

Article

The Determinants of CDS Spreads in Multiple Industry Sectors: A Comparison between the US and Europe

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Abstract: The paper analyzes the relationship between the credit default swaps (CDS) spreads for 5-year CDS in Europe and US, and fundamental macroeconomic variables such as regional stock indices, oil prices, gold prices, and interest rates. The dataset includes consideration of multiple industry sectors in both economies, and it is split in two sections, before and after the global financial crisis. The analysis is carried out using multivariate regression of each index vs. the macroeconomic variables, and a Granger causality test. Both approaches are performed on the change of value of the variables involved. Results show that equity markets lead in price discovery, bidirectional causality between interest rate, and CDS spreads for most sectors involved. There is also bidirectional causality between stock and oil returns to CDS spreads.

Keywords: CDS spread; macroeconomic driver; correlation; causality; price discovery

JEL Classification: G12; G13

1. Introduction

Credit risk is a topic of major interest among academics and practitioners in Finance, due to the strong linkage between such a risk and the financial wealth of the banking systems around the world. Institutions and regulators are strongly involved in the search for the right way to manage credit risk, for single counterparties and baskets of credit positions, given factors such as default probability, loss given default, and recovery rate.

In the last decades, credit derivative rose as a powerful tool to handle credit risk. Designed to be an over-the-counter type of instrument, credit derivative can be used to transfer credit risk from one party to another. By synthetically creating or eliminating credit exposures, they allow institutions to more effectively manage credit risks. Credit default swaps (CDS) have become very popular in the last decade, due to their ability to hedge bond holders from the credit risk derived by the potential default of the issuer.

In 2007, the market for CDS was the hottest in the world, with an outstanding notional size of more than \$60 trillion by the end of that year, with no signs of stopping. Currently, the outstanding size of the CDS market is limited to \$10 trillion, after many consecutive years of decline. Still, it represents a big market where big institutions still play a big role. Financial analysts, traders, and economic policy can take huge benefits from understanding the relationship between CDS spreads and macroeconomic drivers (Greatrex (2008)). Over the last few years, academic research has used corporate bond prices or single name CDS spreads to determine the drivers of movements in credit spreads.

Even though corporate bond spreads can deliver the same information as CDS, in the past years, studies from Zhang et al. (2009), Tang and Yan (2010), and Galil et al. (2014), among others,

have focused on the analysis of the determinants of CDS spreads, rather than corporate bond spreads. Aggregate economic variables such as the level of interest rates, leverage, inflation, unemployment, gross domestic product (GDP) growth rates, and more, have been widely considered in the literature as potential factors that affect the credit conditions of a company or an economy, like in [Imbierowicz \(2009\)](#) and [Pu and Zhao \(2010\)](#). The relationship between CDS spreads and macroeconomic variables has been studied, in different forms, by [Baum and Wan \(2010\)](#), [Brandorf and Holmberg \(2010\)](#), [Di Cesare and Guazzarotti \(2010\)](#) and [Chiaramonte and Casu \(2013\)](#) among others. Other scientists like [Huang and Shi \(2010\)](#) and [Ludvigson and Ng \(2009\)](#) focused on the determinants of bond premia.

There are several reasons for restricting the analysis to CDS. First of all the CDS market's rapid expansion in the first few years created a rich platform for the study of credit risk. Moreover bond spreads are too sensitive to factors such as risk-free benchmark yields, tax treatments, and bond-specific contract conditions. CDS spreads are not sensitive to the above factors. A final explanation [Alexander and Kaeck \(2008\)](#) is given by the fact that the CDS market allows for the assumption of positions that are virtually unlimited, and this allows the CDS spreads to be very responsive to changes in the credit conditions associated with the market.

This paper therefore focuses on CDS spreads as the target variable for the analysis. In particular, the paper analyzes the relationship between selected regional sector-wide CDS spreads, and three macroeconomic variables, namely oil prices, regional interest rates, and gold prices. Another limitation is geographical, in that the study is based on a comparison between the drivers of the CDS spreads in Europe and those in the US. It seems logical to us to choose the two economies that represent the western world's method of doing finance, and that have the most differences between them, compared to comparing, for example, the US and the UK, or Europe and the UK. The geographical distance and historically different approaches to the management of the real and financial economy, makes the US and Europe the ideal candidates for such a comparison.

In terms of the choice of variables (drivers), and their motivations, the relationship between oil prices and fixed income has not yet been explored. The choice of oil as one of the dependent variables in the analysis is inspired by the work of [Alexandre and De Antonin \(2010\)](#). The authors show in fact that the oil price is a driver of the risk premium of sovereign bonds. The choice of oil price as a variable for our study is due to the fact that no research has been carried on CDS spreads as a fixed income instrument, or on oil price as a dependent variable for the premia of non-sovereign bonds. The choice of gold relates to an article by [Simakova \(2011\)](#) that analyzes the relationship between gold and oil prices, using quantitative approaches such as Granger causality, Johansen cointegration, and vector error correction. The paper shows that there is a long-term relationship between oil and gold prices. We therefore choose gold as a variable for our study, in order to compare the results of our analysis for gold with the results for oil, and we draw some conclusions.

The contribution of the paper is due to two important innovations that we combine in order to define the bigger picture of what has been going on in the past 10 years in terms of credit conditions. The first innovation comes from pushing the issue of interdependency between the financial and the real economy to a different level. This analysis is in fact focused on economic sectors, rather than credit ratings or single countries, and it is thus very different from what has been done by most of the literature to date. As a second innovative element, the analysis is split into two distinct time periods, namely the crisis years from 2008 to 2012, and the post-crisis years, from 2013 to 2017. The combination of the two above innovative elements allows for an in-depth analysis of the credit conditions, characterizing different production sectors during the rise and fall of the hunt for credit derivatives.

2. The Variables Involved

As mentioned in the introduction, the scope of the paper is to analyze the relationship between CDS spreads and selected macroeconomic drivers. The purpose of this section is to explain the choice of variables for the proposed model. The reason for choosing CDS spreads as the main variable is that the former has been proven to be a much more effective proxy of the credit conditions of a country,

rather than bond premia (spreads). The reasons for such predominance have been exposed in the introduction, and the features of the chosen CDS are explained in the Data section. However, it is also important to recall the importance and use of CDS as tools for credit risk management.

