The Impact of Liquidity on Senior Credit Spreads during the Subprime Crisis

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Abstract

This paper examines the effects of liquidity during the 2007-09 crisis, focussing on the senior tranche of the CDX.NA.IG Index and on Moody's AAA Corporate Bond Index. The aim is to understand whether these senior credit indices were discounted below fair value and to what extent this discount reflects a lack of depth in the relevant markets, scarcity of risk-capital, and liquidity preference exhibited by investors. Using cointegration analysis, the paper shows that during the crisis lower market and funding liquidity and higher investors' risk-aversion are important drivers of the increase in the spread of triple-A structured securities, while they are less significant to explain the spread of a portfolio of unstructured credits. Looking at the experience of the subprime crisis, the study explores the pitfalls of securitization when the conditions under which it can work properly (transparency and tradability) suddenly disappear; leaving investors highly exposed to systemic risk factors.

JEL classification: G01, G10, G12, G13.
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1 Introduction

In recent times, before the subprime crisis started, trading in structured credit derivatives (such as CDOs) grew exponentially. Structured products with complex payoffs were created using securitization technology (pooling and tranching claims with different risk exposures) and were sold in the market. According to data published by the British Bankers Association, the total volume of credit derivatives increased from less than US$1 trillion in 1997 to around US$26 trillions in 2007.[1] In 2003, CDOs represented 20% of the total credit derivatives market. This figure decreased drastically to less than 5% in 2008. In the second half of 2007, disruptions started in the U.S. subprime mortgage market and then spread to other apparently unrelated markets, causing a sudden "drying up" of liquidity and an increase in the premia of all structured finance products (CDOs), including the highly-rated ones.

On the one hand, the rise and fall of the CDO market has boosted the development of theoretical models for pricing of these instruments (see for discussion Collin-Dufresne, 2009). On the other hand, a widespread view about the dysfunctionality in top-rated structured markets during the recent crisis is that their prices have deviated from their fundamentals. This paper explores this view and aims at explaining whether, and to what extent, liquidity frictions in the financial markets have affected structured products during the crisis, in particular those that were initially considered very safe investments. We focus on the senior tranche of the credit default swap index for North American investment grade corporate bonds (ST CDX.NA.IG) in the period that runs from September 2006 to May 2009. Moreover, the work also examines the increase in the spread of Moody's AAA Corporate Bond Index (see Figure 1) in order to detect whether liquidity frictions and shifts in investors' preferences have had the same or

[1]For detailed statistics, see Choudhry (2010) at pages 58-69.

different effects on senior structured versus senior unstructured credit markets.

We identify therefore three possible drivers for movements in credit spreads:

1) Shifts in fundamentals;

2) Changes in investors' risk aversion and sentiment;

3) Market liquidity and funding liquidity.

We base the empirical analysis of the credit fundamentals on the structural model first introduced by Merton (1974). The model uses an options pricing technique to evaluate the default spreads of risky fixed income instruments. The risky debt of a firm is considered as a contingent claim on the value of the firm's assets (a short put position on the firm's asset plus a long position on a riskless bond). Consequently, the main (observable) determinants of the firm's default probability and its credit spread are the firm's financial leverage, the firm's asset volatility, and the term structure of risk-free interest rates. While in the original structural framework of Merton (1974) only the firm's marginal default probability is needed to determine the spread on the bond (or the CDS premium), CDX tranches spreads depend also on the correlation between default probabilities of all the underlying firms.[2]

The post-crisis literature about the pricing of CDOs and CDX tranches is mainly concentrated in the papers of Coval, Jurek and Stafford (2009) and Collin-Dufresne, Goldstein and Yang (2012). Coval, Jurek and Stafford (2009) investigate the pricing of CDX tranches within a copula framework[3] using S&P500 option prices. They demonstrate that the CDX index and its tranches were approximately fairly priced during the crisis and not subject to fire-sales. By contrast, they claim that before

[2]Zhou (2001) and Hull and White (2001) firstly incorporated the default correlation between different issuers in the structural model framework. Hull, Predescu and White (2006) test this modified structural model on market prices for CDX and ITraxx tranches. Duffie and Gârleanu (2001) and Longstaff and Rajan (2008) explain CDO tranche prices using instead intensity-based models with three independent jump processes (firm-specific, sector-specific, and economy-wide).

[3]Copula models (Vasicek, 1987; Li, 2000) are commonly used to model the default correlation.

the subprime crisis the observed spreads on senior tranches of the CDX index were too low relative to the spreads predicted by the model, so their dramatic increase during the crisis can be explained as a correction of a pre-existent mispricing. In other words, before the crisis ST CDX writers were insuring "economic catastrophe bonds" without appreciating their large exposure to systemic risk and demanding an adequate compensation.

Collin-Dufresne et al. (2012) note that these conclusions are hard to reconcile with the sophistication of traders in CDX (and CDO) markets who would not be willing to bear so much risk without a proper evaluation and fair compensation. Calibrating the structural model to match the entire term structure of CDX index spreads (rather than only the five-year spreads), they show that S&P500 options and CDX tranches were on average well integrated before and during the crisis. Thus, they reject the hypothesis of a large mispricing of CDX senior tranches.

Although the predictions of the Collin-Dufresne et al. (2012) model display some improvement in fit relative to Coval et al. (2009), the performance of the model is not completely satisfactory over the crisis period. In particular, the 15-30% CDX senior tranche spread remains much higher than the model-predicted spread, even when base parameters (such as default jump risk) are set to the worst scenarios. One aspect that has been omitted in both Coval et al. (2009) and Collin-Dufresne et al. (2012) analysis is the study of the variation over time in non-default components of the CDX senior tranche spreads, such as the liquidity premium component. The liquidity factor is a potential non-fundamental driver of the increase in structured credit spreads.

Some recent papers have studied fundamental and non-fundamental determinants of asset-backed securities (ABX) indices, rather than CDX indices, during the subprime crisis. For instance, Dungey, Dwyer and Flavin (2013) identify the drying-up of liquidity and the increase in counterparty risk as the main reasons behind the decline of highly-rated ABX tranches. Perraudin and Wu (2008) examine the determinants of the prices of asset-backed securities underlying the ABX indices during the housing sector crisis in 2004 and the subprime crisis in 2007-08. They conclude that liquidity seems quite relevant in the subprime crisis. Stanton and Wallace (2011) investigate the pricing of ABX index credit-default swaps using indicators of mortgage and housing market performance, short sale activity, and risk aversion. The authors find that the changes in ABX Index CDS premia are poorly related to mortgage credit performance, while strongly related to short-sale activity, which suggests an effect of intermediaries' capital constraints. Fender and Scheicher (2009) show that while indicators of housing market activity strongly affect the returns of the subordinated ABX.HE 06-1 sub-indices, during the crisis concerns about market liquidity and declining risk appetite contribute for a significant part to the decrease in value of more senior ABX sub-indices.

The empirical literature on CDX tranche pricing has not yet explored this issue extensively. In a report for the European Central Bank, Scheicher (2008) examines the determinants of the daily price movements in CDS index tranches (North America CDX and European ITraxx). Using simple regression analysis of first differences, he finds that credit-tranche premia are influenced by a large unobservable component (different from the credit fundamentals suggested by a structural model), especially during the crisis period.

Our paper attempts to fill this gap in the literature: it focuses on the senior tranche (15%-30%) of the CDX.NA.IG Index and attempts to isolate the individual contributions of default-risk, illiquidity, and declining risk appetite on the increase in the tranche spread. Moreover, this work analyses differences in the effects of liquidity on the CDX Index top-rated tranche and on the AAA Corporate Bond Index, before and after the subprime crisis. To identify market and funding liquidity components in the spreads of the ST CDX and AAA Corporate Bond Index, we isolate the fundamental default risk component by means of an implicit structural model. We conduct an analysis of long-run and short-run dynamics of credit spreads. Cointegration analysis detects an equilibrium relationship between the credit spreads and those variables (equity price and volatility, equity option implied volatility skew, level and slope of the term structure of interest rate) that the theory of structural models suggests closely related to credit spreads. The short-term movements in the credit spreads are then examined through error correction models (ECMs) where, in addition to structural variables, changes in liquidity and risk aversion are also used as explanatory variables for changes in ST CDX and AAA Bond Index spreads.

We find that the signs predicted by the theory for the relationship between credit spreads and structural variables are all confirmed. The paper rejects the hypothesis of a "pre-crisis model failure" (i.e., that the increase in senior credit spreads over the crisis is driven by the correction of a pre-crisis underpricing). Interestingly, liquidity is found to be one of the main drivers of the increase in the spread of the Senior Tranche CDX Index during the crisis period, while it is not significant during the more stable pre-crisis period. Furthermore, although for the AAA Bond Index spread liquidity has much higher explanatory power during the crisis than before, the liquidity variables are not found statistically significant when used in the ECM regressions.

There are two main elements of novelty in our work. The first element is the application of a simple structural model approach to investigate default and liquidity risk components of credit spread for a complex structured product (senior tranche of CDX index) which has not been broadly examined in the empirical literature until this moment.[4] The second element of novelty is the use of cointegration analysis where the structural model is considered an equilibrium relationship occasionally disturbed by investors' concerns about illiquidity.[5] Some previous studies on implicit structural models have examined the determinants of credit spreads using a first-differences regression approach (e.g., for corporate bonds, Collin-Dufresne et al., 2001; for CDX tranches, Scheicher, 2008). However, such analysis is solely concerned with short-run movements in the variables and disregards potentially useful long-run information. On the contrary, we identify an equilibrium pricing relationship between the structural variables and the credit index spread in levels and detect short-term disturbances/deviations related to higher concerns on illiquidity and higher risk aversion.

The importance of this analysis is two-fold. Firstly, it increases our understanding of how the recent crisis has evolved. In fact, this work addresses and contributes to the recent literature about the subprime crisis which started in the second half of 2007 and "has provided an object lesson of the role of liquidity in financial stability" (Crockett, 2008). Secondly, this work contributes to the newly born empirical literature about spread components and liquidity premia for structured credit products. During the past ten years some research has been devoted to identifying the determinants of credit spreads and the liquidity effects for corporate bonds and single-name credit default swaps, but still very little is known about more complex structured credit derivatives. The subprime crisis has shown academics and regulators that ignorance about the matter could be extremely dangerous for the stability of the whole financial system.

[4] In order to test the structural model, the paper performs also exploratory data analysis (see Hendry, 1995, 2009). The data observed over the crisis period manifest in fact several empirical irregularities and reflect a general market uncertainty which we believe may be better taken into account using a careful data-driven methodology.

[5] Blanco, Brennan and Marsh (2005) paper is the first to examine the CDS and bond arbitrage relationship using cointegration analysis and vector error correction models. Our paper instead is the first (to the best of our knowledge) to examine the arbitrage relationship between CDX senior tranche price and structural variables in this time-series framework.

The remainder of the paper is organized as follows. Section 2 describes the empirical methodology and the variables employed in the analysis. Sections 3 and 4 develop the main analysis and illustrates the results. Section 5 presents robustness checks of the results. Section 6 gives the conclusions.

2 Methodology

2.1 Overview

The main hypothesis we test in this paper is that during the crisis highly-rated structured and unstructured products (such as synthetic CDO senior tranches and corporate bonds) have been hit by illiquidity, increased risk aversion, and market disruptions, rather than solely by adverse movements in the underlying financial fundamentals. We first specify an implicit structural model for credit spreads in order to isolate the effect of movements in fundamentals. Structural models of credit risk suggest that credit spreads should be closely related to the following structural variables: firms' leverage, firms' asset volatility, and risk-free interest rate process. We analyse this relationship using the cointegration analysis proposed by Engle and Granger (1987), with estimation of error correction models (ECMs). This procedure consists of:

- Estimating an equilibrium equation for credit spreads and structural variables (in levels) by means of a least squares regression;
- Analyzing the stationarity of the regression residuals in order to detect cointegration;
- Estimating a valid Error Correction Model.

Next, to test the effect of other factors not considered in the structural model, we augment the ECMs by adding liquidity and risk-aversion proxies (non-structural factors) as explanatory variables.

This methodology aims at detecting:

a) Whether an implicit structural model can represent, albeit in a simplified manner, an equilibrium relation towards which credit spreads tend to align over time (including the crisis period);

b) Whether, in the context of augmented-error correction models, the short-term dynamics of credit spreads over the whole sample, the pre-crisis period, and the crisis period can also be explained by liquidity factors and investors' risk aversion (besides changes in the structural variables).

2.2 Selection and Description of the Variables Employed

2.2.1 Credit Spreads

The analysis is performed on the spread of the senior tranche of the CDX.NA.IG Index and on the spread of Moody's AAA Corporate Bond Index. The CDX senior tranche spread is represented by the quoted premium for the 15-30% tranche of the on-the-run CDX index. The on-the-run CDX index series is composed by the series 7, 8 and 9 of the North American Investment Grade CDX index (CDX.NA.IG.), covering the period that goes from 20/09/2006 to 20/05/2009. Data on CDX.NA.IG. Index Senior Tranche are taken from Bloomberg. The data provider in fact offers a continuous time-series for the tranche premium starting from the third quarter of 2006. After May 2009 the quoting convention across market makers changed and Bloomberg started providing CDX Index tranche information in terms of "points upfront" rather then premia.[6] The equivalent premia on the CDX Index can be estimated making specific assumptions on the recovery rates. However, to avoid using "estimated" ST CDX

[6] If a CDS or a CDX index trades with an upfront fee, the counterparty buying protection on a single-name or a basket of companies' credit must make an initial upfront payment (a percentage of the notional contract value) to the protection seller as well as paying a running spread of 500 bps.

premia and to employ instead only quoted premia, we limit our analysis to the period that goes from September 2006 to May 2009.

The AAA Bond Index spread is represented by the difference between Moody's AAA Bond Index quoted yield and the nominal yield for the 20-years Treasury bonds at constant maturity. Moody's AAA Bond Index yield is the average yield across a large portfolio of AAA industrial bonds. Moody's includes in this portfolio bonds with remaining maturities as close as possible to 30 years and drops bonds when their remaining life falls below 20 years, when they are susceptible to redemption, or when they are downgraded. Data on Moody's AAA Bond Index yield and 20-years Treasury bond yield are provided by the New York Federal Reserve Bank.

2.3 Structural Financial Variables

The structural variables considered in our analysis of fundamental drivers of credit risk are those typically used by the empirical literature on structural models (see, amongst others, Longstaff and Schwartz, 1995; Collin-Dufresne, Goldstein and Martin, 2001; Campbell and Taskler, 2003; Eom, Helwege and Huang, 2004; and Tang and Yan, 2007): equity value, equity volatility, short-term (spot) risk-free interest rate, and slope of the term structure of risk-free interest rates.

The firm's equity value is used to proxy leverage, as the analysis is performed at daily frequency.[7] Since we analyse a broad credit default swap index (CDX) including CDSs on 125 firms and since the index composition changes over time, we employ the S&P 100 index as a proxy for the value of the underlying portfolio of firms. The

[7] To obtain the leverage ratio we need accounting information on the constituents-firms of the CDX and AAA Bond Indexes. However, accounting data on firms' liabilities are available only at quarterly frequency. Additionally, since the liabilities' value of a firm changes much less frequently than its equity value, on a daily frequency changes in leverage are mainly driven by changes in equity value.

structural model predicts that the relation between the credit index spread and the equity index value should be negative: higher firms' values mean higher growth in the firms' earnings, so lower probabilities of default and tighter credit spreads. We measure the equity value using 180 days rolling cumulative log returns on the S&P 100 index ($S\&P100$ $Cum.Ret.$). This is a "normalized" measure of the level of the equity index (i.e. an indication of a "high" or "low" market compared to six months before).[8]

The proxy used for the volatility of the underlying firms is the S&P 100 option implied volatility index (VXO).[9] According to the theoretical model by Merton (1974), when volatility is larger, default probability is higher and the protection seller (or the bond investor) requires larger spreads. Therefore, the relation between credit spreads and equity index volatility should be positive.

In addition, the level of the interest rate may have a significant impact on credit spreads. A higher interest rate increase the risk-neutral expected growth rate of the firms' values, which results in lower probabilities of default and lower credit spreads. Furthermore, a higher interest rate reduces the present value of CDS cash flows, the value of the default protection, and the required premium. We use the 5-year Treasury nominal yield at constant maturity as a proxy for the riskless interest rate ($5y$ $Treasury\ Yield$). According to the structural model predictions, we should find a negative relationship between interest rate and credit spreads.

As the interest rate is a critical input of the structural models, the process that

[8]In preliminary explorative analysis we detect a positive relationship between credit spreads and *daily* equity index price. This result is counter-intuitive in the structural model perspective. The reason for this result is that the equity index price at daily frequency can be a very noisy proxy for the aggregate leverage, which is better captured by our "normalized" measure.

