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Linkages between CDS, bond and stock markets: Evidence from Europe

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Abstract

Veronika Kajurová, Jana Hvozdenská: **Linkages between CDS, bond and stock markets: Evidence from Europe**

Nowadays, when information has a significant role in financial markets and is reflected in prices of instruments very rapidly, investors, who are interested in arbitrage, hedging or speculation activities in markets, and other market participants would like to know in which market information is embedded into price more rapidly. The aim of the presented paper is to find out if new information is reflected in prices earlier in credit default swap market or in stock or bond markets and to confirm or disprove whether the theoretical assumptions about the links between markets hold. Panel co-integration tests, panel vector error correction models and panel Granger causality tests are employed to examine the long-term and short-term interactions between markets. Assessing the leading role of chosen market within price discovery process can be beneficial for all market participants within their decision making processes. Our results indicate that the relations between credit default swap and stock markets are in accordance with the theoretical assumptions. The results on the relationship between credit default swap and bond markets met the theoretical assumptions during the crisis period, however the role of these two markets has changed in the post-crisis period.

Key words

Bond market, CDS market, information, panel data, stock market

JEL: C33, C58, G01, G30, G20

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Introduction

Although the first credit derivatives were created in the 1990s, they have become popular instruments for risk management, especially for credit risk transfer. One can find many various types of credit derivatives; however, relevant data and statistics are available only for credit default swaps (CDS) which allow us to investigate the relations between CDS market and bond or stock market. CDS are defined by the International Swaps and Derivatives Association as contracts designed to transfer the credit exposure of debt obligation between parties. The buyer of the contract receives credit protection, whereas the seller guarantees the creditworthiness of the underlying security (see ISDA). Published statistics point to the fact that CDS market was growing rapidly until the financial crisis hit markets. According to statistics published by the Bank for international settlements (BIS), the total notional value of market with CDS contracts rose from nearly 6.5 billion USD in 2004 to almost 60 billion USD in 2007. The notional value of the market declined together with the outbreak of the financial crisis in 2008. Although the total notional value reached 19.5 billion USD in June 2014 which cannot be considered as a negligible value.

Today, when information plays a significant role in financial markets and is reflected in prices of instruments very quickly, investors and other market participants would like to know in which market information is embedded into price more rapidly. Therefore, the aim of the presented paper is to find out if new information is reflected in prices earlier in CDS, bond or stock market, and to confirm or disprove whether the theoretical assumptions about linkages between markets hold. Blanco (2005) states that price discovery occurs in the market in which informed traders transact most. Generally, the connection between stock returns and credit spread changes can be explained by theoretical assumption that says that the probability of default is the most important determinant of credit spread and that this probability is closely connected to the stock valuation (see Merton 1974). Therefore, information should be firstly incorporated in stock price and then in credit spread, that is why we expect stock market to lead both bond and CDS market. Because of institutional features of CDS market, it is expected that CDS market moves ahead bond market (e.g. see Norden and Weber 2009).

There are only a few related studies dealing with the relationships between CDS and bond or stock markets from the point of view of information and their impact on price discovery process in selected markets. More information on previous research is provided in the following chapter. This paper contributes to the existing literature in several ways. Firstly, it widens a very small literature on the issue since we believe that the knowledge on price discovery can be beneficial for market participants, as well as for authorities and researchers. Secondly, the relations are investigated

separately for non-financial and financial sectors since financial institutions are characterized with different balance sheet structure compared to non-financial. Moreover, companies are separated to panels including investment grade and non-investment grade companies. Thirdly, compared to the majority of existing studies, the dataset used for the empirical part covers long span data that enable to investigate the relationships during different economic circumstances covering the crisis and calm periods as well. Fourthly, the study is the first one including such a large number of contracts and that investigating the relationship between markets in Europe. So far published studies have dealt either with mixed samples including only a few contracts from the U. S., Europe and Asia or were focused primarily on the U. S. market.

The rest of the paper is organized as follows. The next section is devoted to the previous research on the studied subject. Used dataset is described in the section 2 and the section 3 provides methods used in the research part. The empirical findings are presented and compared with other relevant published studies in the section 4. The last section concludes with the main results obtained.

1. Literature review

One can find many papers studying the relationship between bond and stock markets, e.g., see Keim and Stambaugh (1986), Shiller and Beltratti (1992), Kwan (1996), Engsted and Tanggaard (2001), Kim and In (2006) or Tsai (2014). Nevertheless, there are only a few studies dealing with the relationships between CDS and bond markets or CDS and stock markets. The authors were trying to find out which market moves ahead the other one and has the leading role in price discovery process.

