"Explaining arbitrage of CDS and Bond markets"

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ABSTRACT

The focus of this paper is the theoretical arbitrage relationship between the Credit Default Swaps and Corporate Bonds. We find that the arbitrage relationship tends to be violated, creating short term opportunities for traders. Results of VECM suggest that the difference in price of credit risk persists over time. This violation is explained by three sets of factors: 1) firm-specific credit risk proxies, 2) bond and CDS liquidity and 3) overall market conditions. Variables gain more explanatory power during the last financial crisis.

Professor José Faias

Supervisor

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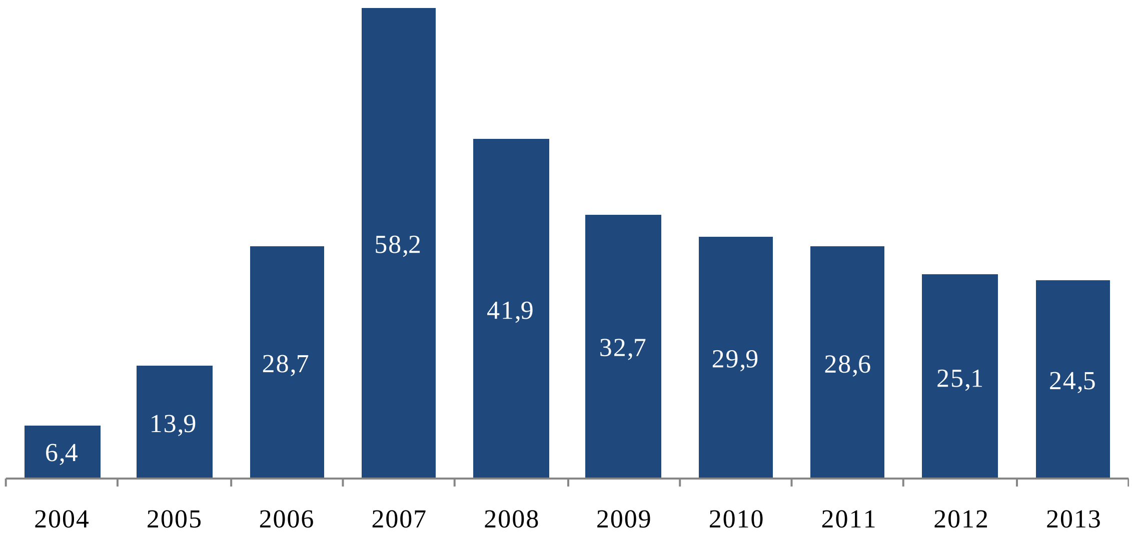
1 Introduction

Credit Default Swap is an exciting innovation in financial markets, which has grown rapidly over the past decade. Since its beginning in early 1990s[1], the CDS market has grown to $58,2 Trillion in 2007, falling to $24,5 trillion in early 2013 according to the International Swaps and Derivatives Association (ISDA).

Figure 1. CDS Market Total Volume Evolution (USD, Trillion)



However, it is still a big market, equal to around 40% of total world market cap and around 30% of world GDP.[2]

This paper analyzes the empirical relationship between CDS contracts and corresponding corporate bonds for a sample of 98 US companies covering the period from May 31, 2002 to October 22, 2013. Those two financial instruments are linked together with an arbitrage relationship. A portfolio consisting of a corporate bond and the respective CDS contract on it is theoretically default-risk free. In case of default the CDS payout should cover for all the losses of the investor; thus the yield of the portfolio

[1] Credit Default Swaps were invented by Blythe Masters of JP Morgan in 1994
[2] Bloomberg

should be equal to risk-free rate. In our sample we find that there are differences in the prices on bond and CDS markets. Credit Default Swap premiums for the US companies are on average higher than the spreads of corporate bonds over the risk-free benchmark, suggesting violations of the arbitrage relationship. The difference between CDS premium and bond spread is called basis, which may take any sign. It is positive when CDS premium is larger than the bond spread and negative otherwise.

There are a few papers about this in the literature. Longstaff et al. (2005) estimate the basis for a set of 68 US entities and they show that there is a significant violation of the arbitrage relationship resulting in positive basis. Norden and Weber (2004), with a set of 58 US and Non-US entities show that the basis is persistent during the period of 2000 to 2002 and positive on average.

De Wit (2006) shows that there is a non-zero basis in the short run for 103 entities with Euro denominated contracts. However, studying the long run relationship finds that on average from 2004 to 2005 the arbitrage relationship holds reasonably well, converging the basis to zero in the long run. Levin et al. (2005) for a larger sample of 306 US entities show that the average basis is not significantly different from zero, confirming the non-arbitrage.

First, our findings suggest that for the 98 US companies the basis is different from zero in the cross section. We also find that financial and speculative graded companies are exposed to larger basis and have bigger standard deviation. The differentiation between investment and speculative grade companies is obvious due to the fact, that low rated companies have larger spreads so the behavior should be different. The idea of differentiating between financial and nonfinancial is caused by the fact that financial companies are major counterparties on the CDS market. Acharya and Johnson (2007) show evidence of informed trading of banks in CDS market, due to this fact the CDS premium is expected to behave differently causing different basis. Due to our large sample, we are also able to study the behavior of the basis during the financial crisis of 2007 - 2009.[3] Fontana (2009) explores the behavior of the basis during financial crisis. He shows that the basis was negative for the sample of 37 companies that he analyzed. Our sample allows us to study the behavior of the basis before, during and after this financial crisis. We confirm that, on average, the basis is negative during this financial crisis.

Second, we study if the mispricing persists over time. Using cointegration tests, we study the long-term relationship between CDS premium and Asset Swap Spread. We use the Johansen Cointegration test for a vector error correction model (VECM), like Trapp (2009), Blanco et al. (2005), Norden and Weber (2004), Hull et al. (2004). With the estimated values we explain which market, if there is cointegration, is the first one to discover the changes in the credit risk.[4] Our findings suggest that before and after financial crisis Credit Default Swaps are the first to price the changes in the credit risk and spilling over the information to the corporate bond market, while during financial crisis we obtain mixed evidence. Another interesting finding is that the US financial companies are exposed to weaker cointegrating relationship than non-financial, suggesting that other factors, rather than default risk have more impact for this subsample.

