Determinants of Credit Default Swap Spreads in the iTraxx Europe Index Family

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Authors: Eva V. Christensen & Arne von Der Lieth

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Supervisor: Mads Stenbo Nielsen

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Abstract

This paper investigates the economic and financial drivers of CDS spreads and their changes. Specifically, the analysis is limited on CDSs with European reference entities over a timeframe between January 2012 and December 2017. Several interesting results are obtained. The paper finds evidence that pockets of the CDS markets are inefficiently priced and that the CDS market is segmented to a certain degree from equity, rates and foreign exchange markets. This finding is complemented by evidence for a credit market specific factor relevant for explaining CDS spreads and their changes independent of the liquidity of the underlying CDS contract. Finally, we find that changes as well as the level of CDS spreads is largely determined by systemic factors as opposed to company specific, fundamental variables. This paper hence contributes to the discussion about adequate pricing and hedging models for credit risk.

Contents

Introduction

Background

The market for credit derivatives has received extensive attention from researchers, academics, investors and other market participants, especially after the severe financial crisis, in which credit derivatives had a central role. Preceding literature on the subject hence have focused their analysis of credit markets on the time around this event. This have provided useful and necessary information to understand how markets behave and respond to deteriorations in the economic environment. In our thesis, however, we seek to investigate how credit markets behaves in times of normalization and which factors influences the credit risk when the economy tends to be more stable. Specifically, we look at the credit default swaps (CDS) market in the period between January 2012 and December 2017. The analysed time series starts shortly before the second Greek government bailout, i.e. at the height of the European debt crisis and ends amid a period characterized by ultra-low volatility and exceptional market calm. The chosen period hence corresponds to a normalization of the credit market.

Credit default swaps are over-the-counter (OTC) instruments that facilitates the exchange of credit risk between market participants. Practically, a CDS is a contingent claim resembling an insurance contract between two market participants, in which the protection is obtained against default of an underlying reference entity. The contract specifies, among other things, the compensation required by the seller for holding the risk of a possible recovery payment in the event of default. This premium is commonly known as the CDS spread and is the main object of our analysis.

Credit derivatives are important tools for understanding the credit markets, and hence an updated analysis on the drivers of such instruments are considered relevant and meaningful since the market continues to evolve over time. Although many researchers use the corporate yield spread as a measure of credit risk, such as Collin-Dufresn, Goldstein, and Martin, 2001, we focus on the CDS spreads since they are perceived to be a cleaner measure of credit risk (Longstaff, Mithal, and Neis, 2005, Blanco, Brennan, and Marsh, 2005, and Bai and Wu, 2016).

With the prominent change in the CDS market from solely consisting of highly liquid single-name CDS contracts, to a significantly more liquid market for CDS index trading, a focus on the latter has motivated our analysis. In addition, the spreads of credit indices are interesting to investigate since aggregated CDS spreads can be a possible measure of systemic risk (Breitenfellner and Wagner, 2012). Further limitations of our study lead us to focus on CDS index spreads in Europe due to their prominent position in the market. The iTraxx Europe accounted for 30% of total notional outstanding in 2017 (Swaps and Association, 2018). According to the Bank of International Settlements, the total notional outstanding of European CDS in 2017 amounted to $5.8 trillion, for which the shares of the single-name CDSs and the iTraxx indices was 42% and 58%, respectively.

Aim

In our thesis, we aim to provide a comprehensive analysis of the determinants of CDS spreads in the iTraxx Europe index family. We start by identifying determinants of credit spreads based on traditional credit risk models, and further incorporate several additional financial and macroeconomic variables. For the single-name spreads, we also include some firm-specific variables. Further, we employ these determinants in regression analyses to investigate the levels and changes of spreads for the selected, generic, CDS indices, a selection of single name CDSs, and generic CDS index tranches. Similar to the research of Collin-Dufresn et al., 2001 and Ericsson, Jacobs, and Oviedo, 2009, among others, we perform a principal component analysis to see if there exists a common systematic factor that cannot be explained by our models. We further extend our analysis to examine whether the equity and credit markets are interconnected. We therefore investigate the lead-lag relationship between stock markets and the CDS market by testing for Granger causality and controling for lagged returns in our regressions.

This thesis differs from the existent research by using recent data with daily frequency on CDS indices, a selection of single name CDSs and tranches on the iTraxx Crossover index. In addition, we stand out by considering both level and changes in credit spreads. While the papers described above focus their analysis on data up until 2012, this thesis investigates a time span of January 2012 until December 2017, and as such contributes to the existing literature with an up-to-date analysis focused on the European market. Furthermore, this paper considers the explanatory power of proxies for inflation, investor confidence and expected growth from securities traded in the financial markets.

Outline

This thesis is outlined as follows. In section 2, we present previous research that has motivated our analysis. Section 3 gives detailed descriptions of the CDS contract, the considered CDS indices, and the evolvement of CDS markets, as well as a discussion of CDS spreads as a measure of credit spread. In addition, theory of the two main approaches to credit risk modelling is briefly explained. In section 4, we present the methodology behind our modelling approach, and explain relevant inputs. This also include the choice of data and variables for our empirical analysis, and time series characteristics. In section 5, we perform the empirical analysis and present the corresponding results. Finally, we conclude our thesis in section 6.

Literature Review

2.1 Determinants of CDS Spreads

Collin-Dufresn et al., 2001 investigate the determinants of changes in credit spreads on individual bond yields and find that variables suggested by traditional models of default risk have limited explanatory power. They argue that, from a contingent-claim stance, credit spreads mainly arise from the risk of default and the uncertainty of the recovery payment, and hence consider numerous proxies to account for the changes in default probability and changes in recovery rate. However, their analysis is only able to explain 25% of the variation in the credit spreads. This emphasizes the critique of inadequacy in structural models, such as that of Merton, 1974. They find, however, after employing a principal component approach on the residuals, high cross-correlation in the residuals that are driven by a single common factor. Confirming that the omitted variables are not firm-specific, they rerun the regression with added explanatory variables to include macroeconomic, liquidity and financial variables as proxies for the systematic common factor. Again, they are unsuccessful in explaining the systematic component. Perhaps due to the pronounced difficulty of implementing structural models in practise, Collin-Dufresn et al., 2001 apply a more direct approach in which the theoretical determinants of credit spreads are identified using the structural approach. The identified variables are then applied to the regression for changes in credit spreads as explanatory variables, instead of using them as inputs to a structural model. This approach has been a major motivation for our analysis, although we examine the CDS spreads rather than corporate bond yield spreads.

Ericsson et al., 2009 assess the explanatory power of structural variables for both changes in credit spreads as well as for the levels of credit spreads, using a sample of CDS in a linear regression framework. In their analysis, they find that structural covariates such as volatility and leverage do, in fact, explain a significant proportion of the CDS spread variation, subsequently 60% (23%) for the levels (changes) of the spreads. Further, using a principal component analysis, they find little evidence of a systematic common factor, contradicting one of the major findings in Collin-Dufresn et al., 2001. When including the same theoretical determinants of default and recovery risk as in Collin-Dufresn et al., 2001, the explanatory power increases, and their regression explains more of the variation in the spreads than what is observed in Collin-Dufresn et al., 2001. This is explained by the enhanced liquidity in the credit market and by the superiority of spread as a measure for credit risk.

Other empirical work on CDS spreads include, among others, Abid and Naifar, 2005 and Zhang, Zhou, and Zhu, 2009. Abid and Naifar, 2005 study the determinants of CDS spreads using linear regression, including credit rating, maturity, risk-free interest rate, slope of the yield curve, and volatility level of equities. Estimated coefficients of these independent variables are found to be significant and consistent with theory, in addition to explaining more than 60% of the total level of CDS spreads. Specifically, credit rating is considered to be the most influential determinant of the CDS spreads. Further, also in this analysis, macroeconomic variables are proven to have significant influence in determination of the CDS spreads. Furthermore, the authors argue for the superiority of CDS spreads relative to corporate bonds as a measure for credit risk.

2.2 Portfolio/Multi-name products

While the empirical literature on the determinants of single-name CDS is extensive, the amount of studies on the empirical components of the spread changes of CDS indices is scarce. Bystrom, 2008 was one of the first researchers to investigate the spreads of CDS indices. In his paper, he analyses the relationship between the iTraxx CDS market and the stock market by looking at the link between CDS spread changes, equity market returns and equity market volatility. This is the first research to look at the connection between stock return volatilities and CDS spreads, which is found to be positively correlated. His analysis indicates that the iTraxx CDS market tends to be led by the stock market. Furthermore, he finds evidence that the current as well as lagged stock returns account for a considerable amount of the variation in CDS spread changes.

