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PRIMARY RESEARCH

Dynamic credit risk discovery and determinants of market leadership in sovereign CDS and bond markets

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Abstract

This study analyzes the price discovery process of credit risk in sovereign Credit Default Swap (CDS) and bond markets of peripheral and core European countries. We consider an extensive time sample that begins with the transformation of the global financial crisis to a debt crisis in Eurozone and ends shortly before the outburst of COVID-19 pandemic crisis. To investigate the relative efficiency between CDS and bond market in credit risk pricing, we apply co-integration and Granger causality methods utilizing rolling windows. We obtain dynamic price discovery measures which allow us to identify the leading market in price discovery in a time-varying context and, thus, to detect potential alternations in the direction of influence from CDS to bond market and vice versa. Indeed, we find that the dominant market in terms of pricing and informational efficiency depends on the examined period, while CDS market leadership is more frequently observed during periods of increased risk and economic uncertainty. To examine the determinants of the leading market in price discovery, we estimate a Logit regression model using a set of economic variables as explanatory factors. The empirical results reveal that the funding cost and the level of systemic risk in financial markets positively affects the probability of CDS market leadership. The level of volatility in stock markets negatively affects the pricing efficiency of the CDS market in core European countries, while its effect is insignificant in peripheral countries. Relative liquidity between CDS and bond market and counterparty risk also have significant effect on the determination of the leading market. However, the sign of the effect depends on the country concerned. Overall, the conclusions of this study provide useful insights for investment, funding, and regulation decisions to participants in sovereign credit risk market.

INTRODUCTION

The global financial crisis of 2007-09 and the recent debt crisis in the European Monetary Union (EMU) have brought to the forefront of interest the sovereign credit risk of developed European countries. The over-indebtedness of several peripheral EMU countries, namely Portugal, Italy, Greece, and Spain, raised concerns about their creditworthiness and contagion effects to the overall Union. Market participants fundamentally reassessed the way of sovereign credit risk pricing, as depicted in elevated spreads of EMU government bonds. At the same time, the spreads of CDS contracts on government debt also increased, reflecting the high level of perceived credit risk and, thus, the investors' greater need for credit risk protection.

CDS are Over-The-Counter (OTC) derivatives that provide to market participants an alternative and unfunded, relative to bonds, way to trade credit risk. Bondholders can offset the credit risk of their positions with that of a third party by entering into the suitable CDS contract. In theory, CDS spread and the corresponding bond spread should be approximately equal, since both of the them measure the credit risk associated with the same underlying entity, i.e., the bond issuer (Coudert & Gex, 2013; Duffie, 1999; J. C. Hull & White, 2000; J. Hull, Predescu, & White, 2004). In practice, this equality is never observed, due to the imperfect match between the two financial instruments. In this context, the investigation of the interrelation between sovereign CDS and bond spreads and their contribution to

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the pricing process of sovereign credit risk, as well, constitutes an especially interesting research area.

The present study aims to shed light on several aspects of the dynamic relation between sovereign CDS and bond spreads of both peripheral and core EMU countries, considering an extensive period that begins with the transformation of the 2007-09 financial crisis to a Euro zone debt crisis and ends shortly before the outburst of the current pandemic crisis of COVID-19. First, we examine both the short-run and the long-run relationship between CDS and bond spreads, by applying dynamic co-integration and Granger causality methods. This approach results in time-varying estimations that allow us to capture the dynamic nature of the CDS-bond spread relation. We test the hypothesis of a long-run CDS-bond spread equilibrium relation, while we examine the relative efficiency between CDS and bond market in credit risk pricing in the short-run. More specifically, we address the issue of which spread leads the credit risk price discovery process, timely and efficiently incorporating new relevant information. The most previous studies on sovereign credit markets are based on the conjecture of a stable price discovery process that occurs in the same direction (Ammer & Cai, 2011; Aktug, Vasconcellos, & Bae, 2012; Bowe, Klimaviciene, & Taylor, 2009; Chan-Lau & Kim, 2004; Coudert & Gex, 2013; Delatte, Gex, & López-Villavicencio, 2012; Fontana & Scheicher, 2016; Hassan, Ngene, & Yu, 2015; Kregzde & Murauskas, 2015; Nguyen, 2017; Palladini & Portes, 2011).

The few studies that consider the dynamic nature of price discovery employ single measure methodologies, ignoring specific characteristics of CDS and bond spread series that affect the detection of the leading market (Arce, Mayordomo, & Peña, 2013; Delis & Mylonidis, 2011; Guidolin, Pedio, & Tosi, 2021). Moreover, these studies do not consider the period after the debt crisis.

Second, this study investigates the determinants of the leading market in the price discovery process, considering factors that proxy for funding cost, relative liquidity between CDS and bond market, counterparty risk, and market uncertainty. The existing literature on the determinants of the leading market in credit risk discovery is very limited, especially concerning sovereign credit markets.

The findings of this study confirm that credit risk price discovery process presents strong dynamic characteristics, while the detection of the leading market depends on the examined period. Indeed, CDS market leadership is more frequent during periods of increased perceived risk and economic uncertainty. The analysis of the determinants of market leadership in price discovery reveals that funding cost and the level of systemic risk in financial markets positively affect the ability of CDS market to lead. The effect of stock market volatility on CDS market's pricing efficiency is negative in case of core European countries, while it is insignificant in peripheral ones. Lastly, counterparty risk and relative liquidity between CDS and bond market also significantly affect the determination of the leading market. The sign of these effects depends on the considered country.

All in all, the conclusions of the study provide useful insights to investment, funding, and regulation decision makers. Participants in sovereign credit risk markets, as they form their investment, hedging or speculative strategies, could detect the market in which credit risk is accurately and efficiently priced, by assessing the proposed determinants of the leading market. Additionally, sovereign bond issuers could assess their credit risk, as perceived by markets, and, thus, their borrowing cost, by utilizing the information regarding the leading market in price discovery.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Section 3 analyzes the data and presents the applied econometric methodology. Section 4 reports and discusses the main findings. Lastly, section 5 presents the conclusions of the study.

LITERATURE REVIEW

In this section, we review the two strands of literature that are related to the main research objectives of this study: price discovery analysis in sovereign credit markets, and determinants of the leading market in price discovery.

Price Discovery Analysis

The investigation of the relation between CDS and bond markets has attracted intense research interest over the past decades. There is extensive literature addressing the issue of price discovery in credit markets and more specifically the identification of the leading one in the price discovery process. Most studies employ either price discovery measures in the context of a Vector Error Correction Model (VECM), i.e., Hasbrouck (1995) or Gonzalo and Granger (1995) measure (GG), or Granger causality test. Prior literature focuses on corporate entities, mainly from North America and Europe, verifying the existence of cointegration between CDS and bond spreads (Baba, Inada, et al., 2007; Blanco, Brennan, & Marsh, 2005; Bank, 2004; Norden & Weber, 2009; Zhu, 2006) and the leading role of the CDS market in price discovery (Bank, 2004; Forte & Pena, 2009; Klenina & Mateus, 2017; Longstaf, Mithal, & Neis, 2005; Norden & Weber, 2009; Zhu, 2006).