[9]Data on S&P 100 implied volatility are provided by Bloomberg. As alternative proxy for equity index volatility we also use the S&P100 historical volatility computed on a rolling window of 30 days.

establishes the spot rate should be equally important. This process depends, amongst other things, on the slope of the term structure of risk-free interest rates ($T.S.\ Slope$) which we proxy with the difference between 30-year and 2-year nominal Treasury yields. The effect of this variable on credit spreads can be mixed. On one hand, an increase in the slope of the term structure may signal expectations of an expansionary monetary policy, rising future short-term interest rates, recovering economy, increase in firms' values and lower default probabilities (Bedendo et al., 2007). In this case, we should find a negative relationship between the slope of the Treasury curve and credit spreads (as in Collin-Dufresne et al., 2001; and Greatrex, 2009). On the other hand, larger liquidity spreads on long-term bonds and flight-to-quality (caused by higher investors' risk aversion) may induce an increase in both the term structure slope and the credit spreads.[10]

We also consider a specification for the structural model including a jump risk component.[11] Controlling for market-wide jump risk is particularly important in our analysis: an increase in correlation between the defaults of several firms may cause systemic contagion phenomena, sudden jumps to default (in particular for safer highly-rated firms) and an increase in the ST CDX spread and in the AAA Bond Index spread. We proxy the market-wide jump risk component using the skew of the S&P100 index implied volatility ($S\&P100\ Option\ Impl.Vol.Skew$), i.e. the difference between the implied volatilities of 90% in-the-money and at-the-money S&P 100 call options

[10] If market participants expect higher volatility in the future, even if interest rates are anticipated to decline, long-term bond yields will increase, generating a steeper positive slope of the term structure. Moreover, if there is a large demand for short-term bonds because of investors' flight-to-liquidity/quality, then the yields of short-term bonds are expected to decrease and the slope of the term structure to increase (other things being equal), irrespective of investors' views about future events.

[11] The jump-to-default risk is the risk that a credit defaults suddenly before the market has incorporated its increased default risk into current spreads. The pioneering work of Leland (2004, 2006) suggests that the jump component in the asset process is critical to match observed default probabilities with theoretical ones. This finding is further confirmed by the empirical work of Cremers, Driessen and Maenhout (2008), Gemmill and Keswani (2011), and Zhang, Zhou and Zhu (2009).

obtained from Bloomberg (see also Collin-Dufresne et al., 2001; and Tang and Yan, 2007).[12] A more negative smirk in the implied volatility of equity index options suggests larger investors' fear of extreme downside risk in the market (i.e. risk connected to the likelihood of extreme crashes, which typically hit several firms simultaneously). Thus, a more negative smirk should lead to higher spreads on senior credit indices. While we consider a proxy for jump risk, we do not include any direct control for default correlation risk in the CDX tranches structure. In fact, as mentioned earlier, jump and correlation risk-components of credit spreads are strictly interrelated and not easy to be distinguished and measured by different variables, especially in the univariate framework of our analysis.[13]

2.3.1 Non-Structural Variables: Liquidity and Risk-Aversion Proxies

Market liquidity and funding liquidity can affect a portfolio of credit spreads. Longstaff (1995) and Ericsson and Renault (2006) develop models of liquidity premia in corporate bond markets based on imperfect marketability: more illiquid bonds carry larger yields as compensation for investors who hold them. Bongaerts et al. (2011) develop a pricing model for credit derivatives and explain liquidity premia (in CDS and CDX) as the result of heterogeneity between buyers and sellers of protection. Existing empirical research has detected significant liquidity components in corporate bond spreads (Longstaff, Mithal and Neis, 2005; Huang and Huang, 2012; Chen, Lesmond and Wei, 2007; and Dick-Nielsen, Feldhütter and Lando, 2012) and in single-name CDSs (Chen,

[12] The Black-Scholes model for pricing options assumes a constant level of volatility. However, the volatility curve implied by the market prices of equity index options at different moneyness levels displays a "smirk" which has been attributed to market participants' fear of large negative jumps in the equity market (Cont and Tankov, 2004).

[13] The market standard model for the implied correlation in the CDO tranche structures is a variant of the one-factor Gaussian copula model. Gaussian copula implied correlations for CDX tranches where quoted by dealers until 2008. Afterwards, the Gaussian model was widely dismissed because it had underestimated the realized losses in highly-rated tranches of CDOs during the crisis.

Fabozzi and Sverdlove, 2010; Tang and Yan, 2007; Chen, Cheng and Wu, 2011; and Leland, 2008).

The lack of funding liquidity causes higher costs for firms to obtain short-term funds. This can prevent firms from operating regularly, increase the likelihood of default for firms already in critical situations and widen their credit spreads. A clustering of defaults may cause the spread of the senior tranche of CDX index to widen. Additionally, an increase in short-term funding costs has a negative impact on financial intermediaries (banks and other financial institutions) who act as liquidity providers in the credit markets. When funding liquidity is scarce, traders are not willing to take on positions, especially in complex high-margin securities, such as tranches of CDOs. The tightening in funding liquidity induces fire sales and exacerbates the loss of market liquidity; in turn, the evaporation of market liquidity adds to the funding shortage. Sometimes, it is market liquidity that evaporates first. For instance, in the summer of 2007, the inability to value and trade complex structured credit products caused a run on the off-balance sheet vehicles (conduits and Special Investment Vehicles - SIVs) where the products were located, as investors refused to renew the asset backed commercial paper that financed them. In turn, the run spread the problems to the interbank market (Borio, 2010).[14]

In our work, funding liquidity is proxied by the 1-month commercial paper spread (over the 1-month Treasury-Bill yield), while market liquidity is proxied by the Senior Tranche CDX bid-ask spread.[15] However, the selection of these proxies may encounter some difficulties. First, the proxies are likely to be imperfect because liquidity and

[14] The inter-relation between funding and market liquidity has been examined by Brunnermeier and Pedersen (2009) and He and Krishnamurthy (2009), among others, and it has gained importance in relation to the recent crisis.

[15] A higher bid-ask spread on ST CDX means higher transaction costs associated with this market. A higher commercial paper spread means higher costs for firms to obtain short-term funds.

risk aversion are vague concepts per se that can be captured only at the cost of a deficient approximation. Second, the proxies need to be as little correlated as possible with the other structural variables (in particular with equity returns and volatility, and level and slope of term structure of interest rates). For instance, market liquidity can be partially captured also by the S&P100 index returns and by the term-structure liquidity spread. Consequently, the effect of the liquidity proxies on credit spreads in our work is likely to be an under-estimation of the overall real impact of liquidity.

We also control for the effect of investors' risk aversion on credit spreads. As a proxy for market sentiment and risk aversion we use the equity put-call ratio provided by the Chicago Board Options Exchange (CBOE), i.e. the ratio between put and call volumes for all equity options traded on the CBOE. Since investors buy put options when they expect the market to fall, and call options when they expect the market to rise, the ratio of puts to calls gives analysts a way to measure the relative pessimism of the marketplace. It follows that the relationship between the put-call ratio and credit spreads should be positive. We also employ the difference between VXO implied volatility index and a 30-days (GARCH estimated) S&P100 historical volatility as alternative proxy for risk aversion. If option markets are relatively efficient, the implied volatility should be an efficient forecast of future realized volatility, as it subsumes the information contained in all other market variables in predicting future volatility.[16] As a result, a wide positive difference between implied and historical equity index volatility may contain information about investors' expectations of a large increase in the future level of market volatility. If investors are risk averse, the expectation of higher volatility should lead them either to trade less in structured products (thereby reducing market liquidity provisions and widening ST CDX bid-ask

[16]The results of two well-known studies (Christensen and Prabhala, 1998; and Fleming, 1998) suggest that implied volatility is, indeed, an efficient forecast of future realized volatility that outperforms historic volatility and contains incremental information for forecasting.

spreads and premia) or to request more protection against correlated defaults (thereby increasing demand for and premia on the CDX Index).

2.4 Steps of the Analysis

2.4.1 First step: Cointegration using OLS

Given the vector of variables $\boldsymbol{x}_t$ and the vector of cointegrating parameters $\boldsymbol{\alpha}$:

$$\boldsymbol{x}_t = \begin{pmatrix} ST\ CDX\ Spread_t \\ Constant\ 1 \\ S\&P100\ Cum.Ret._t \\ 5y\ Treasury\ Yield_t \\ T.S.\ Slope_t \\ VXO_t \end{pmatrix} \qquad \boldsymbol{\alpha} = \begin{pmatrix} -1 \\ \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \end{pmatrix}$$

we define the cointegration equilibrium as: $\boldsymbol{\alpha}'\boldsymbol{x}_t = 0$.
Since this equilibrium does not hold at all times, we define a temporary equilibrium error u_t: $\boldsymbol{\alpha}'\boldsymbol{x}_t = u_t$. The variables are said to be cointegrated if their linear combination u_t is stationary over time (i.e. u_t rarely drifts far away from zero and, if it does, it often crosses the zero line).

After testing that all variables are I(1), we estimate the following OLS cointegrating regression:

$$\begin{aligned} ST\ CDX\ Spread_t = \alpha_1 + \alpha_2\ S\&P100\ Cum.Ret._t + \alpha_3\ Treasury\ Yield_t + \\ \alpha_4\ T.S.Slope_t + \alpha_5\ VXO_t + u_t \end{aligned} \tag{1}$$

We obtain the OLS residuals $\widehat{u}_t$ and use them to test the existence of a cointegrating relationship between the dependent variable and the structural variables by means of an Augmented Dickey-Fuller Test, with MacKinnon (2010) critical values. If the null hypothesis of unit root is rejected, then we can classify the structural variables and the credit spreads as cointegrated.

2.4.2 Second Step: Estimation of Error Correction Model (ECM)

If the variables are found cointegrated, we estimate the following error correction model by OLS:

$$\Delta \; Log \; ST \; CDX_t = \vartheta \; ECT_{t-1} + \sum_{i=1}^{p} \rho_i \Delta \; Log \; ST \; CDX_{t-i} + \sum_{i=0}^{p} \beta_i \Delta \; S\&P100 \; Cum.Ret._{t-i} + \sum_{i=0}^{p} \gamma_i \Delta \; Treasury \; Yield_{t-i} + \sum_{i=0}^{p} \delta_i \Delta \; T.S.Slope_{t-i} + \sum_{i=0}^{p} \theta_i \Delta \; VXO_{t-i} + \nu_t \tag{2}$$

where p is the number of lags included and $ECT_{t-1} = \widehat{u}_{t-1}$ is the so-called error correction term represented by the first lag of the residuals from the cointegrating regression (1). By estimating this ECM we test whether and to what extent daily changes in the ST CDX spread are driven by: (i) changes in structural variables; and (ii) correction of ST CDX spread deviation from the long-run equilibrium relationship. The error correction term coefficient ϑ represents the speed of adjustment towards the equilibrium (proportion of yesterday's disequilibrium that is corrected today).

The procedure we employ to estimate a parsimonious ECM is the following. We initially introduce a number of lags p for changes in the variables which are enough to make the residuals of the ECM serially uncorrelated (we use Q-statistics for this purpose). Next, we eliminate the insignificant lagged variables and re-estimate the model again, ensuring that the residuals are still not serially correlated.

2.4.3 Third Step: Inclusion of Liquidity and Risk Aversion Proxies in ECM

In the third step of the analysis we examine whether changes in market and funding liquidity and investors' risk aversion are significant to explain short-run movements in the ST CDX spread. We add to the right-hand side of the ECM equation (2) the current and lagged terms of the proxies for changes in funding liquidity (commercial paper spread), market liquidity (ST CDX bid-ask spread), and risk aversion/market sentiment (proxied either by the difference between VXO index and S&P 100 GARCH volatility, or by the equity option put-call ratio).[17]

After estimating this Augmented ECM model over the whole sample, we want to distinguish whether, according to our initial hypothesis, liquidity effects on structured credit spread are stronger during the crisis period. We therefore re-estimate the Augmented ECM model over different sub-samples: *pre-crisis* sub-sample (20/09/2006 - 20/07/2007), *middle crisis* sub-sample (21/07/2007 - 20/05/2008), and *all-crisis* sub-sample (20/07/2007 - 20/05/2009).

2.4.4 Comparison between Structured and Unstructured Credit Spreads

We repeat all the analysis (Steps 1, 2 and 3) for the AAA Bond Index spread. The structural variables used for AAA Bond Index spread are the same as for the ST CDX spread. As liquidity proxies we employ the commercial paper spread and the 5-year swap spread.[18]

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[17] These variables are all stationary in levels. They are not included in the cointegrating term, as the cointegrating equation represents the implicit structural model which holds in the long-run. Frictions are tested instead as short-run disturbances to the structural equilibrium.

[18] Collin-Dufresne et al. (2001) also use the 5-year swap spread as an indicator of bond market illiquidity, as it is derived from a parallel market of corporate transactions. Sun, Sundaresan and Wang (1993), Brown, Harlow and Smith (1994) and Grinblatt (2001) find that liquidity risk is a more plausible explanation for swap spreads than credit risk. Huang et al. (2003) and Duffie and Singleton (1999)

2.4.5 Discussion on the Validity of the Cointegration Analysis

For the cointegration analysis we prefer the Engle and Granger (1987) procedure to the Johansen (1991) VECM procedure. The Engle and Granger (1987) test assesses the existence and the nature (i.e. the parameters) of the cointegrating relationship independently from the exogenous variables and the number of lags introduced in the ECM. The disadvantages of the Johansen VECM estimation procedure are instead the following: 1) instability of cointegrating parameters: the estimation returns different estimates of the coefficients of the cointegrating equation depending on the number of lags and the exogenous variables included in the VECM, while the cointegration test disregards the exogenous variables; 2) test of lagged effects: using a vector error correction model we cannot test whether changes in the dependent variable (credit spread) can be explained by *contemporaneous* changes in the structural variables. Nevertheless, Johansen (1991) VECMs (including frictional variables as exogenous regressors) are also estimated in order to control for potential endogeneity of the structural variables (see Section 5).

One criticism that can arise against the use of cointegration analysis is that the sample of 20 months of daily data (about 660 observations) is too short to detect a long-run equilibrium. Blanco et al. (2005) overcome similar criticism by reporting the results of Hakkio and Rush (1991). The answer to the question of how long the "long run" must be in order to use cointegration analysis meaningfully depends on the nature of the data being used. If the half-life of deviations from the long-run equilibrium is relatively short, then also a relatively short sample of observations might be enough to determine if the variables are cointegrated.[19]

confirm the prevailing view among swap traders that over short horizons swap spreads are mainly an indicator of "market liquidity", while their dynamics are influenced significantly by "credit risk" over longer horizons.

[19] Moreover, in this case, employing higher frequency observations, such as daily data, could be useful

We conduct a heuristic analysis about the length of the deviations from the long-run equilibrium of the structural model by looking at the frequency of switches of sign in the co-integrating residuals. We anticipate here the results of this analysis. The residuals do not drift away from zero; instead they often cross the zero line taking both positive and negative values. Heuristically, we proxy the average half-life deviations with half average number of days that pass before the residuals switch sign. We find that the average half-life of deviations across our sample is around 8 days. Another way to look at the half-life of deviation is to examine the correlogram of the residuals series and identify the lag (or number of days) at which the autocorrelation coefficient becomes 0.50. Table 7 shows that the half-life of residuals is relatively short (about 8 days) for both ST CDX spread and AAA Bond Index spread. This finding confirms the previous result and supports the idea that the cointegration technique can be validly used for our study.[20]

3 Results and Analysis

3.1 Descriptive Statistics for Credit Spreads

From relatively low levels in 2006 and in the first semester of 2007, the ST CDX spread increases in the second semester of 2007 and comes back to previous levels towards the end of the same year (Figure 1). The spread increases again during the

since the expansion of the number of observations can increase the precision of the estimation.

[20]The ratio between the total length of the selected sample and the half-life of deviations from the structural equilibrium for ST CDX spread is about 82.5 (=660 days/8 days). To draw a parallel with the literature on exchange rates and purchasing power parity (PPP), where cointegration analysis is widely employed, Rogoff (1996) describes the "remarkable consensus" about half-lives of PPP deviations as of 3 to 5 years (using long-horizon data). More recent papers using post-1973 data report shorter half-lives of 2 to 2.5 years. Even taking the lowest estimation (2 years), a researcher would need around 165 years of data on exchange rates to obtain a ratio of 82.5 between the length of the sample and the half-life deviation. Most papers rely instead on samples not longer than 30-50 years. See also Blanco et al. (2005) on this topic.

first semester of 2008 in response to the Bear Stearns failure, and then it registers a huge spike around Lehman Brothers bankruptcy in September 2008. Later on, during the first quarter of 2009, the spread decreases, but it maintains a much higher level than the initial one. The pattern followed by the AAA Bond Index spread is similar.