Ignoring the very basics of CDS functioning and pricing, it is important to recall that, as any other financial derivative; they can be used for either hedging, speculation or arbitrage purposes. In terms of speculation, naked CDS positions have been very popular among speculators in the last 10 years. One should recall that a short position in a CDS is equivalent to a synthetic long position on the underlying bond, and that the buyer of CDS protection is considered as “short” on the CDS and the underlying bond as well. Some critics have argued that the above is equivalent to buying insurance on someone else’s property, and there is a strong debate in both the EU and the US about the possibility of banning naked positions on CDS. Hedging with CDS on the other hand, allows bond owners to buy protection in exchange of the payment of the spread, therefore transferring the risk. Banks use CDS to reduce their concentration risk, and to diversify their portfolio of clients, by entering into CDS positions to relieve the risk by transacting with a counterparty that is not the actual client. Arbitrageurs have developed capital structure forms of arbitrage, by selecting CDS with high negative correlation to the reference asset, so as to benefit from market inefficiencies when it comes to opposite movements of asset prices and CDS spreads. The combined trading of all types of investors has ultimately generated controversial trends in the CDS markets in the last decade. This is how the idea for this study developed.

The main research question that we are trying to answer is: what factors have been driving the CDS markets in the last 10 years, and does how the answer change if we consider different production sectors within the economy? As a follow-up question, we consider how the results change if we look at the years of the most severe financial crisis that the world ever experienced, compared to the following years. In order to answer the two above questions, we started thinking about what variables could be good candidates as an explanatory factor for the dynamics of the credit situation in the selected sectors. The factors chosen were oil prices, regional interest rates, and gold prices.

3. Data and Methodology

We considered 5-year CDS data for nine different sectors in Europe and USA. The overall time horizon comprised the period from 14 December 2007 to 1 September 2017. This time period is divided in two sub-periods. The first sub-period was the crisis period (from 14 December 2007 to 31 December 2012) where CDS spreads grew considerably. The second sub-period encompassed the less acute phase of the crisis, or the post-crisis period (from 1 January 2013 to 1 September 2017). This period was used to examine the beginning of the recovery phase.

Table 1 summarizes the dependent and independent variables, and Table 2 shows the results of the OLS regression. All of the variables are gathered from Thompson Reuters. We ran ordinary least squares regression (OLS) regression with robust standard errors using the Guber-White sandwich estimators, where each of the nine different sectors’ CDS were the dependent variables, and the other variables were control variables. The following is the generic model used in this paper for the multivariate form of change in spreads:

$$\Delta s = \alpha + \beta_1(\Delta Ind) + \beta_2(\Delta Oil) + \beta_3(\Delta Int) + \beta_4(\Delta Gld) + \varepsilon \quad (1)$$

where:

ΔInd is the change in the value of the stock index.

ΔOil is the change in oil prices.

ΔInt is the change in interest rates.

ΔGld is the change in gold prices.

Table 1. Variable description.

Variable	Description
Bank CDS	
Europe	DS Europe Banks 5-Year Credit Default Swap Index
USA	DS North America Banks 5-Year Credit Default Swap Index
Consumer Goods CDS	
Europe	DS Europe Consumer Goods (CSMG) 5-Year Credit Default Swap Index
USA	DS North America CSM Goods 5-Year Credit Default Swap Index
Electrical Power CDS	
Europe	DS Europe Electrical POW 5-Year Credit Default Swap Index
USA	DS North America Electrical Power 5-Year Credit Default Swap Index
Energy Company CDS	
Europe	DS Europe Energy Company 5-Year Credit Default Swap Index
USA	DS North America Energy Company 5-Year Credit Default Swap Index
Manufacturing CDS	
Europe	DS Europe Manufacturing 5-Year Credit Default Swap Index
USA	DS North America Manufacturing 5-Year Credit Default Swap Index
Other Financial Co. CDS	
Europe	DS Europe Other Financial 5-Year Credit Default Swap Index
USA	DS North America Other Financial 5-Year Credit Default Swap Index
Service Co. CDS	
Europe	DS Europe Service Company 5-Year Credit Default Swap Index
USA	DS North America Service Company 5-Year Credit Default Swap Index
Telephone CDS	
Europe	DS Europe Telephone 5-Year Credit Default Swap Index
USA	DS North America Telephone 5-Year Credit Default Swap Index
Transportation CDS	
Europe	DS Europe Transport 5-Year Credit Default Swap Index
USA	DS North America Transport 5-Year Credit Default Swap Index
Stock Index	
Europe	S&P Europe United States Dollar
USA	Dow Jones Industrials
Oil	
Europe	London Brent Crude Oil Index United States Dollar/Barrel
USA	Crude Oil-West Texas Intermediate Spot Cushing United States Dollar/Barrel
Interest Rate	
Europe	Euro Marginal Lending (European Central Bank)
USA	United States Federal Funds Effective Rate
Gold	
Europe	Gold Bullion London Bullion Market U\$/Troy Ounce
USA	North America Spot Gold Prices U\$/Troy Ounce

Table 2. Ordinary least squares (OLS) regression. The table represents the robust regression of 5-year CDSs of nine different sectors in Europe and USA on stock index returns, returns on oil prices, change in interest rates, and return on gold prices (refer Table 1 for variable definition). Nine regressions are reported for during and post-crisis period: one for each sector. *p* values are reported in parentheses. Asterisks indicate significance at 1% (***), 5% (**), and 10% (*) levels.