Third, we study the determinants of non-zero basis. There are three broad reasons: issuer credit risk, liquidity, other market related variables. Increase in issuer credit risk increases uncertainty about its future, which is followed by higher volatility of the

[3] See National Bureau of Economic Research definition of Financial Crisis in the world

[4] Blanco et al. (2005) shows that 26 out of 33 companies are cointegrated, CDS tends to lead bonds, Chan-Lau and Kim (2004) obtain mixed results in terms of lead lag relationship with 5 out of 8 companies showing cointegration, Norden and Weber (2004) state that for 36 out of 58 cointegrated time series CDS lead bonds, Zhu (2004) with 15 cointegrated out of 24 time-series show that CDS lead bonds only in the US.

respective assets, increasing the Asset Swap Spreads. We check which market is the one to be more exposed to effects transferred from the issuer specific credit risk changes. The second reason is important because it is a well known fact that liquidity of any financial instrument has direct impact on its value. We extend analysis of Longstaff et al. (2005) and Tang and Yan (2007) suggesting that CDS and Bond market liquidity both significantly impact the basis. As a third reason we study are the aggregate market conditions and their effect on the basis. Contrasting to Zhu (2004) whose focus is on stock market and interest rate level, we find that slope of the rate curve and overall market liquidity have significant impact on the basis, but risk free rate has impact only for subsamples of speculative grade rated companies.

2 Theoretical Background

2.1 CDS

Credit Default Swap premium is the cost per annum for protection against a default by the company [Hull et al., 2004]. Buyer buys protection from contract seller against the credit event (which is default) and agrees to pay a certain cost - Credit Default Swap premium - to the seller until the maturity of the contract or until the credit event occurs. In case of the credit event, the seller has to pay the buyer the face value of the contract deducted the recovery rate.[5] Hence, CDS has two components - fixed and floating (contingent). Fixed leg is the present value of all the payments that will be made to the protection seller:

$$PV(CDS\ Payments) = \sum_{t=1}^{M} \frac{Z*NP}{(1+R)^t} \tag{1}$$

where Z is the spread charged by the seller, NP is the face value of the contract, and R is a risk free rate. Basically it is the sum of present values of all payments made to the

[5] Rate which is equal to the amount received for the sale of the defaulted asset.

protection seller by protection buyer. The floating (contingent) leg is the present value of the payment that will be made if the credit event occurs:

$$PV(Expected\ Payout) = \sum_{t=1}^{M} \frac{p_t * NP(1-RR)}{(1+R)^t} \quad (2)$$

where RR is the recovery rate, NP is the face value, p_t is the probability of default. In case of the credit event the seller will basically have to pay the NP (face value) minus the recovery rate, which is indicated in (1-RR).

2.2 Asset Swap Spreads

Like CDS premium, bond spreads over a risk-free benchmark mainly compensate investors for default risk embedded in credit-risk assets [De Wit, 2006]. So, there is a clear theoretical link between CDS premium and bond yield spreads for floating rate par bonds, if the two quantities are viewed as a pure measure of credit risk [Duffie, 1999]. Instead of floating rate par bonds, fixed coupon bonds with a use of a fixed-to-floating interest rate swap can be used [Duffie, 1999]. If there is a violation and the difference in pricing of credit risk appears - it is called the basis. Basis is the difference between the CDS premium and the Bond spread over the benchmark. Putting it simply it is the difference in price of the credit risk between CDS market and Cash-Bond market [Choudhry, 2006].

A bond has three types of risk: the credit, interest rate and funding. Two of those risks can be eliminated simply by swapping the bond and making its coupons variable [JP Morgan, 2010]. As Duffie (1999) states, the best way is to use floating rate bonds, but in case if they are not available we can synthetically make a floating rate by swapping the bond. Basically remaining component is the Asset Swap Spread, which is close to the pure credit risk represented in the CDS premium.

$$ASWspread = CashBondYield - SwapRate \quad (3)$$

We can also use risk-free rate as a benchmark for estimating the Asset Swap Spread. However, Hull et al. (2004) empirically show that Swap Rate works better for this matter.

2.3 Relationship between CDS and Asset Swap Spread

With the two simplifying assumptions, we depict the equivalence relationship. Assume a par risk-free bond with a fixed coupon rate R and a risky bond with a fixed coupon C, both with face value of USD 100. p_t is defined as a risk-neutral probability density function, such that the probability of survival of the reference entity until t is defined as:

$$\pi(t) = 1 - \int_0^t p(t)dt \tag{4}$$

The fixed CDS premium amounts to P_{cds} and the payment dates coincide with the coupon payments of the bonds until the maturity T or a credit event t. The market value of the reference obligation equals D_t at time t. Present value of the premium payments is equal to the sum of all the discounted premiums paid during the life of the contract or until the default:

$$\sum_i^T e^{-rt}\pi(t_i)P_{cds} \tag{5}$$

while the expected value of the insurance payment in case of credit event is:

$$\int_0^T e^{-rt}(100 - D_t)\pi(t)dt \tag{6}$$

The value of the CDS at the start time has to be equal zero because there are no cash payments between the two counterparties. Carrying this in mind, Equations (6) and (7) have to be equal:

$$\sum_i^T e^{-rt}\pi(t_i)P_{cds} = \int_0^T e^{-rt}(100 - D_t)\pi(t)dt \tag{7}$$

The present value of the reference bond consists of three parts. First component is the present value of all the coupons paid. The final payment of the bond, in case of no default, is the second component [Zhu, 2006]. The last component is the expected market value at default. It can be formalized in the following equation:

$$100 = \sum_i^T e^{-rt}\pi(t_i)c + 100e^{-rt}\,\pi(T) + \int_0^T e^{-rt}\, D_t\pi(t)dt \tag{8}$$

Investor establishes a long position in the risk-free bond with a face value of 100 USD, which he funds by a short position in the risky bond of the same amount. The long position coupons are used to make the short position payments. If there is no default, both mature at time T and there is no net cash-flow needed. In case of a credit event, the long position is liquidated for 100 USD and risky bond is acquired for the market value of D_t. Initial payment is zero, no arbitrage condition requires the expected value of the payments of the portfolio to be equal zero. Mathematically:

$$0 = \sum_i^T e^{-rt}\pi(t_i)r + 100e^{-rt}\pi(T) + \int_0^T e^{-rt}\, 100\pi(t)dt - \sum_i^T e^{-rt}\pi(t_i)c - 100e^{-rt}\pi(T) - \int_0^T e^{-rt}\, D_t\pi(t)dt \tag{9}$$

Simplifying the relationship:

$$\sum_i^T e^{-rt}\pi(t_i)(c - r) = \int_0^T e^{-rt}\,(100 - D_t)\pi(t)dt \tag{10}$$

subtracting this from the Equation (8), we get:

$$P_{cds} = c - r \tag{11}$$

Equation (11) shows that theoretically CDS premium should equal the credit spread (we use Asset Swap Spread) of bond yields above the risk-free benchmark. Equation (11) can be rewritten as follows:

$$P_{cds} - (c - r) = 0 \tag{12}$$

The left side of Equation (12) represents basis spread and should be equal to zero. Equation (12) is used to estimate the basis. We use US Swap rate as the risk-free benchmark as Hull et al. (2004) empirically prove that it is a better proxy for estimation of the basis.