Alexander and Kaeck, 2008 investigate the determinants of iTraxx Europe spreads by using a Markov switching model. They find strong evidence that the significant influence from the theoretically suggested determinants are regime-dependent. During volatile periods, CDS spreads become highly sensitive to stock volatility, and the spreads are more strongly affected by stock volatility than stock returns. Moreover, in tense periods, CDS spreads are found to be more or less immune to changes in risk-free interest rates. In contrast, CDS spreads become more sensitive to stock returns than to stock volatility in more tranquil periods, and during these periods, the majority of the CDS indices has increased sensitivity to interest rate changes. In line with Collin-Dufresn et al., 2001, the amount of variations in CDS spreads are found to be limited to 20-30% with the majority of unexplained variation being linked to a common systemic factor.

Giammarino and Barrieu, 2009 use an adaptive nonparametric model to investigate systemic factors influencing daily changes of default risk in the iTraxx Europe index. The estimated regression coefficients include the Euro interest rate swap rate versus 1-year Euribor, Eurostoxx 50 returns and changes in the VStoxx 50 volatility index. Variables are selected to exhibit time-varying conduct and risk of sudden and significant jumps.

Breitenfellner and Wagner, 2012 examine the risk factors explaining daily changes in spreads of the iTraxx Europe CDS indices before, during and after the global financial crisis. They document time-varying significance of the spread determinants. They find that particularly stock returns and implied volatility significantly determine spread changes before and after the crisis, while global financial variables tend to have explanatory power during the pre-crisis and crisis period. In their research different proxies for liquidity reveal a significant influence on spread changes for financials, while being unrelated to spread changes of non-financial companies. Furthermore, they examine the lead-lag relationship between spread changes and stock returns. During the crisis period they find that stock market returns lead spread changes, while a bidirectional relationship appears in the post-crisis period. From this, the authors state the hypothesis that changes in credit spreads could provide equity market participants with useful information related to systemic risks.

Relation between credit and equity markets

Norden and Weber, 2009 examine the lead-lag relationship between CDS, bond and stock markets using a vector autoregressive model. Their empirical findings reveal a leading position for stock markets relative to CDS and bond markets, while CDS spread changes "Granger cause" bond spread changes. The authors additionally find that the co-movement between CDS spreads and bond returns is pronounced for companies with low credit quality or large bond issues. Further, in line with Blanco et al., 2005, a vector error correction analysis reveals that the CDS market leads the price discovery process relative to the bond market.

Finally, Fung, Sierra, Yau, and Zhang, 2008 analyse the relationship between the equity market and the CDS market, using American CDX indices. Their results indicate that the information flow between the US stock market and the CDS market depends on the credit quality of the underlying reference entity. Particularly, in the pricing process, a bidirectional relationship is found between the stock market and the high-yield CDS market. For the CDS index with investment grade rated constituents, Fung et al., 2008 find that the stock market is unidirectionally leading changes in the index spread. Moreover, the researcher find that CDS markets play a vital role in volatility transmission between markets, with stronger signals from investment-grade CDS indices. Hence, the authors conclude that CDS and equity markets provide relevant information for price discovery to participants of both markets.

This thesis differs from the existent research by using recent data with daily frequency on CDS indices, a selection of single name CDSs and tranches on the iTraxx Crossover index. In addition, we stand out by considering both level and changes in credit spreads. While the papers described above focus their analysis on data up until 2012, this thesis investigates a time span of January 2012 until December 2017, and as such contributes to the existing literature with an up-to-date analysis focused on the European market. Furthermore, this paper considers the explanatory power of proxies for inflation, investor confidence and expected growth from securities traded in the financial markets.

CDS Theory

3.1 Credit Derivatives

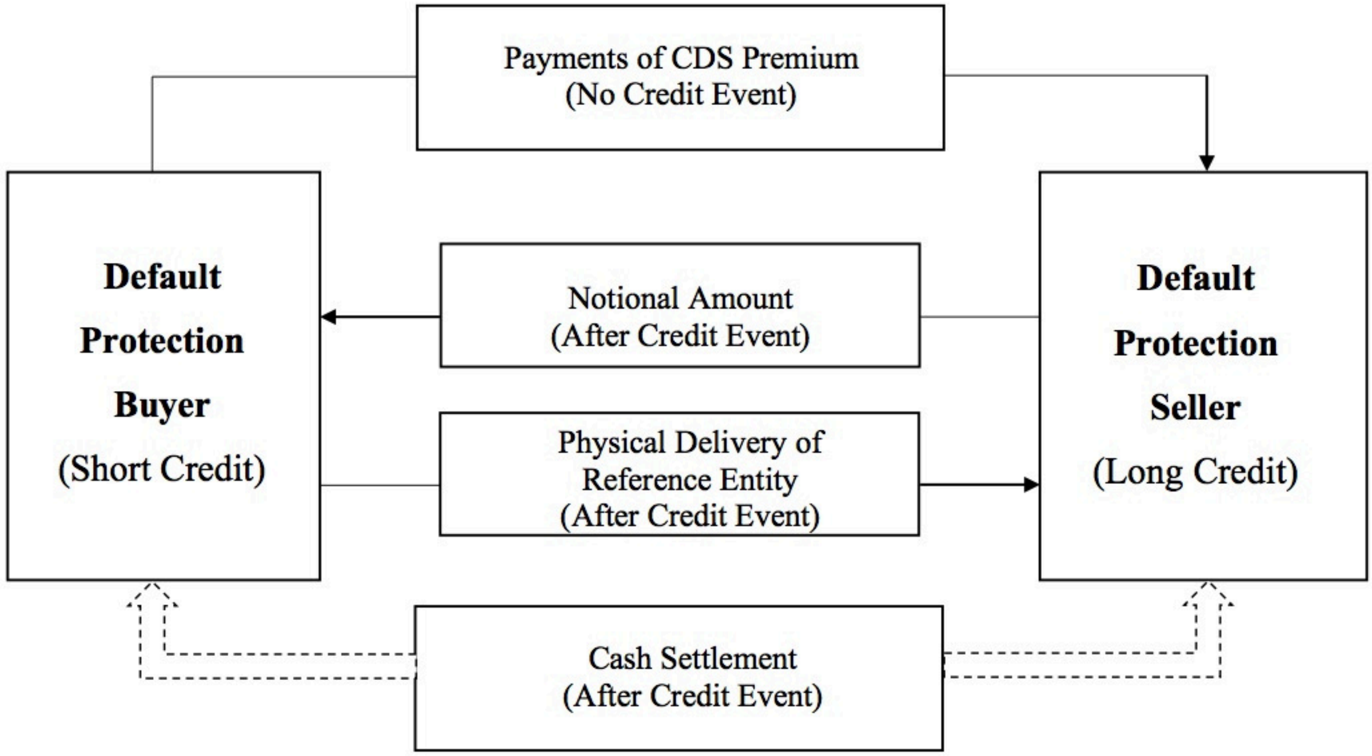
Credit derivatives are contracts where the payoff depends on the creditworthiness of one or more companies, institutions or countries. They are over-the-counter (OTC) instruments that allow for credit risk transfer between two parties. As opposed to exchange-traded products, they are subject to their own documentation, typically written under master terms developed by the International Swaps and Derivatives Association, henceforth abbreviated by its acronym, ISDA. The importance of the development of credit derivative contracts lies in the availability for market participants to trade credit risk in the same manner as they trade market risk and that the supply of these contracts is theoretically unlimited, which increases market liquidity. Specifically, for financial institutions, credit derivatives are thereby means to actively manage portfolios of credit and counterparty risks by entering derivative contracts to protect themselves against credit events and offering derivatives contracts to gain exposure to otherwise unavailable corners of the credit market. Unsurprisingly, banks and insurance companies have historically been the most active buyers and sellers, respectively, of credit derivatives Hull, 2012. This may also be because banks and financial institutions can have an informational advantage in trading credit derivatives. The advantage arises as a financial institution that works closely with a company by providing advice, granting loans and handling new issues of securities traded in the financial markets is likely to have more information about the creditworthiness of the company than other financial institutions that have no dealing with the company. This informational asymmetry may lead to speculative utilization of credit derivatives due to superior information to the market, rather than as a risk management tool.

Overall, credit markets have adopted the definitions proposed by ISDA as means to minimize legal risk. Since 1992, with the first publication of the ISDA Master Agreement, the ISDA has advocated standardization and played a significant role in the growth of the CDS market by contributing to high liquidity through trading of standardised contracts. Definitions provided by ISDA are continuously modified, as the credit market evolves over time. While the CDS is an OTC product and the contractual terms specified by ISDA are relatively flexible, the definitions have contributed to the development of a standard CDS contract in the market O'Kane, 2010.