Even though there are some studies devoted to the relationship between sovereign CDS, bond or stock indices, e.g., see Fontana and Scheicher (2010), Palladini and Portes (2011), Hammoudeh and Sari (2011), Arce et al. (2013), Coudert and Gex (2013) or between sovereign CDS and other financial factors like Wang et al. (2013), the following text summarizes the studies that investigates the relations between markets for corporates.

Longstaff et al. (2003) investigated the lead-lag relations for 68 U. S. entities in their study. They focused on the relations between CDS premia, corporate bond prices and equity prices. Their motivation for the research was the assumption that the information about a company's situation can be reflected first in the credit derivatives market and later in the corporate bond and stock market. For examining the relation between mentioned three markets, a vector-autoregression framework was used. The results showed that the assumption that the information tends to flow first into CDS and equity markets before corporate bond market holds.

Blanco et al. (2005) focused also on the information content of indicators of the price of credit risk to find out which market provides more timely information. Their research took into consideration data for 33 entities from the United States (16) and European countries (17). The results of their study confirmed that in the majority of the cases the CDS market leads the bond market in determining the price of credit risk.

Zhu (2006) also studied the short-term dynamic linkages between the CDS and bond spreads. He wanted to find out which market is more efficient in reflecting changes in the credit risk of underlying entities. Their dataset includes 24 entities totally, mostly coming from the North America (19), following by European entities (3) and entities from Asia (2). The results of conducted research showed that in short-run there are significant discrepancies between CDS and bond markets and that derivative market tends to lead bond market.

The next study investigating the dynamic price relationship between spreads in corporate bond market and CDS market was conducted by Dötz (2007). It is focused on 36 European reference entities listed in the iTraxx CDS index. He found that price discovery contributions by the CDS and bond market vary at corporate level and that both markets made net contributions to price discovery, but the CDS market dominated slightly.

Forte and Peña (2009) examined the market efficiency by analysing the relationship between the changes in bond spreads, changes in CDS spreads and changes in stock market implied credit spread for the sample of 17 North American and European non-financial firms. The results of the study confirmed that the stock market leads the CDS market and the bond market more frequently than the opposite and that the CDS market moves ahead the bond market.

Norden and Weber (2009) empirically analysed the co-movement of the CDS, bond and stock markets. The sample covers 58 firms from which 35 are from Europe, 20 from USA and 3 from Asia. They concluded that stock returns lead CDS and bond spread changes, that the CDS spread changes Granger cause bond spread changes for a higher number of firms than oppositely.

The following paper focused on the link between stock and credit markets for 13 U. S. financial institutions under stress during the financial crisis (see Trutwein and Schiereck 2011). They found that the relationships between markets is regime dependent and that equity markets lead credit markets.

Coudert and Gex (2013) focused on the interactions between sovereign CDS and bond spreads and financials as well during financial turmoil. Since in our study we are not interested in sovereign

contracts, we pay attention to the research they devoted to financials. Their results are in line with previous studies on corporate CDS and indicate that CDS market led bond market in price discovery process for financials during the crisis period.

Compared to the studies mentioned above, Nayaran et al. (2014) studied price discovery from panel data models of CDS and stock returns with using panel co-integration and panel VECM with respect to sectors and investment grade for 212 companies from the S&P 500. The results showed that the stock market contributes to price discovery in nine sectors from ten included and that the CDS market contributes in six sectors.

Except the previous studies, we would like to mention two papers which deal with the relationship between markets using indices. The paper by Byström (2005) examines the link between iTraxx CDS index market and the stock market. The results of the study confirmed that current and lagged stock returns explain much of the variability in CDS spreads which implies that concrete information is reflected in stock prices before it is reflected in CDS spreads. The next study (see Fung et al. 2008) brings the evidence on the lead-lag relationship between the U. S. stock market and CDS market with focus on investment-grade and high-yield CDSs. They found that the stock market moves ahead the investment-grade CDS index in the pricing process.

Appendix 1 summarizes the empirical contributions investigating the relationships between CDS and bond or stock markets and basic information about contribution including period, number of companies, observed markets and used methods.

2. Data

Our dataset is obtained from Bloomberg database on daily basis. We focus on CDS contracts of 5year maturity since this maturity-provider combination reflects new information more rapidly (see Mayordomo et al. 2014). When assessing causalities between stock and CDS markets, we obtained stock prices and corresponding CDS spreads that were available for 256 companies totally from which 205 are of investment grade and 51 of non-investment grade. 183 companies from the total sample represent a non-financial sector, and remaining 73 companies a financial sector. The series cover 10year period from January 2004 to December 2013 that is divided into three sub-periods according to trends in the Markit iTraxx Europe index that reflects the development of the European CDS market. The whole period covers the pre-crisis period (January 2004 – May 2007), the crisis period (June 2007 – December 2009), and the post-crisis period (January 2010 – December 2013).

