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Contagion Inside the Credit Default Swaps Markets in Light of the 2008 Crisis

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Abstract:

In large parts of literature, an increase in correlation coefficients of returns across countries is regarded as evidence for contagion in financial markets. This paper checks this hypothesis in the Credit Default Swaps (CDSs) markets. We construct a sample of 43 CDSs on major U.S. and European financial institutions. Then we study the effect that five financial institutions (four American and one Icelandic institution) in their role as CDS market players have on the whole CDS market as the institutions entered either into bankruptcy (Lehman Brothers, Landsbanki Bank, and Washington Mutual) or passed through trouble periods (Merrill Lynch and Bear Stearns) in 2008. We remark a contagion effect for the failure of Lehman Brothers and Landsbanki, a competition effect for Washington Mutual, a small decrease in the correlation coefficient for Merrill Lynch, and a small increase in the coefficient for Bear Stearns.

Key words: Credit Default Swaps, correlation coefficient, contagion effect, competition effect.

Introduction

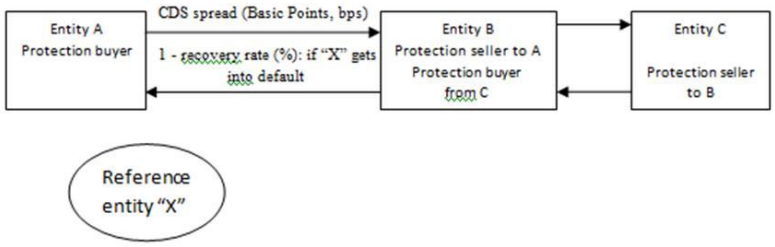
Since its first standardized contract version in 1998, the CDS market was experiencing an expansion. According to a survey by the International Swaps and Derivatives Association ISDA (April 2010), the market went from $918 billion in 2001 to an outstanding gross notional amount of $62.2 trillion by the end of 2007, falling to $38.6 trillion by the end of 2008. The period from 2004 to 2007, during which the Credit Default Swaps evolved as the main credit derivative instrument, was characterized by low financial market volatility, financial and insurance sector growth, and stable interest rates. However, the financial turmoil in 2008 has clearly shown the influence of unregulated over-the-counter "OTC" instruments on financial stability.

We draw your attention to two points. First, this market is concentrated around a few major players. According to June 2009 statistics taken from the Depository Trust and Clearing Corporation DTCC, five large financial institutions (JP Morgan, the Goldman Sachs Group, Morgan Stanley, Deutsche Bank, and the Barclays Group) were counterparties to almost 50% of the total notional amounts of contracts. Besides, the market forces are concentrated in the hands of financial institutions and are interconnected with each other through a chain of OTC derivative contracts.

As banks and all Financial Institutions "FI" have massively committed themselves in the CDS market, they are now highly dependent on market continuity and its smooth functioning. The failure of a major participant, can put at stake all the other players. In other words, due to the high degree of concentration and interconnectedness, counterparty risk is remarkable. Due to the OTC nature of the CDS market, each buyer negotiates with a seller directly, without global clearing. The buyer thinks he escapes from the default risk of reference entity (say X), but he is still exposed to the counterparty risk of the CDS seller. What aggravates the counterparty risk is also the technique of offsetting risk which creates a chain interaction, as illustrated in Figure 1 below.

Figure1

How an entity offset its counterparty CDSs' premium volatility risk



This chart describes the techniques of offsetting CDSs' premium risk. Entity "B" offsets its risk by purchasing a CDS from "C." There is no limit for this technique. In its turn "C" may undertake an additional hedging transaction by concluding an offsetting position contract with another party "D," the latter could also offset its positions etc. Thus, a chain of linked exposures will originate in which the market participants know their immediate direct counterparties, but not the other market players.

According to this figure, we can identify at least three different channels of counterparty risk. The first source is through jump risk or jump to default risk when the reference firm underlying the CDS contract defaults, especially if the financial problem is unanticipated. The second channel is through mark-to-model changes in CDS prices. The third counterparty risk in CDS markets is through the collateral channel (mainly through collateral rehypothecation).

Since the start of the crisis, the CDS market has been especially affected. Premia have been driven upward (see Figure 2), reaching all-time peaks.