	Stock Index				Oil				Interest Rate				Gold			
	During		Post		During		Post		During		Post		During		Post	
	coeff	<i>p</i>	coeff	<i>p</i>	coeff	<i>p</i>	coeff	<i>p</i>	coeff	<i>p</i>	coeff	<i>p</i>	coeff	<i>p</i>	coeff	<i>p</i>
Bank CDS																
Europe	0.086	0.24	−1.186	0.00 ***	0.045	0.41	−0.110	0.41	0.002	0.00 ***	−0.005	0.37	0.026	0.75	0.069	0.73
USA	0.025	0.89	−1.066	0.00 ***	0.002	0.98	−0.036	0.21	0.003	0.00 ***	0.000	0.75	−0.046	0.71	0.047	0.46
Consumer Goods CDS																
Europe	−0.042	0.47	−0.486	0.00 ***	0.057	0.17	−0.038	0.29	0.002	0.00 ***	0.000	0.87	−0.085	0.21	0.110	0.04 **
USA	−0.033	0.67	−0.376	0.00 ***	−0.010	0.62	−0.028	0.34	0.001	0.00 ***	0.000	0.96	0.071	0.23	0.045	0.47
Electrical Power CDS																
Europe	−0.092	0.60	−0.703	0.00 ***	0.141	0.27	−0.161	0.28	0.001	0.72	0.011	0.07 *	−0.311	0.13	−0.061	0.78
USA	−0.084	0.73	−1.065	0.08 *	0.081	0.28	−0.042	0.83	0.002	0.37	−0.004	0.75	0.045	0.78	−0.164	0.71
Energy Company CDS																
Europe	−0.092	0.59	−0.704	0.00 ***	0.141	0.26	−0.248	0.00 ***	0.001	0.72	−0.002	0.39	−0.311	0.13	0.160	0.06 **
USA	−0.865	0.00 ***	−0.903	0.00 ***	−0.136	0.21	−0.133	0.22	−0.002	0.44	−0.006	0.44	−0.08	0.71	−0.093	0.70
Manufacturing CDS																
Europe	−0.335	0.44	−0.274	0.57	−0.301	0.34	−0.311	0.36	−0.004	0.32	−0.016	0.26	−0.265	0.59	−0.264	0.63
USA	−0.906	0.00 ***	−0.934	0.00 ***	0.035	0.54	0.039	0.49	−0.001	0.60	−0.002	0.61	−0.087	0.46	−0.082	0.51
Other Financial Co. CDS																
Europe	0.072	0.34	−1.502	0.00 ***	0.109	0.05 **	0.985	0.00 ***	0.002	0.00 ***	−0.013	0.33	−0.009	0.91	0.671	0.20
USA	−0.406	0.13	−0.448	0.10 *	−0.081	0.34	−0.083	0.36	−0.001	0.52	0.000	0.96	−0.048	0.79	−0.079	0.68
Service Co. CDS																
Europe	0.345	0.00 ***	−0.685	0.00 ***	−0.021	0.78	−0.081	0.05 **	0.001	0.12	−0.001	0.48	−0.111	0.34	0.180	0.00 ***
USA	−0.766	0.00 ***	−0.773	0.00 ***	0.047	0.62	0.048	0.61	−0.002	0.41	0.005	0.43	0.077	0.69	0.088	0.68
Telephone CDS																
Europe	0.056	0.71	−0.525	0.00 ***	0.094	0.34	−0.365	0.00 ***	0.001	0.46	−0.003	0.40	−0.108	0.49	−0.031	0.83
USA	−0.571	0.00 ***	−0.581	0.00 ***	0.107	0.00 ***	0.104	0.01 **	−0.001	0.31	0.003	0.19	−0.019	0.82	−0.019	0.83
Transportation CDS																
Europe	−0.532	0.00 ***	−0.525	0.00 ***	−0.351	0.00 ***	−0.365	0.00 ***	0.001	0.47	−0.003	0.43	−0.031	0.82	−0.031	0.83
USA	−0.947	0.02 **	−0.396	0.32	0.009	0.94	−0.036	0.76	0.003	0.25	−0.007	0.38	−0.292	0.34	−0.037	0.88

The Granger causality test by Granger (1981) is employed to test whether the past values of x influence (Granger cause) the current values of y . Granger causality tests the short term interactions between variables and it aptly identifies the variable that leads in price discovery. If variable x Granger causes variable y , past or lagged values of x can explain the changes in, or provide information about y . Therefore, x leads y in the price discovery and provides statistically significant information about the future values of y . In this study, Granger causality tests partly supported the short term dynamic analysis, interactions and price discovery among 5-year CDS for all nine sectors, their return on the stock index, return on the oil prices, incremental difference in interest rates and their return on gold prices.

The Granger test takes the form:

$$z_t = \lambda_t + \sum_{i=1}^p \alpha_i z_{t-i} + \sum_{i=1}^p \beta_i y_{t-i} + \varepsilon_t$$

The F-test is on the null hypothesis that $\beta_1 = \beta_2 = \dots = \beta_p = 0$ and the hypothesis of causality is rejected for values of the statistic above 5%. The causality was tested with bi-directionality (Table 3) and Table 4 provides the summary results of Granger causality tests during-crisis and post-crisis periods for USA and Europe respectively. Table 5 summarizes the pair-wise Granger causality tests for during-crisis and post-crisis periods between CDS for Europe and USA for all nine different sectors.

Table 3. Pair-wise Granger causality tests for during-crisis and post-crisis periods between the nine different sectors of CDS in the US, and the independent variables stock index, oil, interest rate, and gold. We use a lag of 30 (past 30 days) for each variable. *, **, and *** mean that the null hypothesis is rejected at 10%, 5%, and 1% significance level respectively.

Null Hypothesis	During Crisis Period			Post Crisis Period		
	<i>obs</i>	<i>f</i>	<i>p</i>	<i>obs</i>	<i>f</i>	<i>p</i>
US Banks						
US banks does not granger cause stock index	1287	1.092	0.33	1189	0.616	0.95
Stock index does not granger cause US banks	1287	0.922	0.58	1189	2.923	0.00 ***
US banks does not granger cause oil	1287	0.810	0.75	1189	1.353	0.09 *
Oil does not granger cause US banks	1287	0.841	0.71	1189	0.791	0.78
US banks does not granger cause US interest rate	1287	4.492	0.00 ***	1189	0.659	0.92
US interest rate does not granger cause US banks	1287	3.873	0.00 ***	1189	1.132	0.29
US banks does not granger cause gold	1287	1.092	0.33	1189	0.758	0.82
Gold does not granger cause US banks	1287	1.552	0.02 **	1189	0.789	0.78
US Consumer (CSM) Goods						
US CSM goods does not granger cause stock index	1287	0.771	0.81	1189	1.265	0.15
Stock index does not granger cause US CSM goods	1287	1.035	0.41	1189	1.645	0.01 ***
US CSM goods does not granger cause US interest rate	1287	1.377	0.08 *	1189	0.425	0.99
US interest rate does not granger cause US CSM goods	1287	2.264	0.00 ***	1189	0.987	0.48
US CSM goods does not granger cause gold	1287	0.837	0.72	1189	2.106	0.00 ***
Gold does not granger cause US CSM goods	1287	0.851	0.69	1189	1.205	0.20
US Electricity Sector (ELEC) power						
US ELEC power does not granger cause gold	1287	0.417	0.99	1189	1.172	0.24
Gold does not granger cause US ELEC power	1287	0.562	0.97	1189	1.883	0.00 ***
US Energy Co.						
US Energy Co. does not granger cause stock index	1287	1.255	0.16	1189	1.265	0.15
Stock index does not granger cause US Energy Co.	1287	1.627	0.02 **	1189	1.603	0.02 **
US Energy Co. does not granger cause oil	1287	2.597	0.00 ***	1189	2.401	0.00 ***
Oil does not granger cause US Energy Co.	1287	1.998	0.00 ***	1189	1.904	0.00 ***

Table 3. Cont.