We understand the crisis period as a period of the biggest chaos in financial markets since the banking crisis had started earlier then Lehman Brothers went bankrupt.

A dataset used for examining linkages between CDS and bond markets differs and includes a lower number of companies than the previous one since not all companies in the previous sample issued bond(s). A sample includes 230 companies for which bond and CDS spreads were available in the database, 186 of investment grade, and 44 of non-investment grade, 165 representing a non-financial sector and 65 a financial sector. The observed period is shorter than in case of stock prices and CDS spreads since data for bond spreads were available from June 2008 in the database, therefore a relationship between markets is not observed during the pre-crisis period, however data on daily frequency allow us to investigate causalities between markets from the crisis period.

Following Forte and Peña (2009), Forte (2011) or Nayaran et al. (2014), we converted all data into natural logarithmic form. Table 1 summarizes descriptive statistics of the studied variables. Normality was rejected in all cases since probabilities of Jarque-Bera tests are equalled to zero.

Table 1. Descriptive statistics (natural logs).

	Bond spreads	CDS spreads	Stock returns
Mean	4.6502	4.8462	3.8415
Median	4.6683	4.7175	3.7739
Maximum	4.9642	8.4216	8.6207
Minimum	3.4095	3.0799	-3.9120
Std. dev.	0.1212	0.7571	1.8839
Skewness	-2.3402	0.8873	0.0149
Kurtosis	13.5615	3.7602	3.1829
Jarque-Bera	1114836.0000	31137.9000	286.9812
Probability	0.0000	0.0000	0.0000

3. Methods

The structure of our data set allows us to employ panel estimation techniques. The long-run and short-run causalities are examined between CDS spreads and stock returns and between CDS spreads and bond spreads. Panel co-integration is employed to find if the long-run relationship exists between variables and panel vector error correction model (VECM) for identification of the direction of this relationship and for the identification of short-run dynamics. Subsequently the Gonzalo and Granger measures are calculated to quantify the contribution of one market to the second one. However, if co-integrating relationship which would confirm a causal relation between the variables is not found, the VECM representation is not valid, therefore Granger causality tests are performed

to observe dynamic price relationship. EViews software is used for employing panel cointegration tests, panel VECMs and panel Granger causality tests.

Prior to examining the causalities between the variables, data should be tested for the presence of a unit root. There are several types of the panel unit roots tests in Eviews software (e. g. tests proposed by Maddala and Wu 1999, Choi 2001, Levin et al. 2002 and Im et al. 2003) which we employ in the research.

3.1 Panel cointegration

When stationarity is established, panel co-integration is employed as a first since it is a prerequisite for a vector error correction estimation. A several procedures were developed for testing panel co-integration (e. g. see Kao 1999, Maddala and Wu 1999).

A general formula for panel co-integration can be written in the following form (see Pedroni 2004):

$$y_{it} = \alpha_i + \delta_{it} + \beta_{1i}x_{1i,t} + \beta_{2i}x_{2i,t} + \ldots + \beta_{Mi}x_{Mi,t} + e_{it} \quad (1)$$

where y_{it} and x_{it} are time series panels of observables and are assumed to be integrated of I(1) and where $i = 1, \ldots, N$, $m = 1, \ldots, M$, $t = 1, \ldots, T$. We consider y_{it} to be CDS spreads and x_{it} to be stock price or bond spread. The parameters α_i and δ_i allow for the possibility of unit specific effects and deterministic trends.

It is assumed that under the null hypothesis of no co-integration, the residuals e_{it} will also be of I(1). To find out if the residuals are of order one, the subsequent regression is employed:

$$e_{it} = \rho_i e_{it-1} + u_{it} \quad (2)$$

Pedroni provides various statistics for testing the null hypothesis of no co-integration: $\rho_i = 1$. But there are two alternative hypotheses – the heterogeneous alternative: $\rho_i < 1$ for all i (between-dimension statistics tests – panel v-Statistic, panel rho-Statistic, panel PP-Statistic and panel ADF-Statistic); or the homogeneous alternative: $(\rho_i = \rho) < 1$ for all i (within dimension statistics test – group rho-Statistic, group PP-statistic and group ADF-Statistic).