The distribution of daily ST CDX spread has a high positive skew (Table 1 reports the summary statistics). The range of variability in the spread, measured by its standard deviation, is also large. The series goes from a minimum value of 0.018% (or 1.8 bps) to a maximum value of 2.10% (or 210 bps). The first difference in log ST CDX spread is very volatile over the selected sample, with huge peaks concentrated in the year 2007 (Figure 2). Its distribution is leptokurtic and positively skewed, so clearly non-normal (Table 2 reports the summary statistics). The range of variability in the values of the changes in logs is also wide. The series goes from the minimum value of -60% to the maximum value of 93%.

The distribution of the AAA Bond Index spread has a positive skew of the same magnitude as the ST CDX spread (see Table 1) and varies widely from a minimum value of 0.45% (or 45 bps) to a maximum value of 2.02% (or 202 bps). However, the mean and median of the AAA Bond Index spread are almost double the mean and median of the ST CDX spread. Also the first difference in log AAA Bond Index spread is quite volatile, but mostly in the second and third quarters of 2007 and at the end of 2008 (Figure 3) and with values going from a minimum of -15.7% to a maximum of 16.8%. Its distribution is strongly leptokurtic (see Table 2).

Figures 2 and 3 compare the first difference in the *spreads* with the first difference in the *log spreads*, both for the ST CDX and for the AAA Bond Index. The variability of the first difference in the spreads over the pre-crisis period (from September 2006 to July 2007) is much lower than over the crisis period and almost negligible. Thus, a time-series comparison between the two sub-samples would not be particularly effective. We favour therefore a comparison between first differences in log ST CDX spread and log AAA Bond Index spread; however, we will repeat the analysis using also the other measure as a robustness check (see Section 5 for discussion).

Over almost all of the sample the ST CDX spread level remains below the AAA Bond Index spread (see Figure 1 and Table 1). The relation is opposite in terms of innovations (see Figures 2 and 3, and Table 2)[21]. The higher spread for the AAA Bond Index and its narrower change over time may be due to infrequent trading of AAA bonds which causes stale prices. To confirm this intuition, Table 3 presents the analysis of autocorrelations. The ST CDX spread displays some degree of autocorrelation only in levels, while the AAA Bond Index spread shows larger autocorrelation both in levels and changes.

3.2 Results from the First and Second Steps of the Analysis (Cointegration Test and ECM Estimation)

In the analysis of stationarity, both the Augmented Dickey-Fuller test and the Phillips-Perron test cannot reject the hypothesis that the CDX senior tranche spread, the AAA Bond Index spread and all structural variables are non-stationary I(1) processes (see Table 4).[22] All non-structural proxies are found instead stationary. We proceed therefore with the steps required for the Engle and Granger (1987) cointegration and

[21] The comparison between the spreads of the two indices is subjected to some caveats. The CDX.NA.IG index includes CDSs written on bonds of both financial and industrial firms, while Moody's AAA Bond Index includes only corporate bonds for industrial firms. Moreover, the CDS constituents of the CDX index have 5 years maturity, while in the AAA Bond Index only bonds with remaining maturities as close as possible to 30 years are included. Finally, the underlying companies of the AAA Bond Index are all AAA-rated firms. Contrarily, the CDX senior tranche is obtained by tranching of default risk of the CDX Index. The underlying companies of the CDX index are mainly BBB or A-rated firms.

[22] In particular, the non - stationarity is consistent with the 5-years maturity structure of the CDSs constituents of the CDX.NA.IG index. The ST CDX spread patterns change over time progressively towards the maturity of its CDS components.

ECM analysis.

The parameters of the implicit structural model for credit spreads are estimated using OLS. We provide four different specifications (Models I, II, III, and IV). The difference between Models I - III and Models II-IV is that the latter include also the S&P100 index option implied volatility smirk, which captures the jump risk component in credit spreads. Moreover, while in Models I and II we use the VXO index (S&P100 option implied volatility index) as proxy for equity volatility, in Models III and IV we use the S&P100 30-rolling-days historical volatility. Thus, the results of the estimations can also help to detect whether there is a substantial difference between the effects of forward and backward-looking measures of volatility.

The results of the OLS cointegrating regressions for AAA Bond Index spread and ST CDX spread are show in Table 5.[23] The coefficients for equity cumulative returns, interest rate, and slope of term structure are higher for the ST CDX spread than for the AAA Bond Index spread. All signs predicted by the structural model are found in the results. The term structure slope and the equity volatility have a positive sign for both credit spreads. The Treasury yield and S&P100 cumulative returns have a negative effect on both credit spreads. There are no major differences in the results delivered by the various models. When the implied volatility smirk is included, the coefficients of the other variables become only slightly lower. When the historical volatility is used instead of the VXO index, the coefficients are also slightly lower.

The sensitivity of credit spreads to interest-rate factors is quite large, in particular for the CDX senior tranche spread. In Model I a positive daily change in interest rates of 25 basis points would lead to around 4.5 basis points decrease in the spread on the

[23] All structural variables, the CDX.NA.IG Index Senior Tranche spread and the AAA Bond Index spread are preliminary filtered from potential outliers.

senior tranche ($-0.18 \times 0.25 \approx -0.045$). A large change in the spread between 30-year and 2-year Treasury yields of 100 basis points would lead to a 9 basis points increase in the spread of the CDX senior tranche. The positive estimated coefficient for the slope of the term structure can be also explained by the positive effects that liquidity premia and risk aversion have on both the term structure slope and the spread of CDX tranches. Thus, the slope of the term structure already captures some of the liquidity and risk-aversion effects that may explain the surge in the ST CDX spread.

In Table 5 we observe that the relationship between credit spreads and the 5-year Treasury yield is stronger than the relationship between credit spreads and the S&P100 Index level, in terms of the magnitude of the estimated coefficients. Structural models consider a corporate bond to be equivalent to a risk-free bond less a put option on the firm's value. A possible explanation for the limited magnitude of the equity index coefficient is that for senior credits the put option is so far out-of-the-money that it represents a small position in the underlying asset. Thus, the equity level is a less important variable for their prices.

Although we cannot make any inference on the estimated coefficients of the OLS cointegrating regressions, we analyse whether their residuals are stationary (see Table 6 for the results). For all model specifications and for both the ST CDX and the AAA Bond Index spreads we can reject the null hypothesis of no cointegration between credit spreads and structural variables.[24]

In the error correction models (ECMs) estimated for log ST CDX and AAA Bond Index spread innovations, the changes in the structural variables display the expected signs that the theory suggests and that the cointegrating regressions have already

[24] The only exception is Model III for the AAA Bond Index spread where the ADF statistics suggests no evidence of cointegration. For this reason in the following part of the analysis we disregard this model specification.

confirmed for the relationship between the variables in levels (see Table 8). Moreover, the negative and significant error correction terms in all the estimated ECMs suggest a reversion of credit spreads to their long-run level predicted by the implicit structural model. The estimated speed of adjustment towards this cointegration equilibrium is around 6.5% for the ST CDX spread and 4% for the AAA Bond Index spread.

3.3 Results from the Third Step of the Analysis (Liquidity Effects)

Next, we add the proxies for changes in funding and market liquidity and investors' sentiment and risk aversion as regressors in the ECMs[25] (see results in Table 9 - Panels A and B), after filtering out potential outliers. In Panel B of Table 9 we notice that the adjusted R^2s increase for log ST CDX spread innovations with respect to the adjusted R^2s reported in Table 8, while they remain invariant for log AAA Bond Index spread innovations. Accordingly, the non-structural variables are found highly significant in the ECMs for the ST CDX spread, but always insignificant in the ECMs for the AAA Bond Index spread.[26]

Table 10 shows the results of the ECMs estimation in terms of economic significance (standardized beta) of the explanatory variables. The economic significance is measured as the impact of one-standard deviation change in the explanatory variable on the dependent variable, divided by the standard deviation in the dependent vari-

[25] In the Model specifications I and II, the proxy used for investors' sentiment is the put-call ratio. The difference between VXO and S&P 100 GARCH-estimated volatility is used as proxy for risk-aversion only in Model IV.

[26] To capture market liquidity effects on the ST CDX spread we use the ST CDX bid-ask spread. For the AAA Bond Index spread we employ the 5-years swap spread. This variable is generally considered in the literature as a good indicator of both market and funding liquidity. However, when we exclude the swap spread change from the ECM regression, we notice that the coefficient for the innovations in commercial paper spread remains invariant (this suggests no collinearity problem). Consistently, the correlation between innovations in 5-years swap spread and innovations in commercial paper spread is quite low (only 6%). These results support the idea of using the swap spread to capture changes in corporate bond market liquidity, rather than in funding liquidity.

able. The ST CDX spread changes appear to be driven mainly by innovations in the level and slope of the equity index implied volatility and by the disequilibrium adjustment. Interestingly, the other main drivers of changes in ST CDX spread are the non-structural variables, especially market liquidity (ST CDX bid-ask spread) and risk aversion, which display relatively high standardized betas.

In Model II, an increase of one standard deviation (SD) in VXO between two consecutive days can generate an average increase of 0.145 SD in the log ST CDX spread, if all the other variables remain constant; while a daily one SD negative movement in the volatility skew can cause an increase of 0.11 SD in the log ST CDX spread on average. Equity (historical) volatility has a much lower effect on the AAA Bond Index spread (around 0.02 SD increase in log spread for a one SD change in volatility).

A daily increase of one standard deviation (SD) in the log ST CDX bid-ask generates on average an increase of 0.14 SD in the log ST CDX spread. Similarly, the positive effects of a one SD increase in commercial paper spread and risk aversion on log ST CDX spread are respectively 0.08 and 0.13 SD (the lagged put-call ratio has also a standardized beta equal to 0.09 SD). The economic impact of changes in risk aversion and commercial paper spread on the log ST CDX spread is about 20 times larger than their impact on log AAA Bond Index spread. Moreover, innovations in market liquidity (5-years swap spread) and risk aversion are found statistically insignificant to explain daily changes in the log AAA Bond Index spread.

In order to understand whether the crisis has exacerbated the effect of liquidity on credit spreads, we re-estimate the ECMs for Model I, II and IV and for both ST CDX and AAA Bond Index spread on three different sub-samples: the "pre-crisis period" (20 Sep 2006 - 20 July 2007), the "mid-crisis period" (20 July 2007 - 20 May

2008), and the "all crisis period" (20 July 2007 - 20 May 2009).[27] Unreported results show that there are no significant differences in the effects of structural variables on the log AAA Bond Index and ST CDX spread changes across the three sub-periods considered. Table 11 reports only the results of the ECM estimations for the ST CDX spread relative to the coefficients of the non-structural variables. For Model I and II the non-structural variables are found insignificant over the pre-crisis period, but become highly significant over the crisis period. Additionally, their estimated coefficients increase from one period to the other. Over the mid-crisis period we find that the first difference of the log ST CDX bid-ask spread (proxy for changes in market liquidity) is the only significant frictional variable. Its beta coefficient also records the highest value in this sub-sample. The coefficient for changes in the commercial paper spread switches from insignificant and negative in the pre-crisis sub-period, to positive and statistically significant in the crisis periods. For Model IV, current and lagged changes in risk aversion are found significant in both pre-crisis and crisis periods, the funding liquidity variable becomes significant only in the all-crisis sub-period, while the bid-ask spread is significant also in the mid-crisis sub-period. For all the estimated models the adjusted R^2s are much higher over the crisis sub-periods than over the pre-crisis period. Table 12 reports the economic significance of the three non-structural explanatory variables in Model II. In all sub-samples, the log ST CDX bid-ask spread records the highest impact on log ST CDX spread, followed by the put-call ratio and the commercial paper spread. The market liquidity impact reaches the highest level during the mid-crisis period, when an increase of 1 standard deviation (SD) can generate alone 0.23 SD increase in log ST CDX, everything else being equal.

[27] The estimated equations represent non-standard ECMs, because we use the lagged value of the residuals obtained from the estimation of the long-run equations over the whole sample (Sept. 2006 - May 2009) as error correction terms, in order to study movements in the dependent variable over the shorter pre-crisis and crisis sub-samples.

To compare the economic significance of liquidity and risk aversion with respect to the structural variables and to analyse how they change over time, we group the variables into five factor-blocks: Adjustment Factor (including lagged values of credit spreads changes and error correction term); Equity Factor (including current and lagged equity index returns, and changes in the level and smirk of the VXO index); Interest Rate Process Factor (including current and lagged changes in interest rates and term structure slope); Risk Aversion Factor (including current and lagged values of changes in put-call ratio); and Liquidity Factor (including changes in the commercial paper spread and in log ST CDX bid-ask spread or in swap spread)[28]. For each block we sum the individual standardized betas of all variable-components over the pre-crisis and crisis sub-samples. The results are reported in Table 13. The net positive impact of the Equity Factor (obtained by adding up the negative impact of an increase in equity index returns and in volatility smirk and the positive impact of an increase in equity volatility) decreases from the pre-crisis to the crisis period. Contrarily, the net negative impact of the Interest Rate Factor (obtained by summing the negative impact of an increase in interest rate and the positive impact of an increase in the slope) switches from positive to negative from the pre-crisis to the crisis periods. These results shed some light on the power relationships between the variables within each factor-block determining the prevalent sign of its impact. Noticeably, the positive impacts of the Liquidity and Risk Aversion Factors increase from very low levels in the pre-crisis period (respectively 0.04 and 0.06) to much higher levels in the crisis periods (0.25 and 0.21), if compared to the other Factors.

Further, we analyse which factor categories have the highest explanatory power in

[28]Since in Model II for the AAA Bond Index spread, the Equity Factor includes only current and lagged values of the equity index level, we repeat the analysis using Model IV that instead includes in the Equity Factor also the historical volatility of the equity index. However, we find that the results for Model II and Model IV do not differ substantially.

terms of adjusted R^2s by estimating five regressions for the first difference of log ST CDX and AAA Bond Index spreads on each of these five factor-blocks over the pre-crisis and crisis sub-samples. The results are reported in Tables 14 and 15. For the ST CDX spread the adjusted R^2s of all five factor-block regressions increase from the pre-crisis to the crisis period. For the AAA Bond Index spread the adjusted R^2s of the Equity Factor and the Risk Aversion Factor remain almost invariant, whereas the adjusted R^2 of the Adjustment Factor decreases over the crisis period. On the contrary, the adjusted R^2 of the Liquidity Factor largely increases over the mid-crisis sub-sample (from 0.31% to 6.48%) with respect to the other blocks (quite noticeable also the increase in the R^2 of the Interest Rate block regression). Therefore, while the liquidity proxies do not display significant coefficients in the ECM regressions for log AAA Bond Index spread innovations, they carry more explanatory power during the mid-crisis periods in comparison to other factors (e.g., the equity factor).

Finally, we examine how the individual explanatory power of liquidity and risk aversion has changed over time. For this purpose we estimate rolling bivariate correlations (based on a moving window of 60 days) between first difference in log ST CDX spread changes and innovations in: 1) the log bid-ask spread; 2) the commercial paper spread; and 3) the put-call ratio. Figure 4 shows a clear increase in the correlation between changes in log ST CDX bid-ask and changes in log ST CDX spread in July 2007 (beginning of the crisis), and then around the peaks of the crisis (March 2008: Bear Stearns bankruptcy; September 2008: Lehman Brothers bankruptcy). The correlation between the first differences in log ST CDX spread and commercial paper spread records the highest peaks towards the end of 2007 and in September 2008 (Figure 5). The correlation between the first differences in log ST CDX spread and put-call ratio increases during the second half of 2007, decreases at the beginning of 2008, then increases and remains high from March 2008 until the end of the year (Figure 6).

In conclusion, all these findings confirm that market and funding liquidity had a large impact on the dramatic increase in the spread of the Senior Tranche of CDX.NA.IG Index during the crisis period (i.e. starting from July 2007). Although for the AAA Bond Index we find some evidence that the explanatory power of the Liquidity Factor alone is much higher during the crisis than before (also with respect to the structural variables), the liquidity variables are never statistically and economically significant when used in the ECM regressions. These findings do not rule out the possibility that the corporate bond index spread contains a liquidity premium (which increased during the crisis period); it only shows that, given the methodology and the proxies employed, changes in liquidity and risk aversion do not appear to be statistically and economically significant to explain changes in spreads of simple unstructured credit, while they are significant for more complex structured credit derivatives.