The early studies on sovereign credit markets focus on

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emerging economies (Ammer & Cai, 2011; Aktug et al., 2012; Bowe et al., 2009; Chan-Lau & Kim, 2004; Coudert & Gex, 2013; Hassan et al., 2015; Kregzde & Murauskas, 2015). Most of these studies consider the period before the global financial crisis of 2007-09, providing conflicting results regarding both the existence of co-integration and the leading market in price discovery. The 2007-09 global financial crisis and the subsequent debt crisis in the euro area brought to the forefront of research interest the sovereign credit markets of developed economies, mostly, from the euro area. Palladini and Portes (2011) analyzing six euro area sovereigns from 2004 to 2011, suggest that price discovery occurs in the CDS market.

Fontana and Scheicher (2016) and Coudert and Gex (2013) find that in core Europe the CDS market moves ahead of the bond market in the pricing process, while they find the contrary for the peripheral countries. Delatte et al. (2012) suggest that in periods of financial distress the CDS market drives up the information transmission between CDS and bond markets. In addition, they verify the existence of nonlinearity in the CDS-bond spread relation. Similar conclusions are provided by Nguyen (2017), who considers both the financial and the debt crisis period (2008-2017).

All the studies mentioned in previous paragraphs employ their analysis utilizing the entire sample period at once. Thus, they make the implicit assumption of a constant CDS-bond spread relation and a stable price discovery process that continuously occurs in the same direction. Delatte et al. (2012) argue against the conjecture of a transmission mechanism from one market to the other that always occurs in the same direction. They verify that the price discovery process in sovereign credit markets depends on the specific market characteristics and especially on the level of perceived credit risk. Similarly, Agiakloglou and Deligiannakis (2020) examine the relationship between sovereign CDS and bond spreads in EU countries, considering both the global financial crisis and the subsequent debt crisis. They find that the existence of co-integration between the two markets as well as the leading market in price discovery depend on the period of reference.

A handful of research papers, taking into consideration the time-varying nature of the relation between CDS and spreads, utilize dynamic methods to investigate its short-run and long-run aspects. Delis and Mylonidis (2011); Mylonidis and Kollias (2010) applying a rolling Granger causality method on southern European countries from 2007 to 2010, verify that the relation between CDS and bond spreads evolves over time. The authors observe causality from CDS to bond spreads since 2007, while they find bidirectional causality during periods of increased uncertainty. Arce et al. (2013) perform a time-varying price discovery analysis on 11 European countries from 2004 to 2012, concluding that in general the sovereign indebtedness impeded the leadership of the CDS market in price discovery. Guidolin et al. (2021) provide a price discovery analysis in a recursive manner to examine the sovereign credit markets of 10 euro area countries, over a period from 2006 to 2015. According to their findings, the CDS market leads the price discovery process in tranquil times, while the reverse seems to hold during periods of crisis.

The present study performs an empirical methodology that complements and expands the studies that follow dynamic approaches in several ways. First, we investigate the relation between CDS and bond spreads on a series of successive subsamples by applying, interchangeably, alternative price discovery methods, i.e., speed of adjustment coefficients, GG measure and Granger causality test. This procedure addresses the methodological issue that stems from the time-varying nature of price discovery process and allows us to detect any alternation in the leading market. Prior dynamic studies apply either the Granger causality test (Delis & Mylonidis, 2011), or the GG measure (Arce et al., 2013), or both but not in a rolling window context (Guidolin et al., 2021). Second, this study considers an extensive time sample that begins with the transformation of the global financial crisis to a sovereign debt crisis in Eurozone and ends shortly before the outburst of the COVID-19 pandemic crisis. Thus, we can provide evidence regarding the CDS-bond market interrelation and the leading market in price discovery during periods that differ substantially in terms of credit risk and financial uncertainty. Delis and Mylonidis (2011); Mylonidis and Kollias (2010), Arce et al. (2013) and Guidolin et al. (2021) consider samples that end in 2010, 2012 and 2015, respectively. Third, to enhance the robustness of our findings, we examine the evolution of the credit risk price discovery for each of the high-risk peripheral EMU countries in comparison to low-risk core EMU countries. Delis and Mylonidis (2011) examine only highly indebted sovereigns of Southern Europe. To our knowledge, our study is the first that incorporates at the same time the three above contributions.

The Determinants of the Leading Market in Price Discovery

There is a considerable number of papers examining the relation between CDS and bond markets and the concept of credit risk price discovery. A strand of studies addresses the determinants of CDS and bond spreads

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(Beber, Brandt, & Kavajecz, 2009; Bernoth, Von Hagen, & Schuknecht, 2012; Blommestein, Eijffinger, & Qian, 2016; Chen, Lesmond, & Wei, 2007; Codogno, Favero, & Missale, 2003; Collin-Dufresn, Goldstein, & Martin, 2001; Elton, Gruber, Agrawal, & Mann, 2001; Ericsson, Jacobs, & Oviedo, 2009; Favero, Pagano, & Von Thadden, 2010; Fu, Li, & Molyneux, 2021; Geyer, Kossmeier, & Pichler, 2004; Kartal, 2020; Longstaf, Mithal, & Neis, 2003; Malhotra & Corelli, 2018; Muvunza & Jiang, 2021; Naifar, 2020; Paniagua, Sapena, & Tamarit, 2017; Samaniego-Medina, Trujillo-Ponce, Parrado-Martínez, & di Pietro, 2016; Khan, Jam, Akbar, Khan, & Hijazi, 2011) while other authors analyze the factors that determine the difference between the CDS spread and the corresponding bond spread, namely the basis (Arce et al., 2013; Augustin & Schnitzler, 2021; Jennie Bai, 2011; Bai & Collin-Dufresne, 2019; Foley-Fisher, 2010; Fontana & Scheicher, 2016; Küçük, 2010; Levy, 2009; Lin, Man, Wang, & Wu, 2020; Molleyres, 2018; Subrahmanyam, Nashikkar, & Mahanti, 2008; Trapp, 2009; Shahbaz, Jam, Bibi, & Loganathan, 2016; Waheed, Kaur, Ain, & Hussain, 2016). However, the literature on the identification of the determinants of price discovery leadership, especially, in sovereign credit markets is still limited.

Molleyres (2018) attempts to detect the economic variables that determine the price discovery process in US corporate credit markets during the 2004-2010 period. The author suggests that under conditions of elevated risk the price discovery is uniquely affected by counterparty risk, while market participants seem to ignore interbank liquidity risk, global risk, and financing costs. In particular, he finds that the higher the counterparty risk, the higher the probability of bond market leadership in price discovery.