3 Data

3.1 CDS and Bond Data Set

We first collect all the available CDS contracts for US Companies from Markit. Our focus is the 5 year CDS contracts as the most widely available.[6] We remove all the CDS time series with different from 5 year maturities. This results in 2900 time series of CDS contracts with daily observations of the premium. Our next step is to remove all the time-series which have less than 1500 observations, as we would like to capture the behavior of the premiums before, during and after the Financial Crisis. This results in 330 time series of daily observation of the CDS premiums. We also extract the premiums for the same tickers from Bloomberg to confirm the consistency of the data. Our final CDS sample consists of 330 US companies with 5 year CDS contracts having observations of the premium from May 31, 2002 to October 22, 2013.

The second variable of our equation are the bonds. To match the 5 year maturity of the CDS contracts we need to find 5-year bond yields of the respective entities. We use Bloomberg terminal to obtain a time series of bond yields. As our time-series length is close to 11 years and the maturity of the contracts is only 5 years, some of the bonds are already matured. Most of the times the corresponding 5 year maturity bonds were not available, so we collected bonds with maturity up to 10 years, one bond with maturity less than 5 years and one with more than . The obtained yields were then linearly interpolated to estimate an artificial 5-year bond yield. To keep the prices comparable, only "plain vanilla" bonds were included in the search. This means that all bonds with special features, e.g. embedded options, deferred coupons or sinking funds were excluded. Bonds are priced and have yields, only if they are traded and bidders submit their quotes, this result in a great number of illiquid bonds not having any or having very few historical observations on the yields, forcing us to decrease the total estimation

[6] see Bai, Collin-Dufresne (2012), p. 15; Longstaff et al. (2005), p. 2217.

sample. After matching bonds with the CDS premiums we were left with 98 entities having daily observations of both CDS premiums and Bond yields from May 31, 2002 to October 22, 2013, which compares well with previous studies, like 68 entities of Longstaff et al. (2003), 37 entities of Fontana (2009), 33 entities of Blanco et al. (2005). We subdivide the data set into subsets based on: credit ratings: AAA-BBB (Investment Grade), BB-CCC (Speculative Grade) [7], industry sector: Financial, Non-Financial [8], economic conditions: Before Financial Crisis (05/31/2002 to 06/01/2007), Financial Crisis (06/01/2007 - 06/01/2009), After Financial Crisis (06/01/2009 to 10/22/2013).
There are 81 companies rated AAA-BBB, 17 rated BB-CCC, 16 Financial and 82 Non-Financial Companies. Speculative grade (BB-CCC) companies have more volatility, bigger CDS premiums and bigger basis, which is represented in Table 1. With financial companies we have different expectations, on one hand their assets are supposed to be more liquid, on the other hand they are more affected by market fluctuations.
We explain the breakdown in to different time sets by the fact that during the turmoil, basis turned negative, stated by Fontana (2009), however no one has studied it after the Financial Crisis, the breakdown allow us to do it. From Table 1 we see that for both CDS and ASW the volatility increases for speculative graded and financial companies. The CDS premiums are on average higher than ASW for all subsamples except Financial, this is caused by more liquidity in both markets for financial than for non-financial companies. The higher Spreads for Speculative graded companies are accompanied by lower liquidity.

[7] Investment grade companies have less volatile bond yields and CDS premiums [Trapp, 2009].
[8] Longstaff et al. (2005) document that the non-default component of bond yield spreads for financial firms is significantly larger than for non-financial firms.

Table 1. Descriptive statistics of the Data

The table contains descriptive statistics of each data sample used. Asset Swap Spreads are estimated using interpolated 5 year corporate bonds. CDS mid premiums are in basis points per annum for a 5 year CDS contracts. Volatility is the option implied volatility of at the money options with 12-month maturity in percentage points. Bond liquidity is the standard deviation of all observed bond yields for a given firm on a given date in percentage points. CDS liquidity is the bid-ask spread of a 5 year CDS contract for a particular entity, measured in basis points. Risk-Free is a 5 year US government bond yield, measured in percentage points. Slope is the difference between 10 year and 1 year US government bonds in percentage points. Market liquidity is CITIGROUP US Market Liquidity indicator, measured using five different variables of US market liquidity.

	Credit Rating		**Industry**		
	AAA-BBB	BB-CCC	Financial	Non-Financial	All
# of companies	81	17	16	82	98
# of observations	159.884	29.715	28.886	160.713	189.599
			Asset Swap Spreads		
Mean	92,5	415	116,7	169,4	120,8
Std. Deviation	160,5	589,7	195,4	346,4	121,7
Maximum	8.628,5	7.612,9	4.179,2	8.628,5	8.628,5
Minimum	-534,6	-798,3	-352,3	-798,3	-798,3
			Credit Default Swap Premium		
Mean	95,2	302,7	123,8	132,6	131,2
Std. Deviation	83,9	221,7	129,8	103,5	107,8
Maximum	9.183,4	5.658,9	3.606,6	9.183,4	9.138,4
Minimum	4,9	6,3	4,9	5,6	4,9
			Firm-Specific Explanatory Variables		
			Volatility		
Mean	32,7	50,0	46,2	33,2	35,3
Std. Deviation	12,1	23,1	26,3	11,8	13,6
Maximum	110,9	176,2	185,1	107,9	120,5
Minimum	20,1	24,9	18,1	20,2	20,8
			Bond Liquidity		
Mean	1,3	1,1	0,3	1,5	1,3
Std. Deviation	8,2	3,2	0,4	8,2	7,0
Maximum	90,5	39,4	3,0	90,0	77,3
Minimum	0,1	0,1	0,1	0,1	0,1
			CDS Liquidity		
Mean	7,7	19,5	9,2	9,6	9,5
Std. Deviation	4,0	18,2	6,8	5,9	5,9
Maximum	29,3	158,1	39,6	49,7	47,9
Minimum	1,3	0,0	1,5	0,5	1,5
			Market-Wide Explanatory Variables		
	Risk-Free		Slope of Yield Curve		Market Liqidity
Mean	2,8		1,9		0,1
Std. Deviation	1,3		1,2		0,5
Maximum	5,2		3,7		1,9
Minimum	0,5		-0,5		-0,9

3.2 Company specific factors

We employ firm's rating and variables derived from traded stocks and stock options as company specific measures of credit risk [Trapp, 2009]. First, we use S&P ratings.

Aunon-Nerin et al. (2002) find that the rating is the major determinant of the CDS premium. They show that it explains 40% of their sample and increase to 66% in sovereign sub-sample. We obtain S&P credit ratings for the companies in our sample from Bloomberg. We consider a dummy variable, r_t^k, equal to one when there is a rating change and zero otherwise.