	During Crisis Period			Post Crisis Period		
US Manufacturing Goods Sector (MNFG)						
US MNFG does not granger cause stock index	1287	2.218	0.00 ***	1189	2.106	0.00 ***
Stock index does not granger cause US MNFG	1287	3.283	0.00 ***	1189	3.229	0.00 ***
US MNFG does not granger cause oil	1287	2.102	0.00 ***	1189	2.039	0.00 ***
Oil does not granger cause US MNFG	1287	2.262	0.00 ***	1189	2.174	0.00 ***
US MNFG does not granger cause US interest rate	1287	0.294	0.99	1189	2.061	0.00 ***
US interest rate does not granger cause US MNFG	1287	0.372	0.99	1189	1.416	0.06 *
US Other Financial Companies (FIN)						
US other FIN does not granger cause stock index	1287	0.935	0.56	1189	0.906	0.61
Stock index does not granger cause US other FIN	1287	2.247	0.00 ***	1189	1.959	0.00 ***
US other FIN does not granger cause US interest rate	1287	1.521	0.03 **	1189	1.031	0.42
US interest rate does not granger cause US other FIN	1287	0.611	0.95	1189	1.533	0.03 **
US other FIN does not granger cause gold	1287	1.415	0.06 *	1189	1.337	0.11
Gold does not granger cause US other FIN	1287	1.148	0.26	1189	1.021	0.43
US Telephone Sector						
US Telephone does not granger cause stock index	1287	1.211	0.21	1189	1.239	0.17
Stock index does not granger cause US Telephone	1287	3.475	0.00 ***	1189	3.173	0.00 ***
US Telephone does not granger cause oil	1287	2.372	0.00 ***	1189	2.299	0.00 ***
Oil does not granger cause US Telephone	1287	2.328	0.00 ***	1189	2.237	0.00 ***
US Telephone does not granger cause US interest rate	1287	0.401	0.99	1189	1.005	0.45
US interest rate does not granger cause US Telephone	1287	0.801	0.76	1189	4.053	0.00 ***
US Transportation (TRSP) Sector						
US TRSP does not granger cause US index	1287	2.226	0.00 ***	1189	0.231	0.99
US index does not granger cause US TRSP	1287	1.371	0.08 *	1189	0.298	0.99
US TRSP does not granger cause gold	1287	0.741	0.84	1189	0.942	0.55
Gold does not granger cause US TRSP	1287	1.339	0.10 *	1189	1.301	0.12
Other relationships						
Oil does not granger cause stock interest	1287	1.156	0.25	1189	1.273	0.14
Stock index does not granger cause oil	1287	2.078	0.00 ***	1189	2.055	0.00 ***
Gold does not granger cause US interest rate	1287	2.026	0.00 ***	1189	0.583	0.96
US interest rate does not granger cause gold	1287	2.095	0.00 ***	1189	0.669	0.91

Table 4. Pair-wise Granger causality tests for during-crisis and post-crisis periods between the nine different sectors of CDS and independent variables stock index, oil, interest rate, and gold for Europe. We use a lag of 30 (past 30 days) for each variable. *, **, and *** means that the null hypothesis is rejected at 10%, 5%, and 1% significance level respectively.

Null Hypothesis	During Crisis Period			Post Crisis Period		
	<i>obs</i>	<i>f</i>	<i>p</i>	<i>obs</i>	<i>f</i>	<i>p</i>
Europe Banks						
Europe banks does not granger cause stock index	1287	1.092	0.33	1189	1.819	0.00 ***
Stock index does not granger cause Europe banks	1287	0.922	0.58	1189	2.137	0.00 ***
Europe bank does not granger cause oil	1287	0.832	0.72	1189	2.952	0.00 ***
Oil does not granger cause Europe bank	1287	1.241	0.17	1189	2.168	0.00 ***
Europe banks does not granger cause Euro interest rate	1287	0.906	0.61	1189	0.123	0.99
Euro interest rate not granger cause Europe banks	1287	2.095	0.00 ***	1189	0.216	0.99
Europe banks does not granger cause gold	1287	1.302	0.13	1189	1.475	0.04 **
Gold does not granger cause Europe banks	1287	1.065	0.37	1189	0.741	0.84

Table 4. Cont.