Considering sovereign credit markets, Arce et al. (2013) investigate the determinants of market leadership in price discovery, using a sample of 11 European countries from 2004 to 2012. They include in their analysis risk factors, funding cost, market liquidity and other market frictions. According to their findings, counterparty risk, stock market volatility and private banks' voluntary acceptance of losses on their positions on Greek sovereign debt reduced the possibility of CDS market leadership in price discovery. Contrariwise, funding cost, flight-to-quality behavior and ECB intervention through the purchase of sovereign debt negatively affected the informational efficiency of the bond market and, thus, its ability to lead in price discovery.

More recently, Raja, Procasky, and Oyotode-Adebile (2020) find strong correlation between the relative liquidity of the CDS to the bond market and the price discovery contribution for a sample of eight emerging sovereign markets. More specifically, the increase of the relative liquidity of the CDS market enhances its contribution to the credit risk price discovery.

Our study, apart from the detection of the leading market in price discovery, investigates the specific factors that determine the leading market in price discovery. Therefore, the study provides another significant contribution to the limited existing literature. Utilizing the results of the rolling window price discovery analysis, we examine the potential factors that define which market contributes faster to credit risk pricing. Specifically, we consider funding cost, relative liquidity between CDS and bond markets, counterparty risk, and measures of market uncertainty as potential determinants of leadership in credit risk price discovery. To the best of our knowledge Arce et al. (2013) is the only study that examines the determinants of market leadership in European sovereign credit markets. Beyond the differences in terms of time sample and price discovery analysis methodology, our study presents another methodological departure from Arce et al. (2013) since it provides country-level rather than panel data analysis.

DATA & METHODOLOGY

Data and Sample

The data comprise five-year daily CDS spreads and five-year daily bond yields for four peripheral EMU countries, namely Portugal, Italy, Greece, and Spain, as well as for three core EMU countries, namely Austria, France, and Germany. In line with prior literature, we utilize maturity of five years, which is considered as the most liquid and actively traded CDS market segment. The sample period runs from December 2007 to December 2019 for Italy, Greece, Spain, France, and Germany. In case of Portugal and Austria the sample period runs from February 2008 to December 2019 and from April 2009 to December 2019, respectively. We calculate the bond spreads based on the euro area yield curve and, specifically, the spot rate of AAA government bonds of 5-year maturity. We use this rate, provided by the ECB statistical data warehouse, as proxy of risk-free rate in the euro area. CDS spreads and bond yields are retrieved from Thomson Reuters Datastream.

Tables 1 and 2 present the descriptive statistics of the examined CDS and bond spread series.

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TABLE 1. CDS spreads' descriptive statistics

	Mean	Median	Std. Dev.	JB (*p*-value)	Observations
Portugal	2.575	1.508	2.893	3391.81 (0.00)	3,101
Italy	1.348	1.045	0.920	3104.49 (0.00)	3,143
Greece	67.233	9.611	70.576	503.53 (0.00)	3,143
Spain	1.140	0.721	0.100	1220.68 (0.00)	3,143
Austria	0.342	0.187	0.330	1225.18 (0.00)	2,786
France	1.140	0.721	0.999	1220.68 (0.00)	3,143
Germany	0.189	0.127	0.1605	1945.11 (0.00)	3,138

This table presents the descriptive statistics CDS spread series. Columns 2, 3, and 4 report mean, median,and standard deviation, respectively, of the CDS spread series for each country. Column 5 displays the results of the Jarque-Bera test statistic and the respective *p*-values. CDS spreads are expressed as percentages.

TABLE 2. Bond spreads' descriptive statistics

	Mean	Median	Std. Dev.	JB (*p*-value)	Observations
Portugal	3.052	1.539	3.761	3910.94 (0.00)	3,101
Italy	1.417	1.037	1.058	1333.37 (0.00)	3,143
Greece	17.352	9.214	21.652	898.21 (0.00)	3,143
Spain	1.215	0.711	1.1684	1961.67 (0.00)	3,143
Austria	0.131	0.095	0.1446	7927.25 (0.00)	2,786
France	1.215	0.711	1.168	1961.67 (0.00)	3,143
Germany	-0.1637	-0.0933	0.187	1703.77 (0.00)	3,138

This table presents the descriptive statistics of the bond spread series. Columns 2, 3, and 4 report mean, median,and standard deviation, respectively, of the bond spread series for each country. Column 5 displays the results of the Jarque-Bera test statistic and the respective *p*-values. Bond spreads are expressed as percentages.

Figures 1, 2 display the plots of the examined CDS and bond spread series. The fundamental reassessment of sovereign credit risk, as a result of the 2007-09 financial crisis and the subsequent EMU debt crisis, is depictured to the elevated CDS and bond spreads, especially considering peripheral EMU countries.

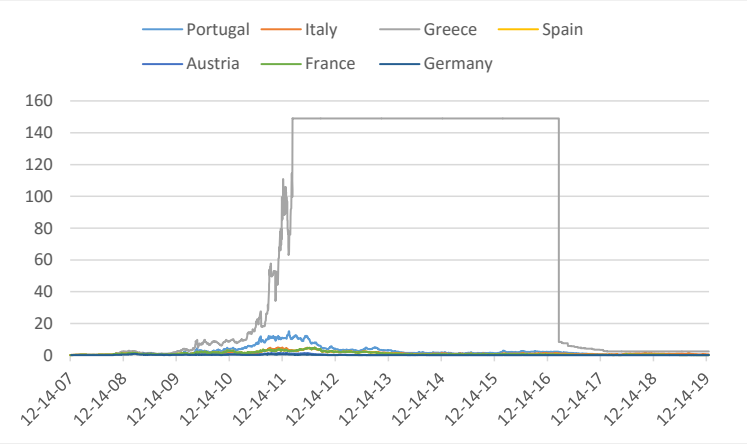

FIGURE 1. CDS spreads (This figure plots the five-year daily CDS spreads for the examined countries. CDS spreads are expressed as percentages. Data obtained from Thomson reuters datastream.)

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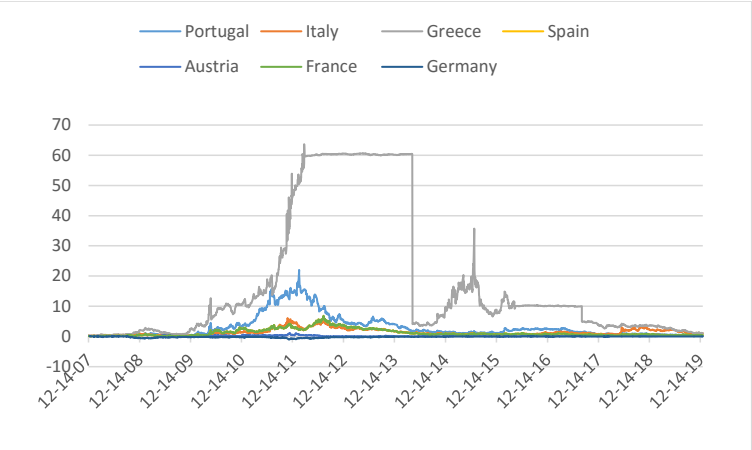

FIGURE 2. Bond spreads (This figure plots the daily five-year sovereign bond spreads for the examined countries. Bond spreads are expressed as percentages. Data obtained from Thomson reuters datastream.)