3.2 CDS Contract

Credit derivatives can be grouped into single-name or multi-name contracts, with the most common credit derivatives from both groups being credit default swaps (CDS) and collateralized debt obligations (CDO), respectively Hull, 2012. Credit default swaps can be categorized again into three types: single-name CDS, basket CDS and CDS indices Bank, 2009. Essentially, the credit default swap works as an insurance against the default of a so-called reference entity. In plain vanilla form the contract offers protection for a single corporate or sovereign reference entity Bank, 2009. In exchange for protection the CDS buyer pays a regular premium, often referred to as the CDS spread, to the protection seller until either the maturity of the contract or a credit event, whichever event occurs first. More generally a CDS may be thought of as a put option on a corporate bond with a strike price equal to face value, exercise right at the prespecified default events and otherwise knock-out at maturity. The protection buyer is hence protected from losses incurred by a value decline of the bond that is caused by a credit event. The CDS spread is typically defined as a percentage of the notional amount of the contract insured and quoted in basis points paid for protection per calendar year. Insurance premia are usually paid every quarter on the four IMM-dates; March 20, June 20, September 20 and December 20 and are calculated on an Actual/360 basis of the full year. If the reference entity defaults, i.e. a credit event occurs, the protection seller must provide compensation for the credit loss to the buyer in form of a cash settlement or physical delivery of the reference obligation and the protection buyer compensates the seller with the accrued spread since the last IMM date. The method settlement of the contract upon default of the reference entity is determined at contract entry by the two counterparties. In a physically settled contract, the buyer of the protection obtains the right to sell the underlying obligations, for example a bond, to the protection seller, who in turn is obligated to buy the obligations at face value. One feature of physical delivery, known as cheapest-to-deliver (CTD) obligation or delivery option, allows the buyer of the protection to choose what option to deliver from a list of qualifying obligations, irrespective of currency and maturity as long as they are pari passu or senior to the reference obligation Houweling and Vorst, 2005. Naturally, the CTD feature is accounted for in the CDS spreads of such contracts as the protection seller requires compensation for the risk of receiving a lower-quality obligation. Alternatively, in cash settled contracts, the protection buyer receives the difference between the contract notional and the post-default market value of the reference obligation from the seller, also called the loss given default (LGD). The market value, also referred to as the recovery value, is determined as the mid-market value of the obligation through a Credit Event Auction organized by ISDA Hull, 2012. Nowadays cash settlement is most common, and often necessary when the total notional principal outstanding in the market exceeds the face value of total outstanding debt issued by the reference entity. This is possible due to the absence of a formal requirement for the buyer of the protection to actually hold the underlying reference obligation. Hence investors may purchase "naked" CDS protection to speculate on the credit quality of the reference entity or to hedge a position in the entity's equity [1] Prior to the introduction of CDS auctions and cash settlements, investors had to seek for alternative obligations to deliver once a credit event occurred. As the supply of debt claims was limited, investor demands would drive up the price on these deliverable obligations higher than the recovery value of the contract Markit, 2010. This lead to the motivation to develop a new and improved settlement mechanism, credit event auctions, more transparent and trustworthy price for the whole market to use.

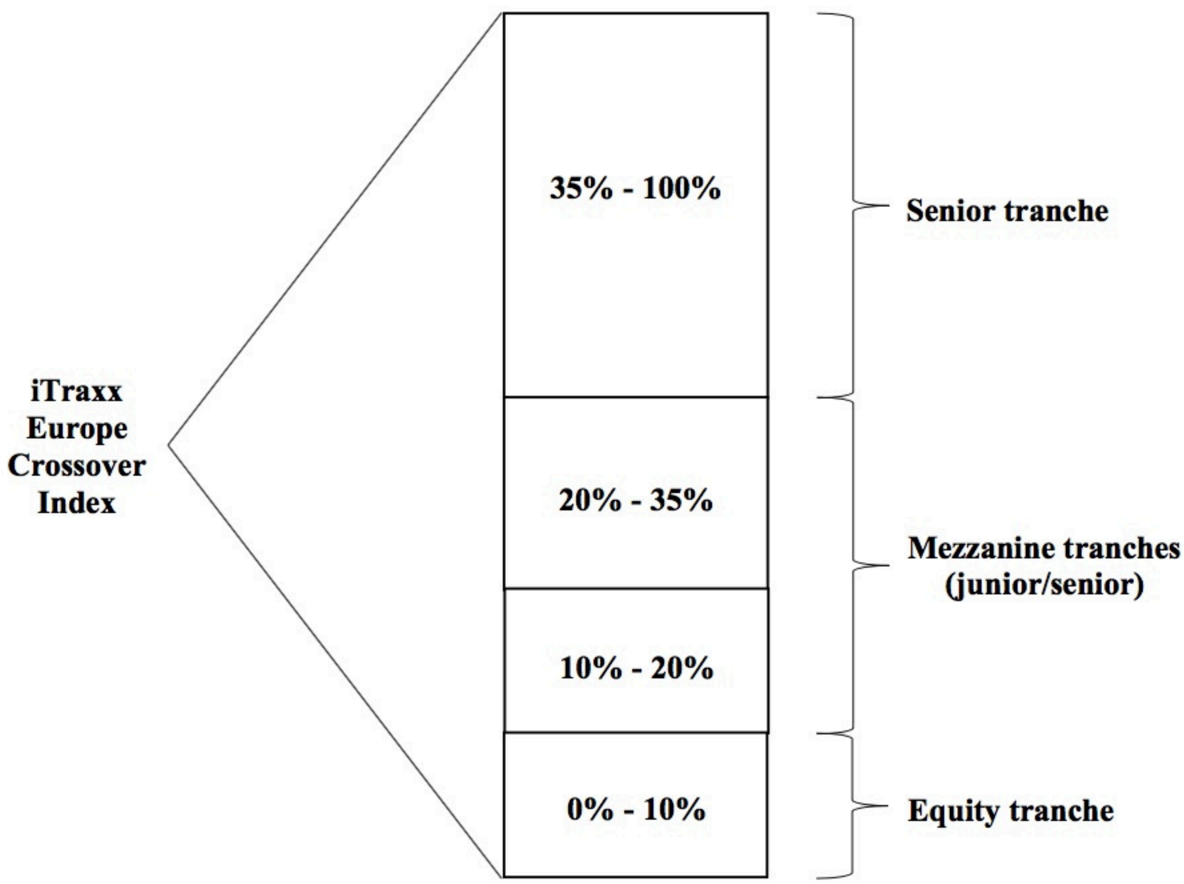
[1]A naked position in a CDS refers to buying CDS protection without holding a position in the underlying entity. This means that the investors are not exposed to the credit risk for which the protection is bought for, and hence typically use the CDS to bet on the direction of the market.



The basket CDS involves multiple reference entities, and in its simplest version provides a payoff once the first of these entities defaults (first-to-default CDS). This is less expensive than buying credit protection on each single name of a portfolio of debt claims, but also provides less insurance, as only the first to default is compensated for. One common expansion is hence the first-m-of-n-to-default CDS, in which the first m defaults of n issues are insured Lando, 2004.

CDS indices can be defined as an insurance against the default risk on the pool of single-names in the index, in which each entity has an equal share of notional amount. Liquidity of the index is enhanced by limiting the constituents to the most liquid single-name CDSs. The special feature of this type of CDS is that, if a credit event occurs, the CDS index does not cease to exist, but continues to trade with reduced notional amount Bank, 2009. CDS indices are explained in more detail in the next section.

Moreover, a market has evolved for trading of CDS index tranches, or synthetic collateralized debt obligations (CDOs), where CDS contracts relate to specific tranches in a portfolio of CDSs, typically an index of reference entities such as the iTraxx Europe Bank, 2009. Each tranche represents a portion of credit risk, with ascending risk levels. Specific risk levels will be determined by the attachment and detachment points of a tranche as they clarify which portion of losses from the occurrence of credit events in the underlying CDS index will be covered by the tranche. Synthetic CDOs thus have the attractive feature of added flexibility for their buyers and exposure to credit risk that is limited to their individual preference or investment mandate. For illustration Figure X shows the tranche mechanism of the iTraxx Europe Crossover Index. The lowest and most risky tranche is called the Equity tranche. The tranche is exposed to the first 10% of the losses from defaults in the index portfolio. Next, the mezzanine tranches, split up in junior and senior mezzanine, absorbs the losses on the index portfolio exceeding the 10% and 20% thresholds, respectively. Finally, the senior tranche covers losses of the portfolio that exceed 35% of the notional. Clearly for the senior tranche to absorb losses a large part of the index constituents would have to default. Intuitively, expectations that losses reach this point are low and, as such, the senior tranche is considered very safe. Closely connected to their varying risk profiles, tranches have different individual returns and premium payments.