Figure 2
The evolution of CDS iTraxx Europe premium and
CDX North American Investment Grade from March 2007 to September 2009

Source: Bloomberg - Authors' Calculations

Accordingly, our main aim in the article is to concentrate empirically on the first and the second channels of counterparty risk. In other words, does counterparty risk in Credit Default Swap markets constitute a channel of contagion of the type "cascade effects" to the financial system? To our knowledge, this is the first paper trying to assess counterparty risk through the question of contagion in two different markets.

To answer the question, we will analyze the effect of bankruptcy announcements on credit default swap spreads of creditors. More concretely, we check the effect of U.S. financial institutions credit events during 2008 and the effect of their bankruptcies on their local CDS markets and on European CDS markets as well. The year 2008 is ideally suited for studying and analyzing the effects of counterparty credit risk on financial markets as the fear of counterparty risk reached its peak.

The remainder of the paper is organized as follows. The first section briefly discusses the relevant literature. Data selection, research methodology, and empirical models are described in the second section. The fourth section analyzes and interprets the empirical findings. The last section concludes the paper with a brief summary and some areas in which future work along the same lines would be useful.

Literature review

The paper is related to the literature on financial contagion by focusing empirically on counterparty credit risk effects on CDS markets. This market is considered one of the most interconnected and concentrated markets (DTCC statistics, June 2009). The major CDS contracts are concentrated in the hands of financial institutions (Bank of international settlement "BIS" statistics, April 2009).

There is still wide debate among experts about the definition and the causes of contagion inside the CDS markets. The theoretical literature about why contagion can occur is mainly divided into two broad groups: the fundamental causes (common shocks, trade linkages and financial linkages) (Van Rijckeghem & Weder (2001) have concluded that the main source of financial contagion is due to financial linkage among countries and markets. A shock in a country can reduce its ability to supply bank lending and other forms of investment to a second country) and investors' behavior such as liquidity problems, informational asymmetries, market coordination problems and investor reassessment (Moser (2003) conducted a survey on financial contagion from an investor's behavior view).

Kaminsky, Reinhart, and Vegh (2003) have shown the main strands of financial contagion, such as speculative attacks and banking crises.

Contagion is generally characterized by increased co-movements in the returns of risky assets, followed by an initial drop in one specific market or a group of markets[1] (Forbes and Rigobon, 2002, Corsetti et al., 2005).

Jorion and Zhang (2007) have tested the effect of counterparty risk on financial stability. They chose a multi-industry sample of American institutions filing chapter 11 and 7 bankruptcies during the period from 2001 until 2004. Then, they checked the effect of these institutions' credit events on the American CDS market. A correlation test between counterparty credit event and CDSs premium around the event date showed a net dominant contagion effect for chapter 11 bankruptcies and for jump events (with the difference that the effect is stronger for the latter). However, their test indicated a net competition effect (anticorrelation) for chapter 7 bankruptcies. In this case, the liquidation of one competitor may result in a favorable competitive effect. These results confirm the works of Lang and Stulz (1992), who have studied the repercussions of bankruptcy announcements on the stock market.

In a related work, Jorion and Zhang (2009) have selected a sample of 250 public bankruptcies from 1999 to 2005 to analyze their impact on stock prices and CDSs for industrial and financial institutions. They found that the counterparty risk effect is stronger for the industrial sector than for the financial one for many reasons such as recovery rate and expertise risk management. They concluded that counter-party risk is a potential channel of credit contagion.

In a recent article, Coudert and Gex (2010) used the case of the General Motors and Ford crises in 2005 to see if credit derivatives markets are particularly susceptible to contagion effects. To confirm or refute this hypothesis, they took a sample containing daily CDS data in two main markets: North American "CDX indices" and European "iTraxx" from January 2004 to January 2007. Then, the authors calculated correlation coefficients, using different methods in order to cross-check the results: the global index correlations, intra-sectoral correlations between CDSs, correlations between firm's CDSs and those of GM and Ford before and during the crisis, adjusted correlations "shift contagion" (to take into account the volatility impact during the crisis period) as defined by Forbes and Rigobon (2002). Their main results show a contagion effect in CDS markets in the sense of a significant rise in correlations during the crisis period.

Our paper adds a contribution to the literature by presenting additional empirical evidence of the effect of counterparty risk on the CDS market by checking the contagion effect intercontinentally on two major markets. Our analysis will check whether we can also observe a rise of correlations during the crisis period as Coudert and Gex did.