Regarding the rest data required for the empirical analysis, we use the difference between the 3-month Euribor and the EONIA as a proxy for funding cost. Both rates are obtained from the ECB statistical data warehouse. We consider the CDS spreads of the main CDS dealers in the market to measure counterparty risk in the CDS market. These CDS series are also retrieved from Thomson Reuters Datastream. To measure uncertainty in European markets we use two proxies: the VSTOXX implied volatility index and the Composite Indicator of Systemic Stress (CISS). We obtain historical data of VSTOXX index from the stoxx.com website, while CISS data are retrieved from the ECB statistical data warehouse.

Methodology

Price discovery analysis

To investigate the relation between CDS and bond spreads we follow a three-step empirical procedure. Firstly, we employ the standard augmented Dickey-Fuller (ADF) unit root test (Dickey & Fuller, 1979) to check the stationarity of the series. We also employ the Zivot-Andrews unit root test (Zivot & Andrews, 2002), allowing for an endogenously determined breakpoint in the examined series. Given the detection of unit root in both CDS and bond spreads and their integration in the same order, we can move to the second step and the application of the co-integration test of Johansen (1991). The evidence of co-integration implies that there is a long-run equilibrium relation between the two spreads. The Johansen (1991) test is employed in the context of a Vector Autoregressive Model (VAR), providing consistent estimations of the co-integrating matrix.

Proceeding to the third step, we consider co-integrated spread series in a Vector Error Correction Model (VECM) to examine the short-run aspects of their relation and the adjustment process towards the long-run equilibrium. The co-integrating relationship is specified as follows:

$$\text{CDS spread}_{\ t} = \alpha + \beta\ \text{bond spread}_{\ t} + z_t \tag{1}$$

Equation (1), can be written:

$$\text{CDS\_spread}_t - \beta\text{bond\_spread}_t - \alpha = z_t = I(0) \tag{2}$$

Coefficient β determines the long-run relation between CDS and bond spreads, while z_t should be level stationary. The VECM is represented by the following equations:

$$\Delta CDS\_\text{spread}_t = c_1 + \alpha_1 z_{t-1} + \sum_{j=1}^{p} \gamma_{1j} \Delta CDS\_\text{spread}_{t-j} + \sum_{j=1}^{p} \delta_{1j} \Delta \text{bond\_}spread_{t-j} + \varepsilon_{1t} \tag{3}$$

$$\Delta\text{bond\_spread}_t = c_2 + \alpha_2 z_{t-1} + \sum_{j=1}^{p} \gamma_{2j} \Delta CDS\_\text{spread}_{t-j} + \sum_{j=1}^{p} \delta_{2j} \Delta\text{bond\_spread}_{t-j} + \varepsilon_{2t} \tag{4}$$

Where $_1$ and $_2$ are the speed of adjustment coefficients that are considered as price discovery measures. To determine the leading market in price discovery, we consider the signs and the magnitudes of alphas. If $_1$ is statistically significant and negative, the CDS spread adjusts to the equilibrium, implying that the bond spread is the leading one in pricing

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process. On the contrary, if $_2$ is significant and positive, the bond spread adjusts to the equilibrium, conceding the price discovery leadership to the CDS spread. In case that both alphas are statistically significant and properly signed, the leading spread is identified through the Gonzalo-Granger (GG) price discovery measure (Gonzalo & Granger, 1995) since both CDS and bond spreads contribute to the pricing process. The GG measure is specified as follows:

$$GG = \alpha_2 / (\alpha_2 - \alpha_1) \quad (5)$$

Provided that the existence of co-integration cannot be verified and, thus, the VECM specification in not valid, we utilize the Granger causality test (Granger, 1969) to detect the leading market in price discovery. The Granger causality test is applied in the context of a VAR model. More specifically, causality from bond to CDS spread means that the pricing process occurs in the bond market, and vice versa, while feedback causality implies that both markets contribute to price discovery.

Dynamic price discovery analysis

Taking into consideration previous evidence regarding the dynamic nature of the price discovery process in sovereign credit risk markets (Arce et al., 2013; Agiakloglou & Deligiannakis, 2020; Delatte et al., 2012; Delis & Mylonidis, 2011), we extend the methodology described above to a time-varying framework. We apply rolling window estimation techniques, utilizing a fixed length window of 250 daily observations. The standard-length window moves consecutively from the start to the end of the sample, by adding one observation to the end and removing the starting one. This approach considers a series of subsamples, delivering a respective series of estimated coefficients and test statistics. Thus, it allows the examination of the evolution of the relationship in request and the detection of structural breaks, addressing the subsample instability issue (Arce et al., 2013; Delis & Mylonidis, 2011; Kollias, Mylonidis, & Paleologou, 2012).

We examine a series of 2,894 subsamples (beginning with 14/12/2007-27/11/2008 and ending with 16/01/2019-31/12/2019) for Italy, Greece, Spain, and France, 2,852 subsamples (beginning with 12/02/2008-26/01/2009 and ending with 16/01/2019-31/12/2019) for Portugal, 2,537 subsamples (beginning with 28/04/2009-12/04/2010 and ending with 16/01/2019-31/12/2019) for Austria, and 2,889 subsamples (beginning with 21/12/2007-04/12/2008 and ending with 16/01/2019-31/12/2019) for Germany. In total, we employ the price discovery analysis 20,000 times, considering all the countries of the sample.

The determinants of market leadership

To analyze the determinants of market leadership in sovereign credit risk pricing process, we examine the impact of potential explanatory factors on the dynamics of the price discovery measures employed in previous section. More specifically, we utilize the results obtained from the rolling window estimation analysis to construct a dummy variable for each country of the sample. The dummy takes the value one (1) in case that CDS market is identified as the dominant one in price discovery and zero (0) otherwise. Then, we estimate a Logit model, regressing the dummy variable on a set of economic variables.

The economic variables that follow are considered as potential determinants of the market that leads the price discovery process:

Funding cost (FC): The funding cost affects in different way the bond and the CDS market. Given that investing in bonds requires funding, higher cost of funding could negatively affect the demand and, thus, the prices of bonds. In turn, this would lead to higher bond spreads. Contrariwise, the relative unfunded market of CDS contracts is rather preferable for investors when funding cost increases since it allows for high-leveraged positions. Therefore, one would anticipate that a rise in funding cost impairs the ability of the bond market to lead in price discovery. Considering that we examine European sovereign credit markets we use the spread between the 3-month Euribor and the EONIA as proxy of funding cost (Arce et al., 2013).