In a default swap, the buyer of the protection is exposed to the risk of default of the protection seller. If a credit event occurs on the reference entity and the protection seller defaults, the protection buyer might not receive the compensation specified in the contract as the protection seller might default from a contagion effect. This may particularly happen as CDS transactions per se are unfunded transfers of credit risk. That is that in principle, the protection seller can sell protection for credit events without bringing any funds at inception of the transaction. The Credit-Linked Note (CLN) is a *funded* alternative that minimises counterparty risk. In a CLN the protection seller buys a bond from the protection buyer, and the cash flow of this bond is linked to the performance of a reference issuer Lando, 2004. In this way default protection is funded in the sense that the protection seller, by buying the bond, has provided funds initially.

One essential aspect of standardized CDS contracts is the definition of a credit event that triggers the pay-out of CDS contracts. As can be seen from below list default of the CDS contract might not necessary coincide with default of a loan or bond, which causes risks for investors and opens the door to strategic default of reference entities Association, 2018. Widely followed ISDA master terms currently define credit events as one of the following events:

1. Bankruptcy
2. Obligation Acceleration
3. Obligation Default
4. Failure to Pay
5. Repudiation/Moratorium (sovereign entities)
6. Restructuring

Still the contracting parties may decide which credit events to include, specific to the individual contracts. However, Bankruptcy, Failure to Pay and Restructuring are typically considered the most important definitions of credit events. While this definition is uniquely specified in each contract, there exist some differences between credit markets with regards to standard specifications, especially related to restructuring. The definition of restructuring as a credit event has been modified multiple times by the ISDA, resulting in the currently existing range of restructuring types. Currently restructuring types range from full restructuring (CR), to modified restructuring (MR), and modified-modified restructuring (MMR), to no restructuring (XR) Augustin, Subrahmanyam, Tang, Wang, et al., 2014. Markit's iTraxx Europe indices and the single name CDS that we will use for analysis use MMR in the standard contracts.

Initiatives to further standardize the CDS market were taken by the ISDA through the implementation of the CDS Big Bang and CDS Small Bang protocols in 2009, for American and European CDS markets respectively. These protocols introduced significant changes to the standard contract and trading conventions as a response to the global financial crisis, with the aim of restarting the market and improving efficiency and transparency in the CDS market as well as to facilitate central clearing. Previously, standard CDS contracts were issued at a par spread - a zero cost of entry - such that the fair value of the CDS was zero. To standardize cash flows, fixed coupons were introduced for single-name CDS contracts with upfront payments that account for differences relative to the running par/marked-to-market value. This has been the standard for CDS indices since their inception of trading. Similar for Europe and North America, corporate investment grade credits and high yield credits will typically trade with a fixed coupon of 100 and 500 basis points, respectively. In Europe, additional coupons are available, allowing for more flexibility. Several different fixed coupons exist to minimize the upfront payments, since high yield credit typically trade with a higher spread than credit with higher rating. Markit, 2009. One of the benefits of the standardization of the coupon payments is greater operational efficiency, but also the enhanced eligibility for central clearing.

If the CDS premium is different from the fixed coupon, an upfront payment must be exchanged. This can go in the favour of both parties, depending on the size of the annualized CDS premium. In the case the premium is higher than the fixed coupon, the upfront amount is paid by the buyer of the protection, while the seller of the protection must compensate the buyer for "overpaying" for protection if the opposite is true. Counterparty credit risk is hence reduced. On the first coupon date, the buyer must pay the full coupon price, and the seller pays "accrued interest" to the buyer for the portion of the coupon related to the time before the CDS protection is active (referred to as the value date in the contract) Association, 2018.

The standardization of single-name CDS contracts was further initiated through changes in the maturity dates, first by the 2009-protocols and again in 2015. Previously, single-name CDS contracts traded on the dates of the coupon payments, i.e. quarterly. New contractual definitions from ISDA was introduced to align the standard maturity dates of the single-names with those of the CDS indices, i.e. on the roll dates of June 20 and December 20 Association, 2018.

Another aspect of the Big Bang and Small Bang Protocols of 2009 was to implement the abovementioned auction settlement mechanism into the standard CDS documentation. Furthermore, the responsibility to formally determine whether a credit event has occurred was fully transferred to the Determination Committees (DCs). This was previously controlled for by the two parties in the CDS contract. In order to establish a consistent process to determine the occurrence of a credit event on a market-wide basis, and to enable clearing and offsetting trades, ISDA constructed the DCs. Hence, on the basis of information provided by the market participants, the DCs employ the standard market-definitions in order to decide upon the occurrence of a Credit Event, or similar issues, in individual cases. The decision to hold a CDS Auction or not after a Credit Event, in compliance with the Determination Committee Rules, also lies with the DCs. The 2003 Credit Derivative Definitions provided by ISDA were updated in 2014. Alterations following the new standard definition were mainly related to European financials and global sovereign CDS (see Swaps and Association, 2014).

Hedging and trading

CDS contracts are used in various ways, but in practice we typically separate between the application of CDSs in hedging activities, and the more speculative approach through different trading activities.

In its most basic form, the form for which it was originally developed, a CDS contract is used by financial institutions to hedge their credit exposure from lending without selling the underlying debt security. Practically, if a bank purchases a bond, but does not want to be exposed to the risk of a default by the bond issuer, the bank may purchase CDS protection on this bond. This provides the bank with capital relief and insurance against credit losses (ECB, 2009). This trade is known as the CDS-bond basis trade, and should in theory, under a no-arbitrage argument, yield a return equal to the risk-free rate. However, as we will see in section Xx(CDS as credit spread), several factors cause deviations from this argument. One of the attractive features of such a hedging strategy is that it allows investors to hedge credit risk in isolation from interest rate risk and currency risk, as the underlying bonds or loans do not have to be sold (Naifar and Abid, 2005). CDS contracts might also be used to hedge counterparty risk between dealers and other financial institutions. Such demand tends to be high in times of distress. Thereby investors are protected from widening credit spreads of their counterparties Bank, 2009.

Over time, CDS contracts have evolved into widely used tools for speculation and arbitrage Bank, 2009. Intuitively, market participants can acquire credit exposure without having to provide initial funds by selling uncovered CDS protection and in addition receive premium payments as compensation. The return on equity is hence higher in such a trade than by e.g. directly purchasing cash bonds that requires funding. Moreover, going long the credit by selling CDS protection facilitates the use of leverage in a credit position. Another important aspect of the CDS contract in trading activities is that it provides a viable and less expensive way for market participants to short credit risk Houweling and Vorst, 2005. Buying CDS protection gives the same credit exposure as shorting the corresponding underlying reference entity. This is an attractive feature of the CDS, as shorting cash bonds can be difficult and costly in practice as bond markets tend to be illiquid and security lenders hence demand high lending fees Bank, 2009.

3.3 Credit Indices

Participants in credit markets have developed indices to track credit default spreads and as benchmarks for credit risk as perceived by global markets. The indices usually consist of an equally weighted portfolio of single name CDS with same sized notional. The index notional thus equals the number of constituents multiplied by their notional. Naturally, by the law of one price and arbitrage forces in the market, the index spread trades close to the average of the constituents CDS spreads. More specifically, the index will normally trade at spreads slightly lower than the referenced entities average CDS spread, as the index is traded more often and the CDS index market is more liquid [2]. Generally, no arbitrage requirements will be satisfied if the index bid spread is larger or equal the average constituents bid while the index ask is smaller or equal the average constituents ask spread. If arbitrage requirements are violated, "skew" traders will push spreads back to no arbitrage requirements. When one of the index members defaults, the buyer of the index CDS receives a payoff equal to the single name CDS payoff and premium payments are reduced by the index weighting of the defaulted reference entity. The two most important families of portfolios used by index providers are the CDX family, which covers both corporate and sovereign reference entities in North America and in emerging markets, and the iTraxx family, which covers those in Europe and Asia. Both families are owned and administrated by the Markit Group Limited. The underlying portfolios of CDS are updated on the first and third IMM date, usually 20 March and 20 September, each year. Companies that do no longer satisfy the portfolio rules leave the index while companies that satisfy the requirements enter the index and together with the remaining corporates form the latest series of the given index. Furthermore, a given series is offered with differing maturities, e.g. 3, 5, 7 and 10 years, of which the 5-year maturity tends to be traded most liquidly. In case of a default, the series that include the defaulted reference entity are updated and get a v. N? added to their names, where N is the number of credit events at reference entities up until the most recent trading day. The iTraxx Europe index, also referred to as "The Main" or the benchmark, consists of the 125 most

[2] See DTCC http://www.dtcc.com/repository-otc-data

liquidly traded European entities with investment grade rating. In addition, several subindices of the iTraxx Europe are traded in the market. The iTraxx Europe Crossover index is composed of the 75 most liquid sub-investment grade names trading in Europe. The iTraxx Europe Subordinated Financials and the iTraxx Europe Senior Financials comprises the 30 financial entities from the benchmark index, referencing subordinated and senior debt, respectively. Furthermore, the iTraxx Europe Non-Financials Index are composed of the remaining 95 non-financial entities of the benchmark index. Finally, the iTraxx Europe HiVol index is grouping the 30 entities with the highest spreads from the benchmark index Markit, 2016.