3.2 Panel vector error correction model

A VECM represents a restricted vector autoregression (VAR) designated for use with nonstationary series which are co-integrated. If co-integration is established between variables, there must exist a causal relation in at least one direction (see Granger 1988), therefore the following VECM can be employed:

$$\Delta y_{it} = \vartheta_{1j} + \lambda_{1i}\varepsilon_{it-1} + \sum_k \vartheta_{11il}\Delta y_{it-l} + \sum_k \vartheta_{12il}\Delta x_{it-l} + u_{1it} \quad (3)$$

$$\Delta x_{it} = \vartheta_{2j} + \lambda_{2i}\varepsilon_{it-1} + \sum_k \vartheta_{21ik}\Delta y_{it-k} + \sum_k \vartheta_{22ik}\Delta x_{it-k} + u_{2it} \quad (4)$$

where Δ denotes first differencing, λ is the coefficient of the error correction term and *l* and *k* epresent lag length specified according to the Schwartz information criterion.

The causality between the variables can be identified by testing for the significance of the coefficients of dependent variables in formulas (3) and (4). The significance of the coefficient λ indicates long-run relationship from the explanatory variable to the dependent variable and shows how quickly variable(s) re-converge to the long-run relationship after a deviation. Therefore, H_0: $\lambda_{1i} = 0$ for all *i* and $\lambda_{2i} = 0$ for all *i* are tested. Short run causal effects are studied by using a Wald test (Chi-square test statistic: χ^2) for the significance of the lagged explanatory variables.

We follow Gonzalo and Granger (1995) and Nayaran et al. (2014) to obtain the measures of price discovery which are calculated from the coefficients of the error correction terms. In case when we consider the negative relationship between variables meaning, e. g. between CDS spreads and stock prices, the contribution of one market to the second one can be specified as follows:

$$GG_1 = \lambda_1 / \lambda_1 - \lambda_2 \quad (5)$$

where GG_1 means price discovery contribution of one market to the second one, λ_1 and λ_2 are the coefficients of error correction terms gained from the employed VECMs. However, if the positive relationship is expected between variables such in case of CDS spreads and bond spreads, the GG_1 measure is calculated as:

$$GG_1 = \lambda_1 / \lambda_1 + \lambda_2 \quad (6)$$

The value of GG_1 should lie in the interval [0, 1]. However, the value can lie outside of the interval in the case when the coefficient of error term has no expected sign. The contribution of the second market to the first one can be calculated analogously. The equality condition $GG_1 + GG_1 = 1$ should hold.

3.3 Panel Granger causality

When no co-integration relationship is confirmed between studied variables, panel Granger causality tests are employed. These tests do not confirm the existence of a causal relationship, however, they can provide information on dynamic price formation at least. Formulas are specified as a vector autoregressive model:

$$y_{it} = \alpha_{0i} + \alpha_{1i}y_{it-1} + \ldots + \alpha_{li}y_{it-1} + \beta_{1i}x_{it-1} + \ldots + \beta_{li}x_{it-1} + \epsilon_{1it} \quad (7)$$

$$x_{it} = \alpha_{0i} + \alpha_{1i}x_{it-1} + \ldots + \alpha_{li}x_{it-1} + \beta_{1i}y_{it-1} + \ldots + \beta_{li}y_{it-1} + \epsilon_{1it} \quad (8)$$

4. Empirical results

Co-integration analysis can be employed when the variables are integrated of order one I(1), hence we start our analysis with panel unit roots tests. The null hypothesis of non-stationarity is tested. The results of performed panel unit root tests are presented in Table 2. They indicate that log forms of bond spreads, CDS spreads and stock returns are stationary at first differences, hence co-integration tests can be conducted in the next step. The relationships are examined more in detail in the following section.

Table 2. Results of panel unit root tests (natural logs, first differences).

Test	Bond spreads	CDS spreads	Stock returns
Levin, Lin and Chu test	-516.2517*	-768.3593*	-762.0345*
Im, Pesaran and Shin w-stat	-445.5988*	-679.2693*	-673.4744*
ADF – Fisher Chi-square	32190.7727*	22902.0699*	18541.5340*
PP – Fisher Chi-square	26037.4828*	13364.8798*	6955.6046*

Note: * denotes the statistical significance at 1% level.

4.1 CDS market vs. stock market

The presence of co-integration is investigated separately for non-financial and financial companies with respect to their investment grade during all sub-periods. The Pedroni residual co-integration tests are employed to reveal co-integration between the variables. When the existence of co-integration is confirmed, panel VECM can be specified. The results of panel co-integration tests for non-financial companies are reported in Table 3. They indicate that there is a long-run relationship between CDS spreads and stock returns. This relationship was confirmed for both investment grade and non-investment grade companies within all sub-periods.