While we base our methodology on Coudert and Gex (2010), our paper constitutes an extension of their achievement in that we select a different period of time (March 2007 to September 2009) and focus on a different sector type. Our principal focus will be on American (and one Icelandic) financial institutions going through either default or experiencing a difficult period in 2008 and their impact on the CDS financial market. The crisis period is long enough to include a sufficient number of observations. This was not the case in (Coudert and Gex 2010) work where the CDS market's response to the GM and Ford crisis was very prompt.

Data and Methodology

Data

The necessary information concerning credit events including chapter 11 "reorganization," chapter 7 "liquidation" and jump events has been collected from the website www.bankruptcydata.com, which was also used as a source by Jorion and Zhang (2009). It provides instant access to extensive information on business bankruptcy filings from federal bankruptcy districts. Using Bloomberg as a source, we found the necessary data for three big FI going into default in 2008: *Lehman Brothers*, *Landsbanki,* and *Washington Mutual, Inc*. Additionally, we added *Merrill Lynch* and *Bear Stearns* because they represent entities that were acquired by other institutions as a result of passing a difficult period in 2008. Bank of America purchased Merrill Lynch, and JP Morgan acquired Bear Stearns in a rescue effort partly financed by the Federal Reserve Bank of New York.

We measure the effect of the credit events on CDS prices by observing CDS indices. In June 2004, a harmonized global family of CDS indices was launched by Markit Group, namely CDX in North America and iTraxx in Europe and Asia. The release of this credit index family provides a commonly accepted benchmark for credit markets where investors express their bullish or bearish expectations for an asset class. The difference between the indices and single name CDS is that the indices represent the CDS premium on an equally weighted basket of the currently most

[1] We will use this definition in this paper. Accordingly, if two markets show a high degree of co-movement during stability period, even if the markets continue to be highly correlated after a crisis, this may not constitute contagion (Forbes and Rigobon, 2002).

actively traded firms (125 for iTraxx Europe main and CDS NA IG) from different sectors: energy firms, industrial entities, consumer cyclical and non-cyclical firms, insurance companies, banks, telecoms, and automobile firms.

We took the Main 5-year CDS spread, as the 5-year maturity is the most widely traded and liquid index. The spreads are denominated in basis points (100 basis points equal to 1 percentage point). We are concerned about financial entities included in the indices plus the five originator reference entities (Lehman Brothers Holdings Inc., Landsbanki Islands hf., Washington Mutual Inc., Bear Stearns, and Merrill Lynch). The underlying reference entities are senior single name contracts.

For the period March 2007-September 2009, we used the iTraxx series 7, 8, 9, 10, and 11. For CDX NA IG, we used the series 8, 9, 10, 11, 12.

We used the Bloomberg database to obtain the daily last price CDS premium of the reference entity and for entities included in the series[2].

To prevent bias of our sample entities, we included the CDS entities present in all series during the entire period under review.

Methodology

By using Augmented Dickey-Fuller t-statistics (ADF), we remark that almost all CDS premium in our sample have a unit root (see table 1).

Table 1
Unit root test using ADF test

	t-Stat		t-Stat
United States	**23 companies**	**Europe**	**20 companies**
Originators	5	Financials	20
Lehman Brothers Holdings Inc.	-0.963	Aegon NV	-1.362
Landsbanki Islands hf.	-3.648	Allianz SE	-2.025
Washington Mutual Inc.	3.074	Assicurazioni Generali SPA	-1.461
Merrill Lynch	-1.988	Aviva PLC	-1.488
Bear Stearns	-3.467	AXA	-0.951
		Banca Monte dei Paschi de Siena SPA	-2.063
Financials	18	Banco Bilbao Vizcaya Argentaria SA	-2.413
ACE Limited	-2.102	Banco Espirito Santo SA	-2.247
Aetna Inc	-1.188	Banco Santader Central Hispano SA	-2.322
The Allstate Corporation	-0.926	Barclays Bank PLS	-1.869
American Express Comp.	-0.486	BNP Paribas	-2.538
American International Group, Inc	-2.444	Commerzbank AG	-2.719
Capital One Bank	-3.186	Deutsche Bank AG	-2.953
The Chubb Corporation	-2.225	Hannover Rueckversicherung AG	-1.898
CIGNA Corporation	-1.085	Intesa Sanpaolo	-1.695
CIT Group Inc	-2.867	Muenchener Rueck AG	-2.047
General Electric Capital Corporation	-0.543	Swiss Reinsurance	-0.324
The Hartford Financial Services Group	-1.116	The Royal Bank of Scotland PLC	-3.06
International Lease Finance Corporation	-1.246	Unicredito Italiano SPA	-2.11
Loews Corporation	-1.527	Zurich Insurance Company	-1.306
Marsh & McLENNAN Companies, INC.	-2.061		
Metlife, Inc.	-1.058		
Simon Property Group, L.P.	-0.273		
Wells Fargo & company	-1.401		
XL Capital LTD	-0.723		
Total		**43 Companies**	

[2] Bloomberg aggregates the prices of several contributors.