Markit, 2014 emphasizes several benefits of using CDS indices. For one, credit indices provide tradability in the sense that they can be traded and priced more easily than a basket of cash bond indices or single-name CDS. Further, CDS contracts provide significant liquidity, and this is even more pronounced for CDS indices. Operational efficiency is enhanced through standardized terms, legal documentation and electronic straight-through processing, which supports low transaction costs. By allowing for rules, constituents, fixed coupons and daily prices to be publicly available, CDS indices offer high transparency. Finally, Credit indices are supported by all major dealer banks, buy-side investment firms, and third parties.

3.4 CDS Markets

The market for actively managing credit risk did not develop until mid-1990s, when JP Morgan created the first CDS contract Augustin et al., 2014. By its original nature, the CDS contract was meant to reduce the risk exposure for banks related to its lending activities. Traditionally, the buyer of protection had a "real" position in the CDS market, meaning that they also held the underlying credit security. From the early 2000's, the CDS market grew tremendously until the onset of the global financial crisis, particularly evident in the growth of the total gross notional amount outstanding that grew from $6 trillion in 2004 to $60 trillion prior to the crisis in 2007 Augustin et al., 2014.This growth can be seen in light of increased standardization through new contractual definitions introduced by ISDA in 2003, but also due to a less see-through and regulated market [3]. Furthermore, the introduction of new types of credit derivatives such as CDS indices and synthetic CDOs attracted new market participants and boosted the trading volume, and the speculative use of the market evolved as the new participants started to buy "naked"

[3]The Commodity Futures Modernization Act of 2000 stated that CDSs were neither futures nor securities and so are outside the remit of the SEC and the CFTC (Tett, 2009)

protections.

The growth in the market ended abruptly with the advent of the financial crisis, after which the CDS market declined significantly due to its central role in the crisis Augustin et al., 2014. Another factor causing the decline was related to the regulators initiative to decrease the dealers' net exposure to counterparty risk through "portfolio compression". [4] Because of the collapse, growing concern from regulators lead to several regulatory developments for the CDS market in order to provide more transparency. Through the before-mentioned Big Bang Protocol and Small Bang Protocol in 2009, CDS contracts started to be centrally cleared through newly introduced Central Counterparties (CCPs). The underlying motivation was that fixed payment dates, fixed coupons and central clearing would facilitate trade in CDSs again as there would be centrally agreed on prices, less counterparty risk and easier exiting of trades. Further, the Dodd-Frank Act in 2010 increased the role of the CCPs with imposed regulatory framework Augustin et al., 2014. One feature of the latter made it more expensive for major banks to take (short) positions in CDSs. These measures can be seen as a response to the substantial bailout of AIG, who had the largest net position as CDS seller, amounting to $182 billion, as a result of its sudden requirement of posting collateral after its credit downgrade and the large amount of defaults on its almost exclusively short position in the CDS market D'Errico, Battiston, Peltonen, and Scheicher, 2017. AIGs major position in the CDS market made this bailout historic. The subsequent decline in CDS market activity after the crisis has mainly been driven in the decline of single-name contracts, as the market share of CDS indices has increased significantly relative to the single names.

Initially, as previously stated, insurance companies held the largest part of the short CDS positions (long the credit) and banks typically held the major part of the long CDS position (short the credit). One interesting trend noted from the CDS statistics provided by the Bank of International Settlement (BIS) is that the insurance companies, while hedging with positions on both sides of the market, have a net position as buyers of protection. Furthermore, hedge funds tend to have a net position as protection sellers, and with a three times bigger total position in the CDS market than the insurance companies. According to BIS, reporting dealers have historically held a significant part of the total notional CDS outstanding. Although, the shares for the dealers are overstated as they do not represent net positions. Intuitively, dealers typically hedge

[4] According to Augustin et al., 2014 "Portfolio compression refers to the process through which two counterparties cancel their existing contracts so as to replace them with new ones such that they reduce the number of contracts and gross notional value amounts outstanding, while maintaining the same net exposure and risk profile."

their positions through new CDS contracts with other dealers until an investor is found who is willing to take on the risk. However, over the past three years, the shares held by reporting dealers have continuously decreased from close to 50% in the first half of 2014, to roughly 25% in the second half of 2017. Interestingly, we note that, over the same period, reporting dealers and CCPs have together accounted for 76%-80% of the total notional outstanding, showing the inverse trend for the CCPs. This indicates the trend of the market for CDS trading to continuously move towards more central clearing, away from bilateral trading. While most of the CDS index trading in Europe is now centrally cleared, the fragmentation of the single-name CDS market is persistent. The portion of centrally cleared CDS index contracts has fluctuated between 74% and 83% the last three years, while for the single names this has accounted for around 40%-50% over the same period.

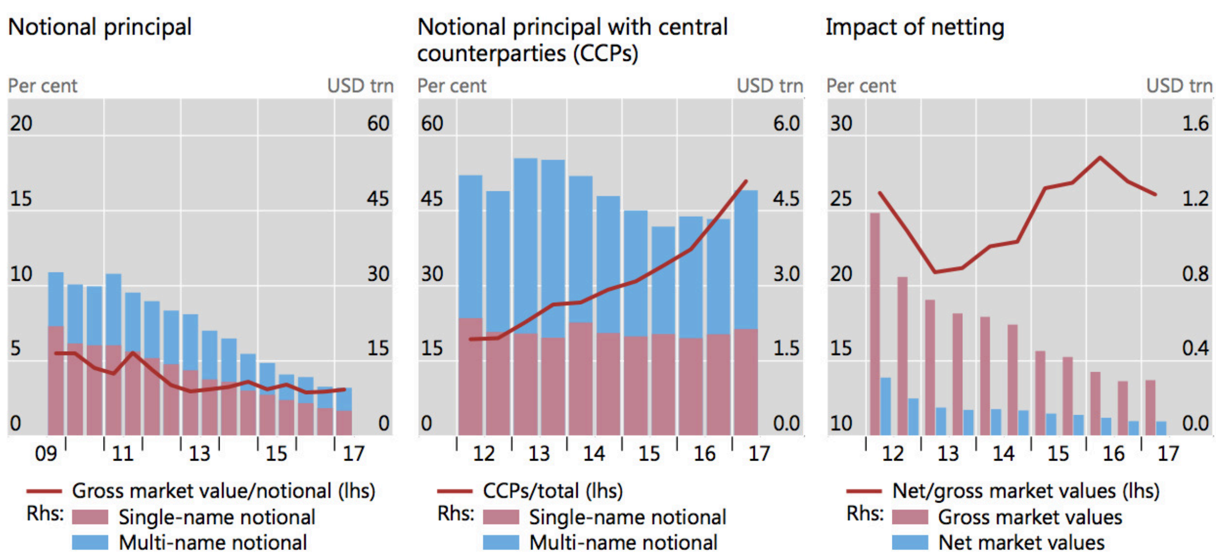


Figure: Single-name and multi-name CDS market, 2009/2012 - 2017. Source: BIS Semiannual OTC derivatives statistics.

Total notional outstanding for European CDS, including single-names and the aggregate iTraxx Europe index family, was $5.8 trillion as of 29 September 2017. Of these, single names accounted for 42% and the various iTraxx Europe indices accounted for the remaining 58% ICMA, 2018.

3.5 CDS Spreads as Credit Spreads

Credit risk has received widespread attention by researchers, academics and investors, and can be measured by the CDS spread or the corporate bond yield spread, where the latter is calculated as the difference between the yield on risky corporate bonds and the risk-free rate. The use of credit spread measures in the existing research is twofold. On one side, Collin-Dufresn et al., 2001 and Campbell and Taksler, 2003, among others, use the corporate bond spread. On the other side, the use of CDS spreads as a measure of credit risk are employed in Ericsson et al., 2009, Bai and Wu, 2016, among others. According to Bai and Wu, 2016, both measures should give similar results, however, they point out several practical implications that follow from the use of corporate bond yield spreads. For instance, term structure effects are more difficult to control for with corporate bonds due to non-fixed maturities. Further, they point out a liquidity factor inherent in the bond spreads that is driven by characteristics of the bond and its trading conventions rather than firm-specific factors.