Table 3. Pedroni residual co-integration test results for relationship between CDS spreads and stock returns – non-financial companies.

	Pre-crisis period		Crisis period		Post-crisis period	
Statistic	IG	NG	IG	NG	IG	NG
Panel v-Stat.	8.2507*	3.1821*	3.4787*	2.3513*	10.5242*	5.9011*
Panel rho-Stat.	-10.5875*	-3.3077*	-9.3391*	-4.0901*	-7.8219*	-4.9894*
Panel PP-Stat.	-6.2385*	-1.3945**	-9.6582*	-3.1387*	-5.4317*	-3.5379*
Panel ADF-Stat.	-0.5577	0.2648	-9.4586*	-2.7066*	-5.3703*	-4.2685*
Group rho-Stat.	-7.4325*	-3.2303*	-5.4248*	-2.9101*	-7.3148*	-5.3064*
Group PP-Stat.	-4.6747*	-3.2266*	-8.3289*	-4.1935*	-6.4336*	-5.2176*
Group ADF-Stat.	-0.6637	-2.6538*	-8.2926*	-2.4160*	-6.1541*	-4.6269*

Note: * denotes that the null hypothesis of no co-integration is rejected at 1% level, ** 5% level.

Table 4 summarizes the results of panel co-integration tests for financial companies. Compared to non-financial companies, the null hypothesis of no co-integration was not rejected in all cases. The results obtained for the panel with financial companies of non-investment grade do not confirm the existence of co-integration relationship during the crisis and the post-crisis period, therefore a VECM cannot be employed, Granger causality test are performed instead separately for these panels (see Table 7).

Table 4. Pedroni residual co-integration test results for relationship between CDS spreads and stock returns – financial companies.

	Pre-crisis period		Crisis period		Post-crisis period	
Statistic	IG	NG	IG	NG	IG	NG
Panel v-Stat.	-327.0397	2.9060*	-51.6412	-0.0710	-413.7298	-0.2958
Panel rho-Stat.	-5.9572*	-9.5270*	-8.3624*	-1.4440	-7.5210*	-0.2258
Panel PP-Stat.	-3.3640*	-4.6116*	-7.9951*	-1.4119	-5.5809*	0.4343
Panel ADF-Stat.	-1.6391*	-0.7850	-7.7864*	-0.9931	-6.0187*	0.6421
Group rho-Stat.	-7.0631*	-9.2183*	-5.3613*	0.3782	-6.7709*	1.2547
Group PP-Stat.	-4.1138*	-2.4273*	-7.1811*	-0.2895	-5.8026*	1.5269
Group ADF-Stat.	-1.1835*	0.1513	-7.4584*	0.3336	-6.2815*	1.3017

Note: * denotes that the null hypothesis of no co-integration is rejected at 1% level.

If a long-term equilibrium relationship exists between CDS spreads and stock returns, a panel VECM is conducted for the further study of this relationship. In case of no co-integration relationship between the variables, Granger causality tests are employed. The results on price discovery between CDS spreads and stock returns of non-financial companies are reported in Table 5.

Table 5. Price discovery between CDS spreads and stock returns – non-financial companies.

	Pre-crisis period		Crisis period		Post-crisis period	
	IG (6)	NG (4)	IG (7)	NG (5)	IG (9)	NG (4)
λ_1	-0.0009*	-0.0004**	-0.0035	-0.0024*	-0.0020*	-0.0024*
t-stat.	-5.0871	-1.7875	-15.1581	-7.2631	-10.3978	-6.0457
χ^2_1	100.4216*	48.7758*	203.7181	96.4490*	312.2580*	347.1187*
λ_2	-8.15E-06	1.94E-06	2.35E-06	-5.54E-06	0.0001*	0.0001*
t-stat.	-0.4751	0.0610	0.8373	-0.3622	6.0737	2.9392
χ^2_2	0.0004	4.3905**	35.2719*	1.6023	19.3904*	4.4407**
GG_1	1.0091	**0.9952**	**0.9993**	1.0023	**0.9524**	**0.9600**
GG_2	-0.0091	**0.0048**	**0.0007**	-0.0023	**0.0476**	**0.0400**

Notes: Lag length in parentheses is specified according to the Schwartz information criterion.
* denotes statistical significance at 1% level and ** at 5% level.