	During Crisis Period			Post Crisis Period		
Europe CSM Goods						
Europe CSM Goods does not granger cause stock index	1287	0.877	0.65	1189	0.722	0.86
Stock index does not granger cause Europe CSM Goods	1287	1.102	0.32	1189	3.368	0.00 ***
Europe CSM Goods does not granger cause oil	1287	0.616	0.94	1189	1.482	0.04 **
Oil does not granger cause Europe CSM Goods	1287	0.913	0.60	1189	1.011	0.45
Europe CSM Goods does not granger cause Euro interest rate	1287	2.929	0.00 ***	1189	1.187	0.22
Euro interest rate does not granger cause Europe CSM Goods	1287	2.625	0.00 ***	1189	1.165	0.24
Europe CSM Goods does not granger cause gold	1287	1.317	0.12	1189	0.930	0.06
Gold does not granger cause Europe CSM Goods	1287	2.007	0.00 ***	1189	1.174	0.23
Europe ELEC power						
Europe ELEC does not granger cause stock index	1287	0.624	0.94	1189	1.111	0.31
Stock index does not granger cause Europe ELEC	1287	0.463	0.99	1189	1.608	0.02 **
Europe Energy Co.						
Europe energy does not granger cause stock index	1287	0.534	0.98	1189	0.702	0.88
Stock index does not granger cause Europe energy	1287	0.808	0.75	1189	4.231	0.00 ***
Europe energy does not granger cause oil	1287	0.651	0.92	1189	2.303	0.00 ***
Oil does not granger cause Europe energy	1287	1.045	0.40	1189	2.750	0.00 ***
Europe energy does not granger cause Euro interest rate	1287	1.603	0.02 **	1189	0.572	0.96
Euro interest rate does not granger cause Europe energy	1287	2.472	0.00 ***	1189	0.465	0.99
Europe energy does not granger cause gold	1287	1.068	0.37	1189	1.306	0.13
Gold does not granger cause Europe energy	1287	1.497	0.04 **	1189	0.792	0.77
Europe MNFG						
Europe MNFG does not granger cause stock index	1287	0.657	0.92	1189	0.657	0.92
Stock index does not granger cause Europe MNFG	1287	1.364	0.09 *	1189	1.355	0.09 *
Europe other FIN						
Europe other FIN does not granger cause stock index	1287	1.083	0.35	1189	1.051	0.39
Stock index does not granger cause Europe other FIN	1287	1.558	0.02 **	1189	1.903	0.00 ***
Europe other FIN does not granger cause oil	1287	0.992	0.48	1189	1.905	0.00 ***
Oil does not granger cause Europe other fin	1287	2.489	0.00 ***	1189	5.434	0.00 ***
Europe other FIN does not granger cause gold	1287	1.007	0.46	1189	0.897	0.62
Gold does not granger cause Europe other FIN	1287	1.011	0.45	1189	1.561	0.02 **
Europe Service Co.						
Europe service co. does not granger cause stock index	1287	0.762	0.81	1189	1.080	0.35
Stock index does not granger cause Europe service co.	1287	1.185	0.22	1189	4.310	0.00 ***
Europe service co. does not granger cause oil	1287	1.561	0.02 **	1189	2.969	0.00 ***
Oil does not granger cause Europe service co.	1287	1.021	0.43	1189	1.082	0.34
Europe Telephone						
Europe telephone does not granger cause stock index	1287	0.759	0.82	1189	0.696	0.88
Stock index does not granger cause Europe telephone	1287	0.852	0.69	1189	5.276	0.00 ***
Europe telephone does not granger cause oil	1287	0.724	0.86	1189	1.525	0.03 **
Oil does not granger cause Europe telephone	1287	0.878	0.65	1189	1.203	0.20
Europe telephone does not granger cause gold	1287	1.402	0.07 *	1189	0.939	0.56
Gold does not granger cause Europe telephone	1287	0.827	0.73	1189	1.475	0.04 **
Europe TRSP						
Europe TRSP does not granger cause stock index	1287	0.705	0.88	1189	0.696	0.88
Stock index does not granger cause Europe TRSP	1287	5.596	0.00 ***	1189	5.276	0.00 ***
Europe TRSP does not granger cause oil	1287	1.577	0.02 **	1189	1.525	0.03 **
Oil does not granger cause Europe TRSP	1287	1.218	0.19	1189	1.203	0.20
Europe TRSP does not granger cause gold	1287	0.965	0.51	1189	0.939	0.56
Gold does not granger cause Europe TRSP	1287	1.508	0.03 **	1189	1.475	0.04 **
Other relationships						
Oil does not granger cause stock index	1287	1.117	0.30	1189	1.154	0.26
Stock index does not granger cause oil	1287	4.379	0.00 ***	1189	4.105	0.00 ***
Gold does not granger cause Euro interest rate	1287	1.342	0.10 *	1189	3.123	0.00 ***
Euro interest rate does not granger cause gold	1287	1.770	0.00 ***	1189	0.959	0.52

Table 5. Pair-wise Granger causality tests for during-crisis and post-crisis periods between the nine different sector CDSs from Europe and USA. We use a lag of 30 (past 30 days) for each variable. *, **, and *** means that the null hypothesis is rejected at a 10%, 5%, and 1% significance level respectively.

	During Crisis Period			Post Crisis Period		
	<i>obs</i>	<i>F</i>	<i>p</i>	<i>obs</i>	<i>f</i>	<i>p</i>
Null Hypothesis						
US banks CDS does not granger cause Europe banks CDS	1287	3.566	0.00 ***	1189	1.141	0.27
Europe banks CDS does not granger cause US banks CDS	1287	2.518	0.00 ***	1189	1.978	0.00 ***
US consumer goods CDS does not granger cause Europe consumer goods CDS	1287	1.138	0.27	1189	2.207	0.00 ***
Europe consumer goods CDS does not granger cause US consumer goods CDS	1287	1.745	0.00 ***	1189	0.855	0.69
US ELEC power CDS does not granger cause Europe ELEC power CDS	1287	3.492	0.00 ***	1189	0.054	1.00
Europe ELEC power CDS does not granger cause US ELEC power CDS	1287	9.982	0.00 ***	1189	0.048	1.00
US energy co. CDS does not granger cause Europe energy co. CDS	1287	2.69	0.00 ***	1189	0.693	0.89
Europe energy co. CDS does not granger cause US energy co. CDS	1287	0.966	0.51	1189	1.017	0.44
US other financial CDS does not granger cause Europe other financial CDS	1287	0.989	0.48	1198	0.637	0.93
Europe other financial CDS does not granger cause US other financial CDS	1287	1.235	0.17	1198	1.382	0.08 *
US manufacturing CDS does not granger cause Europe manufacturing CDS	1287	0.827	0.73	1198	0.637	0.93
Europe manufacturing CDS does not granger cause US manufacturing CDS	1287	0.562	0.97	1198	1.382	0.08 *

4. Summary of Results

4.1. Bank 5-Year CDS

The coefficient of interest rate difference was positive and significant for both USA and Europe during the crisis period, indicating that interest rate is positively and significantly related to bank 5-year CDS. This is expected because despite the reduction of reference interest rates that are normally operated by Central Banks in periods of crisis, (and affecting banks operations), the differences keep growing due to the attitude towards saving. During the post-crisis period, we found that the coefficient of returns on the stock index were negative and significant, indicating that the return on stock market index is significantly and negatively related to bank 5-year CDS for both USA and Europe. This confirms that a commonly observed phenomenon of decrease in stock returns during the recovery period, combined with a high perception of risk in the economy, results in high (even if progressively lowering) CDS spreads.

4.2. Consumer Goods 5-Year CDS

The coefficient of difference in the interest rate is positive and significant for both USA and Europe during the crisis period, indicating that the interest rate is positively and significantly related to consumer goods 5-year CDS. This is expected because consumption is normally negatively affected by increasing interest rates, with consequences on the perception that investors have on the riskiness of the consumer goods sector. During the post crisis period, we found that the coefficient of returns on the stock index was negative and significant, indicating that the return on stock market index was significantly and negatively related to the consumer goods 5-year CDS for both USA and Europe. This can be explained by the general considerations mentioned above for the bank sector. In addition, the coefficient of returns on gold prices was positive and significant at 5% Level of Significance (LOS) during the post-crisis period for Europe, indicating an accumulated effect from the crisis years, when normally investors would react to crises by heavily investing in gold.