Relative liquidity (RL): The level of liquidity of a market constitutes a decisive factor of pricing and informational efficiency (Ammer & Cai, 2011). Hence, a rise in the liquidity of the CDS market in relation to the bond market is expected to enhance the leading role of the CDS market in price discovery. To measure the relative liquidity between the CDS and the bond market, we calculate the ratio of bid-ask spread of CDS spread to bid-ask spread of bond yield. As the liquidity in the CDS market increases, the ratio declines. Utilizing the CDS spreads and the bond yields, we apply the absolute Roll measure proposed by Christopoulos (2020) to estimate the bid-ask spreads of CDS spreads and bond yields, respectively.

Counterparty risk (CP): Principally, CDS contracts are subject to counterparty risk, which refers to the probability of default of the credit protection seller. The level of the counterparty risk specifies the quality of protection sold and the overall stability in the CDS market. This effect in en-

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hanced by the over-the-counter nature of the CDS market and the high concentration on a small group of dealers, as well. Thus, one might expect that the contribution of the CDS market in price discovery decreases as counterparty risk increases. To measure counterparty risk, we use the average CDS spread of the main active CDS dealers. This proxy is commonly used in relative literature (Arce et al., 2013; Lin et al., 2020; Molleyres, 2018).

European market uncertainty: Previous empirical evidence confirms that the price discovery process in sovereign credit markets is highly affected by the overall economic uncertainty and financial stability. During periods of increased market risk and financial stress, the CDS market may attract market participants who seek for credit risk protection. Consequently, the CDS market's role in price discovery is enhanced. To measure market uncertainty, we use two proxies: the VSTOXX implied volatility index and the Composite Indicator of Systemic Stress (CISS). The VSTOXX is considered as indicator of the level of uncertainty in the European equity markets (Arce et al., 2013; Kaya, 2018; Stanescu, 2012). The CISS index, provided by ECB, measures the level of systemic risk in the European financial markets (Holló, Kremer, & Duca, 2012). The Logit model is specified as follows:

$$\ln\left(\frac{P_{it}}{1-P_{it}}\right) = c_i + \beta_{1i}FC_t + \beta_{2i}RL_{it} + \beta_{3i}CP_t + \beta_{4i}VSTOXX_t + \beta_{5i}CISS_t + \varepsilon_{it} \quad (6)$$

Where P_{it} is the probability of CDS market leadership in price discovery for country I at day t; c_i is the intercept coefficient; β_{1i}, β_{2i}, β_{3i}, β_{4i}, β_{5i} are the coefficients of the explanatory variables of the model, and ε_{it} is the error term. The $(P_{it}/_{(1-P_{it})})$ ratio represents the odds ratio. The coefficients of the Logit model are estimated using the maximum likelihood estimation method.

EMPIRICAL RESULTS

The following paragraphs present the results of the analysis of the price discovery process in the selected sovereign credit risk markets.

Price Discovery

Preliminary analysis

The results of the ADF unit root test (Tables 3, 4) indicate integration of order one (I (1)) for all the examined series, except for CDS and bond spreads of Italy, which can be described as level stationary processes. According to the Zivot-Andrews test, all CDS and bond spread series are trend stationery with a breakpoint (Tables 3, 4). The breakpoints in the CDS spread series are identified between June and July 2012 for Portugal, Italy, Spain, Austria, France, and Germany, and in March 2017 for Greece. Considering bond spreads, the breakpoints occurred in May 2012 for Portugal and Austria, in July 2021 for Italy and Germany, in November 2012 for Spain and France, and in April 2014 for Greece.

TABLE 3. CDS spreads unit root tests

		ADF Test		IVOT-Andrews Test		
		Test Statistic (*p*-value)	Unit Root	Test Statistic	Unit Root	Breakpoint
Portugal	level	-1.230 (0.902)	Yes	-5.910*	No	06/06/2012
	1st Diff.	-13.552* (0.000)	No	-	-	-
Italy	level	-3.547* (0.037)	No	-4.919*	No	25/072012
	1st Diff.	-15.756* (0.000)	No	-	-	-
Greece	level	-0.904 (0.954)	Yes	-4.908*	No	03/03/2017
	1st Diff.	-60.011* (0.000)	No	-	-	-
Spain	level	-1.043 (0.935)	Yes	-6.042*	No	25/07/2012
	1st Diff.	-15.176* (0.000)	No	-	-	-
Austria	level	-3.160 (0.095)	Yes	-6.889452*	No	13/06/2012
	1st Diff.	-13.346* (0.000)	No	-	-	-
France	level	-2.444 (0.356)	Yes	-6.042071*	No	25/07/2012
	1st Diff.	-13.177* (0.000)	No	-	-	-

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Table 3 Continue.....

Germany	level	-3.067 (0.117)	Yes	-4.740901*	No	10/01/2012
	1st Diff.	-15.056* (0.000)	No	-	-	-

This table reports the results of the ADF and Zivot-Andrews unit root tests applied on the CDS spread series.* indicates the rejection of the null hypothesis of unit root at 5% significance level.

TABLE 4. Price discovery leadership (VECM estimations, full sample)

		ADF Test		IVOT-Andrews Test		
		Test Statistic (*p*-value)	Unit Root	Test Statistic	Unit Root	Breakpoint
Portugal	level	-1.448 (0.844)	Yes	-4.893*	No	25/05/2012
	1st Diff.	-14.113* (0.000)	No	-	-	-
Italy	level	-4.302* (0.004)	No	-4.116*	No	25/07/2012
	1st Diff.	-11.059* (0.000)	No	-	-	-
Greece	level	-1.515 (0.825)	Yes	-6.496*	No	22/04/2014
	1st Diff.	-36.056* (0.000)	No	-	-	-
Spain	level	-2.824 (0.190)	Yes	-4.573*	No	20/11/2012
	1st Diff.	-16.328* (0.000)	No	-	-	-
Austria	level	-2.163 (0.508)	Yes	-8.274*	No	21/05/2012
	1st Diff.	-22.180* (0.000)	No	-	-	-
France	level	-2.535 (0.311)	Yes	-4.573*	No	20/11/2012
	1st Diff.	-12.795* (0.000)	No	-	-	-
Germany	level	-3.421 (0.051)	Yes	-4.763*	No	03/07/2012
	1st Diff.	-13.302* (0.000)	No	-	-	-

This table reports the results of the ADF and Zivot-Andrews unit root tests applied on the bond spread series. * Indicates the rejection of the null hypothesis of unit root at 5% significance level.

Given that both CDS and bond spreads are first-order integrated, we test for co-integration using the Johansen (1991) test. The results (Table 5) indicate the rejection of the null hypothesis of no co-integration and, thus, the existence of a long-run equilibrium between the two spreads for Portugal, Spain, Austria, France, and Germany. Contrariwise, there is no evidence of co-integration between Italy and Greece.