When the coefficient λ_1 of error term is negative and statistically significant, the existence of a long-run relationship is confirmed and therefore stock returns contribute to price discovery of CDS spreads. Such relationship was confirmed almost in all panels instead of the panel including non-financial companies of investment grade during the crisis period.

To reveal short-run causality between markets, the Wald-tests are employed. According to the results of Chi-square test statistics χ^2_1, short-run causality coming from stock market to CDS market was explored in same panels like in the case of long-run causality.

The positive and statistically significant coefficient λ_2 points to a major adaptation in stock market and price domination by CDS market. However, the existence of this relationship was not found during the pre-crisis and the crisis period. The results for the post-crisis period indicate that the situation has changed compared to previous two periods and that CDS spreads contribute to price discovery of stock prices of both investment grade and non-investment grade non-financial companies. Short-run causality from CDS market to stock market was found in the panel with non-investment grade companies during the pre-crisis period, a panel with investment grade companies during crisis period and both panels within the post-crisis period. The values of GG_1 measure show the contribution of stock market to price discovery in CDS market. The average contribution is 97.7 % which points to the significant price domination of stock market over CDS market. The values of GG_2 measure represent the contribution of CDS market to price discovery in stock market.

The results on price discovery between CDS spreads and stock prices of financial institutions are carried in Table 6. During the pre-crisis period, the existence of long-run relationship and short-run relationship was found between stock prices and CDS spreads of investment grade and non-investment grade financial institutions, however the relationship was not found for the opposite link between CDS spreads and stock returns. Stock market including investment grade companies contributed to price discovery of CDS spread both in the crisis period and post-crisis period in the long-run and short run. Moreover, the results show that CDS market contributed to price discovery of stock prices during this period. The average contribution of the stock market to price discovery of CDS spreads is 97.3 %.

Table 6. Price discovery between CDS spreads and stock returns – financial companies.

	Pre-crisis period		Crisis period		Post-crisis period	
	IG (4)	NG (3)	IG (6)	NG	IG (7)	NG
λ_1	-0.0010*	-0.0046**	-0.0055*	-	-0.0044*	-
t-stat.	-2.8394	-1.8275	-12.9149	-	-10.7378	-
χ^2_1	256.6123*	7.2618*	16.9459*	-	222.8325*	-
λ_2	1.32E-05	5.30E-06	-2.96E-05**	-	0.0003*	-
t-stat.	0.7856	0.0596	-2.2772	-	5.2053	-
χ^2_2	0.0022	1.7114	6.5511*	-	7.4605*	-
GG_1	**0.9870**	**0.9989**	1.0054	-	**0.9312**	-
GG_2	**0.0130**	**0.0011**	-0.0054	-	**0.0688**	-

Note: Lag length in parentheses is specified according to the Schwartz information criterion.
* denotes statistical significance at 1% level and ** at 5% level.

Since the existence of co-integration was not proved for non-investment grade companies during the crisis and the post-crisis period, the Granger causality tests were conducted to reveal dynamic price formation. The results presented in Table 7 show that the first null hypothesis can be rejected both in crisis and post-crisis period and therefore stock prices "Granger cause" CDS spreads, meaning that the past values of stock prices improve the prediction of CDS spreads. The second null hypothesis cannot be rejected in any case.

Table 7. Granger causality tests results – financial non-investment grade companies (F-statistic).

Null hypothesis	Crisis period	Post-crisis period
1) EQ does not Granger cause CDS	14.9956*	56.2014*
2) CDS does not Granger cause EQ	1.2514	0.3637

Note: * denotes statistical significance at 1% level and ** at 5% level.

The results on price discovery between CDS and stock market are in accordance with the results found by Longstaff et al. (2003), Byström (2005), Fung et al. (2008), Forte and Peña (2009), Norden and Weber (2009), Trutwein and Schiereck (2011) and Nayaran et al. (2014) who evidenced that stock market dominates price discovery process meaning that the information is reflected into stock prices earlier than into CDS spreads. We found that the contribution of stock market to price discovery in CDS market was a bit lower in the post-crisis period for both financial and non-financial sector. Any other significant differences between panels covering financial and non-financial sectors or within investment grade and non-investment grade companies were not found.

4.2 CDS market vs. bond market

As in the previous section, we start our investigation with the Pedroni residual co-integration tests to find co-integrating relationship between the studied variables. Because of data unavailability for underlying bonds, the relationship between markets is investigated from June 2008. The results of conducted panel co-integration tests for non-financial companies are reported in Table 8.

Table 8. Pedroni residual co-integration test results for relationship between CDS and bond spreads – non-financial companies.