However there is evidence that credit ratings are lagged, since the rating agencies claim that their ratings are result of a through-the-cycle evaluation, and borrowers' creditworthiness may be reflected in CDS before the rating adjusted. An example supporting this concern by Hull et al. (2004) shows that CDS premium anticipates rating changes while only reviews for rating downgrades contain information that significantly affect the CDS market. More recently, Lehman Brothers was still rated A a month prior to its bankruptcy, CDS premiums skyrocketed. Since the previous results are mixed, we investigate if there is impact on basis. Together with credit rating change, we use option-implied volatility. They may provide more accurate information on changes in the firm's specific creditworthiness in short-run. Cremers et al. (2004) and Benkert (2004) show that implied volatilities have additional explanatory power in excess of the rating. We obtain series of option-implied volatilities from Bloomberg. The implied volatilities for European vanilla at-the-money options with 12-month maturities are also used by Trapp (2009), because they are most widely available. We obtain bid and ask prices from Markit and estimate a bid-ask spread of a CDS and use it as a direct liquidity proxy.

For bonds we follow Houweling et al. (2004) who identify factors which impact bond liquidity. They find that among the others the bond yield volatility on a given date is one of the factors with most explanatory power. [9] We expect the Asset Swap Spreads to increase with the increase in illiquidity.

3.3 Market wide factors

In the market wide factors, we identify three, which might affect the basis. First one is the slope of the interest rate curve. We expect it to have impact, because it is related to the future business conditions, steeper slope of the term structure is considered to be an indicator of improving economic activity in the future. Estrela and Mishkin (1995) find that yield curve has the most explanatory power, estimating the probability of recession, with a decrease in the slope being associated with an increase in probability of the recession. Together with that Aunon-Nerin (2002) shows that curve slope has significant negative impact on CDS premiums in the US. Duffee (1998) observes the decrease in the yield spreads, when the slope of the Treasury curve increases. Therefore we introduce the slope of the US risk-free curve as the difference of a 10 year and a 1 year risk-free. As we have both CDS premiums and Asset Swap Spreads, when estimating basis, the impact of the curve is not clear.

Second factor is the risk-free interest rate, the effect of which is not clear. On one hand, the decrease of the interest rate is usually associated with the recession phases in the economy, as governments implement monetary policy, decreasing the borrowing costs. Together with this the risk in the country is higher, so the CDS premiums and yields spreads increase, as happened during the recent financial crisis. On the other hand the higher the risk-free the more costly it is to borrow for particular institutions, firms, which depend more on short term financing, are exposed to an increase of uncertainty around their viability, which is reflected by increase in the CDS premiums and yields

[9] Shulman et al. (1993) and Hong and Warga (2000) show that higher yield volatility is connected with higher illiquidity and higher yields.

spreads, another mixed, unclear event. We expect to study the effect of the risk-free to full extent, as we have the latest financial crisis and after financial crisis subsamples when the risk free became historically low in our sample.

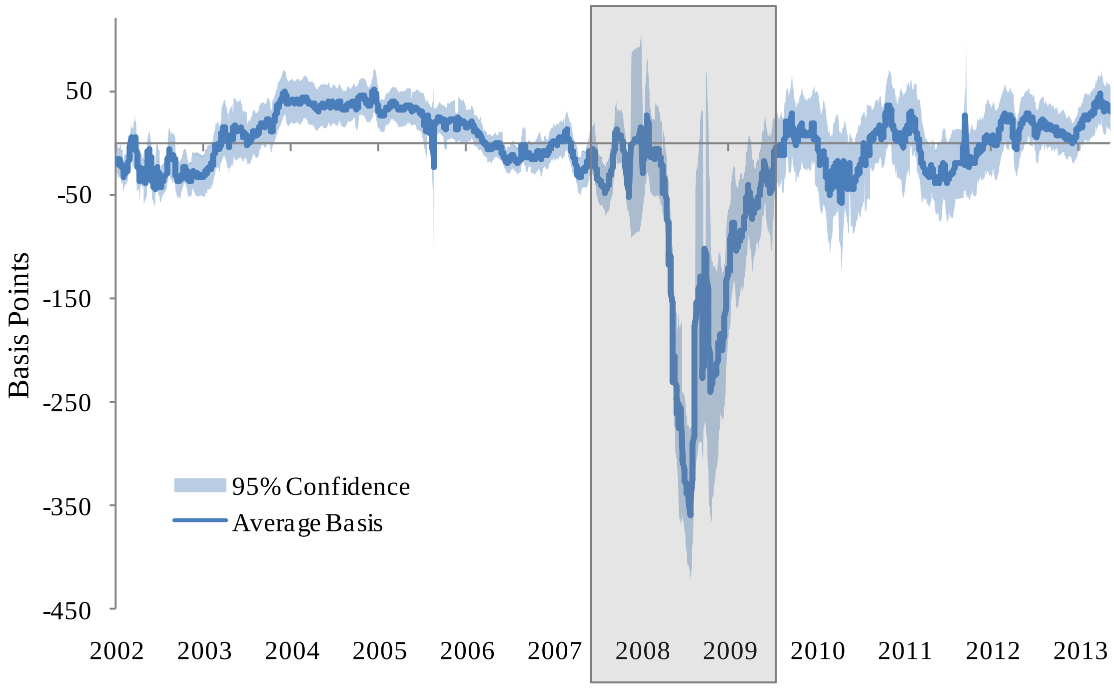
The third factor is the measure of market-wide liquidity, we use CITIGROUP US Market Liquidity Index, obtained from Bloomberg, which is estimated using 5 different parameters, which represent liquidity conditions, on a daily basis. Market-Wide factors descriptive statistics is presented in Table 1.

4 Results

4.1 Basis

If the arbitrage relationship holds, pricing of credit risk with CDS and Asset Swaps should be the same, this should result in equal CDS premiums and Asset Swaps spreads for all the entities in the sample. We use Equation (12) from estimate the basis. Results are represented in Figure 2.

Figure 2. Average Basis May 31, 2002 to October 22, 2013



From Figure 1 we see that from 2002 to mid 2007 the average basis for US companies was mostly positive, this confirms with the previous research of Norden and Weber (2004), Hull et al. (2004), Longstaff et al. (2004). During the financial crisis basis turns negative, indicating that Asset Swap Spreads were higher than CDS premiums, which we explain by the fact that the bond market was affected by the liquidity problems, increase in risk and decrease in risk-free (made by the government to boost the economy). To get a more detailed overview we look at the subsample results presented in Table 2.

Table 2. Basis for 98 US companies

This table shows the descriptive statistics of average basis. The basis is estimated with Equation (11), and presented in basis points. First row shows the number of companies in each period of time, last row shows the number of observations of the basis.