Therefore, before calculating volatility and correlations, we should make our data stationary by using their log first differences x_t^i (Acharya and Johnson 2007):

Formula 1

$$x_t^i = \log(c_t^i) - \log(c_{t-1}^i)$$

Where, c_t^i= the CDS premium of firm i, i (in our case) = 1, 2,…, 43 for period t. The resulting x_t^i series are then stationary and comparable to financial asset returns. When CDSs premia fluctuate in line with each other, it means a positive correlation and vice-versa.

As crisis periods are generally characterized by a high volatility, the next step is to calculate the daily volatility (Coudert and Gex 2010) for the reference entities taken into account in order to split our period into three sub-periods (pre-crisis, crisis and post crisis period).

We set out to test the hypothesis of an increase in correlations between the CDSs during the financial turmoil period. Thus, we move to calculate the correlation to check the relationship between the two main variables: the credit financial institution event and the CDSs premiums taken from the indices, and compare them between the pre-crisis and crisis periods. If they rise significantly during the crisis, we can deduce a contagion effect. Otherwise, it will be a competitive effect (Jorion and Zhang 2007). For this purpose, we will use first the Pearson correlation coefficient ρ or r:

Formula 2

$$\rho_{x,y} = \text{corr (X,Y)=corr(Y,X)=}\frac{Cov(X,Y)}{\sigma x \sigma y}=\frac{E[(X-\mu x)(Y-\mu y)]}{\sigma x \sigma y}$$

Then, we can analyze and interpret the result:

+1 in the case of a perfect positive (increasing) linear relationship (correlation),

- 1 in the case of a perfect decreasing (negative) linear relationship (anticorrelation),

Some value between -1 and 1 in all other cases, indicates the degree of linear dependence between the variables. As it approaches zero there is less of a relationship (closer to uncorrelated). The closer the coefficient is to either -1 or +1, the stronger the correlation between the variables.

Notice that if the variables are independent, Pearson's correlation coefficient is 0, but the converse is not true because the correlation coefficient detects only linear dependencies between two variables.

Identification of the crisis period

We calculate and use volatility to identify the crisis period because financial crises are usually characterized by a rise in volatility (Acharya et al., 2008; Beltratti and Morana, 1999). For this aim, we have used the Exponential Weighted Moving Average "EWMA" method to calculate volatility for many reasons:

- It is clear using the daily CDSs prices for the reference entity that the models used to calculate the volatility will be models with non-constant volatility as there is a huge deviation between the minimum and maximum CDSs values. Thus, we cannot use models that assume that volatility is constant over time and assign an equal weight to each day's return. An important point to bear in mind is that among the five financial institutions there are three companies which ceased to exist: Lehman Brothers Holding Inc. and Washington Mutual, Inc. left the market on September 2008. Landsbanki Islands hf. ceased to exist on December 9th2008. For these companies, there will be no post-crisis periods. Thereby, we will compare the correlation coefficient between them and the other financial institutions in our sample just before and during the crisis;
- Concerning the models with non-constant volatility, there are the EWMA and (G) ARCH models. We compare the equations for EWMA and GARCH:

Formula 3

$$\sigma = \sqrt{\lambda\sigma_{t-1}^2 + (1-\lambda)X_t^2} \quad \textit{(EWMA)}$$

Formula 4

$$\sigma = \sqrt{\omega + \beta\sigma_{t-1}^2 + \alpha X_{t-1}^2} \quad \textit{(GARCH)}$$

Where:

λ= decay factor, $0< \lambda < 1$. We will put a fixed value of 0.94 on our sample of daily CDS premia following the one found by Morgan (1996) on a sample of several financial markets;

$1 - \lambda$= parameter defining a relative weight which is applied to the last return;

σ= a dispersion estimate for the day calculated at the end of the (n-1) day;

σ_{t-1}^2= a dispersion estimate for the day n-1;

X_{n-1}= CDS premium for the day (n-1).