	Crisis period		Post-crisis period	
Statistic	IG	NG	IG	NG
Panel v-Stat.	0.2177	0.8561	5.86803*	1.0669
Panel rho-Stat.	-3.3081*	-2.5723*	-3.2001*	-2.6335*
Panel PP-Stat.	-4.2090*	-2.6922*	-1.7903*	-2.8488*
Panel ADF-Stat.	-4.4806*	-1.7679**	-2.4192*	-2.7056*
Group rho-Stat.	-2.3213*	-2.5248*	-1.6988*	-0.7924*
Group PP-Stat.	-4.0515*	-2.9083*	-0.2099	-1.5396**
Group ADF-Stat.	-3.9908*	-2.5848*	-0.2265	-0.3297

Note: * denotes that the null hypothesis of no co-integration is rejected at 1% level and ** 5% level.

The majority of statistics confirmed the existence of co-integrating relationship between CDS and bond spreads for investment grade and non-investment grade companies both in the crisis and post-crisis period. Table 9 provides the results of panel co-integration tests for financial companies. Since a long-term equilibrium relationship was found between CDS and bond spreads almost in all cases, panel VECM can be conducted for the detailed study of the existing relationship.

Table 9. Pedroni residual co-integration test results for relationship between CDS and bond spreads – financial companies.

	Crisis period		Post-crisis period	
Statistic	IG	NG	IG	NG
Panel v-Stat.	5.9811*	2.1652*	2.7396*	-0.0756
Panel rho-Stat.	-9.0484*	-5.8609*	-2.2920*	-3.7368*
Panel PP-Stat.	-5.3786*	-3.1520*	-2.2761*	-2.2284*
Panel ADF-Stat.	-4.4014*	-3.1985*	-3.2275*	-2.7034*
Group rho-Stat.	-6.9853*	-1.7271**	0.7872	-0.6488
Group PP-Stat.	-5.7719*	-1.5513**	-0.2129	-1.4648**
Group ADF-Stat.	-5.2549*	-1.8300**	-1.2944**	-0.9752

Note: * denotes that the null hypothesis of no co-integration is rejected at 1% level and ** 5% level.

Table 10 brings the results on price discovery between CDS and bond spreads of non-financial companies. The results can be presented analogously as in the previous section dealing with the relationship between CDS and stock markets. In case the coefficient λ_1 of error term is negative and statistically significant, the existence of a long-run relationship can be confirmed, pointing to the contribution of bond spreads to price discovery of CDS spreads. Such relationship was confirmed almost in all panels except of the panel including non-financial companies of investment grade during the crisis period. The short-run causality coming from bond market to CDS market was found in all panels.

Table 10. Price discovery between CDS and bond spreads using panel VECM – non-financial companies.

	Crisis period		Post-crisis period	
	IG (7)	NG (6)	IG (9)	NG (7)
λ_1	-0.0034*	-0.0010	-0.0008*	-0.0016*
t-stat.	-9.1761	-1.1526	-6.9870	-4.2130
χ^2_1	3.9988**	21.4582*	130.4303*	30.5530*
λ_2	0.8550*	-0.0078*	-0.0011*	-0.0006*
t-stat.	139.4933	-4.6309	-7.3259	-2.6899
χ^2_2	90.1972*	116.0316*	1294.6690*	307.7987*
GG_1	-0.0040	**0.1136**	**0.4211**	**0.7272**
GG_2	1.0040	**0.8864**	**0.5789**	**0.2728**

Notes: Lag length in parentheses is specified according to the Schwartz information criterion.
* denotes statistical significance at 1% level and ** at 5% level.

The negative and statistically significant coefficient λ_2 points to price domination in CDS market and major adaptation in bond market. The results indicate that CDS spreads contribute to price discovery of bond spreads in all panels, however in panel including investment grade companies, the coefficient is not of expected sign. Short-run causality coming from CDS market to bond market was found in all panels.

The GG_1 measures show the contribution of bond market to price discovery of CDS market. The contribution of markets was changing during the observed periods and sectors. The average contribution was 42.1 %. It is remarkable that the contribution of bond market to price discovery of CDS market was 11.4 % during the crisis period for panel of non-investment grade companies and 72.7 % during the post-crisis period.

The results on price discovery for the panel including financial institutions are carried in Table 11. The results of VECMs employed for panels including investment grade companies during the crisis and post-crisis period evidenced a contribution of both markets to each other in price discovery as well as the existence of short-run causalities between variables both coming from bond market to CDS market and from CDS market to bond market. Same relations were found for the panel including non-investment grade companies during the post-crisis period. However, during the crisis period, we evidenced the dominance of CDS market.