TABLE 5. Johansen co-integration test (full Sample)

	Trace Statistic (*p*-value)	Max-eigenvalue Statistic (*p*-value)	Co-integration
Portugal	47.982* (0.000)	45.495* (0.000)	Yes
Italy	14.759 (0.064)	9.803 (0.225)	No
Greece	9.975 (0.283)	8.2614 (0.353)	No
Spain	24.518* (0.000)	19.310* (0.000)	Yes
Austria	47.569* (0.000)	40.025* (0.000)	Yes
France	24.518* (0.000)	19.310* (0.000)	Yes
Germany	40.713* (0.000)	36.027* (0.000)	Yes

This table presents the results of the Johansen cointegration test on the full sample. For each country we select the number of lags of the VAR model using the Schwarz information criterion. * indicates the rejection of the null hypothesis of no co-integration at 5% significance level.

To analyze the dynamics of the short-run relation between the co-integrated CDS and bond spread series, we consider them in a VECM specification. The results of the estimation of the speed of adjustment co-efficients and the GG measure Table 6 verify that the CDS market leads in price discovery in Spain, Austria, and France. The bond market dominates the price discovery process in Portugal, while for Germany, the leading role cannot be attributed to the CDS or the bond market.

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TABLE 6. Price discovery leadership (VECM estimations, full Sample)

		Coeff.	*t*-statistic	GG	Leading Market
Portugal	$\alpha 1$	-0.028*	-4.485	0.36489759	Bond
	$\alpha 2$	0.016*	1.994		
Spain	$\alpha 1$	0.005	1.452	-	CDS
	$\alpha 2$	0.016*	4.117		
Austria	$\alpha 1$	-0.003	-1.667	-	CDS
	$\alpha 2$	0.010*	5.571		
France	$\alpha 1$	0.005	1.452	-	CDS
	$\alpha 2$	0.016*	4.117		
Germany	$\alpha 1$	-0.013*	-4.172	-	Unidentified
	$\alpha 2$	-0.020*	-3.561		

This table presents the results of the estimation of the speed of adjustment coefficients ($\alpha 1$ and $\alpha 2$) the CDS market leads the and the calculation of the GG measure (where is meaningful). If $\alpha 1$ ($\alpha 2$) is significant and negative (positive), the CDS (bond) spread adjusts to the equilibrium, implying that the bond (CDS) spread is the leading one in pricing process. If both α1 and α2 are significant and properly signed,the GG measure is used to define the leading market. If GG is greater than 0.5, the CDS market leads the pricing process and vice versa. * indicates the statistical significance at 5%.

According to Table 5, co-integration cannot be verified for Italy and Greece. Thus, we test for causality between CDS and bond spreads to identify the leading market in price discovery. We employ the Granger causality test using the levels and first differences of the spread series for Italy and Greece, respectively. The results are reported in Table 7.

TABLE 7. Price discovery leadership (Granger Causality, full Sample)

	Null Hypothesis		Causality	Leading Market
	No Causality from CDS to Bond Spread	No Causality from Bond to CDS Spread		
Italy	68.244* (0.00)	19.274* (0.00)	Feedback	Unidentified
Greece	2.960 (0.085)	4.467* (0.035)	Bond $\rightarrow$ CDS	Bond

This table presents the results of the Granger causality test. We select the number of lags of the VAR model using the Schwarz information criterion. Columns 2 and 3 report the *F*-statistics. In parentheses are reported the *p*-values. * indicates the rejection of the null hypothesis at 5% significance level.

Considering the entire sample period, we find evidence of long-run equilibrium relation between CDS and bond spreads for Portugal, Spain, and the core European countries (Austria, France, and Germany). Regarding the short-run dynamics of the CDS-bond spread relation, the results are rather mixed. For Spain, Austria, and France, we conclude that the CDS market leads the pricing process of sovereign credit risk. Contrariwise, we find that the bond market contributes more than the CDS one in price discovery for Portugal and Greece. In the case of Italy and Germany, the leading market cannot be identified. Overall, the above results are only indicative since we assume a time-invariant price discovery process.

Dynamic analysis

To provide a dynamic price discovery analysis, we apply a rolling window estimation procedure. The following paragraphs summarize the main results. Provided the results of the rolling ADF unit root test, the Johansen co-integration test is applicable in more than 12,000 windows. We find evidence of co-integration between CDS and bond spreads in 4,152 windows (34.18%). The highest percentage is observed for Portugal, with co-integration existence in 48.89% of the windows. Austria exhibits the lowest percentage, with evidence of co-integration in 15.46% of the windows. In general, the core European countries present lower percentages of co-integration existence than peripheral ones. As argued by Fontana and Scheicher (2016) and

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Agiakloglou and Deligiannakis (2020), this finding could be attributed to the flight-to-quality behavior of investors who shift their trading interest from bonds issued by the risky countries of the EU periphery to bonds issued by the safe core EU countries. The rolling window co-integration results are summarized in Table 8.

TABLE 8. Co-integration results (rolling windows)

	Windows	
	Examined	Co-integration Existence (%)
Portugal	2,162	1,057 (48.89%)
Italy	1,930	538 (27.88%)
Greece	909	372 (40.92%)
Spain	2,112	773 (36.60%)
Austria	1,662	257 (15.46%)
France	2,112	776 (36.74%)
Germany	1,259	379 (30.10%)
Total	12,146	4,152 (34.18%)

This table summarizes the results of the Johansen co-integration test on rolling windows of 250-day length. Column 3 reports the number of windows for which co-integration is verified.

To determine the leading market in price discovery for each window, we consider either speed of adjustment coefficients or GG measure or the Granger causality test, depending on the co-integration results. Table 9 summarizes the results of the dynamic price discovery analysis considering the entire sample period and two subperiods, as well. The first sub-period, from December 2008 to December 2012, contains the global financial crisis and the subsequent sovereign debt crisis in the Euro zone, while the second one, from January 2013 to December 2019, represents the crisis recovery period. Our findings confirm the suggestions of previous studies (Agiakloglou & Deligiannakis, 2020; Arce et al., 2013; Delatte et al., 2012; Delis & Mylonidis, 2011; Guidolin et al., 2021) for the state-dependent nature of price discovery in sovereign credit markets. Indeed, we find frequent alternations regarding the leading market and, thus, the direction of influence from CDS to bond market and vice versa.

As far as the entire sample is concerned (Table 9, Panel A), the highest percentage of CDS market leadership is observed for Portugal (in 28.26% of the windows), while Spain and France also exhibit high percentages (in 24.95% and 24.78% of the windows, respectively). The country with the lowest percentage of windows for which we find evidence of CDS market leadership (7.80%) is Austria. In line with Guidolin et al. (2021), the above findings imply that CDS market leadership in price discovery coincides with the existence of co-integration between CDS and bond spreads. On the other hand, the highest percentage of bond market leadership is observed in Italy. It is worth noting that in most of the windows, for all the countries, the leading role in price discovery can be clearly attributed neither to the CDS nor to the bond market.