4 Test on the Failure of the Pre-Crisis Structural Model

So far we have investigated liquidity and risk aversion effects on senior credit spreads assuming a structural model (in cointegration) and then examining short-term movements in ECMs in order to see what happens that cannot be explained by the structural variables. However, besides higher illiquidity and risk aversion, another possible reason for the unexpected increase in ST CDX spreads during the crisis is that market participants "have changed their minds" about the *correct* model for pricing structured credit. Coval, Jurek and Stafford (2009) claim that the large "repricing" of investment-grade structured credit securities during the subprime crisis represents the correction of an ex-ante failure of investors to appropriately charge for systemic risk. Prior to the crisis, the senior tranches of the CDX.NA.IG Index were under-priced (i.e. spreads were too low). The crisis may have caused a new permanent equilibrium between credit pricing and its structural determinants, rather than a temporary deviation from the existing (pre-crisis) equilibrium.

Although in our paper we do not calibrate an explicit pricing model, as Coval et al. (2009) do, the cointegration analysis takes into account the same fundamental drivers of credit spreads considered by their structural model. If the mispricing hypothesis of Coval et al. (2009) is correct, then we should observe that: (i) the pre-crisis structural model generates a spread on the senior CDX tranche which is too low for its level of riskiness; and (ii) the subsequent widening of the senior tranche spread during the crisis represents a departure from the predictions of the flawed pre-crisis structural model (i.e. a correction of the mispricing). We test the Coval et al. (2009) hypothesis against our alternative hypothesis that the pre-crisis model predicts correctly only the default component of the tranche spread, but cannot capture the extra-premia due to market and funding illiquidity which widened during the crisis.

To test the Coval et al. (2009) hypothesis we perform the analysis in four steps:
1) We estimate an implicit structural model over the pre-crisis period (20/09/2006 - 20/02/2007);
2) We obtain model-predicted ST CDX spreads over the crisis sample, using the structural-model parameters estimated over the pre-crisis period and updated values of structural variables over the crisis period;
3) We obtain the deviations of the model-predicted spreads from the actual spreads (so-called "forecast errors");
4) We regress changes in log ST CDX spread over the crisis period on structural and non-structural proxies, and lagged forecast error which should capture the adjustment towards/away the pre-crisis model. This OLS regression represents an "atypical" ECM:

the correction term is in fact represented by the lagged forecast error, rather than by the lagged residuals from the cointegrating regression.[29]

This last analysis seeks to distinguish in particular whether:
a) ST CDX spread movements during the crisis period represent adjustments towards the pre-crisis equilibrium relationship (i.e. the lagged forecast error carries a significant negative coefficient); or
b) during the crisis the ST CDX spread drifts away from the pre-crisis equilibrium relationship (i.e. the lagged forecast error carries a significant positive coefficient).
Additionally, this analysis examines whether changes in funding and market liquidity, and investors' risk aversion continue to explain short-term (daily) changes in the ST CDX spread, even after controlling for the pre-crisis model forecast error.

In Figure 7 we observe that the predicted level of the ST CDX spread is much lower than the observed spread. As Model I, II and IV deliver the same unsatisfactory results, we focus the rest of the analysis only on Model II. Figures 8 - 12 show instead that over the crisis sample the model-predicted changes fairly track daily changes in observed ST CDX spreads over the crisis period, although the latter remain much wider on average. Table 16 shows that, depending on the sub-sample considered, the model-predicted changes are between 22 and 43% correlated with the actual changes in log ST CDX spread. By performing Principal Component Analysis (unreported results) we also discover that the first principal component explains more than 50% of the predicted changes and around 20% of the actual changes, but captures almost 80% of common movements between the two series.

Table 17 shows the results of the "atypical" error correction model. We find that the

[29] We use the same ECM parsimonious specification which has been used in the previous analysis for Model II (see Section 3).

lagged forecast error is never significant to explain changes in the actual ST CDX spread over the crisis period, also when changes in liquidity and risk aversion are not included as regressors. However, in all cases the sign of the estimated coefficient for the forecast error is negative. Although the lack of significance prevents us from drawing clear conclusions, we do not observe a positive significant coefficient for the lagged forecast error. This would suggest that the ST CDX spread during the crisis did not drift away from the pre-crisis structural model predictions (no mispricing correction), rather it widened above the structural model predictions because it incorporated investors' concerns of a "drying up" of market and funding liquidity (which are found consistently significant).

As a further analysis to confirm this intuition, we perform an OLS regression to detect whether, during the crisis period, liquidity frictions and risk aversion are drivers of the deviations of observed spreads from the spreads predicted by the pre-crisis structural model. In Table 18 we observe that the widening of illiquidity and investors' risk aversion cause a significant increase in the structural model forecast error.

In sum, there is no clear evidence of the effect of a *pre-crisis model failure* on the increase of the ST CDX spread over the crisis period, while strong effects of liquidity and risk aversion are detected.

5 Robustness Checks

In this last part of the work we perform several robustness checks.[30]

The first check is on the effects of the staleness of AAA bond prices in our analysis.

[30] All the results from the robustness checks are unreported for brevity, but they are available upon request.

There is a limited number of AAA bonds in the corporate bond market and they trade only rarely. Since AA corporate bonds are more numerous and more frequently traded, we repeat the whole 3-steps analysis of Section 3 for Moody's AA Bond Index spread. We observe stronger evidence in favour of cointegration between the AA Bond Index spread and the structural variables. However, as for the AAA Bond Index, in the error correction models the proxies for risk aversion and liquidity lack significance, even when the analysis concerns solely the crisis sub-period.

As second check, we re-estimate the error correction models using as dependent variables first differences in credit spreads, rather than first differences in log credit spreads, to ascertain that there is no substantial difference in the results. In the error correction models for first differences in ST CDX spread, the level of economic and statistical significance of the liquidity and risk aversion proxies is very similar to the one found for first differences in log ST CDX spread, although for all model specifications the adjusted R^2s of the ECMs are much higher, on average by 10 percent.

As third check, we control for non-linear effects of structural and non-structural variables (squares and cubes) in both the cointegrating regression and the error correction models, in order to mitigate our concerns relative to a specification error caused by the linear estimation of a non-linear structural model. We do not observe any major impact of non-linear terms on the regression results. Only the first difference in the squared implied volatility is found significant in the ECM estimation, which is consistent with the non-linear relationship between credit spreads and equity volatility predicted by the structural model theory. Most importantly, the signs and levels of significance of the liquidity and risk aversion proxies remain invariant.

Finally, in the fourth robustness check, we control for potential endogeneity of structural variables by means of: 1) re-estimation of Engle-Granger ECMs, excluding contemporaneous changes in structural regressors; and 2) estimation of Johansen Vector Error Correction Model (VECM), including as endogenous variables the credit spreads and the structural variables, and as exogenous variables the changes in market/funding liquidity and risk-aversion. The Engle-Granger ECM re-estimations deliver very similar results to the original ECMs (discussed in Section 3). Likewise, in the VECM analysis no substantial differences are observed in the level of statistical and economic significance of frictional variables. However, changes in equity index price and implied volatility skew appear now insignificant to explain changes in the ST CDX spread, despite the fact that the equity implied volatility skew displays a much larger coefficient in the cointegrating equation. Finally, in the VECMs for the AAA Bond Index, we detect positive (albeit weak) effects of changes in the swap spread (proxy for market liquidity) on the credit spread, which have not been found in the previous ECM analysis.

6 Conclusions

In this work we examine the effect of liquidity on senior credit spreads through:
(i) A cross-asset comparison between structured and unstructured top-rated portfolios of credit instruments, i.e. Senior Tranche of CDX.NA.IG Index (ST CDX) and AAA Bond Index;
(ii) A time-series comparison of the determinants of credit spreads before and during the subprime crisis 2007-09.

To distinguish the liquidity effects from the credit risk effects, we examine various components of credit spreads using cointegration analysis and error correction models. We consider a set of structural variables and a set of non-structural variables which represent changes in market and funding liquidity and in investor's "sentiment".

The signs predicted by the structural model theory for the relationship between credit spreads, equity index returns, equity index volatility, and interest rates are all verified by the cointegration analysis, for both the ST CDX and the AAA Bond Index spreads. The implicit structural model represents an "equilibrium" towards which the ST CDX and the AAA Bond Index spreads tend to align over time. However, in the short term, liquidity and risk aversion have significantly positive impact on movements in ST CDX spread over the crisis period (July 2007 - May 2009). By contrast, the non-structural variables lack significance to explain changes in ST CDX spread over the pre-crisis period (September 2006 - July 2007) and they are irrelevant to explain changes in AAA Bond Index spread over both the pre-crisis and crisis periods. Thus, this paper suggests that highly-rated complex credit markets (such as senior CDO tranches) can be greatly affected by frictional factors which may be instead less prominent in simpler credit markets.

Further analysis suggests that the increase in senior credit spreads is more likely due to wider concern of a "drying up" of market and funding liquidity than to the correction of a pre-existing underpricing of these credit instruments. Consistently, we observe that the deviations between observed ST CDX spreads and spreads predicted by the pre-crisis structural model (forecast errors) are significantly explained by market and funding liquidity and investors' risk aversion.

While new literature on the correct pricing model for structured credit derivatives flourishes and contrasting explanations are offered as to why top-rated structured credit premia have dramatically increased during the recent crisis, our empirical analysis sheds some light on the critical role of market and funding liquidity. This work supports the hypothesis that market and funding liquidity contributed to the surge in the spread of the Senior Tranche CDX.NA.IG Index during the subprime crisis.

Regulators, rating agencies and risk-managers should take liquidity into account in the evaluation of senior tranches of structured credit derivatives and should develop more sophisticated tools to appreciate the time-varying liquidity premia. A sudden drying-up of liquidity can in fact drastically reduce the benefits of securitization, while leaving investors highly exposed to systemic risk.

References

Bedendo, M., L. Cathcart, and L. El Jahel (2007): "The Slope of the Term Structure of Credit Spreads: An Empirical Investigation," *Journal of Financial Research*, 30(2), 237–257.

Blanco, R., S. Brennan, and I. W. Marsh (2005): "An Empirical Analysis of the Dynamic Relation between Investement-Grade Bonds and Credit Default Swap," *Journal of Finance*, 60(5), 2255–2281.

Bongaerts, D., F. de Jong, and J. Driessen (2011): "Derivative Pricing with Liquidity Risk: Theory and Evidence from the Credit Default Swap Market," *Journal of Finance*, 66(1), 203–240.

Borio, C. (2010): "Ten Propositions about Liquidity Crises," *CESifo Economic Studies*, 56(1), 70–95.

Brown, K. C., W. V. Harlow, and D. J. Smith (1994): "An Empirical Analysis of Interest Rate Swap Spreads," *Journal of Fixed Income*, 3, 61–78.

Brunnermeier, M., and L. Pedersen (2009): "Market Liquidity and Funding Liquidity," *Review of Financial Studies*, 22(6), 2201–2238.

Campbell, J. Y., and G. B. Taksler (2003): "Equity Volatility and Corporate Bond Yields," *Journal of Finance*, 58(6), 2321–2350.

Chen, L., D. A. Lesmond, and J. Wei (2007): "Corporate Yields Spreads and Bond Liquidity," *Journal of Finance*, 62(1), 119–149.

CHEN, R., X. CHENG, AND L. WU (2011): "Dynamic Interactions Between Interest-Rate and Credit Risk: Theory and Evidence on the Credit Default Swap Term Structure," *Review of Finance*.

CHEN, R., F. FABOZZI, AND R. SVERDLOVE (2010): "Corporate Credit Default Swap Liquidity and Its Implications for Corporate Bond Spreads," *Journal of Fixed Income*, 20(2), 31–57.

CHOUDHRY, M. (2010): *Structured Credit Products: Credit Derivatives and Synthetic Securitization (2nd Ed.)*. John Wiley & Sons.

CHRISTENSEN, B. J., AND N. R. PRABHALA (1998): "The Relation between Implied and Realized Volatility," *Journal of Financial Economics*, 50, 125–150.

COLLIN-DUFRESNE, P. (2009): "A Short Introduction to Correlation Markets," *Journal of Financial Econometrics*, 7, 12–29.

COLLIN-DUFRESNE, P., R. S. GOLDSTEIN, AND J. S. MARTIN (2001): "The Determinants of Credit Spread Changes," *Journal of Finance*, 56(6), 2177–2207.

COLLIN-DUFRESNE, P., R. S. GOLDSTEIN, AND F. YANG (2012): "On the Relative Pricing of Long Maturity Index Options and CDX Tranches," *Journal of Finance*, 67(6), 1983–2014.

CONT, R., AND P. TANKOV (2004): *Financial Modelling with Jump Processes*. Chapman and Hall.

COVAL, J. D., J. W. JUREK, AND E. STAFFORD (2009): "The Pricing of Investment Grade Credit Risk during the Financial Crisis," Harvard University Working Paper.

Cremers, K. J. M., J. Driessen, and P. Maenhout (2008): "Explaining the Level of Credit Spreads: Option-Implied Jump Risk Premia in a Firm Value Model," *Review of Financial Studies*, 21(5), 2209–2242.

Crockett, A. (2008): "Market Liquidity and Financial Stability," *Banque de France Financial Stability Review - Special Issue on Liquidity*, 11, 1127–1162.

Dick-Nielsen, J., P. Feldhütter, and D. Lando (2012): "Corporate Bond Liquidity before and after the Onset of the Subprime Crisis," *Journal of Financial Economics*, 103(3), 471–492.

Duffie, D., and K. J. Singleton (1999): "Modeling Term Structures of Defaultable Bonds," *Review of Financial Studies*, 12(4), 687–720.

Dungey, M., G. P. Dwyer, and T. Flavin (2013): "Systematic and Liquidity Risk in Subprime-Mortgage Backed Securities," *Open Economies Review*, 24, 5–32.

Engle, R. F., and C. W. J. Granger (1987): "Co-Integration and Error Correction: Representation, Estimation, and Testing," *Econometrica*, 55(2), 251–276.

Eom, Y. H., J. Helwege, and J. Huang (2004): "Structural Models of Corporate Pricing: An Empirical Analysis," *Review of Financial Studies*, 17(2), 499–544.

Ericsson, J., K. Jacobs, and R. Oviedo (2009): "The Determinants of Credit Default Premia," *Journal of Financial and Quantitative Analysis*, 44, 109–132.

Ericsson, J., and O. Renault (2006): "Liquidity and Credit Risk," *Journal of Finance*, 61(5), 2219–2250.

Fender, I., and M. Scheicher (2009): "The Pricing of Subprime Mortgage Risk in good times and bad: Evidence from the ABX.HE Indices," European Central Bank

Paper Series, No. 1056.

Fleming, J. (1998): “The Quality of Market Volatility Forecasts implied by S&P 100 Index Option Prices,” *Journal of Empirical Finance*, 5, 317–345.

Gemmill, G., and A. Keswani (2011): “Downside Risk and the Size of Credit Spreads,” *Journal of Banking and Finance*, 35(8), 2021–2036.

Greatrex, C. A. (2009): “Credit Default Market Determinants,” *Journal of Fixed Income*, 18(3), 18–32.

Grinblatt, M. (2001): “An Analytic Solution for Interest Rate Swap Spreads,” *International Review of Finance*, 2(3), 113–149.

Hakkio, C. S., and M. Rush (1991): “Cointegration: How Short is the Long Run?,” *Journal of International Money and Finance*, 10, 571–581.

He, Z., and A. Krishnamurthy (2012): “Intermediary Asset Pricing,” *American Economic Review*, 103(2), 732–770.

Hendry, D. (1995): *Dynamic Econometrics*. Oxford University Press.

——— (2009): “The Methodology of Empirical Econometric Modelling: Applied Econometrics Through the Looking-Glass,” in *Palgrave Handbook of Econometrics, Volume 2: Applied Econometrics*, ed. by T. Mills, and K. Patterson. Palgrave MacMillan.

Huang, J., and M. Huang (2012): “How Much of Corporate-Treasury Yield Spread Is Due to Credit Risk?: A New Calibration Approach,” *Review of Asset Pricing Studies*, 2(2), 153–202.

HUANG, Y., S. NEFTCI, AND I. JERSEY (2003): "What Drives Swap Spreads, Credit or Liquidity?," ICMA Centre Discussion Paper in Finance 2003-05.

HULL, J., AND A. WHITE (2001): "Valuing Credit Default Swaps II: Modeling Default Correlations," *Journal of Derivatives*, 8(3), 12–22.

JOHANSEN, S. (1991): "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models," *Econometrica*, 59(6), 1551–1580.

LELAND, H. (2004): "Predictions of Default Probabilities in Structural Model of Debt," *Journal of Investment Management*, 2, 5–20.

——— (2006): "Structural Models in Corporate Finance - Lecture 2: A New Structural Model," Princeton Lectures in Finance, September 20-22.

——— (2008): "Structural Models and the Credit Crisis," C.R.E.D.I.T. Liquidity and Credit Risk, Venice, September 22.