β in GARCH is equivalent to λ in EWMA; λ in GARCH is equivalent to $(1 - \lambda)$ in EWMA. Therefore, EWMA is a special case of GARCH with a zero constant and where the persistence is equal to 1.

- Additionally, several studies (Beltratti and Morana 1999; Berkowitz and O'Brien 2002; Ferreira and Lopez 2005) have concluded that the EWMA model performs better than other methods to estimate volatility (such as historical volatility, Parkinson Historical Volatility, Implied Volatility) especially for time series data.

The EWMA formula can be rearranged as the following:

Formula 5

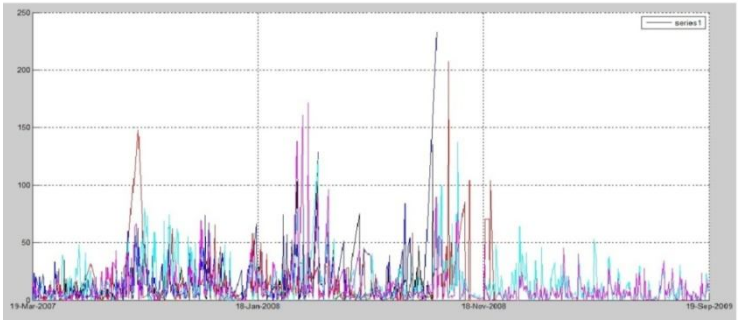
$$\sigma_{\mathrm{n}}^2 = (1 - \lambda) \sum_{t=1}^{1} \lambda^{t-1} * r_{n-1}^2$$

Thus, the older returns bear lower weights.

The results show (see Figure 3) a sudden jump in volatility for almost all companies in March 2008: CDS volatility went from 50 to 170 basis points (almost 3.4%). Volatility remained high until the end-December 2008.

Figure 3

Volatility of the five originator American Financial Institution (in %). Dotted lines stand for especially the year 2008 ((20 January 2008 to December 2008). Source: Bloomberg. Authors' calculations.



—— : Lehman Brothers; —— : Landsbanki; —— : Merril Lynch;

—— : Bear stearns; —— : Washington

If we consider that crisis periods are correlated with periods of high volatility, we can conclude that the crisis period begins with the jump in volatility at the end of August 2007, which coincides with Lehman's announcement to close one of its home lending units "BNC Mortgage" and to terminate 1,200 employees.

Consequently, we can divide the sample into three sub-periods:

- Pre-crisis period: this period corresponds to the period when premia and volatility were particularly low from March 2007 (20 March 2007) to the end of July 2007: this relatively short reference period (4 months

and 11 days) meets the work of Dungey (2001): he found that correlation tests might be biased if the reference period "pre-crisis" is too large;

- The crisis period extends from the beginning of August 2007 until the end of September 2008. It should be noted that August 9, 2007, was the date when BNP Paribas suspended redemptions worth $2.2 billion of assets-backed funds. About 14 months later, in middle of September 2008, Bank of America announced the purchase of Merrill Lynch and Lehman Brothers filed for Chapter 11 bankruptcy ;
- Post-crisis period: it corresponds to the stage when CDS premia (figure 3) and volatility calm down. It comprises the period of beginning of October 2008 to the end of our duration period (20th September 2009): 1 year;

Empirical results

Summary statistics

Table 2 shows our summary statistics, and we can notice the following:

- The big deviation between the minimum and maximum CDS value
- The high standard deviation for all variables