Time period		**Credit Ratings**		**Industry**		**All**
		AAA-BBB	BB-CC	Financial	Non-Financial	
Whole Sample	# of companies	81	17	16	82	98
(05/31/2002 - 10/22/2013)	Mean	2,3	8,0	16,9	1,4	3,4
	Std. Deviation	55,7	114,4	83,0	61,7	61,7
	Maximum	123,9	345,9	343,2	148,4	175,5
	Minimum	-331,1	-729,2	-609,8	-371,7	-374,4
	# observations	2826	2813	2824	2826	2825
Before Crisis	# of companies	81	17	16	82	98
(05/31/2002-06/01/2007)	Mean	15,45	42,87	30,9	26,9	25,9
	Std. Deviation	9,31	27,8	30,8	7,7	11,5
	Maximum	56,9	294,5	189,1	67,9	64,7
	Minimum	-57,75	-146,4	-80,7	-54,0	-52,2
	# observations	1286	1273	1284	1286	1286
Financial Crisis	# of companies	77	14	13	78	91
(06/01/2007-06/01/2009)	Mean	-79,5	-118,2	-54,8	-93,1	-85,9
	Std. Deviation	95,3	199,4	167,8	104,0	109,2
	Maximum	60,7	266,5	343,2	37,2	40,4
	Minimum	-331,1	-729,2	-609,8	-371,7	-374,4
	# observations	439	439	439	439	439
After Crisis	# of companies	74	14	12	76	88
(06/01/2009-10/22/2013)	Mean	1,45	50,9	28,2	6,6	9,4
	Std. Deviation	33,5	82,9	57,8	35,1	34,4
	Maximum	123,9	345,9	231,8	121,3	120,5
	Minimum	-130,7	-350,7	-217,7	-137,3	-136,3
	# observations	1100	1100	1100	1100	1100

Credit rating subgroups show that for the overall sample, as well as for the time period subgroups, standard deviation of the basis is growing bigger for companies in the speculative grade bucket, this is consistent with the idea that the liquidity of speculative grade financial instruments is lower as well as that there is less information on the market, as one of the factors to give grades by rating agencies.

We also see higher standard deviation for financial companies than for non-financial companies with bigger mean returns, what is interesting, that during the financial crisis the financial companies show average basis less negative than non financial.

Looking at the overall sample in different time frames, we see that before crisis the standard deviation was low at 11,5 with low mean basis of 25,9 which is consistent with previous research, during the financial crisis standard deviation increased to 109,2 basis point supported by basis becoming negative as stated by Trapp (2009) and Fontana (2009), after crisis the standard deviation fell to 34,4 on average with a positive basis of 9,49 basis points.

We clearly see, that there is a cross-sectional deviation from the arbitrage relationship, which pushes us to the next step, estimating the long-run relationship between Credit Default Swap premiums and Asset Swap Spreads.

4.2 Long-Run equilibrium relationship

We explore the relationship between Asset Swap Spreads and CDS premiums for each firm. If credit risk is the only priced factor, we should see a very closed comovement of ASW spreads and CDS premiums, theoretically this was explored by Duffie (1999). Hull et al. (2004), Blanco et al. (2005), de Wit (2006) documented a positive covariance, negative cointegration of yield spreads and CDS premiums. The relationship for Asset Swap Spreads should be even tighter. If on one hand we find a significant cointegration we conclude that both markets price credit risk equally in the long run, if we don't find the significant cointegration we intuitively ask which factors are priced together with the credit risk.

We proceed with three steps to ensure the VECM is applied correctly, first we apply Augumented Dickey-Fuller test on daily data for each company. Both ASW spread and CDS premium need to have the same order of integration, if they don't have it, we exclude those companies from further estimation process, because the relationship between stationary and non-stationary variables is hard to interpret economically. We run Johansen Test. The results of the Johansen Test are presented in table 3.

Table 3. Results of Johansen Test

This table shows the number of companies where the hyphothesis of at least one cointegrating vector cannot be rejected and the respective P-Value at different lags.

	# of companies	P-Value
Lag		
1	72	1,47%
2	70	1,39%
3	66	1,46%
4	65	1,49%
5	63	1,57%

We have considered different lags to capture the cointegration up to weekly level. The results make us pick lag 1 as the most appropriate as it has the biggest number of companies for both US and Europe and the P-Values are lying within the 5% level. We observe for the US only 70% of the sample to be cointegrated which implies that differences between CDS and Bond markets are persistent, and affected by time varying factors.

To capture the impact of markets we estimate the Vector Error Correction Model as following:

$$\begin{pmatrix} \Delta asw_t^k \\ \Delta cds_t^k \end{pmatrix} = \begin{pmatrix} \alpha_{asw}^k \\ a_{cds}^k \end{pmatrix} (1\ \beta^k) \begin{pmatrix} \alpha sw_{t-1}^k \\ cds_{t-1}^k \end{pmatrix} + \Gamma^k \begin{pmatrix} \Delta \alpha sw_t^k \\ \Delta cds_t^k \end{pmatrix} + \begin{pmatrix} \varepsilon_{asw,t}^k \\ \varepsilon_{cds,t}^k \end{pmatrix} \qquad (13)$$

where asw_t^k is the asset swap spread and cds_t^k is the CDS premium of company k at date t. α_t^k and a_t^k are the error correction coefficients for the asset swap spread and the CDS premium changes. β^k is the cointegration coefficient and Γ^k is the 2x2 coefficient matrix for the first differences.

Table 4. Long-Run Relationship between CDS and Asset Swap Spreads

This table shows the estimated coefficients of the vector error correction model in Equation (13). β is a cointegrating coefficient. α asw and α cds show the error correction terms estimations. Top row presents the number of firms for which a) identical order of integration could not be rejected at 10% level, b) Johansen test could not reject cointegration of time series at 10% level, c) augumented Dickey-Fuller test could reject a unit root in the residuals of the VECM at 10% level. Coefficients are given for premium in basis points.

	AAA-BBB	BB-CCC	Financial	Non-Financial	All
# companies	81	17	16	82	98
# Significant	54	10	11	61	72
Mean β	-1,79	-0,56	-1,18	-1,93	-1,83
Std. Dev.	1,64	1,84	0,98	1,97	1,71
# Significant	59	9	10	58	68
Mean α asw	-0,011	-0,003	-0,002	-0,011	-0,009
Std. Dev.	0,02	0,009	0,02	0,019	0,019
# Significant	39	10	8	41	49
Mean α cds	0,009	0,003	0,010	0,007	0,008
Std. Dev.	0,007	0,006	0,008	0,007	0,007

Only 72 out of 98 companies show significant cointegration relation between Asset Swap Spreads and Credit Default Swap premiums. For the overall sample we may see the average cointegration coefficient is equal to -1,83, which points out on the fact that Asset Swap Spreads and Credit Default Swap premiums are moving together, the error correction coefficient α is larger on average (absolute value) for Asset Swap Spreads suggests that they are affected to more extent by long-run relationship deviations, thus credit risk changes are priced first by the Credit Default Swaps. However when we consider the standard deviation we conclude that this comovement differs across companies, that is why it is interesting to look at sub samples we have, to better understand long-run relationships.