LI, D. X. (2000): "On Default Correlation: A Copula Function Approach," RiskMetrics Working Paper.

LONGSTAFF, F. A. (1995): "How Much Can Marketability Affect Security Values?," *Journal of Finance*, 50(5), 1767–1774.

LONGSTAFF, F. A., S. MITHAL, AND E. NEIS (2005): "Corporate Yields Spreads: Default Risk or Liquidity? New Evidence from the Credit Default Market," *Journal of Finance*, 60(5), 2213–2253.

LONGSTAFF, F. A., AND E. S. SCHWARTZ (1995): "A Simple Approach to Valuing Risky Fixed and Floating Rate Debt," *Journal of Finance*, 50(3), 789–819.

MacKinnon, J. H. (2010): "Critical Values for Cointegration Tests," Mimeo, Department of Economics, Queen's University Working Paper.

Merton, R. (1974): "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates," *Journal of Finance*, 29, 449–470.

Perraudin, W., and S. Wu (2008): "The Determinants of Asset-Backed Security Prices in Crisis Periods," Imperial College Working Paper.

Scheicher, M. (2008): "How has CDO Market Pricing changed during the Turmoil? Evidence from CDS Index Tranches," European Central Bank Paper Series, No. 910.

Stanton, R., and N. Wallace (2011): "The Bear's Lair: Indexes Credit Default Swaps and the Subprime Mortgage Crisis," *Review of Financial Studies*, 24(10), 3250–3280.

Sun, T., S. Sundaresan, and C. Wang (1993): "Interest Rate Swaps: An Empirical Investigation," *Journal of Financial Economics*, 34, 77–99.

Tang, D. Y., and H. Yan (2007): "Liquidity and Credit Default Spread," AFA 2007 Chicago Meetings Paper.

Vasicek, O. (1987): "Probability of Loss on Loan Portfolio," KMV Working Paper.

Zhang, B. Y., H. Zhou, and H. Zhu (2009): "Explaining Credit Default Swap Spreads with the Equity Volatility and Jump Risks of Individual Firms," *Review of Financial Studies*, 22(12), 5099–5131.

Zhou, C. (2001): "An Analysis of Default Correlations and Multiple Defaults," *Review of Financial Studies*, 14(2), 555–576.

Figures and Tables

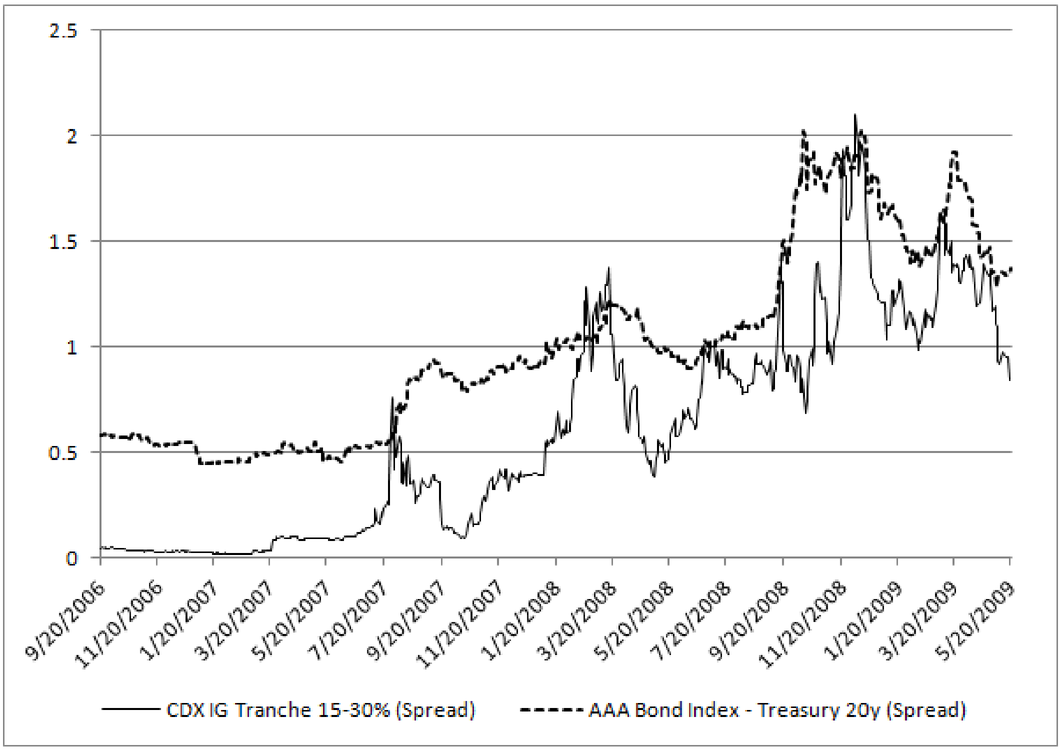

Figure 1: Time-series of Moody's AAA Bond Index Spread and CDX.NA.IG Index Senior Tranche Spread

(Percentage Units; Daily Frequency; Period: 20th Sep 2006 - 20th May 2009)

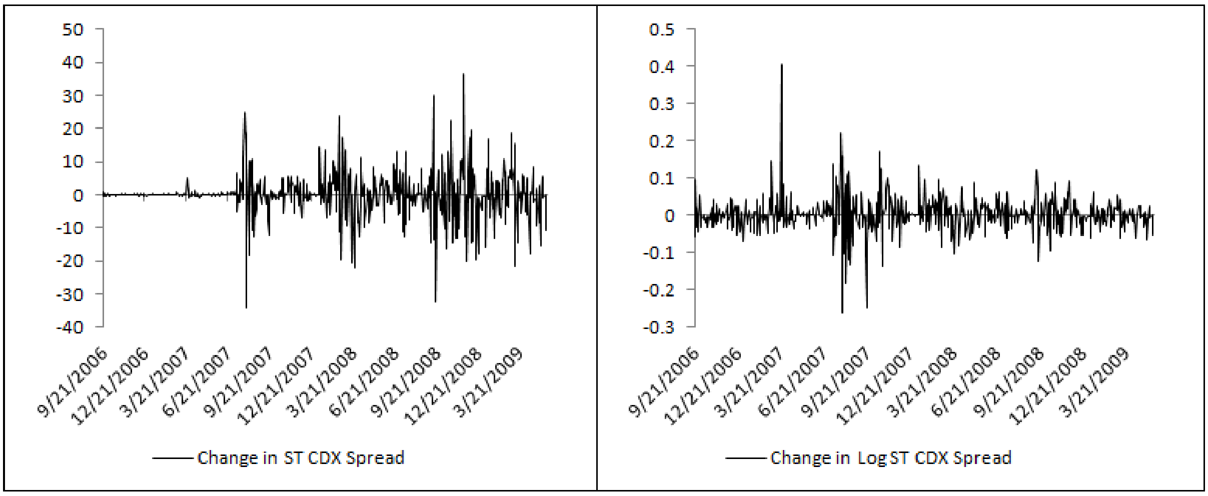

Figure 2: Time-series of Changes in Spread (bps) and Log Spread of CDX.NA.IG Index Senior Tranche
(Daily Frequency; Period: 20th Sep 2006 - 20th May 2009)

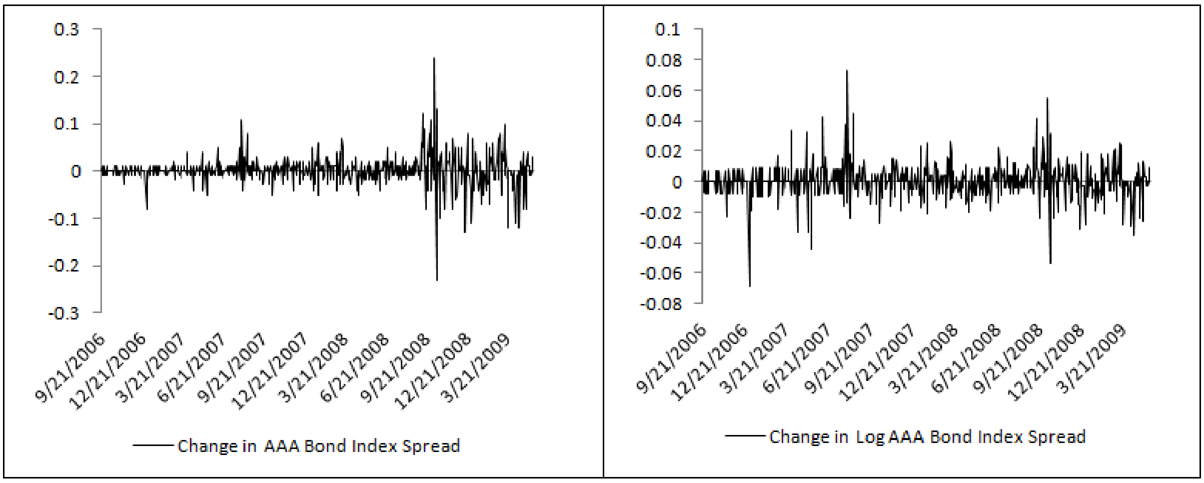

Figure 3: Time-series of Changes in Spread (%) and Log Spread of Moody's AAA Bond Index
(Daily Frequency; Period: 20th Sep 2006 - 20th May 2009)

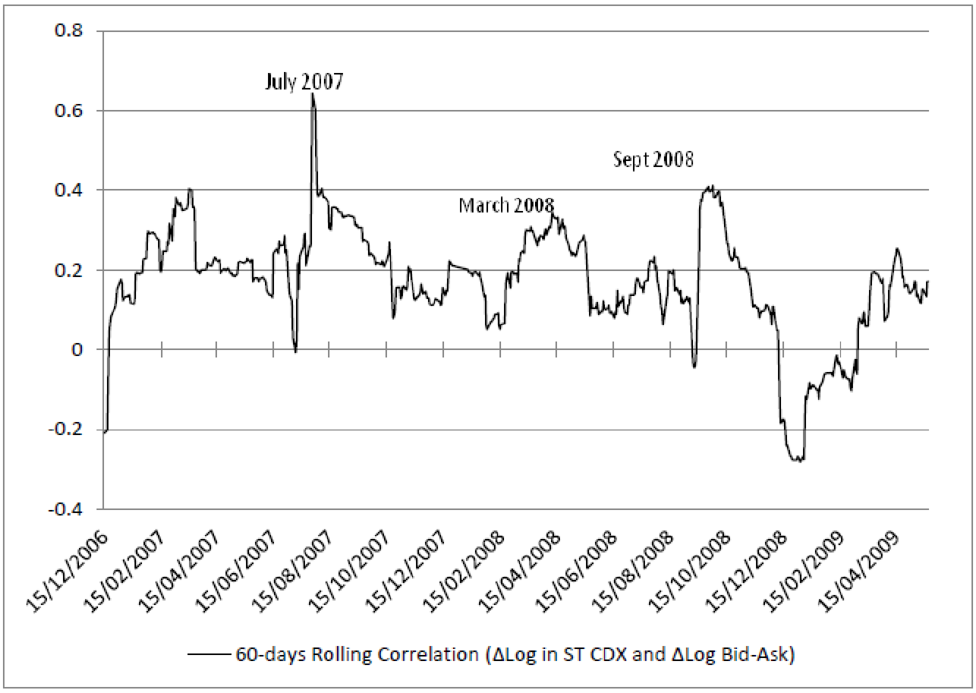

Figure 4: Rolling Correlation between Changes in Log CDX.NA.IG Index Senior Tranche Spread and Changes in Market Liquidity

(Market liquidity measured by ST CDX bid-ask spread. Rolling window of 60 consecutive days)

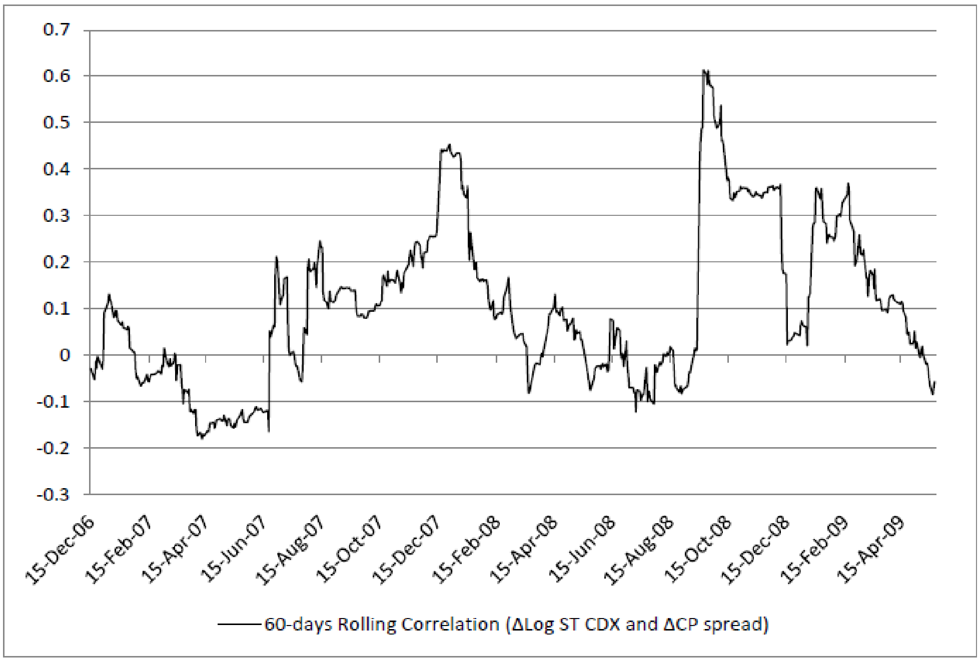

Figure 5: Rolling Correlation between Changes in Log CDX.NA.IG Index Senior Tranche Spread and Changes in Funding Liquidity

(Funding liquidity measured by commercial paper spread. Rolling window of 60 consecutive days)

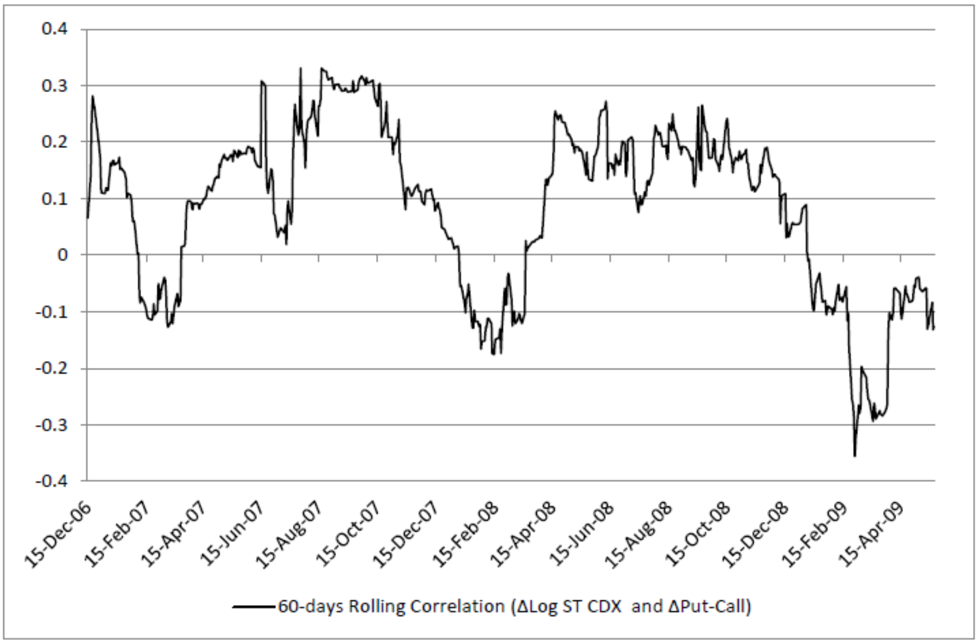

Figure 6: Rolling Correlation between Changes in Log CDX.NA.IG Index Senior Tranche Spread and Changes in Risk Aversion

(Risk aversion measured by CBOE put-call ratio. Rolling window of 60 consecutive days)