Table 2

Summary statistics of our sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Reference Entities Financial Companies					
Lehman Brothers	388	152.4366	111.9987	29.418	641.911
Landsbanki	446	425.0641	480.0157	18.533	3006.693
Washingtom	387	316.1952	360.1252	28.431	3350
Merril	653	192.6019	120.5928	24.548	561.907
BearStearns	653	122.6502	73.56415	30.313	727.143
CDX NA IG Financial Institutions					
Ace Limit.	653	75.13761	38.95393	22.149	197.4
Aetna Inc	653	73.4896	40.56169	12.587	194.125
The allstate corp	653	115.5483	101.3172	11.158	410.051
American Express	653	204.313	170.5431	10.827	685.747
AIG	653	664.0123	792.4872	10.525	3758.987
Capitalone Bank	653	297.4296	111.2386	72.767	562.764
The Chubbcorp	653	61.08909	32.4896	11.267	180.511
CIGNA Corp.	653	111.1651	85.98804	15.209	382.111
CIT Gr.	653	1002.168	1095.432	36.7	6054.679
General Elec.	653	264.6817	234.1034	12.851	1000.263
Hartford Financial	653	316.0017	307.2867	11.233	1122.27
International Lease	653	512.8602	488.1274	16.2	1785.535
Loews	653	50.03602	25.47468	11.264	111.114
Marsh & McL	653	67.72838	19.6051	35.264	135.561
Metlife	653	285.9012	267.1025	10.998	961.692
Simon	653	246.417	227.993	16	876.434
Wells Fargo & CO.	653	98.67953	68.69943	8.15	304.125
Xl Cap Ltd	653	373.437	322.7608	26.25	1163.65
iTraxx Europe Financial Institutions					
Aegon	653	175.4613	140.9265	9.05	608.25
Allianz SE	653	68.40126	38.41804	8.233	190.809
Assicurazioni Gen.	653	68.61537	42.02684	5.818	198.325
Aviva PLC	653	129.8951	100.3657	6.86	494.15
AXA	653	101.5555	65.13498	9.1	270.485
Banca Monte dei	653	68.49795	37.57013	6.125	168.995
Banco bilbao	653	71.50035	39.72083	7.722	181.066
Banco Espirito	653	88.628	49.03127	8.6	228.325
Banco Santander	653	72.71382	40.33031	7.622	179.851
Barclays Bank	653	98.15929	63.19666	6.15	261.122
BNP Paribas	653	52.25914	28.35143	5.7	139.358
Commerzbank	653	72.82646	36.44798	8.16	164.497
Deutsche Bank	653	79.50057	42.12874	9.82	171.996
Hannover Rueck AG	653	58.5788	29.77614	10.36	146.795
Intesa Sanp.	653	60.81729	40.11079	5.761	200
Muenchener	653	47.85994	23.39198	7.354	128.238
Swiss reinsurance	653	206.4463	203.389	9.688	841.625
Royal Bank of Scotl	653	100.0222	64.21892	5.477	304.893
Unicredito Italian	653	80.46538	51.45806	7.478	276.234

Table 2 shows the results of the author's calculations, based on Bloomberg. We remark that all the entities, apart from the reference entities, have the same number of observations (653). When we found a missing day value, we usually put the value of the day before as an approximation.

Correlations between firms' CDS and those of the five reference entities

Instead of calculating the correlation coefficient for each CDS institution with the reference entities, we calculated an average value for iTraxx European and CDX NA IG Financial Institutions taken in the sample and then calculated the correlation coefficient during period 1 (pre-crisis), period 2 (crisis), period 3 (post-crisis) and for the whole period.

Table 3

Correlations coefficient between the five reference entities and the sample of European and North American Financial Institutions during period 1 (pre-crisis period): 20 March 2007 to 31 July 2007 (number of observation=95)

	Lehman Brothers	Landsbanki	Washington Mutual	Merrill Lynch	Bear Stearns
iTraxx Europe FI[3]	0.3262	0.0644	0.5576	0.4283	0.3952
CDX NA IG FI[4]	0.3164	0.0603	0.3963	0.3680	0.4524
Global index[5]	0.3963	0.0773	0.6144	0.4997	0.5102

Data taken from Bloomberg database. Authors' arrangement of the data (to make each entity observation equal, number of observation are equal for all entities "95") and correlation calculation. *All CDS entities have equal number of observation, number of observation equal to period 1 to 262. When we find a missing value we usually put the same value as the day before.*

Table 4

Correlations coefficient between the five reference entities and the sample of European and North American Financial Institutions during period 2 (crisis period): 1th August 2007 to End Septmeber2008 except Landsbanki till its last CDS value on the third of December 2008

	Lehman Brothers	Landsbanki	Washington Mutual	Merrill Lynch	Bear Stearns
iTraxx Europe	0.3424	0.1651	0.0727	0.3303	0.4104
CDX NA IG FI	0.6324	0.1745	-0.0652	0.2657	0.5193
Global Index	0.5518	*0.3185*	*0.0954*	*0.3453*	*0.5842*

- *Lehman Brothers number of Observations is 292;*
- *Landsbanki Bank number of observations in this period is 350;*
- *Washington Mutual, Inc. number of observations is 294;*
- *Merrill Lynch and Bear Stearn number of observations is equal to 304 observations*

Table 5

Correlations coefficient between the two left financial which survived the crisis by getting acquired by other entities (JP Morgan acquires Bear Stearns on March 24th 2008. The operation was partially financed by Federal Reserve Bank of New York; on September 15th 2008 Bank of America announces the purchase of Merrill Lynch)

	Merrill Lynch	Bear Stearns
iTraxx Europe	0.0151	0.3789
CDX NA IG FI	0.2794	0.4663
Global Index	0.1568	0.5042

Number of Observations is equal to 253 numbers.