In the Credit Rating subsample the long-run relationship holds better for the investment grade subset (on absolute level), the standard deviation once again points at great diversity of results between different companies within subsamples. For the speculative grade subsample the error correction terms suggest that both Asset Swap Spreads and Credit Default Swap premiums react more frequently to deviations from long-run than investment grade subset. The price discovery is made as often for bond market as for CDS.

The coefficients are also different, when looking at Financial and Non-Financial industry sectors, financial exhibit significant cointegration less frequently, values are smaller on average (absolute). Credit Default Swap Premium reacts less frequently to the deviations from long-run equilibrium. The link for financials is weaker and more asymmetric than for non financial.

For the total sample, the results imply that price of credit risk can strongly differ between Credit Default Swaps and Bonds in the short run and not hold in the long-run. Significant comovement is registered only for 72% of the sample. This makes us think that there are time-varying factors, which affect the theoretical equilibrium.

4.3 Explanatory Regressions

We have shown with the cointegration analysis that Asset Swap Spreads and CDS premiums often evolve independently from one another. Even if there is a significant cointegration relation, the often insignificant error correction coefficients imply that there are no stable long-run relationships between two time series. Now we explore if the independence of two time series is related to time-varying firm-specific and market-wide risk factors. Results of this test will also allow understanding which conditions make cash and synthetic markets converge.

Equation that we will use is given by:

$$basis_t^k = a_0^k + \beta_1 r_t^k + \beta_2 vol_t^k + \beta_3 bliq_t^k + \beta_4 cliq_t^k + \beta_5 govt_t^k + \beta_6 slope_t^k + \beta_7 MLiQ_t^k + v_t^k \tag{14}$$

where a_0^k is a time-invariant firm-specific fixed effect, $\beta_1 r_t^k$ - S&P Credit Rating Change (Dummy Variable), vol_t^k is the option-implied volatility (replaced, if unavailable with historical stock return volatility), $bliq_t^k$ is the bond market liquidity proxy, $cliq_t^k$ CDS market liquidity proxy, described before, $govt_t^k$ - 5 year government rate level, $slope_t^k$ - government rate slope (difference between 10-year and 1-year), $MLiQ_t^k$ - market liquidity index at date t.

The model is estimated in three steps. Identify the firms, which had at least 20 observations of basis on days, with all explanatory variables, estimate OLS and determine significance with Newey-West test to adjust for autocorrelation and heteroskedasticity (Campbell et al., 1997). Results are presented in Table 5.

Table 5. Impact of Firm-Specific and Market-Wide Factors

This table shows coefficient estimates, significance level and adjusted R^2 for the model in Equation (14). Dependent variable, estimated with Equation (12). Independent variables are: $S\&P_t^k$ – dummy variable, which indicates credit rating change as 1 or no change as 0 for company k on time t, $cliq_t^k$ - proxy for a CDS market Liquidity, estimated by the difference between CDS bid and CDS ask in basis points, $bliq_t^k$ – volatility of bond yields as proxy for bond market liquidity, vol_t^k - option implied volatility (replaced by historical if unavailable), $govt_t^k$ - 5 year US treasury rate, $slope_t^k$ – slope of yield curve, difference between 10 year and 1 year US risk-free, $MLiQ_t^k$ – Citigroup US market liquidity indicator. ***, **, * represent the 1%, 5% and 10% significance level for a t-test using Newey-West errors. Adjusted R^2 is in percentage points. The last two rows give number of firms and number of basis observations.

	AAA-BBB	BB-CCC	Financial	Non-Financial	All
r_t^k	-1,28	-10,53**	-22,43	-1,22*	-2,72*
$cliq_t^k$	0,60***	0,40***	2,71***	1,07***	0,44***
$bliq_t^k$	-67,89***	-43,15***	-90,42***	-58,75***	-64,03***
vol_t^k	1,04***	0,51***	0,50***	1,25***	0,96***
$govt_t^k$	-5,89	-4,46**	1,65	-1,95	-1,35
$slope_t^k$	-18,01***	3,82	-18,72***	-15,20***	-15,79***
$MLiQ_t^k$	55,54***	140,78***	64,15***	69,80***	68,86***
Adj. R^2	52%	59%	62%	50%	52%
# Firms	81	15	16	80	96
# Obs.	154.768	23.275	27.949	150.094	178.043

First we analyze the overall sample. Looking at firm-specific factors, all but credit ratings have a significant impact at 1%. Credit Ratings decrease the basis with 10% significance together with option implied volatility, if there is an increase in the credit risk this increases the basis, this can be explained by the fact, that the markets price credit risk with a lag, which was suggested before. The impact on CDS premium is higher than the one on the ASW spread, this causes the basis increase. Decrease in CDS market liquidity increases the basis because when markets become illiquid this pushes CDS premium up, at the same time the Asset Swap Spreads do not catch up, the opposite happens for the bond market liquidity, lower liquidity increases Asset Swap Spreads, decreasing the basis. An increase of CDS market liquidity and decrease of bond market liquidity push basis to convergence.

In market-wide explanatory variables, only slope and overall market liquidity have a significant impact on basis, not significant impact of risk-free interest rate supports our idea of selecting swap rate as a benchmark for estimation of the basis. Higher slope of the interest rate curve increases the basis, suggesting that overall market credit risk indicator increases the difference of pricing between CDS and Asset Swaps. Market liquidity proxy suggests that when the illiquidity of the market increases – the basis increases as well.

Comparing the estimation results for investment grade and speculative grade companies, we observe that in speculative grade subset credit ratings has a positive impact on the basis, increasing it, suggesting that uncertainty around credit risk of the company is reflected in the CDS premiums before it is reflected in bonds. Surprising is the impact of risk-free rate, as it is only significant for speculative grade companies, decreasing the basis. Adjusted R^2 is higher for speculative grade subset, suggesting that market-wide and firm-specific factors better explain the divergence of the CDS premiums and Asset Swap Spreads.

Regarding Financial and Non-Financial firms in Table 5, we find that rating is significant for the non-financial at 10% and not significant for financial in explanation of the basis variation. This is reasonable due to the fact, that financial companies have bigger media coverage and more publicly available information, making credit ratings impact negligible. Higher R^2 suggests that for financial firms overall market liquidity, slope of the interest rate curve bond and CDS market liquidity and option volatility have bigger explanatory power.