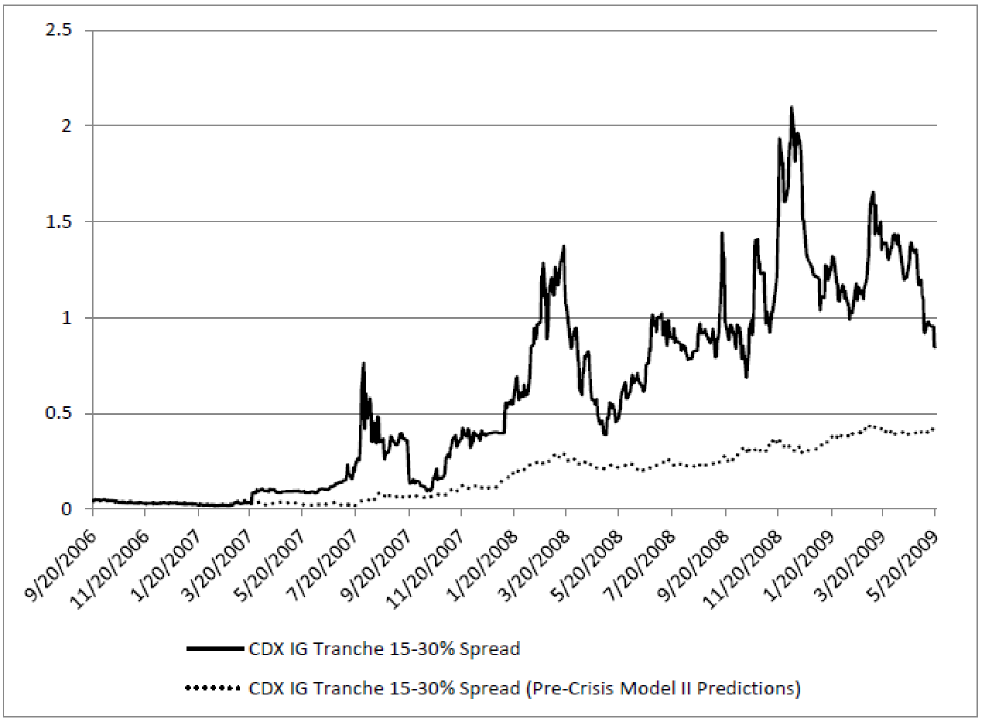

Figure 7: Observed CDX.NA.IG Index Senior Tranche Spread vs. Spread predicted by the Pre-Crisis Model II

(Percentage Units; Daily Frequency; Period: 20th Sep 2006 - 20th May 2009)

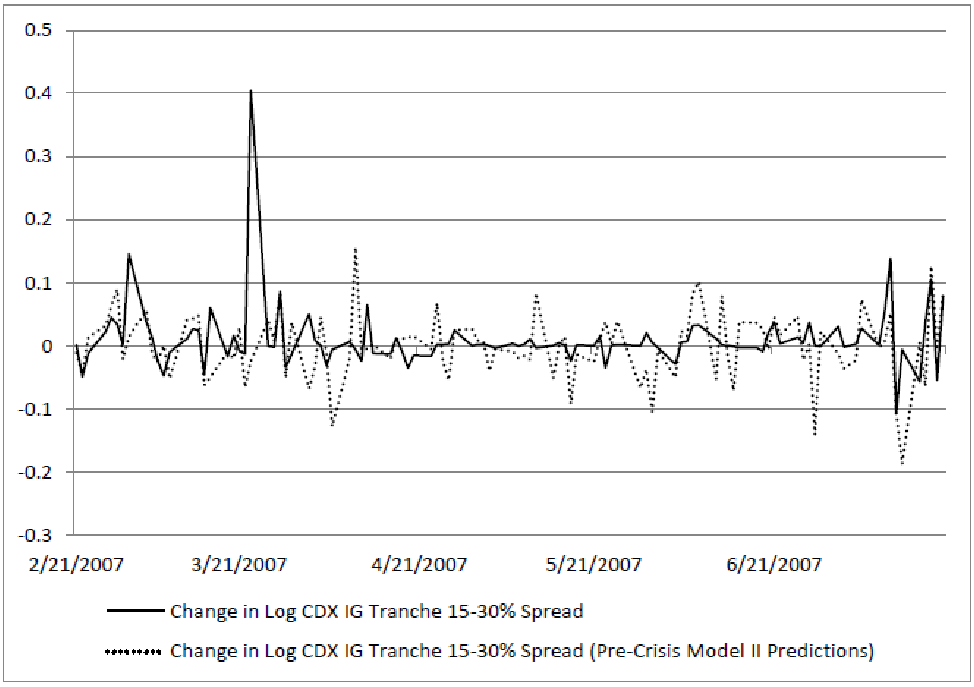

Figure 8: Observed Changes in Log CDX.NA.IG Index Senior Tranche Spread vs. Changes predicted by the Pre-Crisis Model II - (Feb 2007 - Jul 2007)
(Percentage Units; Daily Frequency; Period: 20th Feb 2007 - 20th Jul 2007)

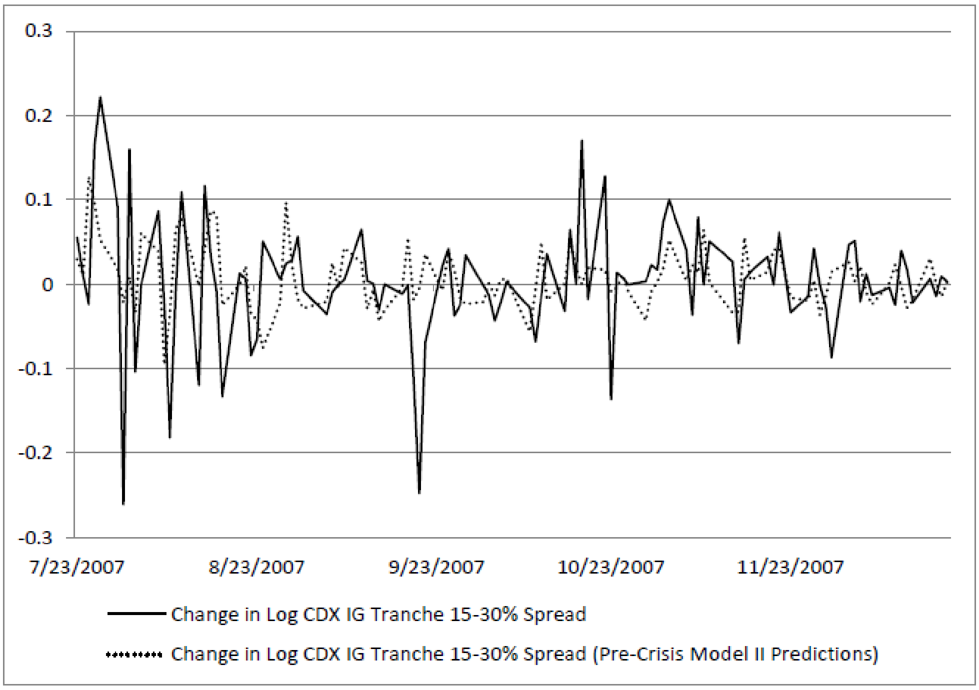

Figure 9: Observed Changes in Log CDX.NA.IG Index Senior Tranche Spread vs. Changes predicted by the Pre-Crisis Model II - (Jul 2007 - Dec 2007)
(Percentage Units; Daily Frequency; Period: 21st Jul 2007 - 20th Dec 2007)

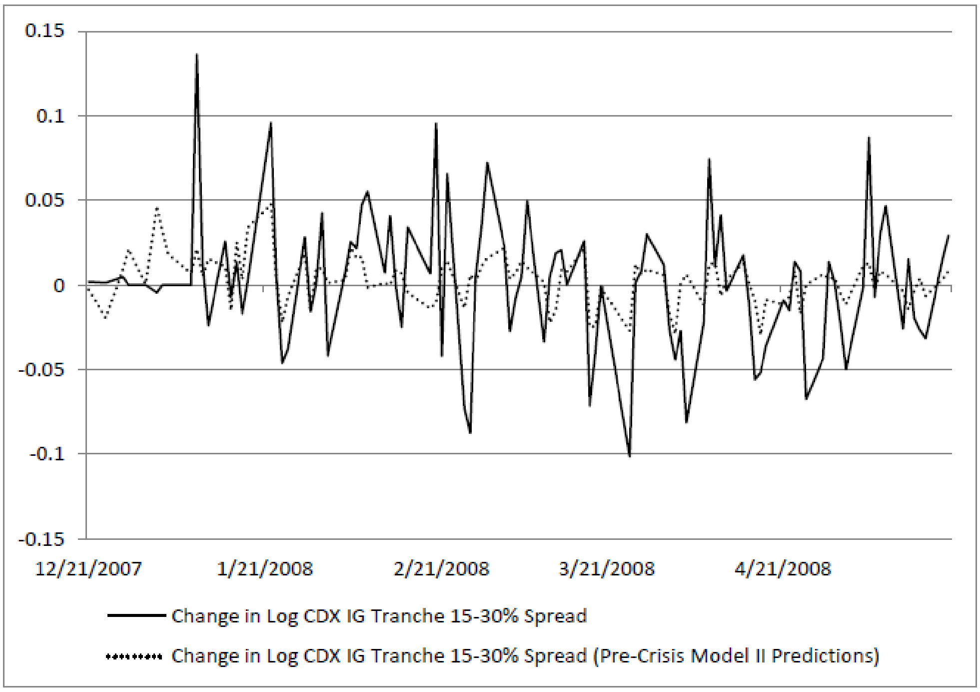

Figure 10: Observed Changes in Log CDX.NA.IG Index Senior Tranche Spread vs. Changes predicted by the Pre-Crisis Model II - (Dec 2007 - May 2008)
(Percentage Units; Daily Frequency; Period: 21st Dec 2007 - 20th May 2008)

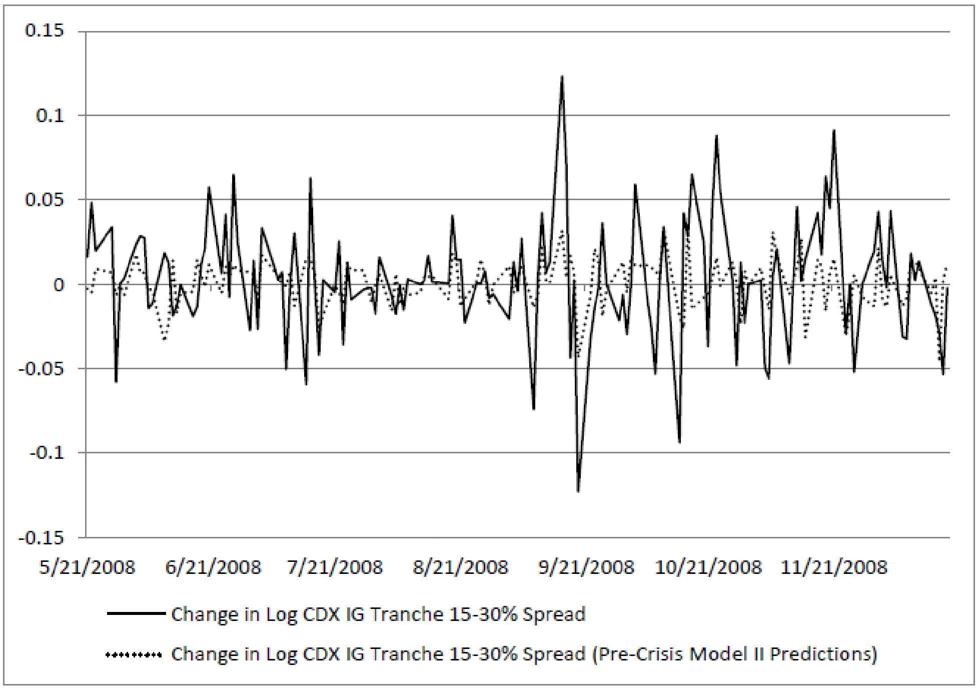

Figure 11: Observed Changes in Log CDX.NA.IG Index Senior Tranche Spread vs. Changes predicted by the Pre-Crisis Model II - (May 2008 - Dec 2008)
(Percentage Units; Daily Frequency; Period: 21st May 2008 - 20th Dec 2008)

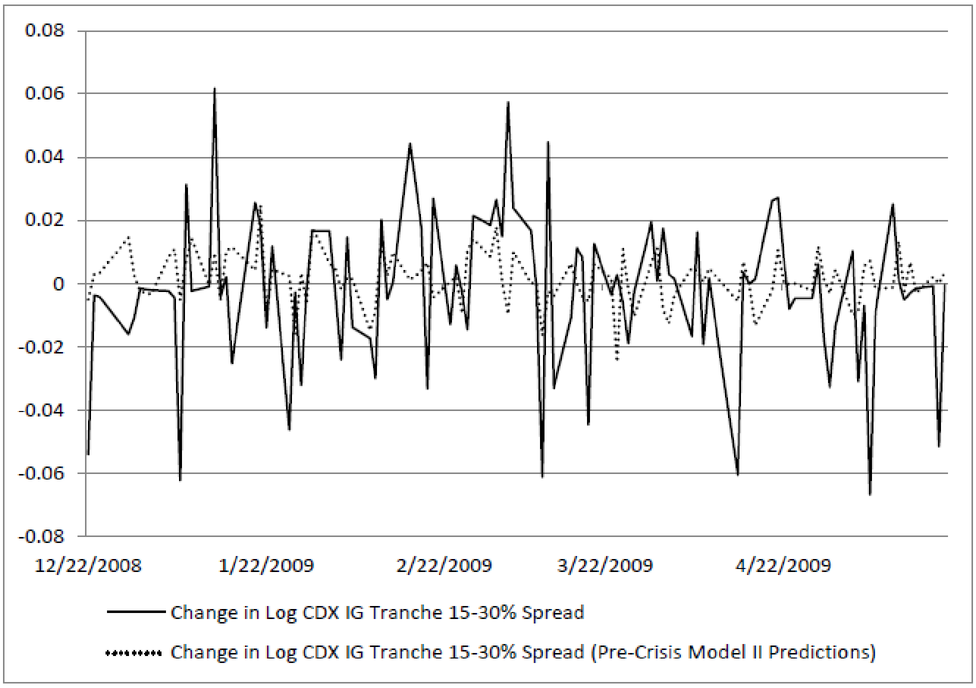

Figure 12: Observed Changes in Log CDX.NA.IG Index Senior Tranche Spread vs. Changes predicted by the Pre-Crisis Model II - (Dec 2008 - May 2009)
(Percentage Units; Daily Frequency; Period: 21st Dec 2008 - 20th May 2009)

Table 1: Summary Statistics for Moody's AAA Bond Index Spread (over 20y TCM) and CDX.NA.IG Index Senior Tranche Spread
(Variables measured in Percentage Units; Daily Frequency; Period: 20th Sep 2006 - 20th May 2009)

	AAA Bond Index Spread	ST CDX Spread
Mean	0.999	0.597
Median	0.940	0.502
Maximum	2.020	2.100
Minimum	0.450	0.018
Std. Dev.	0.447	0.507
Skewness	0.588	0.537
Kurtosis	2.283	2.268
Jarque-Bera	52.382	46.587
Probability	<0.0001	<0.0001
Observations	662	662

Table 2: Summary Statistics for Changes in Log Moody's AAA Bond Index Spread (over 20y TCM) and in Log CDX.NA.IG Index Senior Tranche Spread
(Variables measured in Percentage Units; Daily Frequency; Period: 20th Sep 2006 - 20th May 2009)

	Change in Log AAA Bond Index Spread	Change in Log ST CDX Spread
Mean	0.130	0.441
Median	0.000	0.019
Maximum	16.834	93.069
Minimum	-15.719	-59.996
Std. Dev.	2.551	10.192
Skewness	0.143	0.920
Kurtosis	10.780	18.300
Jarque-Bera	1671.858	6540.788
Probability	<0.0001	<0.0001
Observations	662	662

Table 3: Analysis of Autocorrelation for Moody's AAA Bond Index Spread and CDX.NA.IG Index Senior Tranche Spread
(5 Lags considered; in Column 7 significant lags of AR(5) OLS regressions are indicated in bold)

	Lag	**Auto Corr.**	**Partial AC**	**Q-Stat**	**Prob.(Q)**	**OLS Coefficient**	**Std. Errors**	**t-stat**	**P-value**
$ST\ CDX_t$	**1**	0.991	0.991	653.0	**0.000**	**0.010**	0.0004	26.065	**0.000**
	2	0.981	-0.028	1294.6	**0.000**	0.000	0.0006	0.740	0.460
	3	0.971	-0.061	1923.4	**0.000**	**-0.001**	0.0006	-1.801	**0.072**
	4	0.961	0.030	2540.4	**0.000**	-0.001	0.0006	-1.167	0.244
	5	0.953	0.086	3147.8	**0.000**	**0.001**	0.0004	2.542	**0.011**
$\Delta\ Log\ ST\ CDX_t$	1	-0.021	-0.021	0.3	0.586	-0.013	0.0390	-0.337	0.736
	2	-0.008	-0.009	0.3	0.844	-0.011	0.0390	-0.287	0.775
	3	0.022	0.022	0.7	0.880	0.024	0.0390	0.609	0.543
	4	-0.009	-0.008	0.7	0.948	-0.011	0.0390	-0.257	0.797
	5	-0.029	-0.029	1.3	0.936	-0.029	0.0390	-0.743	0.458
AAA_t	**1**	0.997	0.997	660.4	**0.000**	**0.010**	0.0004	26.065	**0.000**
	2	0.993	-0.003	1317.1	**0.000**	0.000	0.0006	0.740	0.460
	3	0.990	0.073	1970.9	**0.000**	**-0.001**	0.0006	-1.801	**0.072**
	4	0.987	-0.079	2621.0	**0.000**	-0.001	0.0006	-1.167	0.244
	5	0.983	-0.042	3267.1	**0.000**	**0.001**	0.0004	2.542	**0.011**
$\Delta\ Log\ AAA_t$	1	-0.038	-0.038	0.9	0.322	-0.039	0.0392	-0.989	0.323
	2	-0.089	-0.090	6.2	**0.044**	**-0.075**	0.0389	-1.916	**0.056**
	3	0.096	0.089	12.4	**0.006**	**0.090**	0.0389	2.319	**0.021**
	4	0.101	0.102	19.2	**0.001**	**0.101**	0.0390	2.580	**0.010**
	5	-0.058	-0.035	21.4	**0.001**	-0.035	0.0392	-0.886	0.376

Table 4: Unit Root Analysis for Moody's AAA Bond Index Spread, CDX.NA.IG Index Senior Tranche Spread, Structural and Non-Structural Variables

(Augmented Dickey Fuller and Phillips-Perron Tests are performed. For all ADF and PP test-equations a constant is included, but no trend. ** and * indicate respectively 1% and 5% significance level in rejecting the unit root hypothesis. The appropriate lag lengths are chosen according to Schwartz criterion.)