[3] It is the daily average of the sample of 20 Financial institutions
[4] It is the daily average of our sample of 18 American Financial Institutions. There are a lot of missing values for Capital One Bank Financial Institutions.
[5] Index composed by all the CDS in the sample except the five reference entities (Lehman Brothers, Landsbanki, Washington Mutual, Merrill Lynch, Bear Stearns)

By checking the results in tables 3, 4, and 5; we can derive the following observations:

I. For the period before the crisis

In general, we remark a significant correlation coefficient between the reference financial institutions entities and both European (iTraxx financial) and North-American (CDX NA IG FI) markets, except for Landsbanki as it was not a major player on CDS markets:

- The high correlation coefficients among Lehman Brothers, Washington Mutual, Merrill Lynch and Global index CDS (39%, 61%, and 49% respectively) are expected. According to GFI consulting group statistics from May 2008, these three financial institutions "FI" in addition to CIT and Fannie Mae were the most actively traded CDSs on the U.S. market.
- However, what is impressive is that the impact of these FI is bigger on foreign markets than on their local market. We remark that the correlation coefficient (see table 3) is bigger for iTraxx Europe FI index than CDX NA IG FI. These results show clearly the high degree of interconnectedness in CDSs markets.
- For the relation between the second originator company (Landsbanki) and the CDS indices, the coefficient correlation is not as high as other company effects (6.44% for iTraxx and 6.03% for CDX). This may come to the reason that Landsbanki is not a major and active CDS player, unlike the other institutions;
- As Bear Stearns is also an active player on the CDS market, the coefficient ρ is also relatively high on both the European and local market (39.5% and 45.24% respectively). Nevertheless, we remark that the coefficient correlation of Bear Stearns on its home market is bigger (45.24%) than that of Lehman (31.64%), Washington Mutual (39.63%), and Merril Lynch (36.80%). There is a relatively large gap between the figures of Bear Stearns and Lehman, amounting to a difference of 13 percentage points.

II. For the crisis episode

If we look on our calculation for the impact of credit events on European and North American CDS markets, we observe the following:

- For the Lehman bankruptcy's impact on the CDS market, we can easily notice that the effect on its local market is much bigger than that of the European FI CDS market (63.24% for CDX NA IG and 34.24% for iTraxx Euroope: almost double) (see the second row of table 4). The correlation coefficient on Lehman brothers' local market during the crisis period has increased twofold, which implies a sign of contagion on the other FI in North American market. However, the ρ before and during the crisis period for Lehman on the European market increases but not as significantly as we have expected (it goes from 32.62% to 34.24%): a variation for just 5 percent. The local contagion impact created by the failure of Lehman confirms the result of Jorion and Zhang (2007), who stated that when a credit event is unanticipated by the market, it will create a contagion impact. The bankruptcy of Lehman Brothers has also affected the European Market but not as much as its home market.
- We notice a remarkable increase in the correlation coefficient for Landsbanki on both the European and North American markets. It goes from 6.44% to 16.51% (an increase of almost 10 percentage points) on iTraxx index and from 6.03% to 17.45% on CDX NA IG (an increase up to 11.42 percentage points). We can conclude from these numbers that even if a FI is not a major player in the CDS market, its unanticipated failure affects both markets;
- We observe a big and significant decrease in ρ for the effect of Washington Mutual bankruptcy on the CDS market. It dropped from 61.44% to 9.5% (last row, third column in tables 3 and 4). On iTraxx Europe, ρ went from 55.76% to 7.27% (a decrease of almost 50 percentage points). On the local market, the correlation ρ decreased by almost 46.15 percentage points. These results also confirm the work of Jorion and Zhang (2007). By making a correlation test between counterparty credit risk event and CDS premium around the period of the credit event, they showed a net competition effect (anticorrelation "narrower CDS spreads") for anticipated credit events. The downfall of Washington Mutual, Inc. has been widely

anticipated for some time because of the company's heavy mortgage-related losses. One month before its collapse on 25 September 2008, it suffered a rating downgrade by S&P[6];