As a summary, we find that there is a significant impact of 6 out of 7 explanatory variables on the basis. Credit Ratings have significant impact only for 2 out of 4 subsamples, for speculative graded and non-financial companies. Bonds are more sensitive to Credit Ratings than CDS. The effect of option implied volatility is significant for all the subsamples and is the opposite, suggesting that the CDS react first, we support this with the idea that option implied volatilities are more sophisticated tools, and CDS traders rely on them more, while bond traders rely more on traditional credit ratings. Decrease in CDS market liquidity increases the basis, and decrease in bond market liquidity drives the basis down. Assumption that CDS markets are perfectly liquid does not hold, as liquidity has a significant impact. Adjusted R^2 points out that for speculative grade and financial companies, variables have more explanatory power. Deterioration in overall market conditions has a significant effect on the basis as well. As market liquidity decreases, the difference between ASW and CDS increases. With the increase in slope we observe an opposite effect, suggesting that slope increase decreases current rates and increases the yields of the bonds.

5 Robustness Tests

First of all in the robustness checks, we test if the relationship estimated before holds during the time of financial turmoil from June 2007 to June 2009, defined by NBER. We get the respective subsample out of the initial sample, first thing that we notice the number of companies during financial crisis decreases by 10%. Then we start with the VECM model to estimate the long-run relationship. It is estimated using the same methodology as in Section 4.2. We also conduct the test before and after the financial crisis to see if the results are persistent. There might be deviations due to different macroeconomic conditions and market conditions. Before the crisis there was a stable economy growth supported by high liquidity in both CDS and Bond Markets.[10] After the crisis there is a recovery period, CDS markets are less liquid, risk free rates are historically low and the US economy is boosted by quantitative easening conducted by the Federal Reserve. The results of VECM are presented in Table 6.

[10] CDS as one of the causes of financial crisis are less traded, which is represented by the Volumes in Figure 1. Fixed coupon bonds are less used, more floating rate bonds are issued (Bloomberg)

Table 6. Long Run relationship time subsamples

This table shows the estimated coefficients of the vector error correction model in Equation (13). β is a cointegrating coefficient. α asw and cds show the error correction terms estimations. Top row presents the number of firms for which a) identical order of integration could not be rejected at 10% level, b) Johansen test could not reject cointegration of time series at 10% level, c) Augmented Dickey-Fuller test could reject a unit root in the residuals of the VECM at 10% level. Coefficients are given for premium in basis points.

	AAA-BBB	BB-CCC	Financial	Non-Financial	All
# companies	81	17	16	82	98
Panel A: Before Crisis May 31, 2002 to July 1, 2013					
# Significant	62	13	15	60	75
Mean β	-2,29	-1,36	-1,51	-2,1	-1,92
Std. Dev.	1,11	1,28	1,98	1,39	1,38
# Significant	48	11	13	46	59
Mean α asw	-0,005	-0,003	-0,002	-0,003	-0,003
Std. Dev.	0,008	0,006	0,004	0,002	0,005
# Significant	45	8	10	43	53
Mean α cds	0,003	0,001	0,002	0,003	0,002
Std. Dev.	0,009	0,004	0,005	0,009	0,008
Panel B: Crisis July 1, 2007 to July 1, 2009					
# Significant	24	9	12	21	33
Mean β	-1,29	-0,36	-0,76	-1,13	-0,72
Std. Dev.	1,44	1,34	0,98	1,97	1,98
# Significant	18	7	8	17	25
Mean α asw	-0,011	-0,002	-0,010	-0,010	-0,011
Std. Dev.	0,030	0,009	0,020	0,019	0,021
# Significant	17	6	8	15	23
Mean α cds	0,010	0,003	0,010	0,007	0,012
Std. Dev.	0,046	0,008	0,020	0,007	0,010
Panel C: After Crisis July 1 , 2009 to October 22, 2013					
# Significant	50	12	14	48	62
Mean β	-1,37	-1,14	-1,45	-1,53	-1,40
Std. Dev.	1,01	1,56	1,65	1,34	1,98
# Significant	45	8	10	43	53
Mean α asw	-0,021	-0,013	-0,016	-0,018	-0,023
Std. Dev.	0,030	0,015	0,021	0,020	0,021
# Significant	40	5	6	39	45
Mean α cds	0,011	0,012	0,013	0,010	0,007
Std. Dev.	0,015	0,011	0,021	0,013	0,015

The results differ from ones, estimated for the overall sample and presented in section 4.2. Number of companies, for which there is a strong cointegrating relationship decreases significantly from 72 out of 98 to 33, this is not a surprise, as it was suggested in Table 2, when looking at basis we observe that during financial crisis the basis became larger with a much larger standard deviation across the firms giving us a feeling that the cointegrating relationship is weaker, which is proven by the VECM. From section 2 we also know that during the turbulent phase of the market there was a dry up of the liquidity, both firm-specific and market-wide factors. The CDS market decreased almost twice in volumes during financial crisis, suggesting high illiquidity.

In Panel A we see that there is a higher cointegrating relationship across all the subsamples. This confirms the results of the previous research, conducted for the samples before financial crisis.[11]. The lower absolute error correction terms, suggest that there were less deviations from long run relationship. Higher frequency of significant alphas for ASW together with larger error correction suggests that there is a spillover of information from the CDS market to the Bond market. In Panel C we see similar pattern as in Panel A, despite the fact, that the cointegrating relationship is smaller and error correction is bigger for both ASW and CDS, the spillover effect is persistent, across all of the subsamples, the cointegration is stronger for Non-Financial and Investment Grade companies.

So the second part of robustness check is to test, whether the factors, suggested in section 4.3 have explanatory power during financial crisis and whether they behave similarly. The results of the regression are presented in Table 7.

[11] See Trapp (2009), Blanco Brennan and Marsh (2005), Norden and Weber (2004), who show that on average for their samples 70% show significant cointegrating relationship.

Table 7. Impact of Firm-Specific and Market-Wide Factors time subsamples

This table shows coefficient estimates, significance level and adjusted R^2 for the model in Equation (14). Dependent variable, estimated with Equation (12). Independent variables are: $S\&P_t^k$ – dummy variable, which indicates credit rating change as 1 or no change as 0 for company k on time t, $cliq_t^k$ - proxy for a CDS market Liquidity, estimated by the difference between CDS bid and CDS ask in basis points, $bliq_t^k$ – volatility of bond yields as proxy for bond market liquidity, vol_t^k - option implied volatility (replaced by historical if unavailable), $govt_t^k$ - 5 year US treasury rate, $slope_t^k$ – slope of yield curve, difference between 10 year and 1 year US risk-free, $MLiQ_t^k$ – Citigroup US market liquidity indicator. ***, **, * represent the 1%, 5% and 10% significance level for a t-test using Newey-West errors. Adjusted R^2 is in percentage points. Panel A presents results for the sample before crisis, Panel B during financial crisis, Panel C after crisis.