Since both spreads are considered as proxies for credit risk, interests have arisen for investors to speculate on the difference between the two. Certain factors, such as the cheapest-to-deliver option and liquidity, reduce the validity of the CDS spread as a clean measure of credit risk. However, the amount of spread caused by the cheapest-to-deliver option accounts for only a small part O'Kane, 2010. In contrast to corporate bonds, CDS contracts are liquidly traded and CDS spreads from a liquidity perspective can hence be considered the better measure for credit risk. Additionally, the spread between corporate debt securities and the risk-free rate suffers from disagreement over what is the applicable risk-free rate and often not matching cash flows or only approximately matching maturities. Therefore, the CDS spread is usually considered as a cleaner measure of credit risk Blanco et al., 2005, Longstaff et al., 2005. The perception of the CDS spread as a purer measure of credit risk is further explained by the trading conventions. While CDS contracts typically trade with standardized contracts, corporate bond yields are likely to be affected by contractual differences such as coupon rates, seniority and embedded options Zhang et al., 2009.

Credit derivatives, due to their pronounced liquidity [5] relative to bonds, quickly process relevant information e.g. for monitoring the creditworthiness of a single company. Furthermore, portfolio products, such as credit indices, are well suited to reflect systemic information concerning the creditworthiness of a sector or an overall economy (Breitenfellner and Wagner, 2012. Ac-

[5] See DTCC http://www.dtcc.com/repository-otc-data

cording to Blanco et al., 2005, the CDS spreads and bond spreads tend to relate in the long run, while the quicker reaction of CDS spreads in the short run is explained by the fact that the CDS is typically unfunded and does not face short-sale restrictions.

3.6 Credit Risk Models

Two approaches

Credit risk models are widely divided into two main approaches, the structural model and the reduced-form model. Structural models root back to the seminal papers of Black and Scholes, 1973 and Merton, 1974, while reduced-form models originated with the seminal work of Jarrow and Turnbull (1995), and subsequently studied by Lando, 1998, Duffie and Singleton, 1999, Hull and White, 2000, among others. In the former model, default is treated endogenously, while exogenously for reduced-form models.

A structural model takes as a starting point some fundamental object to the firm, such as the market value of the firm?s assets or the cash-flow of the firm. In structural models based on Merton's seminal work Merton, 1974, the value of a firm's assets is assumed to evolve randomly over time and is typically modelled by a stochastic process such as a geometric Brownian motion. This type of model assumes that default is triggered when the value of a firm's asset falls below a particular threshold, the default boundary, expressed as a function of the amount of debt outstanding (Collin-Dufresn et al., 2001) or possibly debt covenants. The main determinants of credit spreads in these models are suggested by the original Merton, 1974 model to include maturity of debt issued, leverage, asset value, asset volatility and interest rates. However, various extensions and modifications have been proposed in later research, such as random default at any time, stochastic interest rates, jumps and strategic defaults Huang and Huang, 2012, as well as including several additional determinants of spreads. While structural models are widely used in credit risk modelling, they have proven to do a poor job in empirically explaining the magnitude of the credit spreads. This result is commonly known as the credit spread puzzle.

In reduced-form models, also known as intensity-based models, credit risk is jointly determined by the occurrence of default and the recovered amount at default. Default is often represented by a random stopping time with a stochastic or deterministic arrival intensity (hazard rate), while the recovery rate is usually assumed to be constant. This illustrates a key motivation behind reduced form models well, namely to avoid the detailed modelling of the asset dynamics and capital structure of an issuer. While reduced-form models are recognized as more successful practically, the main drawback of these models is that they often assume a latent default process and are thus silent on the economic determinants of spreads (Ericsson et al., 2009).

The empirical literature on reduced form models has focused on estimating the parameters of one of three processes: the hazard rate process, the spread process or the risky short-rate process. Especially for the hazard rate process, firm-related variables may be used for modelling. One of the first reduced form models was presented by Jarrow and Turnbull, 1995, in which default and recovery is determined by the Poisson default process.

For our analysis we take inspiration from both the structural model and the reduced form model approaches.

Methodology/Employed Models

In this section, we introduce the motivation behind our empirical analysis, while the specifications of the performed analysis and regressions will be presented in section X. For the empirical analysis, we take inspiration from reduced form models, particularly the pricing model released by the ISDA (White, 2013) as this model is also employed by Bloomberg for reporting CDS spreads. Influence from the reduced model can be seen in our model specification, while influence from Merton's structural model and extensions can be seen in our variable selection for explaining the variation in CDS spreads of CDS Indices, single name CDSs the senior tranche of a generic CDS index and the payment upfront made for junior and mezzanine tranches of the same generic synthetic CDO.

Yield and credit curves are key inputs to credit risk modelling as they determine the discount factors and survival probabilities related to the debt obligation of interest and therefore are used for pricing derivative contracts on the obligation of interest. However, the focus of this paper is not on modelling default, as the iTraxx Europe index constituents are investment grade rated firms for which default rarely occurs and the referred to index is renewed every 6 months and there has been no default occurrence in an on-the-run index during the period that we investigate. For this reason, we only show how default is modelled and the intuition behind the modelling. We do not strive to model defaults or default probabilities. We take the quoted prices of single name CDS, CDS indices and tranches on these indices - synthetic CDOs - as given but explain the motivation for and intuition behind the standard pricing model for credit default swaps as published by the ISDA. Further details on how pricing and valuation of credit derivatives is done in practice can be found in numerous textbooks and research papers, some of which will be referred to directly in our text.

The theoretical foundation behind the tremendous growth in size, scope and complexity of derivatives markets has been the development of the risk-neutral pricing framework. In efficient, complete capital markets and under the principle of no arbitrage (check whether correct) the risk neutral pricing framework starts by acknowledging that every derivative security must be superfluous in the market, have the same price as its replicating portfolio and hence should be hedgeable. Under given assumptions, issuers of credit derivatives can hedge their position by trading the underlying asset, such that their net portfolio of derivatives and hedging position is not affected by market movements. By no arbitrage principles the issuers of credit derivatives should hence earn the risk-free rate on their hedged portfolio of assets.

Intensity based models are mainly based on two exogenous variables, the recovery-rate and the hazard rate. Consider the hazard rate to be the 1 year probability of default in a risk-neutral world, given that no default has occurred so far. Here, we note that the risk neutral default probability is a composite of the actual default probability and investors' default risk premium.

Yield curve

All credit derivative securities with future cash flows consider the time value of money, hence a discount curve is required for pricing. The term structure of interest rates is sufficient for this. The interest rate chosen can have a significant effect on the price of the derivative, which implies the importance of an adequate choice of the interest rate that is applied to expected cash flows for pricing the derivative. Given this importance, there is a debate on which term structure is applicable for derivatives pricing. To understand the debate, it becomes important to acknowledge that commercial and investment banks typically have major net short positions in the derivatives market, as pointed out above. One faction argues that, since commercial and investment banks need to hedge their risks, the interest rate used to discount the cash flows is the one at which they fund the purchase of the hedging instruments. In Europe, this is the Euribor rate (specifically the swap rate against 6m Euribor rates). The 6 months Euribor is the rate at which a panel of commercial and investment banks can obtain unsecured Euro funding with 6 months maturity from the inter-bank lending market. The swap rate on the Euribor 6-months rate is hence the risk neutral market expectation of the cost at which commercial and investment banks can obtain long term funding for a period equal to the swap tenor. For a 5-year derivative contract, it can hence be argued that the applicable discount rate is hence the Euribor interest rate swap rate with a tenor of 5 years.

A different faction argues that derivatives should be priced at the interest rate that is closest to the risk-free rate, the OIS swap rate, and subsequently adjusted for counterparty credit risk by adding counterparty specific debt value adjustment (DVA), credit value adjustment (CVA) and collateral rate adjustment (CRA) to the value of the swap. Hence, their argument is that using the Euribor swap rate for pricing hides true counterparty risk as the rate is determined from a panel of banks with outliers removed (see e.g. Hull, 2012). As we are using transformations of Bloomberg quoted market spreads and payments upfront as dependent variables for our analysis, we take a pragmatic approach and use Euribor swap rates of adequate maturity for our analysis. For analysis, these rates may be used to replace the stochastic process of r(t) and price synthetic zero-coupon bonds that can be used as discount factors. The discount factor is then given by:

$$P(t,T) = E^{p}\left[e^{-\int_t^T r(s)ds}|F_t\right] \tag{4.1}$$

Where F_t is the filtration, representing the information set up to time t.

