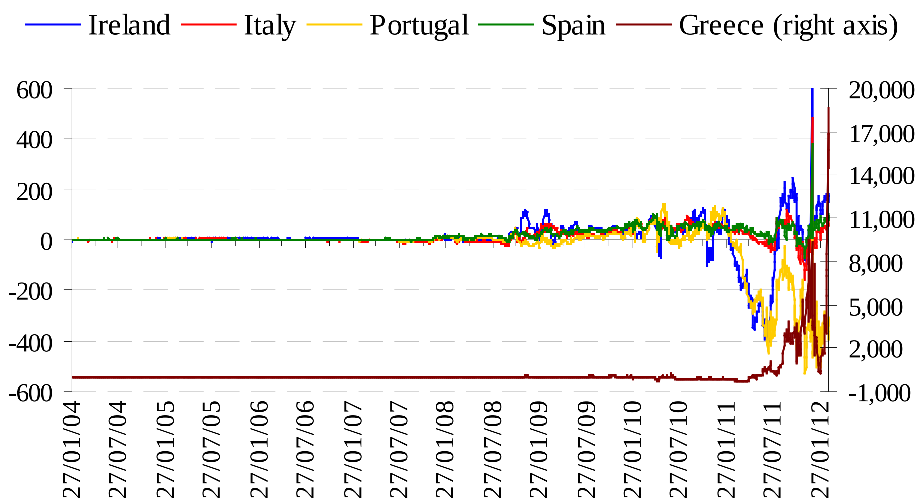


Figure 1: The CDS-bond basis for the peripheral and core countries. This figure shows the difference between the 5-year CDS and bond spreads (in basis points) for two groups of countries: peripheral (Greece, Ireland, Italy, Portugal, and Spain) and core (Austria, Belgium, Finland, France, and The Netherlands).

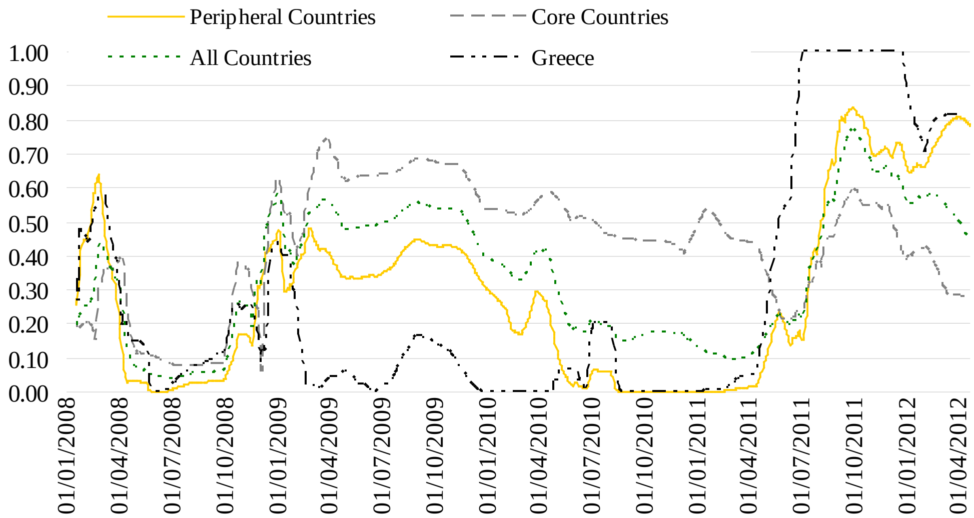


Figure 2: Bond Price-Discovery Metrics for Groups of EMU Countries. This figure shows the 30-day moving average of the Gonzalo and Granger bond (GG_{Bond}) price-discovery metrics for the peripheral, core, and all EMU countries. The price-discovery metrics are estimated using 1,000-day rolling windows. The metrics for each group of countries are obtained as the equally weighted average of the country-specific price-discovery metrics. The price-discovery metrics for Greece correspond to the 30-day moving average of the bond metrics for Greece. The values that are larger (lower) than 0.5 indicate that the bond (CDS) market leads the price discovery process.

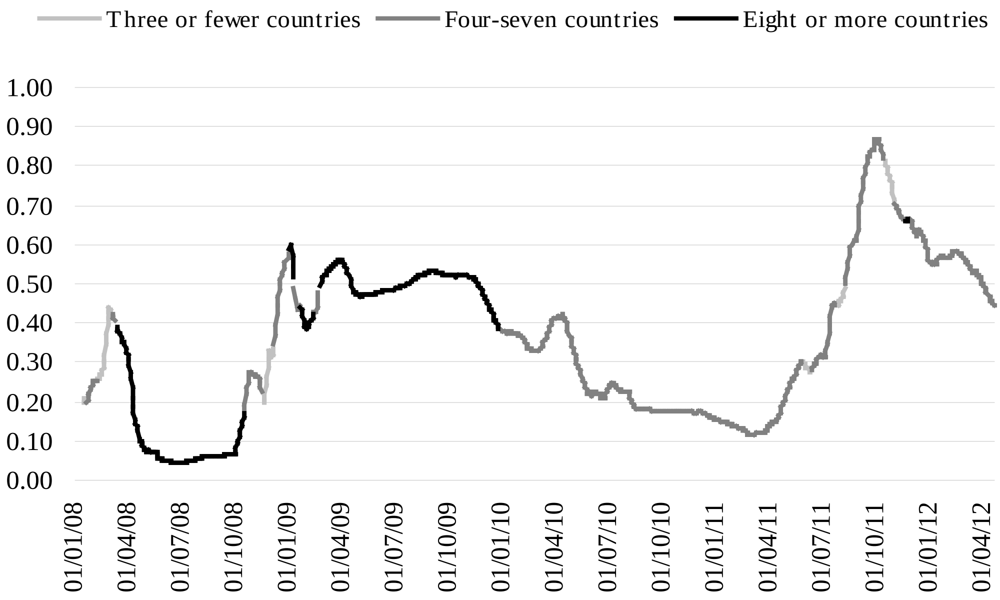


Figure 3: EMU Bond Price-Discovery Metrics and Number of Countries Employed in Their Calculation: This figure shows the 30-day moving average of the EMU countries' Gonzalo and Granger bond (GG_{Bond}) price-discovery metrics that are obtained using 1,000-day rolling windows. These metrics are obtained as the equally weighted average of the country-specific price-discovery metrics. The line shows the number of countries employed to calculate the average metric such that the darker the line, the higher the number of countries employed in its calculation. The values that are larger (lower) than 0.5 indicate that the bond (CDS) market leads the price discovery process.