Variable	Lag Selection (SIC)	ADF Test		PP Test	
		Levels	1st Differences	Levels	1st Differences
SeP100 Cum.Ret.	3	0.09	-14.87^{**}	-0.06	-31.74^{**}
Treasury Yield	0	-0.88	-27.29^{**}	-0.73	-27.22^{**}
T.S. Slope	0	-0.26	-24.28^{**}	-0.28	-24.25^{**}
VXO	4	-1.66	-15.96^{**}	-2.1	-33.0^{**}
Impl.Vol.Skew	2	-2.56	-26.47^{**}	-3.02^{*}	-58.57^{**}
ST CDX Spread	0	-1.77	-25.03^{**}	-1.77	-25.03^{**}
AAA Bond Index Spread	3	-0.95	-13.92^{**}	-0.99	-25.2^{**}
Comm. Paper Spread	3	-3.64^{**}		-4.10^{**}	
ST CDX Bid-Ask Spread	2	-3.59^{**}		-5.58^{**}	
5y Swap Spread	4	-1.68	-18.81^{**}	-3.40^{*}	-61.95^{**}
Put-Call Ratio	2	-7.65^{**}		-16.27^{**}	
Diff Impl.-GARCH Vol.	0	-9.60^{**}		-10.07^{**}	

Table 5: OLS Cointegrating Regression Estimates

(All Variables are measured in Percentage Units; Daily Frequency; Period: 20th Sep 2006 - 20th May 2009; Obs. 661)

Model Specifications:

Model I:

$Credit\ Spread_t = \alpha_1 + \alpha_2\ S\&P100\ Cum.Ret._t + \alpha_3\ Treasury\ Yield_t + \alpha_4\ T.S.Slope_t + \alpha_5\ VXO_t + u_t$

Model II:

$Credit\ Spread_t = \alpha_1 + \alpha_2\ S\&P100\ Cum.Ret._t + \alpha_3\ Treasury\ Yield_t + \alpha_4\ T.S.Slope_t + \alpha_5\ VXO_t + \alpha_6\ S\&P100\ Impl.Vol.\ Skew_t + u_t$

Model III:

$Credit\ Spread_t = \alpha_1 + \alpha_2\ S\&P100\ Cum.Ret._t + \alpha_3\ Treasury\ Yield_t + \alpha_4\ T.S.Slope_t + \alpha_5\ S\&P100\ Hist.\ Vol_t + u_t$

Model IV:

$Credit\ Spread_t = \alpha_1 + \alpha_2\ S\&P100\ Cum.Ret._t + \alpha_3\ Treasury\ Yield_t + \alpha_4\ T.S.Slope_t + \alpha_5\ S\&P100\ Hist.\ Vol._t + \alpha_6\ S\&P100\ Impl.Vol.\ Skew_t + u_t$

Independent Structural Variables	**Constant**	**S&P100 6mo. Cum. Ret.**	**5y Treasury CM Yield**	**TS Slope**	**S&P100 Impl.Vol. VXO**	**S&P100 30d. Historical Vol.**	**S&P100 Impl. Vol. Skew**
Dep. Variables							
Model I							
ST CDX Spread	0.863	-0.003	-0.178	0.095	0.007		
AAA Bond Index Spread	0.973	-0.002	-0.124	0.052	0.014		
Model II							
ST CDX Spread	1.052	-0.004	-0.162	0.087	0.005		-0.011
AAA Bond Index Spread	1.105	-0.002	-0.113	0.046	0.012		-0.007
Model III							
ST CDX Spread	0.886	-0.004	-0.171	0.108		0.004	
AAA Bond Index Spread	0.950	-0.002	-0.104	0.075		0.010	
Model IV							
ST CDX Spread	1.104	-0.004	-0.152	0.093		0.003	-0.013
AAA Bond Index Spread	1.122	-0.002	-0.089	0.062		0.009	-0.010

Table 6: Cointegration Test: ADF Test on Residuals from Cointegrating Regressions
Model Specifications:
Model I:
$Credit\ Spread_t = \alpha_1 + \alpha_2\ S\&P100\ Cum.Ret._t + \alpha_3\ Treasury\ Yield_t + \alpha_4\ T.S.Slope_t + \alpha_5\ VXO_t + u_t$
Model II:
$Credit\ Spread_t = \alpha_1 + \alpha_2\ S\&P100\ Cum.Ret._t + \alpha_3\ Treasury\ Yield_t + \alpha_4\ T.S.Slope_t + \alpha_5\ VXO_t + \alpha_6\ S\&P100\ Impl.Vol.\ Skew_t + u_t$
Model III:
$Credit\ Spread_t = \alpha_1 + \alpha_2\ S\&P100\ Cum.Ret._t + \alpha_3\ Treasury\ Yield_t + \alpha_4\ T.S.Slope_t + \alpha_5\ S\&P100\ Hist.\ Vol_t + u_t$
Model IV:
$Credit\ Spread_t = \alpha_1 + \alpha_2\ S\&P100\ Cum.Ret._t + \alpha_3\ Treasury\ Yield_t + \alpha_4\ T.S.Slope_t + \alpha_5\ S\&P100\ Hist.\ Vol._t + \alpha_6\ S\&P100\ Impl.Vol.\ Skew_t + u_t$
MacKinnon (2010) Critical Values for ADF Test on Residuals from Cointegrating Regression
(T=661; No-trend, only constant):
- 5 Variables in Cointegration: -4.99 (at 1% Sign.Level ***); -4.44 (at 5% Sign.Level **); -4.15 (at 10% Sign.Level *)
- 6 Variables in Cointegration: -5.28 (at 1% Sign.Level ***); -4.73 (at 5% Sign.Level **); -4.44 (at 10% Sign.Level *)

Model Specification	**Dependent Variables**	**t-statistics ADF regression for Residuals**
I	ST CDX Spread	-4.46**
	AAA Bond Index Spread	-4.99**
II	ST CDX Spread	-4.72**
	AAA Bond Index Spread	-5.13**
III	ST CDX Spread	-4.51**
	AAA Bond Index Spread	-4.10
IV	ST CDX Spread	-4.90**
	AAA Bond Index Spread	-4.58**

Table 7: Autocorrelation Coefficients (up to Lag 10) of Residuals from OLS Cointegrating Regressions

Lag	**Depend. Var.**	**Model I**	**Model II**	**Model III**	**Model IV**
1	ST CDX Spread	0.932	0.925	0.928	0.919
	AAA Bond Index Spread	0.874	0.872	0.925	0.897
2	ST CDX Spread	0.876	0.866	0.863	0.853
	AAA Bond Index Spread	0.784	0.778	0.857	0.813
3	ST CDX Spread	0.812	0.799	0.79	0.781
	AAA Bond Index Spread	0.733	0.723	0.818	0.768
4	ST CDX Spread	0.746	0.732	0.72	0.71
	AAA Bond Index Spread	0.669	0.657	0.771	0.711
5	ST CDX Spread	0.693	0.677	0.663	0.652
	AAA Bond Index Spread	0.634	0.617	0.728	0.66
6	ST CDX Spread	0.639	0.623	0.605	0.594
	AAA Bond Index Spread	0.601	0.583	0.695	0.626
7	ST CDX Spread	0.587	0.569	0.549	0.537
	AAA Bond Index Spread	0.56	0.544	0.663	0.593
8	ST CDX Spread	**0.523**	**0.503**	**0.485**	**0.471**
	AAA Bond Index Spread	**0.525**	**0.508**	0.617	**0.519**
9	ST CDX Spread	0.464	0.444	0.429	0.414
	AAA Bond Index Spread	0.49	0.477	0.585	0.549
10	ST CDX Spread	0.405	0.384	0.368	0.352
	AAA Bond Index Spread	0.467	0.455	**0.551**	0.488

Table 8: Estimation of Error Correction Models for Moody's AAA Bond Index Spread and CDX.NA.IG Index Senior Tranche Spread

Sample: 9/22/2006 - 5/20/2009; Obs. 656; White Heteroskedasticity-Consistent Standard Errors in Parenthesis; ***, **, and * indicate resp. 1%, 5%, and 10% confidence level; All Variables are measured in Percentage Units. Procedure for estimation of the parsimonious ECM: 1) Introduction of a number a lags p for changes in variables which are enough to make the residuals serially uncorrelated; 2) Exclusion insignificant variables; 3) Re-estimation.

Dependent variable	Δ *Log ST CDX Spread*			Δ *Log AAA Bond Index Spread*		
Explanatory variables	*Model I*	*Model II*	*Model IV*	*Model I*	*Model II*	*Model IV*
Δ *Log ST CDX Spread (Lag 1)*	-0.06	-0.06	-0.06			
	(0.06)	(0.06)	(0.06)			
Δ *Log AAA Bond Index Spread (Lag 1)*				-0.05	-0.08*	-0.08*
				(0.04)	(0.04)	(0.04)
Δ *Log AAA Bond Index Spread (Lag 2)*				-0.08*	-0.08*	-0.11**
				(0.05)	(0.05)	(0.05)
Δ *Log AAA Bond Index Spread (Lag 3)*					0.06	
					(0.04)	
Δ *Log AAA Bond Index Spread (Lag 4)*					0.11**	
					(0.05)	
Δ *S&P100 Cum. Ret.*	-0.36		-0.73***	-0.18**	-0.14**	-0.13*
	(0.23)		(0.19)	(0.07)	(0.07)	(0.06)
Δ *S&P100 Cum. Ret. (Lag 1)*			-0.29	-0.10*	-0.12**	-0.14**
			(0.21)	(0.06)	(0.06)	(0.06)
Δ *S&P100 Cum. Ret. (Lag 2)*		-0.39**	-0.29	-0.10*	0.13**	-0.13**
		(0.17)	(0.18)	(0.06)	(0.06)	(0.06)
Δ *S&P100 Cum. Ret. (Lag 3)*					-0.13**	-0.15***
					(0.06)	(0.05)
Δ *Treasury Yield*	-21.65***	-21.63***	-23.18***	-6.51***	-6.65***	-6.52***
	(4.95)	(4.81)	(4.95)	(1.3)	(1.23)	(1.26)
Δ *Treasury Yield (Lag 1)*	-17.40***	-16.75***	-15.39***			
	(5.3)	(5.25)	(5.56)			
Δ *T.S. Slope*	8.66	8.38	11.79**	5.71***	5.18***	5.06***
	(5.61)	(5.55)	(5.51)	(1.91)	(1.89)	(1.9)
Δ *T.S. Slope (Lag 1)*					2.46	2.76*
					(1.59)	(1.56)
Δ *VXO*	0.47***	0.58***				
	(0.18)	(0.14)				
Δ *VXO (Lag 1)*	0.49***	0.53***				
	(0.14)	(0.14)				
Δ *S&P100 Hist. Vol.*						0.15**
						(0.07)
Δ *S&P100 Hist. Vol. (Lag 1)*			0.39*			0.04
			(0.22)			(0.12)
Δ *S&P100 Hist. Vol. (Lag 2)*						0.14**
						(0.08)
Δ *S&P100 Option Impl. Vol. Skew (Lag 1)*		-0.87***	-0.90***			
		(0.27)	(0.27)			
ECT	-6.81**	-6.52**	-6.32**	-3.58***	-3.75***	-4.31***
	(2.87)	(2.78)	(2.83)	(1.21)	(1.32)	(1.58)
$Adj-R^2$	*13.1%*	*14.7%*	*12.8%*	*12.2%*	*15.5%*	*14.9%*

Table 9: Estimation of ECMs for Moody's AAA Bond Index Spread and CDX.NA.IG Index Senior Tranche Spread with Non-Structural Variables

PANEL A

Sample: 9/22/2006 - 5/20/2009; Obs. 646; White Heteroskedasticity-Consistent Standard Errors in Parenthesis; ***, **, and * indicate resp. 1%, 5%, and 10% confidence level; All Variables are measured in Percentage Units. Procedure for estimation of the parsimonious ECM: 1) Introduction of a number a lags p for changes in variables which are enough to make the residuals serially uncorrelated; 2) Exclusion insignificant variables; 3) Re-estimation.

Dependent variable	*Δ Log ST CDX Spread*			*Δ Log AAA Bond Index Spread*		
Panel A						
Changes in Structural Variables - Estimated Coefficients and Std. Errors						
Explan. variables	*Model I*	*Model II*	*Model IV*	*Model I*	*Model II*	*Model IV*
Δ Log ST CDX Spread (Lag 1)	-0.06	-0.06	-0.06			
	(0.06)	(0.06)	(0.06)			
Δ Log AAA Bond Index Spread (Lag 1)				-0.05	-0.07*	-0.08**
				(0.04)	(0.04)	(0.04)
Δ Log AAA Bond Index Spread (Lag 2)				-0.08*	-0.08	-0.11**
				(0.05)	(0.05)	(0.05)
Δ Log AAA Bond Index Spread (Lag 3)					0.06	
					(0.04)	
Δ Log AAA Bond Index Spread (Lag 4)					0.11**	
					(0.05)	
Δ S&P100 Cum. Ret.	-0.24		-0.28	-0.18**	-0.15**	-0.15*
	-0.25		(0.22)	(0.07)	(0.07)	(0.09)
Δ S&P100 Cum. Ret. (Lag 1)			-0.04	-0.10*	-0.12**	-0.13**
			(0.23)	(0.06)	(0.06)	(0.05)
Δ S&P100 Cum. Ret. (Lag 2)		-0.42**	-0.34**	-0.09	-0.13**	-0.13**
		(0.18)	(0.17)	(0.06)	(0.07)	(0.06)
Δ S&P100 Cum. Ret. (Lag 3)					-0.14**	-0.15***
					(0.06)	(0.05)
Δ Treasury Yield	-16.01***	-16.24***	-18.58***	-6.12***	-6.14***	-6.30***
	(4.79)	(4.73)	(5.11)	(1.39)	(1.32)	(1.36)
Δ Treasury Yield (Lag 1)	-18.26***	-17.31***	-16.42***			
	(5.06)	(5.02)	(5.42)			
Δ T.S. Slope	4.6	4.57	9.16*	5.42***	4.84**	4.97***
	(5.6)	(5.56)	(5.39)	(1.91)	(1.88)	(1.81)
Δ T.S. Slope (Lag 1)					2.55	2.67*
					(1.61)	(1.56)
Δ VXO	0.45**	0.51***				
	(0.18)	(0.14)				
Δ VXO (Lag 1)	0.49***	0.54***				
	(0.14)	(0.15)				
Δ S&P100 Hist. Vol.						0.15**
						(0.07)
Δ S&P100 Hist. Vol. (Lag 1)			0.70***			0.04
			(0.25)			(0.13)
Δ S&P100 Hist. Vol. (Lag 2)						0.14*
						(0.08)
Δ S&P100 Option Impl. Vol. Skew (Lag 1)		**-0.77*** **	-0.79***			
		(0.26)	(0.26)			
ECT	-6.64**	-6.22**	-6.22**	-3.56***	-3.76***	-4.27***
	(2.85)	(2.76)	(2.8)	(1.21)	(1.32)	(1.57)

(Continued on next page...)