- We see a decrease in the coefficient of correlation for Merrill Lynch (table 4). It went from 42.83% to 33.03% on iTraxx Europe and from 36.80% to 26.57% on CDX NA HY. It decreases on both markets by almost 10 percentage points. This may be due to the fact that the failure of Merrill Lynch and its purchase by Bank of America was expected by market players. The reason is that the market was reassured that this FI would not be left to liquidation as Lehman: "As the financial world crumbled around it, venerable brokerage firm Merrill Lynch & Co. sought refuge and agreed to be taken by Bank of America in an all-stock deal that could be worth $50 billion, but investors seemed cool to the idea by the time the markets closed Monday[7]", "unlike Lehman, which has a mainly institutional client base, Merrill is a household name. A more dramatic run on that institution could create even more fear in the markets than the panic created by Lehman's slow collapse"[8][9];
- Concerning Bear Stearns' credit event impact, the coefficient of correlation around the crisis episode has increased. On the European market, it passed from 39.52% to 41.04% (an increase of 2 percentage points). On CDX indices, it went from 45.24% to 51.93% (increase of 6 percentage points). This relatively small increase in correlation coefficient may be due to the fact that market players were relaxed as the government stepped in to save Bear Stearns on March 24, 2008 when JP Morgan acquired Bear Stearns in a rescue attempt partially financed by the Federal Reserve Bank of New York[10]";
- Overall, by comparing the pre-crisis and crisis period correlation coefficients, we remark an increase for the Lehman Brothers and Landsbanki failures as well as a small increase for the Bear Stearns credit event. There was a decrease for Washington Mutual Bank and Merrill Lynch bankruptcies, which could be due to mitigating factors that may have calmed the markets.

III. For the period after the crisis

The coefficient correlation decreases for the two financial institutions on both the U.S. and the European markets. This is a sign that the market returned to calmness. In another words, the measure of dependencies between the variables returns to a normal "non-turbulence period." What is remarkable is that the coefficient of Merrill Lynch on iTraxx indices dropped so significantly. It decreased from 33% to 1.51%. This result is important in order to understand the big impact of counterparty risk on CDSs markets.

Conclusion

In order to answer our main research query, whether the counterparty risk in CDS markets constitutes a channel of contagion, we empirically checked the effect on the CDS market of big American and Icelandic financial institutions that were subject to either liquidation or acquisition by other institutions. As long as the financial system was sound, there was no fear that counterparty risk could be a problem. However, when one major player in the CDS market fails, especially if its failure is unanticipated by the market, the fear of a domino impact reached its peak. This issue stems from the OTC nature of this market and the high degree of connectedness. Each buyer negotiates with a seller directly, without global clearing. The buyers think they escape from the default risk of a company, but they are still exposed to the counterparty risk of the CDS seller.

Our results confirm the hypothesis of contagion in the CDS markets, particularly in the case of Lehman Brothers and Landsbanki. The data for other financial institutions yield a different behavior of the correlation coefficients. However, those cases were accompanied by circumstances that might have mitigated market nervousness and concerns. However, there is room for future work concerning the methodology, as the standard correlation coefficient used in this paper neither takes into account heterogeneity, nor the assumption of non-normality distribution of the data, nor the high impact of volatility on asset prices during the crisis period. According to Forbes and Rigobon (2002), if the volatility of one asset increases noticeably, its correlation with the other assets will

[6] Washington Mutual collapses in biggest bank failure in U.S. history. Bank fails due to weight of enormous bad bets on mortgage market; U.S. bailout deal talks break down. By the Associated Press. Published 26.09.2008.
[7] "Fearing collapse, Merrill Lynch sells out to Bank of America." By Russ Britt, John Spence and Robert Daniel. Marketwatch.com
[8] Andrew Ross Sorkin (September 14, 2008). "Bank of America in Talks to Buy Merrill Lynch". The New York Times.
[9] See also: LOUISE STORY and JO BECKER (June 11, 2009)."Bank Chief Tells of U.S. Pressure to Buy Merrill Lynch". New York Times. Retrieved June 13, 2009; Scott Lanman and Craig Torres (June 10, 2009)."Republican Staff Says Fed Overstepped on Merrill Deal (Update1)". Bloomberg. Retrieved June 13, 2009.
[10] Reuters, federal reserve of St. Louis: Some timeline of the subprime and financial market crises.

mechanically increment too, even if the underlying linkages between these two assets stay constant. These biases should be taken into account when calculating the adjusted correlation coefficients.

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