	AAA-BBB	BB-CCC	Financial	Non-Financial	All
	Panel A: Before Crisis May 31, 2002 to July 1, 2013				
r_t^k	2,9*	-6,2	-1,3	2,2*	1,6*
$cliq_t^k$	-1,4	15,9**	-0,9	1,6	1,2
$bliq_t^k$	-13,8**	-58,4***	-24,9***	-26,6***	-26,3***
vol_t^k	0,2***	5,6***	0,3***	1,2***	1,0***
$govt_t^k$	-3,4**	-7,3***	7,2	-4,6**	-7,6**
$slope_t^k$	18,7***	25,5***	15,6***	20,5***	19,7***
$MLiQ_t^k$	66,9**	131,4*	42,6**	136,4*	120,6**
Adj. R^2	51%	55%	62%	47%	59%
	Panel B: Crisis July 1, 2007 to July 1, 2009				
r_t^k	-8,37**	21,37	-11,6	-3,0*	-4,5*
$cliq_t^k$	-1,22**	-4,15***	2,5*	-2,4**	-1,6**
$bliq_t^k$	-36,68***	-60,35***	-106,8***	-53,0***	-65,2***
vol_t^k	-2,61**	-2,62*	-1,5	-3,1**	-2,6**
$govt_t^k$	4,19**	8,79***	3,1*	7,6***	6,8**
$slope_t^k$	-14,27	28,43	73,6**	-24,9	-8,6
$MLiQ_t^k$	-31,06***	-63,54***	-6,7***	-101,3***	-83,5***
Adj. R^2	59%	68%	69%	61%	69%
	Panel C: After Crisis July 1 , 2009 to October 22, 2013				
r_t^k	-5,3	10,1**	-3,5	-3,0	-3,0
$cliq_t^k$	2,0***	-1,3***	0,1***	1,7***	1,5***
$bliq_t^k$	-35,3***	-17,5***	-38,8***	-31,8***	-32,7***
vol_t^k	0,5**	0,2***	-1,4***	0,6***	0,5***
$govt_t^k$	-7,8*	9,0**	3,4*	-5,0***	-6,8**
$slope_t^k$	91,1*	-76,4*	8,5*	75,7*	66,6*
$MLiQ_t^k$	66,6***	54,1***	20,8***	78,1***	-64,8***
Adj. R^2	55%	59%	52%	55%	61%

We have a higher adjusted R^2, suggesting that variables have more explanatory power during financial crisis. Interesting is that we observe the change in subsamples, particularly for the financial and speculative graded companies, this shows that those companies were more exposed to the impact of those factors. All factors except the slope, this is caused by the fact, that investors do not care much about the term structure of the overall market risk, and is supported by the fact that risk free rate has significant explanatory power during this period. Risk-free rate tightens the basis, if increase is observed, as most of the assets become illiquid during turbulent market conditions, the increase in risk-free rate decreases the Asset Swap Spread, because it shows more confidence to investors about the borrowing costs and amounts of risk on the market. Market liquidity also tighten the basis, generally we can say that with the improvements in market conditions basis tends to move back to zero. As for Firm-Specific factors, both illiquidity in CDS and bond market drive the basis from zero down. Rating change gains significant impact for all subsamples except speculative grade, they are more exposed to moves in liquidity as the low graded assets are the hardest to sell during the crisis times, a slight move in liquidity impacts the basis much more than the backward looking credit rating changes. Panel A shows that before the financial crisis, the model had less explanatory power, which is supported by the fact that cointegrating relationship was stronger resulting in less exposure to the exogenous impacts in both markets. Financial companies and speculative graded subsamples are more explained by the model. All the impacts are consistent with the overall sample. The same we conclude for Panel C. Summarizing all abovementioned the model is robust for different periods in time.

6 Conclusions

The conducted research was aimed at exploration of the variables that affect the arbitrage relationship, estimated by Duffie (1999) between Credit Default Swaps and Corporate Bonds.

First we show a cross-sectional violation of the arbitrage relationship, estimating the basis as the difference of CDS premium and Asset Swap Spread, widely used by basis traders. For the overall sample the basis is positive on average, turning negative during financial crisis, due to turbulent market conditions, liquidity problems and interest rate manipulations by the government. We show that Investment grade companies are less exposed to having significant basis, with lower standard deviation and lower negative basis during the financial crisis. The same we see for financial companies, when comparing them to non-financial.

We then proceed with the long-run relationship analysis, estimating the cointegration relationship between CDS premiums and Asset Swap Spreads. Only 72 out of 98 companies show significant cointegration, suggesting that there are time-varying factors that drive the basis from the equilibrium. The error correction coefficients suggest that Credit Default Swaps are the first to discover the information spilling it over to the Bond market. This is supported by the fact that Credit Default Swap market is more liquid and it is considered as one of the best proxies, reflecting credit risk of the company. Robustness checks on different time periods show that during financial crisis the relationship weakens to only 30% of the sample showing significant cointegration, mostly present at the investment grade, non-financial companies, which are less affected by the contagion of financial markets. However, the results also suggest that relationship differs strongly across companies.

We study the determinants of the basis. The results suggest that 6 out of 7 explanatory variables cause significant effect on the basis. Higher slope of the interest rate curve affects both CDS premiums and Asset Swap Spreads, supporting the findings of Aunon-Nerin (2002), who shows that CDS premium is negatively related to the curve slope and Duffie (1998) suggests that there is a decrease in yield spreads, when curve slope increases. Risk-Free rate however, does not prove to be significant explanatory variable. The overall market liquidity has positive effect on the basis, increasing it when market is illiquid, meaning that CDS premiums react first on the liquidity conditions in the market. Credit rating changes show significant impact on the Non-Financial companies and the speculative grade companies, decreasing the basis, while option implied volatility has significant impact for all the sample and across it, increasing the basis, this means that option implied volatility is reflected first in CDS premiums, we explain this idea by the fact, that CDS contracts are mostly traded by financial institutions, who use more sophisticated indicators of risk, such as volatility, while companies and private investors rely on credit rating agencies.

Credit Default Swaps incorporate information about credit risk faster than the bond markets, however assumption that CDS markets are perfectly liquid does not hold, as liquidity has a significant impact. Adjusted R^2 points out that for speculative grade and financial companies, variables have more explanatory power. This supports the fact, that they are less cointegrated and more exposed to exogenous factors.

Firm specific risk and liquidity prevent the violations of arbitrage from turning back to equilibrium; together with this overall market conditions also have significant impact. Traders, who trade basis convergence have to take this into account to avoid the losses, occurred during financial crisis. Basis show similar pattern in terms of long-run relationship before and after the financial crisis. Around 70% of the sample is cointegrated in those two subperiods. However during the financial crisis basis gets more exposed to the deviations from the cointegrating relationship and impact of exogenous firm-specific and market-wide factors.

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