Credit curve

In the reduced-form approach to credit risk modelling, default is assumed to follow a Poisson process with an intensity, or hazard rate, at time t denoted by $\lambda(t)$. For single-name products the default is often modelled as the first jump of a Poisson process, as originally introduced by Lando, 1998. This has intuitive meaning, as Poisson processes are often used to model rare events such as default, which normally is a unique event during the life of a company.

If default occurs at the random time τ, then the probability of default between time t and an infinitesimal time-period dt, conditional on no default up until time t, is given by:

$$P(t < \tau \leq t + dt|\tau > t) = \lambda(t)dt \tag{4.2}$$

It is obvious why the term hazard rate as an alternative term for the intensity process has been established. In the Poisson process, the intensity $\lambda(t)$ is assumed to be deterministic. This is sufficient in order to model the default time as a stochastic event, however, it prevents us from modelling the changes in the hazard rate $\lambda(t)$ over time due to the fact that new information in the market affects the expectations about the default risk of the credit. This is reflected in the changes of the credit spreads. (O?Kane, 2010). As a result, there is an incentive to generalize the model to allow for stochastic hazard rates. The resulting new model incorporates two stochastic processes, the first one being the Poisson jump process and the other one is the random evolution of $\lambda(t)$. This model is said to be doubly stochastic, and is known as a Cox process, originally presented by Lando, 1998, in which the probability of surviving at least up to time $T > t$ is given by:

$$Q(t,T) = E^P[e^{-\int_t^T \lambda(s)ds}|F_t] \tag{4.3}$$

Notice that the relationship between the survival probability $Q(t,T)$ and the default intensity $\lambda(t)$, corresponds to that between a zero-coupon bond $P(t,T)$ and the instantaneous short rate $r(t)$ in the yield curve above, which implies that the price of a bullet bond (I.e. with no intermediate payments) is given as:

$$E^P[e^{-\int_t^T (\lambda(s)+r(s))ds}|F_t] \tag{4.4}$$

That is, the default intensity is exactly the element that differentiates the price of a defaultable bond from the price of a corresponding risk-free bond. This analogy can be further extended as we define the forward-looking hazard rate, $h(t,T)$ as:

$$Q(t,T) = e^{-\int_t^T \lambda(s)ds} \rightarrow h(t,s) = -\frac{\partial ln[Q(t,s)]}{\partial s} = -\frac{1}{Q(t,s)}\frac{\partial Q(t,s)}{\partial s} \tag{4.5}$$

And the constant hazard rate function, $\Lambda(t,T)$ as:

$$Q(t,T) = e^{-(T-t)\Lambda(t,T)} \rightarrow \Lambda(t,T) = -\frac{1}{T-t} ln[Q(t,T)] \tag{4.6}$$

The survival probability curve, $Q(t,T)$, the forward-looking hazard rate curve, $h(t,s)$, and the constant hazard rate curve, $\Lambda(t,T)$, are analytically equivalent, and we refer to them generically as credit curves.

In practice, one often assumes independence between interest rate and hazard rate for model convenience. Besides the assumption of independence between interest rates and probability of default one also, inevitably, needs to make assumptions about the recovery value of defaulted debt claims when pricing the protection leg. The easiest and most pragmatic approach is to assume that the recovery rate of defaulted debt is a constant, or equal to some expected value. Mathematically this can be sensible if one assumes independence of the recovery rate from default probability and interest rates. In this approach natural values of the expected recovery rate could be to use long term average recovery rates, differentiated by industries, remaining maturity at default and potentially seniority of debt claims. A typical and pragmatic approach used by the industry is to assume a constant recovery rate of 40%. From a pragmatic approach, the assumption of constant recovery can be justified by the fact that recovery rates are often hard to predict prior to default, as well as the fact that what matters for the value of the CDS contract is the expected loss given default, i.e. the probability of default times (1-recovery), so assuming one of them (recovery) is constant does not reduce model flexibility.

After valuing the protection leg and premium leg it is straightforward to find the CDS spread that makes the protection and premium leg equal in present value. Noting that the premium leg can be written as the spread times a risky annuity with tenor equal to the length of the CDS contract plus the net present value of the fraction of the spread that is paid as accrual on default, one can divide the protection leg by the value of the risky annuity plus accrual and thereby find the CDS par spread at which both legs have equal present value and any transaction would have a net present value of zero. Valuation of multi-name products such as indices can be done in the same way as for single-names, as most indices are weighted averages of single names. Hence, the modelling only needs to be adjusted by the weights of the constituents in the index.

In the ISDA big bang and ISDA small bang world the coupon is fixed, the coupons must be paid in full and payment dates are set, which is why CDSs are traded with payments upfront such that transactions have a net present value of zero at inception. Therefore, the payment upfront must equal the present value of protection minus the present value of the premium leg minus accrued premium payments. Given the new market standard post big bang and small bang it is intuitively clear why payments upfront have become the new indicators for cost of protection. Using the ISDA model one can however recalculate the payment upfront into an implied par spread, which, given the observed term structure for credit and interest rates, is a one-to-one mapping and hence an equivalent measure for the price of protection demanded by the market. This is what Bloomberg is doing when reporting spreads for CDS contracts and what we henceforth mostly base our analysis on.

From an economic and mathematical perspective, the assumption of independence between interest rates, probability of default and recovery rate is restrictive and neglects interdependence between interest rates, probability of default and the recovery rate. Additionally, independence of interest rates and probability of default collides with Merton's structural model, which predicts lower spreads for high risk-free rates as the underlying asset's drift under the risk-neutral measure increases and default becomes less likely Merton, 1974. Mathematically these interdependencies can be accommodated for and sophisticated reduced form models can be built such as done by Lando, 1998 and empirically tested by Altman, Brady, Resti, and Sironi, 2005.

We follow a different approach and take prices for protection observed in the market as a manifestation of the market's expectations on probability of default, recovery rates, interest rates and their interdependence. Thereby we take a financial economist's view on the economic and financial drivers of protection cost. It is intuitive that the probability of default and recovery rates are influenced by economic variables such as business climate or access to funding. Additionally, we argue that interdependencies between the variables are driven by macroeconomic variables and change over time. Possible interdependencies could include easier access to finance for companies in distress during bull markets or markets with high funding liquidity. Additional interdependencies could comprise higher recovery rates in times of high market valuations and high risk tolerance. One could furthermore build an argument on that in times of many defaults (and defaults tend to cluster) achievable recovery values are low as the market for distressed assets is limited in size Altman et al., 2005. Finally, it is observed that defaults tend to cluster in recessions, that is when economic fundamentals are disadvantageous for equity valuations and hence recovery rates can be expected to be low. Hence there are many economic hypotheses which call for an economic and technical investigation of the drivers of CDS spreads.

Relevant Input

In efficient capital markets new information is quickly absorbed and prices are based on rational expectations about the future. Prices for protection from credit risk should hence be based on the expectations of investors about future states of the referenced entity as well as the economy. Additionally, the prices that investors are willing to buy or sell credit securities at depend on their individual risk tolerance, which may change over time and with market conditions. Hence, over time and in different market conditions the same investor may be willing to pay different prices for the same security.

Traditional investors in credit markets such as banks and insurances want to preserve capital and hence focus on potential downside in contrast to equity markets where the focus of investors is on the upside of their investments. The skewed return profile of credit as well as the tendency of debt to default in economic downturns will overweigh the risk neutral probability greatly at which insurers and bank are willing to take on that risk (Hull, 2012). Empirical evidence of this can be seen in research quoting hazard rates and CDS spreads. Changes to their risk tolerance are hence likely to influence prices in CDS contracts significantly.

For our analysis of determinants of CDS spreads and their changes we hence include mostly forward-looking variables to the set of explanatory variables that we use in our regressions. Nevertheless, to challenge the notion of efficiently priced CDS, contracts we include two historic variables to test whether past information truly has been priced into CDSs upon closing of the trading days during the sample period covered by our analysis. In addition, we add variables to the explanatory dataset to investigate the effect of economic expectations and proxies for economic expectations. By including these variables, we implicitly also strive to control for changes in the stochastic discount factor as the risk tolerance of primary participants in CDS markets, such as banks or insurance companies (Hull, 2012), changes.