TABLE 9. Market leadership

Panel A: Entire sample							
	Windows						
	Examined	CDS Market Leadership		Bond Market Leadership		Unidentified	
Portugal	2,852	806	28.26%	570	19.99%	1,476	51.75%
Italy	2,894	369	12.75%	623	21.53%	1,902	65.72%
Greece	2,894	370	12.79%	405	13.99%	2,119	73.22%
Spain	2,894	722	24.95%	490	16.93%	1,682	58.12%
Austria	2,537	198	7.80%	414	16.32%	1,925	75.88%
France	2,894	717	24.78%	486	16.79%	1,691	58.43%
Germany	2,889	240	8.31%	98	3.39%	2,551	88.30%

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Table 9 Continue.....

Panel B: December 2008 – December 2012							
	Windows						
	Examined	CDS Market Leadership		Bond Market Leadership		Unidentified	
Portugal	1,026	495	48.25%	104	10.14%	427	41.62%
Italy	1,068	216	20.22%	109	10.21%	743	69.57%
Greece	1,068	352	32.96%	405	37.92%	311	29.12%
Spain	1,068	418	39.14%	214	20.04%	436	40.82%
Austria	711	173	24.33%	55	7.74%	483	67.93%
France	1,068	416	38.95%	217	20.32%	435	40.73%
Germany	1,063	34	3.20%	53	4.99%	976	91.82%
Panel C: January 2013 – December 2019							
	Windows						
	Examined	CDS Market Leadership		Bond Market Leadership		Unidentified	
Portugal	1,826	311	17.03%	476	26.07%	1,039	56.90%
Italy	1,826	153	8.38%	514	28.15%	1,159	63.47%
Greece	-	-	-	-	-	-	-
Spain	1,826	304	16.65%	276	15.12%	1,246	68.24%
Austria	1,826	25	1.37%	359	19.66%	1,442	78.97%
France	1,826	301	16.48%	269	14.73%	1,256	68.78%
Germany	1,826	206	11.28%	45	2.46%	1,575	86.25%

This table summarizes the results of the dynamic price discovery analysis on rolling windows of 250-day length. Panels A, B, and C present the results considering the entire sample, the crisis period (December 2008 – December 2012), and the recovery period (January 2013 – December 2019), respectively. Column 2 reports the number of the examined windows for each country. Columns 3 and 4 (5 and 6) report the number and the respective percentage of windows for which CDS (bond) market leadership is verified. The last two columns report the number and the respective percentage of windows for which neither the CDS nor the bond market leads the price discovery process

Focusing on the crisis period (Panel B), the results show that for most countries, the confirmation of CDS market leadership is much more frequent than the case in which the entire recovery period is considered. This implies that the ability of the CDS market to dominate the price discovery process, being the most reliable source of information regarding sovereign credit risk pricing, is enhanced under conditions of economic uncertainty and increased perceived sovereign credit risk. The latter conclusion contradicts Mylonidis and Kollias (2010), Arce et al. (2013), and Guidolin et al. (2021), who argue that the escalation of the Euro zone debt crisis hampered the ability of the CDS market to lead in price discovery. This divergence could be attributed to the methodological differentiation of the present study in price discovery analysis. Portugal, Spain, and France are still presenting the highest percentage (48.25%, 39.14%, and 38.95%, respectively) of windows for which CDS leadership is verified. Interestingly, Greece, which found itself in the epicenter of the debt crisis, presents by far the lowest percentage of unidentified windows in terms of market leadership. This implies that in most of the crisis period, the dominant role in price discovery is clearly taken on either by the CDS or by the bond market. Contrarily, in the case of the highly credit rated Germany, the representative market for sovereign credit risk pricing cannot be identified almost throughout the crisis period.

Considering the recovery period (Panel C), the results are substantially different from those that are reported for the crisis period. We find evidence of CDS leadership in price discovery only for short time intervals. Specifically, the percentage of windows for which CDS leadership is confirmed varies from 1.37% (Austria) to 17.93% (Portugal). We verify the leading role of the bond market in credit risk pricing for a few short periods. Nevertheless, the percentage of windows for which we find bond leadership is, in general, higher than in the case of the crisis period, varying from 2.46% (Germany) to 28.15% (Italy). Contrariwise, the results indicate that for most of the recovery period, for all the countries, neither the CDS nor the bond market can clearly lead the price discovery process. Thus, we conclude that market participants should jointly utilize CDS and bond spreads as information sources of sovereign credit risk pric-

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ing rather than rely on a single market.

The Determinants of Market Leadership

This subsection presents the empirical findings of the analysis of the determinants of market leadership in price discovery. The dummy constructed from the rolling window results for each country represents the dependent variable of the Logit regression model. The independent variables are counterparty risk (CP), relative liquidity (RL), funding cost (FC), and the proxies of European market uncertainty, i.e., VSTOXX and CISS indices. To quantify the severity of multicollinearity, we estimate the variance inflation factors. Table 10 summarizes the obtained results. Columns (1), (3), (5), (7), (9), (11), and (13) report the estimated coefficients. Columns (2), (4), (6), (8), (10), (12), and (14) present the marginal effects of these coefficients.

TABLE 10. Determinants of market leadership

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	Portugal		Italy		Greece		Spain		Austria		France		Germany	
	Coeff. (*p*-value)	Marginal Effect	Coeff. (*p*-value)	Marginal Effect	Coeff. (*p*-value)	Marginal Effect	Coeff. (*p*-value)	Marginal Effect	Coeff. (*p*-value)	Marginal Effect	Coeff. (*p*-value)	Marginal Effect	Coeff. (*p*-value)	Marginal Effect
Constant	-1.082*** (0.000)	-0.211	-2.350*** (0.000)	-0.236	0.952** (0.011)	0.211	-0.907*** (0.000)	-0.162	-3.448** (0.000)	-0.118	-0.959*** (0.000)	0.000	-0.761** (0.016)	-0.046
FC	2.685*** (0.000)	0.523	1.608*** (0.000)	0.162	0.826* (0.056)	0.183	2.876*** (0.000)	0.515	5.565*** (0.000)	0.190	2.762*** (0.000)	0.000	-4.390*** (0.000)	-0.262
RL	-0.024 (0.394)	-0.005	-0.165*** (0.004)	-0.017	-0.245*** (0.000)	-0.054	0.068** (0.024)	0.012	-0.064 (0.359)	-0.002	-0.013 (0.803)	0.000	0.072** (0.029)	0.004
CP	-0.009*** (0.000)	-0.002	0.003* (0.084)	0.0003	-0.019*** (0.000)	-0.004	-0.002 (0.272)	-0.0003	0.013*** (0.000)	0.0004	-0.002 (0.338)	0.000	-0.009*** (0.003)	-0.001
VSTOXX	-0.007 (0.518)	-0.001	-0.016 (0.258)	-0.002	-0.019 (0.304)	-0.004	-0.048*** (0.000)	-0.009	-0.102*** (0.000)	-0.003	-0.043*** (0.000)	0.000	-0.072*** (0.000)	-0.004
CISS	3.194*** (0.000)	0.622	0.906 (0.139)	0.091	4.215*** (0.000)	0.935	1.640*** (0.001)	0.294	1.053 (0.292)	0.036	1.667*** (0.001)	0.000	7.572*** (0.000)	0.453
Number of observations	2,842		2,894		896		2,894		2,537		2,894		2,889	
McFadden *R*-squared	0.103		0.056		0,108		0.075		0.316		0.073		0.081	
LR statistic (*p*-value)	348.182 (0.000)		123.014 (0.000)		124.797 (0.000)		244.212 (0.000)		438.940 (0.000)		236.400 (0.000)		134.755 (0.000)	