Table 9: **(...Continued from previous page)**
Estimation of ECMs for Moody's AAA Bond Index Spread and CDX.NA.IG Index Senior Tranche Spread with Non-Structural Variables
PANEL B

Dependent variable	Δ *Log ST CDX Spread*			Δ *Log AAA Bond Index Spread*		
Panel B						
Changes in Liquidity and Investors' Sentiment/Risk Aversion - Estimated Coefficients and Std. Errors						
Explan. variables	*Model I*	*Model II*	*Model IV*	*Model I*	*Model II*	*Model IV*
Δ *Comm. Paper Spread*	5.94** (2.64)	5.06** (2.72)	5.05* (2.73)	0.48 (0.67)	0.24 (0.63)	0.29 (0.61)
Δ *Log ST CDX Bid − Ask Spread*	0.06*** (0.02)	0.06*** (0.02)	0.06*** (0.02)			
Δ 5y *Swap Spread*				0.31 (1.7)	0.59 (1.67)	0.63 (1.71)
Δ *Put − Call Ratio*	0.10*** (0.03)	0.11*** (0.03)		0.004 (0.008)	0.006 (0.007)	
Δ *Put − Call Ratio (Lag* 1)	0.07** (0.03)	0.08** (0.03)				
Δ *Diff Impl. − GARCH Vol.*			0.40*** (0.15)			0.02 (0.05)
Δ *Diff Impl. − GARCH Vol. (Lag* 1)			0.43*** (0.15)			
$Adj-R^2$	17%	18%	17%	12%	15%	15%

Table 10: Economic Significance (Standardized Betas) of Explanatory Variables in the ECMs for Moody's AAA Bond Index Spread and CDX.NA.IG Index Senior Tranche Spread

(The economic significance - Standardized Beta - is measured as the impact of one-standard deviation change in the explanatory variable on the dependent variable. The impact is expressed as a fraction of the standard deviation in the dependent variable)

Dependent variable	Δ *Log ST CDX Spread*			Δ *Log AAA Bond Ind. Spread*		
Explan. variables	*Model I* *Std. Betas*	*Model II* *Std. Betas*	*Model IV* *Std. Betas*	*Model I* *Std. Betas*	*Model II* *Std. Betas*	*Model IV* *Std. Betas*
Δ *Log ST CDX Spread (Lag 1)*	-0.060	-0.060	-0.060			
Δ *Log AAA Bond Ind. Spread (Lag 1)*				-0.013	-0.018	-0.020
Δ *Log AAA Bond Ind. Spread (Lag 2)*				-0.020	-0.020	-0.028
Δ *Log AAA Bond Ind. Spread (Lag 3)*					0.015	
Δ *Log AAA Bond Ind. Spread (Lag 4)*					0.028	
Δ *S&P100 Cum. Ret.*	-0.049		-0.057	-0.037	-0.031	-0.031
Δ *S&P100 Cum. Ret. (Lag 1)*			0.0001	-0.0002	-0.0002	-0.0003
Δ *S&P100 Cum. Ret. (Lag 2)*		-0.001	-0.0008	-0.0001	-0.0003	-0.0003
Δ *S&P100 Cum. Ret. (Lag 3)*					-0.0003	-0.0003
Δ *Treasury Yield*	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
Δ *Treasury Yield (Lag 1)*	-0.002	-0.001	-0.001			
Δ *T.S. Slope*	0.028	0.028	0.056	0.033	0.029	0.03
Δ *T.S. Slope (Lag 1)*					0.015	0.016
Δ *VXO*	0.128	0.145				
Δ *VXO (Lag 1)*	0.139	0.153				
Δ *S&P100 Hist. Vol.*						0.021
Δ *S&P100 Hist. Vol. (Lag 1)*			0.129			0.006
Δ *S&P100 Hist. Vol. (Lag 2)*						0.020
Δ *S&P100 Impl. Vol. Skew (Lag 1)*		-0.113	-0.099			
ECT	-0.108	-0.100	-0.116	-0.035	-0.036	-0.033
Δ *Comm. Paper Spread*	0.096	0.081	0.081	0.008	0.004	0.005
Δ *Log ST CDX Bid − Ask Spread*	0.138	0.138	0.138			
Δ *5y Swap Spread*				0.002	0.005	0.005
Δ *Put − Call Ratio*	0.116	0.127		0.005	0.007	
Δ *Put − Call Ratio (Lag 1)*	0.081	0.093				
Δ *Diff Impl. − GARCH Vol.*			0.127			0.006
Δ *Diff Impl. − GARCH Vol. (Lag 1)*			0.137			

Table 11: Estimation of Error Correction Models for CDX.NA.IG Index Senior Tranche Spread over the Pre-Crisis and Crisis Sub-Periods: Results for Non-Structural Variables only

(Sample: Pre-Crisis 22/09/2006 - 20/07/2007, Middle Crisis 21/07/2007 - 20/05/2008, All Crisis 21/07/2007 - 20/05/2009; White Heteroskedasticity-Consistent Standard Errors in Parenthesis; ***, **, and * indicate resp. 1%, 5%, and 10% confidence level; All Variables measured in Percentage Units)

Dependent Variable: Δ *Log ST CDX Spread*									
	Model I			*Model II*			*Model IV*		
Non-structural Explanatory Variables	*Pre Crisis*	*Middle Crisis*	*All Crisis*	*Pre Crisis*	*Middle Crisis*	*All Crisis*	*Pre Crisis*	*Middle Crisis*	*All Crisis*
Δ *Comm. Paper Spread*	-2.87	4.04	6.56**	-4.67	3.02	5.60**	-7.02	0.70	5.63**
	(7.63)	*(4.06)*	*(2.79)*	*(7.59)*	*(4.12)*	*(2.9)*	*(7.07)*	*(4.61)*	*(2.94)*
Δ *Log ST CDX Bid − Ask Spread*	0.03	0.11***	0.06**	0.03	0.12***	0.07**	0.03	0.12***	0.07***
	(0.02)	*(0.04)*	*(0.03)*	*(0.02)*	*(0.04)*	*(0.03)*	*(0.02)*	*(0.05)*	*(0.03)*
Δ *Put − Call Ratio*	0.07	0.13	0.10**	0.08	0.14	0.10**			
	(0.05)	*(0.08)*	*(0.04)*	*(0.05)*	*(0.08)*	*(0.04)*			
Δ *Put − Call Ratio* (*Lag* 1)	-0.005	0.03	0.08**	-0.01	0.04	0.07**			
	(0.06)	*(0.07)*	*(0.04)*	*(0.07)*	*(0.07)*	*(0.04)*			
Δ *Diff Impl. − GARCH Vol.*							1.07**	0.57	0.37**
							(0.47)	*(0.48)*	*(0.17)*
Δ *Diff Impl. − GARCH Vol.* (*Lag* 1)							1.29**	1.24*	0.31*
							(0.63)	*(0.6)*	*(0.16)*
Adj − R^2	9%	25%	21%	8%	26%	23%	6%	26%	22%

Table 12: Impact of One Standard Deviation Change in Non-Structural Variables on Changes in Log CDX.NA.IG Index Senior Tranche Spread (ECM Model II) over the Pre-Crisis and Crisis Sub-Samples

(The impact is expressed as a fraction of the standard deviation in the dependent variable; ***, **, and * indicate respectively 1%, 5%, and 10% significance level;
Pre-Crisis: 20th Sept 2006 - 20th July 2007, Mid-Crisis: 21st July 2007 - 20th May 2008, All Crisis: 21st July 2007 - 20th May 2009.)

	All Sample	*Pre Crisis*	*Mid-Crisis*	*All Crisis*
Δ *Put − Call Ratio*	0.127 ***	0.076	0.142 *	0.120 ***
Δ *Comm. Paper Spread*	0.081 **	-0.032	0.051	0.104 ***
Δ *Log ST CDX Bid − Ask Spread*	0.131 ***	0.071	0.228 ***	0.150 ***
Δ *Put − Call Ratio (Lag 1)*	0.090 **	-0.013	0.044	0.091 ***

Table 13: Net Impact of One Standard Deviation Change in Explanatory Variables (grouped in 5 Blocks) on Changes in Log CDX.NA.IG Index Senior Tranche Spread (ECM Model II) over the Pre-Crisis and Crisis Sub-Samples

(The impact is expressed as a fraction of the standard deviation of the dependent variable; The five blocks are: Adjustment Factor - including error correction term and lag changes in ST CDX log spread; Equity Factor - including current and lag changes in equity index value, current and lag changes in VXO index and in slope of S&P 100 implied volatility; Interest Rate Process Factor - including current and lag changes in level and slope of the term structure of Treasury yields; Risk aversion factor - including current and lag changes in put-call ratio; and Liquidity Factor - including changes in the commercial paper spread and in log ST CDX bid-ask spread.;
Pre-Crisis: 20th Sept 2006 - 20th July 2007, Mid-Crisis: 21st July 2007 - 20th May 2008, All Crisis: 21st July 2007 - 20th May 2009.).

	All Sample	*Pre Crisis*	*Mid-Crisis*	*All Crisis*
Adjustment Factor	-0.1599	0.1910	-0.2219	-0.1551
Equity Factor	0.0997	0.2553	0.1267	0.0560
Interest Rate Factor	-0.2523	0.1262	-0.3259	-0.2991
Liquidity Factor	0.2122	0.0400	0.2794	0.2539
Risk Aversion	0.2176	0.0627	0.1856	0.2110

Table 14: Adjusted R^2s of Five Block-wise Regressions for Changes in Log CDX.NA.IG Index Senior Tranche Spread (ECM Model II) over the Pre-Crisis and Crisis Sub-Samples

(The five blocks are: Adjustment Factor - including error correction term and lag changes in ST CDX log spread; Equity Factor - including current and lag changes in equity index value, current and lag changes in VXO index and in slope of S&P 100 implied volatility; Interest Rate Process Factor - including current and lag changes in level and slope of the term structure of Treasury yields; Risk aversion factor - including current and lag changes in put-call ratio; and Liquidity Factor - including changes in the commercial paper spread and in log ST CDX bid-ask spread.
Pre-Crisis: 20th Sept 2006 - 20th July 2007, Mid-Crisis: 21st July 2007 - 20th May 2008, All Crisis: 21st July 2007 - 20th May 2009.)

	Pre-Crisis	*Mid-Crisis*	*All Crisis*
Adjustment Factor	0.46%	2.62%	2.34%
Equity Factor	2.39%	9.17%	9.60%
Interest Rate Factor	1.05%	12.57%	9.98%
Liquidity Factor	0.14%	5.15%	4.74%
Risk Aversion Factor	0.88%	6.09%	5.96%

Table 15: Adjusted R^2s of Five Block-wise Regressions for Changes in Log Moody's AAA Bond Index Spread (ECM Model IV) over the Pre-Crisis and Crisis Sub-Samples
(The five blocks are: Adjustment Factor - including error correction term and lag changes in AAA Bond Index log spread; Equity Factor - including current and lag changes in equity index value, current and lag changes in S&P 100 historical volatility; Interest Rate Process Factor - including current and lag changes in level and slope of the term structure of Treasury yields; Risk aversion factor - including current and lag changes in put-call ratio; and Liquidity Factor - including changes in the commercial paper spread and in 5-years swap spread.
Pre-Crisis: 20th Sept 2006 - 20th July 2007, Mid-Crisis: 21st July 2007 - 20th May 2008, All Crisis: 21st July 2007 - 20th May 2009.)

	Pre-Crisis	*Mid-Crisis*	*All Crisis*
Adj. Factor	5.45%	6.31%	1.18%
Equity Factor	2.86%	3.22%	2.74%
Int. Rate Process Factor	3.08%	7.21%	7.76%
Risk Aversion Factor	0.92%	0.44%	0.13%
Liquidity Factor	0.31%	6.48%	2.43%

Table 16: Correlation between Observed Changes in Log CDX.NA.IG Index Senior Tranche Spread and Changes predicted by the Pre-Crisis Models I, II, and IV
(Sample: February 2007 - December 2009; 4 Different Sub-samples are also considered. Correlations are computed on the changes at daily frequency.)

	Corr (Δ *Log ST CDX Spread*, Δ *Log ST CDX Spread* from Pre-Crisis Model I)
Feb 2007 - May 2009	27.70%
Feb 2007 - July 2007	21.40%
July 2007 - Dec 2007	36.71%
Dec 2007 - May 2008	42.48%
May 2008 - Dec 2009	30.39%

	Corr (Δ *Log ST CDX Spread*, Δ *Log ST CDX Spread* from Pre-Crisis Model II)
Feb 2007 - May 2009	26.81%
Feb 2007 - July 2007	20.37%
July 2007 - Dec 2007	35.54%
Dec 2007 - May 2008	42.48%
May 2008 - Dec 2009	31.86%

	Corr (Δ *Log ST CDX Spread*, Δ *Log ST CDX Spread* from Pre-Crisis Model IV)
Feb 2007 - May 2009	28.15%
Feb 2007 - Jul 2007	21.75%
July 2007 - Dec 2007	36.69%
Dec 2007 - May 2008	42.51%
May 2008 - Dec 2009	33.61%

Table 17: Estimation of *Atypical* Error Correction Model II for CDX.NA.IG Index Senior Tranche Spread over the Crisis Period, using Lagged Values of Pre-Crisis Model Forecast Errors as Correction Term

(Sample: 20/02/2007 - 20/05/2009; White Heteroskedasticity-Consistent Standard Errors in Parenthesis; ***, **, and * indicate resp. 1%, 5%, and 10% confidence level; All Variables are measured in Percentage Units).

	ECM without non-structural variables	*ECM with non-structural variables*
Dependent Variables	Δ *Log ST CDX Spread*	Δ *Log ST CDX Spread*
Explanatory Variables		
Δ *Log ST CDX Spread (Lag 1)*	-0.06 (0.06)	-0.06 (0.06)
Δ *S&P100 Cum. Ret. (Lag 2)*	-0.41** (0.16)	-0.43** (0.18)
Δ *TS Slope*	-21.30*** (5.03)	-15.30*** (4.92)
Δ *TS Slope (Lag 1)*	-16.94*** (6.04)	-17.36*** (5.25)
Δ *TS Slope (Lag 2)*	10.19* (5.81)	5.82 (6.02)
Δ *VXO*	0.59*** (0.12)	0.52*** (0.14)
Δ *VXO (Lag 1)*	0.55*** (0.16)	0.55*** (0.15)
Δ *S&P100 Impl.Vol. Skew (Lag 1)*	-1.09*** (0.39)	-0.95*** (0.36)
Forecast Error (Lag 1)	-0.68 (0.53)	-0.54 (0.54)
Δ *Comm. Paper Spread*		5.03** (2.76)
Δ *Log ST CDX Bid − Ask Spread*		0.07** (0.02)
Δ *Put − Call Ratio*		0.12*** (0.04)
Δ *Put − Call Ratio (Lag 1)*		0.08*** (0.04)
$Adj-R^2$	**14%**	**18%**

Table 18: Non-Structural Determinants of Changes in Pre-Crisis Model Forecast Error
(Sample: 20/02/2007 - 20/05/2009; White Heteroskedasticity-Consistent Standard Errors in Parenthesis;
***, **, and * indicate resp. 1%, 5%, and 10% confidence level; All Variables measured in Percentage Units.
Non-structural Explanatory Variables included in OLS Specification (A): Change in Commercial Paper Spread, Change in Log ST CDX Bid-Ask spread; current and lag Changes in Put-Call Ratio.
Non-structural Explanatory Variables included in OLS Specification (B): Change in Commercial Paper Spread, Change in Log ST CDX Bid-Ask spread; current and lag Changes in the difference between Implied Volatility (VXO index) and GARCH-estimated volatility of S&P100 Index.)

	OLS Specification (A)	**OLS Specification (B)**
Dependent Variables	Δ *Log Forecast Error ST CDX Spread*	Δ *Log Forecast Error ST CDX Spread*
Explanatory Variables		
Constant	0.29 (0.68)	0.31 (0.68)
Δ *Log Forecast Error ST CDX Spread (Lag 1)*	-0.06 (0.07)	-0.08 (0.07)
Δ *Comm. Paper Spread*	9.30** (4.54)	9.51** (4.55)
Δ $Log\ ST\ CDX\ Bid - Ask\ Spread$	0.08** (0.04)	0.08** (0.04)
Δ $Put - Call\ Ratio$	0.18*** (0.06)	
Δ $Put - Call\ Ratio\ (Lag\ 1)$	0.24*** (0.06)	
Δ $Diff\ Impl. - GARCH\ Vol.$		0.70*** (0.23)
Δ $Diff\ Impl. - GARCH\ Vol.\ (Lag\ 1)$		0.70*** (0.25)
$Adj - R^2$	**6%**	**6%**