4.3. Electrical Power 5-Year CDS

None of the independent variables were significant for both USA and Europe during the crisis period. During the post crisis period, we find the coefficient of returns on stock index to be negative and significant for Europe and USA (no granger causality found) at 5% and 1% LOS, and the coefficient of difference in interest rates to be positive and significant at 1% LOS for Europe (no granger causality found), again indicating the relationship already mentioned.

4.4. Energy Company 5-Year CDS

Returns on the stock index were negatively and significantly related to the energy company 5-year CDS for USA during the crisis period. During the post-crisis period, the coefficients of stock returns were both negative and significant at 1% for the US and Europe, indicating that energy companies also follow the common trend of stock returns vs fixed income risk. Also, during the post crisis period, there was an inverse and significant (1%) relationship between oil returns and Europe energy company 5-year CDS, which was expected, because the profitability and perceived risk of the energy sector is obviously compromised when oil returns decrease, resulting in a higher perceived risk by investors. There was no relationship between oil returns and US energy company 5-year CDS. There was also a positive and significant relationship between gold returns and European energy company 5-year CDS during the post-crisis period, indicating that gold and oil still represent two different commodities that are substitutes of each other. No significant relationship between the US energy companies 5 year CDS and gold returns was observed.

4.5. Manufacturing Company 5-Year CDS

Returns on the stock index were negatively and significantly related to the US manufacturing company 5-year CDS for USA for during- and post-crisis periods at 1%, indicating again the relationship observed previously. No other significant relationships could be found for US and Europe manufacturing CDS.

4.6. Other Financial Companies 5-Year CDS

Returns on oil prices (at 5%) and incremental interest rates (at 1%) (no granger causality found) were positively and significantly related to Europe's other finance companies' 5 year CDS during the crisis period, indicating that as an oil importer, Europe was negatively affected by the increase of oil returns, and consequently, investors will perceive a higher risk. For the post-crisis period return on the stock index (at 1%) for US and Europe, oil prices returns (at 1%) for Europe were significantly and negatively related to Europe other finance companies 5-year CDS, whereas only stock index returns were negative and significantly (at 10%) related to US other finance companies' 5-year CDS, indicating the aforementioned inverse relationship.

4.7. Service Companies 5-Year CDS

The coefficient of returns on the stock index was positive and significantly related to the Europe Service Company 5-year CDS (no granger causality found), and negatively and significantly related to the US Service Company 5-year CDS for USA during the crisis period at 1% LOS, indicating that American Service companies are exposed to the inverse relationship between equity markets and perceived riskiness, while in Europe that relationship is more direct, most likely due to the differences in how the risk is perceived in the two continents. For the post-crisis period, returns on the stock index were negative, the return on oil prices (no granger causality found) was negatively, and the return on gold prices was positively and significantly related to the Europe Service Company 5-year CDS at 1%, 5%, and 1% respectively whereas returns on the stock index were negatively and significantly related to the US Service Company 5-year CDS, indicating that gold remains the safety commodity in times of crisis, while the other investments are affected by the perception of risk.

4.8. Telephone Company 5-Year CDS

During the crisis period, the stock index return was negative, and returns on oil prices were positively related to the US Telephone company 5-year CDS at 1% LOS, indicating that telephone companies were somehow exposed to the trend of oil prices, and were also exposed to the inverse relationships of equity and the fixed income market. For the post-crisis period, the return on the stock index and the return on the oil index were both negatively and significantly related to Europe

(no granger causality found). The telephone company 5-year CDS and the return on the stock index was negative (at 1%), and the return on the oil index was positively (at 5%) related to the US Telephone company 5-year CDS, indicating that when crisis was over, the relationship with oil became inverse, probably due to the fact that telephone companies may have also significant investments in the oil sector that benefit from an increase in oil returns.

4.9. Transportation 5-Year CDS

During the crisis period, returns on the stock index and the return on oil prices were both negatively and significantly related to the Europe Transportation 5-year CDS at 1% LOS, indicating that transportation sector is sensitive to oil changes, while only the return on the stock index was negatively and significantly related to the US Transportation 5-year CDS (no granger causality found) at 5%, indicating that changes in oil prices have no significant impact on the transportation sector CDS in the US.

5. Results of the Granger Causality Test

During the post-crisis period, we found one-way information flow from lagged changes in the stock index to changes in the US bank 5-year CDS and from lagged changes in the US bank 5-year CDS to changes in oil prices (no regression found), indicating that oil returns can be considered to be a cause of the changes in bank CDS spreads despite not showing a measurable correlation. This relationship was not present during the crisis period. As expected, for the during-crisis period, it appears that there were bidirectional causality and information flows between the change in US banks 5-year CDS and the change in interest rates (US fed funds rate), since both depend on macroeconomic conditions, by the same degree of relationship. It also appears that Granger causality runs one way from returns on gold prices to change in US banks 5-year CDS (no regression found) indicating that information flow is from lagged returns in gold prices to US banks, again indicating a causation relationship that is not sustained by a correlation measure. This causality disappeared during the post-crisis period, indicating that commodities in general have a lower driving power on financial returns and perceived risk.

For US consumer goods 5-year CDS, we found a bidirectional causality and information flow between changes in US consumer goods 5-year CDS and changes in interest rates. However, this relationship seemed to disappear during the post-crisis period, indicating that especially in times of crises, the movements in the interest rates determine the consumption and saving choice of the economic agents, thus affecting the profitability and perceived riskiness of consumer goods companies. We also found that during post-crisis period, there was one-way information flow from the lagged historical change in the stock index to change in the US consumer goods five-year CDS, and from lagged change in US consumer goods 5-year CDS, to changes in gold prices (no regression found). This was not found during the crisis period, indicating that in times of crisis, the role of gold is so important that it becomes a driver of the CDS spreads, even if this is not necessarily captured by a correlation measure, or regression.

During the post-period crisis, we found lagged values of returns in gold prices to cause information flow to change in US electrical company 5-year CDS (no regression found), which was not seen during the crisis period, indicating that the end of crisis probably pushes agents and companies to shift from gold to energy commodities, with a consequent impact on the relationship between those investments and the riskiness of the companies.