This table presents the results of the analysis of the potential determinants of market leadership utilizing a Logit regression model. The dependent variable is constructed from the results of the rolling window price discovery analysis. It takes the value one (1) in case the CDS market is identified as the leading one in price discovery and zero (0) otherwise. The independent variablesare counterparty risk (CP), relative liquidity (RL), funding cost (FC), VSTOXX implied volatility index and Composite Indicator of Systemic Stress (CISS). Columns (1), (3), (5), (7), (9), (11), and (13) report the estimated coefficients. Columns (2), (4), (6), (8), (10), (12), and (14) present the marginal effects of these coefficients. *, **, *** denote statistical significance at 10%, 5% and 1%, respectively.

As expected, and in line with Arce et al. (2013), an increase in Funding Cost (FC) favors the ability of the CDS market to lead in price discovery. The coefficient of the FC is found to be statistically significant and positive for all the countries except for Germany (significant and negative). The estimated marginal effect varies from 0.162 to 0.523, implying that a 1% rise in FC would considerably increase the probability of CDS market leadership. Regarding relative liquidity between the CDS and the bond market, the results are rather inconclusive. In the case of Italy and Greece, the results imply that an increase in relative liquidity ratio (RL) is negatively related to the CDS market's ability to dominate the price discovery process. This finding is in line with the conclusions of (Raja et al., 2020) for emerging sovereign markets. Contrarily, in the case of Spain and Germany, RL is found to enhance the probability of CDS market leadership. Lastly, in line with Arce et al. (2013), we find an insignificant RL coefficient for Portugal, Austria, and France. This implies that participants in credit risk markets make their decisions based on availability and cost of funding rather than on RL. In addition, Arce et al. (2013) attribute the insignificant effect of RL to the ECB intervention in the sovereign bond market. ECB execute its bond purchase program, ignoring the level of bid-ask spreads.

As far as counterparty risk (CP) is concerned, the results are also mixed. We find the expected sign, i.e., negative, and statistical significance for Portugal, Greece, and Germany. Contrariwise, the effect of CP is significant and positive in the case of Austria, while it is insignificant in the case of Italy, Spain, and France. The latter finding implies that participants in these markets tend to underestimate counterparty risk in CDS contracts.

The level of uncertainty in European stock markets negatively affects the ability of the CDS market to lead in price discovery in the case of Spain and core EMU countries (Austria, France, and Germany) since the coefficient of the VSTOXX implied volatility index is found significant and negative. This finding is in agreement with the results obtained by Arce et al. (2013) for European countries during the period of high global risk. On the other hand, the effect of VS-

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TOXX is insignificant for the rest of the peripheral European countries which found themselves in the spotlight of the crisis, i.e., Portugal, Italy, and Greece.

Lastly, the results provide strong evidence of a positive relationship between the level of systemic risk and the probability of CDS market leadership. Indeed, we find significant and positive coefficients of CISS for most of the countries, while the estimated marginal effect varies from 0.294 to 0.935. Under stressful conditions, investors turn to CDS contracts for protection, enhancing the CDS market's role in sovereign credit risk pricing. Our findings may also reflect the intervention policy of the ECB in the sovereign bond market, especially during the debt crisis. More specifically, the bond purchase program of the ECB results in excessive and price inelastic demand in the government bond market. This reduces the ability of bond spreads to provide accurate information regarding sovereign credit risk and, thus, to lead in price discovery.

CONCLUSION

This study provides an integrated analysis of the relationship between sovereign CDS and bond markets of peripheral and core European countries, focusing on the sovereign credit risk pricing process. The examined period starts with the transformation of the 2007-09 financial crisis to a Eurozone debt crisis and ends shortly before the outbreak of the current pandemic crisis of COVID-19.

First, we employ co-integration and Granger causality methods utilizing rolling window estimation techniques, to capture the time-varying nature of the CDS-bond spread relation. The results of the Johansen co-integration test indicate that the theoretical hypothesis of a long-run equilibrium relation between CDS and bond spreads is rejected in most cases, especially when core European countries are considered. The obtained price discovery measures confirm the dynamic nature of the credit risk pricing process, detecting frequent alternations in the direction of influence from CDS to bond spread and vice versa.

Interestingly, the CDS market's ability to lead in price discovery is favored during periods of increased risk and economic uncertainty. Moreover, we observe long time intervals, especially considering the post-crisis period, during which neither the CDS nor the bond market can clearly take on the leading role in price discovery. Therefore, we conclude that market participants should jointly consider CDS and bond spreads as information resources of sovereign credit risk.

To examine the determinants of the leading market in price discovery, we construct a dummy variable utilizing the results obtained from the dynamic price discovery analysis. Then, we regress the dummy in a set of potential explanatory factors in the context of a Logit model. As expected, we find that funding costs positively affect the ability of the CDS market to lead in price discovery, verifying that increased cost of funding constitutes the unfunded CDS market preferable for market participants about the underlying bond market. The level of systemic risk in financial markets is also positively related to the probability of CDS market leadership. Indeed, under stressful conditions, the CDS market's pricing efficiency is enhanced by attracting credit risk protection seekers. Contrariwise, the effect of stock market volatility on the pricing efficiency of the CDS market is negative for core European countries, whereas it is insignificant for peripheral ones. As far as counterparty risk and relative liquidity between CDS and bond market are concerned, we fail to provide clear conclusions about their effect on the determination of the leading market in price discovery. Indeed, the sign of the effect depends on the considered country.

Overall, participants in sovereign credit markets could benefit by considering the concluding remarks of this study. Investment, funding, and regulation decision-makers should pay great attention to the dynamic process of credit risk pricing and the factors that determine the leading market as they form their strategies and take their positions in credit risk markets.

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