Table 11. Price discovery between CDS and bond spreads using panel VECM – financial companies.

	Crisis period		Post-crisis period	
	IG (5)	NG (2)	IG (14)	NG (3)
λ_1	-0.0026*	-0.0029	-0.0018*	-0.0047*
t-stat.	-3.1197	-0.9059	-6.4215	-4.6052
χ^2_1	0.0007	0.4191	23.5076*	1.2122
λ_2	-0.0101*	-0.0774*	-0.0017*	-0.0032**
t-stat.	-7.1814	-5.0823	-6.5361	-2.4447
χ^2_2	103.9387*	0.0883	550.5356*	48.1260*
GG_1	**0.2047**	**0.0361**	**0.5143**	**0.5949**
GG_2	**0.7953**	**0.9639**	**0.4857**	**0.4051**

Notes: Lag length in parentheses is specified according to the Schwartz information criterion.
* denotes statistical significance at 1% level and ** at 5% level.

The values of the GG_2 measures point to the significant contribution to price discovery of CDS market to bond market during the crisis period. The average contribution of CDS market to price discovery in bond market was almost 88 %. The contribution of CDS market diminished in the post-crisis period in favour to bond market, the average contribution lowered to 44 %.

Our results are a bit contradictory to the previously published studies, since the majority of them found that in most of the cases CDS spreads tend to lead bond spreads. However, the majority of so far published studies investigated the relationship between markets only during the pre-crisis period. There is one study which is focused on the interactions between CDS and bond markets during the crisis period – Coudert and Gex (2013), but no one study to our knowledge which would be focused on the relationship between markets during the post-crisis period.

We found that during the crisis period, our results are comparable with those found by Longstaff et al. (2003), Blanco et al. (2005), Zhu (2006), Dötz (2007), Forte and Peña (2009), Norden and Weber (2009) or Coudert and Gex (2013) who showed that the theoretical assumption about the leading role of CDS market holds in majority of cases. But we also found that the relationship between markets changed during the post-crisis period for both financial and non-financial companies. The contribution of CDS market to bond market lowered considerably in the panels including financial and non-financial companies and much more significantly in the panels including non-investment grade contracts.

Conclusions

The aim of the paper was to find out if new information is reflected in prices earlier in CDS and stock or bond markets and to confirm or disprove whether the theoretical assumptions about the links between markets hold. The paper brings a complex insight into relationships between CDS market and bond market or stock market at European level. Employing panel estimation techniques, the long-term and short-term interactions between the studied markets were examined.

When assessing the relationship between stock market and CDS market, we came to the conclusion that the theoretical assumption holds and that stock market has the leading role in price discovery process. Our results are consistent with the results of already published studies, however compared to them, we verified that this relationship is valid during all observed periods, since they were focused preliminary on the limited period in most of the cases.

When evaluating the relationship between CDS market and bond market, we did not find such unequivocal conclusions as in the case of the relationship between stock and CDS markets. We came to the conclusion that our results for the crisis period are corresponding with the results of previously published research and with the theoretical assumptions about this relationship. We also revealed that the nature of the link between CDS and bond market has changed in the post-crisis

period and that the dominance in price discovery process moved from CDS market to bond market. Future research may address the sources of this change.

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Appendix 1

Table 1. Summary of empirical studies dealing with relationships between selected markets.

Study	Period	No. of contracts	Markets	Method(s)
Longstaff et al. (2003)	03/2001 – 10/2002	68	CDS, bond, stock	VAR
Blanco et al. (2005)	01/2001 – 06/2002	33	CDS, bond	Co-integration, VECM, Granger causality
Byström (2005)	06/2004 – 04/2005	7 sectoral indices	CDS, stock	OLS regressions
Zhu (2006)	01/1999 – 12/2002	24	CDS, bond	Co-integration, VECM, Granger causality
Dötz (2007)	01/2004 – 10/2006	36	CDS, bond	Co-integration, VECM, Granger causality
Fung et al. (2008)	01/2001 – 12/2007	2 indices	CDS, stock	VAR
Forte and Peña (2009)	09/2001 – 06/2003	17	CDS, bond, stock	Co-integration, VECM
Norden and Weber (2009)	2000 – 2002	58	CDS, bond, stock	VAR
Trutwein and Schiereck (2011)	01/2007 – 12/2008	13	CDS, stock	VAR
Coudert and Gex (2013)	01/2007 – 03/2010	17	CDS, bond	Panel co-integration and panel VECM
Nayaran et al. (2014)	07/2004 – 03/2012	212	CDS, stock	Panel co-integration and panel VECM