Historical or lagged stock index returns provided information about the change in CDS by Granger causing US energy companies 5-year CDS. There was also bidirectional causality and information flow between change in the US Energy Company 5-year CDS and change in oil prices. This was a predictable observation about the cyclical nature of the Energy Company's relation to oil prices. We observed similar results during the post-crisis period, indicating that the sector adjusts to changes in the economy quite slowly.

There was bidirectional causality and information flow between changes in the US manufacturing 5-year CDS and returns in stock index, and the US manufacturing 5-year CDS and changes in oil prices (no regression found) (not observed in case of Europe). This was also true for the post-crisis period, indicating no change in causality at a 1% level of significance. There was also bidirectional causality and information flow between changes in the US manufacturing 5-year CDS and changes in the interest rates (no regression found) (not observed in case of Europe), which was not observed during the crisis period, indicating that most probably, the American manufacturing sector is more leveraged than the European one, or it is simply more exposed to the fluctuating interest rates.

There was one-way causality where information flow comes from lagged returns in the stock index to change in the US other financial company 5-year CDS during the crisis period, and this relationship remained the same during the post-crisis period, indicating that the financial sector was probably heavily exposed to equity investments. There was also one-way causality between lagged changes in US other financial company 5 year CDS, and changes in interest rates and changes in oil prices. This relationship between the change in the US other financial company 5-year CDS and the changes in interest rates was reversed during the post-crisis period, as information started flowing from changes in the interest rates to changes in the US other financial company 5-year CDS (no regression found) (not observed in case of Europe), indicating that the intersection between the real economy and the financial economy becomes stricter during times of crisis, while relaxing in the periods after crisis. The relationship between changes in the US other financial company 5-year CDS and the change in gold prices disappeared during the post-crisis period (no regression found), indicating that the financial sector tends to disinvest in gold and other safety commodities when troubled periods are over.

There was bidirectional causality between change in the US telephone 5-year CDS and changes in oil prices, indicating a circular flow of information. This relationship continued during the post-crisis period, indicating that either the telecommunication sector was more exposed to oil more expected, or that companies in telecom tended to invest in oil derivatives. Also, lagged returns in the stock index caused change in US telephone 5-year CDS, continuing through the post-crisis period. Historical changes in interest rates caused information to flow to changes in the US telephone 5-year CDS during the post-crisis period, which was not observed during the crisis period (no regression found) (not observed in case of Europe), indicating that most probably, the sector waited for the crisis to be over before engaging in higher leverage in their capital structure.

There was also bidirectional causality between US transportation 5-year CDS and changes in interest rates (observed during the post-crisis period in the case of Europe). There was one-way information flow between the lagged returns on gold prices and the change in the US telephone 5-year CDS (observed during the post-crisis period in the case of Europe). Both the above relationships disappeared during the post-crisis period, indicating that the sector disinvested in gold after the crisis, and it remained less exposed to interest rates, possibly due to debt restructuring (no regression found).

Among other relationships, there was bidirectional causality between the returns on gold prices and the changes in interest rates, and this relationship continued during the post-crisis period, indicating that the demand and supply of money was driven by the corresponding demand and supply of gold. Also, there was a one-way information flow from returns on interest rates to changes in oil prices for both during- and post-periods, indicating that the sectors investing in oil were also exposed to interest rates, probably due to the floating nature of their debt.

Table 4 provides summary results of Granger causality tests during-crisis and post-crisis periods for Europe. During the post-crisis period, there was bidirectional causality between the change in the Europe bank 5-year CDS and the change in stock index. This relationship was not seen during the crisis period, indicating that banks may be heavily involved in the equity markets post-crisis period, as the average returns on stocks were below expectations during the crisis period. Similarly, there was a bidirectional causality between the change in the Europe bank 5-year CDS, and the change in oil prices (no regression found). This relationship was not seen during the crisis period, indicating that banks were probably not active in oil investment during the crisis, and they started investing in commodities

right after the crisis period. Also, during the post-crisis period, we found that a lagged change in the Europe bank 5-year CDS granger caused a return in gold prices (no regression found) (observed during crisis period in case of US), which was not previously found during the crisis period, indicating that, as for the oil, banks were disinvesting in gold progressively. Also, the lagged changes in interest rates caused a change in the Europe bank 5-year CDS, which disappeared during the post-crisis period, indicating that during crisis, investors are more keen to consider the banks as being strictly linked to the interest rates that affect their assets and liabilities.

During the post-crisis period, we found that returns on the stock index causing change in Europe consumer goods 5-years CDS and the lagged change in the Europe consumer goods 5-year CDS caused changes in oil prices (no regression found) (not observed in case of US). This was not observed during the crisis period, which indicates that at the end of the crisis the CDS spreads in the sector were affected by the revamping of consumption in the economy, while being totally disconnected during the crisis period. Also, there was bidirectional causality between the change in Europe consumer goods 5-year CDS and change in interest rates. This relationship disappeared during the post-crisis period, indicating that in time of crisis the interest rates were heavily driven by the reduction of consumption, which in turn affected the savings and investment habits of the consumers. Also, we found that lagged changes in gold prices caused changes in Europe consumer goods 5-year CDS during the crisis period (post crisis in regression) (observed during the post-crisis period in the case of the US), and this relationship also disappeared during the post-crisis period, indicating that there is an inverse relationship between gold investment and consumption, especially in times of crisis, due to the investors putting their money into a safe investment such as gold, rather than consuming.

There was information flow from the lagged returns in the stock index, to change in Europe electric power 5-year CDS, which was not found during the crisis period, indicating that investors are keen to allocate their fixed income investments based on the outcome of the equity market. This causality was found between returns on gold and the US electric power 5-year CDS, where return on gold granger causes the CDS spreads in US (not observed in case of Europe).

There was bidirectional causality between the changes in oil prices and the change in the Europe energy 5-year CDS at during- and post-crisis periods, indicating as expected, that oil prices have an impact on the profitability and consequently on the perceived riskiness of energy companies. There was a one-way causality between the lagged returns on stock index and changes in Europe energy 5-year CDS, which was not found during the crisis period, indicating that in times of recovering economies, the investors tended to give more importance to the outcome of stock markets. There was also bidirectional causality between the changes in Europe energy 5-year CDS, and changes in interest rates (no regression found) (not observed in case of US), which quickly disappeared during the post-crisis period, indicating that energy companies are exposed to interest rate movements that are normally observed during the crisis periods, due to a possible situation of floating debt. We also found a one-way causality between the lagged changes in gold prices and changes in the Europe energy 5-year CDS (post-crisis in regression) (not observed in case of US), which also disappeared during the post-crisis period, indicating that the commodity sector was broadly influenced by the price of gold, thus impacting on other types of commodities that affect the energy sector.

One-way lagged return on stock index caused a change in the Europe manufacturing 5-year CDS for both during- and post-crisis periods indicating that investors are sensitive to the changes in the stock market, when deciding on their fixed income investment opportunities (no regression found).

Lagged returns in stock index and changes in oil prices granger causes changes in Europe other than financial 5-year CDS for both during- (no regression found) and post-crisis periods, indicating that financial companies are most probably heavily exposed to both commodity and equity investments. There was bidirectional causality during the post-crisis period between changes in oil prices and changes in Europe other financial 5-year CDS which was not present during the crisis period (not observed in case of US), indicating that the financial sector probably started disinvesting in other commodities such as gold, and focusing more on oil investments. Also, information flows from

the lagged gold returns to the changes in Europe other financial 5-year CDS only in the post crisis period (no regression found) (observed at during-crisis period in the case of the US) indicating that, as mentioned above, there could have been a massive disinvestment in gold, thus causing the reaction of investors in terms of fixed income investments.

Lagged returns during the post-crisis period of stock market returns explained the change in the Europe service company 5-year CDS, which was not observed during the crisis period, indicating that investors focused on the stock market performance in normal economy, discarding the information coming from stock markets in times of crisis. Also, we found that information flowed from the lagged changes in the Europe service companies 5-year CDS for both during- and post-crisis period. The Europe service CDS in this section and below were not found in the case of the US.

The returns on the stock index (observed during the crisis period in the case of the US) and the return on gold prices (not observed in the case of the US) led the Europe telephone 5-year CDS (no regression found) in price discovery, and provided statistically significant information about the future values of the 5-year CDS in the post-crisis period, which were unobserved during the crisis period, indicating that right after the crisis, the investors in the sector were tied to investments in equity and gold, and probably dismissed them. Similarly, information flowed from lagged changes in Europe telephone 5-year CDS to the returns on oil prices during the post-crisis period, but not during the crisis period, indicating that for many investors the oil sector was most probably considered as a natural alternative to telephone sector (observed during the crisis period in the case of the US).

Lagged returns in the stock index and changes in gold prices granger caused changes in the Europe transportation 5-year CDS for both during- and post-crisis periods (no regression found), indicating that investors engaged in the sector have been always looking at the equity and gold markets, which have been probably perceived as good alternatives to transportation. Also, the lagged changes in the Europe transportation 5-year CDS granger-caused the changes in oil prices for both during- and post-crisis periods (not observed in the case of the US).

Among other relationships, there was a bidirectional causality between the returns on gold prices and the changes in interest rates during the crisis period, but this relationship did not continue during the post-crisis period, where information flow was from the lagged change returns in gold price to changes in the interest rates, indicating that during a crisis, gold prices have been driven by the investment vs consumption choices of the investors, while after crises the two elements have been disconnected. Also, there was a one-way information flow from returns on the stock index to changes in oil prices, for both during- and post periods, indicating that commodity investors have been selecting their investments based on the profitability of the equity portion of their portfolios.

Table 5 shows the results of pair-wise granger causality tests for during- and post-crisis periods for nine different sectors between Europe and the US. We observed a two-way causality between the US bank 5-year CDS and the Europe bank 5-year CDS during the crisis period, but only a one-way information flow from the Europe bank 5-year CDS to the US bank 5-year CDS, only during the post-crisis period, indicating that price discovery occurs from European banks, and the information flow is to US banks.

The price discovery came from the European consumer goods 5-year CDS during the crisis period, but it changed direction, with the information flow coming from the US consumer goods 5-year CDS post-crisis period.

We observed a two-way causality between the US electric power 5-year CDS and the Europe electric power 5-year CDS during the crisis period, but this disappears in the post-crisis period, indicating that during the crisis, the US and Europe energy markets were heavily tied due to the nature of their oil importers, and their consequently common sensitivity to the changes in oil prices.

The price discovery came from the US Energy Company 5-year CDS to the Europe Energy Company 5-year CDS during the crisis period, but it disappeared during the post-crisis period, indicating that in times of crisis, the perception of riskiness of fixed income investments is subject to a higher level of contagion, which spreads uncertainty over different areas of the world.

The European manufacturing and other financial 5-year CDS led in price discovery over the US manufacturing and other financial 5-year CDS during the post-crisis period and not during the crisis period.

6. Conclusions

In this paper, we analyze the relationship between selected regional and sector-wise CDS spreads for three macroeconomic variables and the return on stock index. We select the US and Europe as the regional variables, and oil, gold, and interest rates as the three macroeconomic variables. We run regression equations where the sector-wise CDS spreads are the dependent variable and the three macroeconomic variables, combined with the return on stock index, are independent variables. We also test for Granger causality during the crisis and the post-crisis periods between nine different sectors in the US and Europe, and independent variables.

We observe a decrease in the stock returns index for the post-crisis period, resulting in higher CDS spreads. The Granger causality results show that equity markets lead in price discovery, where information flow comes from the equity markets to the nine different sector CDS. There is also a positive relationship between the interest rate differential and CDS spreads for four sectors. The Granger causality results show bidirectional causality between interest rate and CDS spreads. We also find that three European sectors hedge the CDS spread risk with gold returns. For energy companies, oil and gold are substitutes, where there is an inverse relationship between oil and gold returns. There exists an inverse relationship between oil and four different sector CDSs, including the transportation CDS. This may be due to investments by the sectors into oil companies. There is a bidirectional causality between stock and oil returns to CDS spreads.

We also conduct pair-wise Granger causality tests between both of the regions for all of the nine sectors. We find there is bidirectional causality between the US banks and the European Bank CDS. This disappears in the post-crisis period where the Europe Bank CDS leads in price discovery. The price discovery between the US and Europe consumer goods CDS is reversed from during- to post-crisis period. There is bidirectional causality between the US and Europe electrical power CDS during the crisis period, and the causality disappears during the post-crisis period. The US energy companies lead in price discovery during the crisis period, and this disappears post-crisis.

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