We take inspiration for forward-looking financial variables from Merton's structural model. The model identifies five financial variables, the risk-free rate, debt outstanding, asset value, time to maturity and asset volatility as the drivers of credit spreads. However, the true asset value and asset volatility tends to be unobservable in financial markets and probably every investor has a different view on the fundamental value of a company. We hence substitute asset value and volatility by equity value and volatility, which are functions of asset value and volatility respectively - but also of risky debt market value and volatility, which we neglect at this point. Recalling that in the Merton framework equity and debt are contingent claims on the asset value one could theoretically use this assumption and the fact that risk-free rates, equity prices, (implied) volatility, debt size, debt prices and remaining maturity are observable in the markets to back out an asset value and volatility consistent with observed prices. One well known such procedure is the iterative procedure of Vassalou and Xing, 2004. We however abstain from searching for an asset value as we note that Merton's assumptions such as firm assets traded in financial markets, no frictions no impact of financing decisions on the asset value and symmetric information in financial markets are likely not to be satisfied. Nevertheless, Merton's model serves as good inspiration for us. And since credit spreads are uniquely determined by the current values of the state variables in the model, it follows that also changes in spreads are determined by changes in Merton's five drivers of credit spread.

For variables relevant for the economy and risk tolerance by investors we take inspiration from traditional investment policies of banks and insurers. Traditionally banks earn income by transforming maturities and aggregating deposits to provide stable funding to the economy (Keiding, 2016). Insurances tend to invest in investment grade rated fixed income securities with long maturities, which they will usually hold on their balance sheets until maturity Stark, 2014. Our hypothesis hence is that long-term changes affecting traditional investment policies of banks and insurers will change their risk tolerance and hence their valuation of credit.

Data Description

We base our analysis on a dataset covering a period of 6 years, from January 2012 until December 2017. Observations are collected on trading days within the stated period and comprise the best bid and best ask price at closing of the market for financial instruments. Bid and ask prices have been obtained from Bloomberg's terminal service. Closing prices in our dataset are then calculated as on the Bloomberg terminal, as the arithmetic mean between best bid- and best ask price observed at market close. We furthermore calculate the difference between best ask- and best bid-price as a measure for market liquidity. This measure is included to regressions where evidence found in statistics from the Depository Trust & Clearing Corporation (DTCC), which provides clearing and settlement services to the financial markets, warrants concern about market liquidity of the respective dependent variables.

6.1 Cost of protection, dependent variable dataset

iTraxx generic CDS indices

iTraxx Europe Main:

The iTraxx Europe generic 5-year index always represents the most recent version of the Markit iTraxx Europe CDS index with a 5-year maturity. The generic index is therefore rolled over every 6 months on the issuance date of the newest series, therefore always includes the most recent constituents and has a fixed maturity that decreases from 5,25 years to 4,75 years, before jumping up to 5,25 years at the rollover date. In a sense the generic iTraxx Europe index is hence comparable to an interest rate swap based on the Euribor 6-months rate. The iTraxx Europe thus often serves as a benchmark for credit risk associated with European investment grade rated companies and maturities of approximately 5 years. Cost of protection on the iTraxx Europe index is reported by Bloomberg in basis points cost per year.

iTraxx Crossover:

The iTraxx Crossover generic 5-year index always represents the most recent version of the Markit iTraxx Crossover CDS index with a 5-year maturity. The generic index is therefore rolled over every 6 months on the issuance date of the newest series, therefore always includes the most recent constituents and has a fixed maturity that decreases from 5,25 years to 4,75 years, before jumping up to 5,25 years at the rollover date. The iTraxx Crossover often serves as a benchmark for credit risk associated with European non-investment grade rated, non-financial companies and maturities of approximately 5 years. Cost of protection on the iTraxx Crossover index is reported by Bloomberg in basis points cost per year.

iTraxx Senior Financials:

The iTraxx Senior Financials generic 5-year index always represents the most recent version of the Markit iTraxx Senior Financials CDS index with a 5-year maturity. The generic index is therefore rolled over every 6 months on the issuance date of the newest series, therefore always includes the most recent constituents and has a fixed maturity that decreases from 5,25 years to 4,75 years, before jumping up to 5,25 years at the rollover date. The iTraxx Senior Financials index often serves as a benchmark for credit risk associated with senior debt issued by European Financial Institutions and maturities of approximately 5 years. Cost of protection on the iTraxx Senior Financials index is reported by Bloomberg in basis points cost per year.

iTraxx Subordinated Financials:

The iTraxx Subordinated Financials generic 5-year index always represents the most recent version of the Markit iTraxx Subordinated Financials CDS index with a 5-year maturity. The generic index is therefore rolled over every 6 months on the issuance date of the newest series, therefore always includes the most recent constituents and has a fixed maturity that decreases from 5,25 years to 4,75 years, before jumping up to 5,25 years at the rollover date. The iTraxx Subordinated Financials often serves as a benchmark for credit risk associated with subordinated debt issued by European financial institutions and maturities of approximately 5 years. Cost of protection on the iTraxx Subordinated Financials index is reported by Bloomberg in basis points cost per year.

Single-name CDSs

Note that until December 2015 single name CDS traded with maturities on the quarterly IMM dates, I.e. a CDS contract with 5-year maturity, entered on 12 February 2012 matured on 20 March 2017. However, since 20. December single name CDS maturity dates have been aligned with CDS index maturity dates. In the given example the single name CDS would hence mature on 20 June 2017 instead of 20 March. The cost of protection is reported by Bloomberg in basis points to be paid for protection per year until the given maturity. We continue to use basis points as the measure for cost of protection in our analysis.

AXA:

The 5-year maturity CDS with the French insurer AXA as reference entity.

BASF:

The 5-year maturity CDS with the German chemical goods company BASF SE as reference entity.

EDF:

The 5-year maturity CDS with the French utility company Electricite De France as reference entity.

Telenor:

The 5-year maturity CDS with the Norwegian telecommunications and media company Telenor ASA as reference entity.

iTraxx Crossover Tranches

Generic Equity tranche 0-10%

Generic index of the single equity tranche with detachment point 10% from a synthetic CDO on the iTraxx Crossover 5-year maturity CDS index. The tranche is issued once a year in September on the then on-the-run iTraxx Crossover index and was not available from the Bloomberg terminal for the full sample period, but only starting from September 2014. The maturity of the generic equity tranche hence varies between 5,25 and 4,25 years. Cost of protection of the equity tranche is reported by Bloomberg as payment upfront in percentage points of the tranche notional. In our analysis we use the log of 100 plus the payment upfront as reported by the Bloomberg terminal. The dependent variable in our regression hence resembles a credit linked note with the equity tranche as the credit element.

Generic Junior Mezzanine Tranche 10-20%

Generic index of the single junior mezzanine tranche with attachment point 10% and detachment point 20% from a synthetic CDO on the iTraxx Crossover 5-year maturity CDS index. The tranche is issued once a year in September on the then on-the-run iTraxx Crossover index and was not available from the Bloomberg terminal for the full sample period, but only starting from September 2014. The maturity of the generic junior mezzanine tranche hence varies between 5,25 and 4,25 years. Cost of protection of the junior mezzanine tranche is reported by Bloomberg as payment upfront in percentage points of the tranche notional. In our analysis we use the log of 100 plus the payment upfront as reported by the Bloomberg terminal. The dependent variable in our regression hence resembles a credit linked note with the junior mezzanine tranche as the credit element.

Generic Mezzanine Tranche 20-35%

Generic index of the single mezzanine tranche with attachment point 20% and detachment point 35% from a synthetic CDO on the iTraxx Crossover 5-year maturity CDS index. The tranche is issued once a year in September on the then on-the-run iTraxx Crossover index and was not available from the Bloomberg terminal for the full sample period, but only starting from September 2014. The maturity of the generic mezzanine tranche hence varies between 5,25 and 4,25 years. Cost of protection of the mezzanine tranche is reported by Bloomberg as payment upfront in percentage points of the tranche notional. In our analysis we use the log of 100 plus the payment upfront as reported by the Bloomberg terminal. The dependent variable in our regression hence resembles a credit linked note with the mezzanine tranche as the credit element.

Generic Senior Tranche 35-100%

Generic index of the single senior tranche with attachment point 35% and detachment point 100% from a synthetic CDO on the iTraxx Crossover 5-year maturity CDS index. The tranche is issued once a year in September on the then on-the-run iTraxx Crossover index and was not available from the Bloomberg terminal for the full sample period, but only starting from September 2014. The maturity of the generic senior tranche hence varies between 5,25 and 4,25 years. Cost of protection of the senior tranche is reported by Bloomberg in basis points spread to be paid per year. For our analysis we use the log of the basis points spread reported by Bloomberg as one of the dependent variables.

6.2 Input for explanatory variable dataset

EURIBOR swap rate

We include various swap rates on the Euro Interbank Offered Rate (EURIBOR) 6 months rate into our analysis. The Euribor rates are based on the average interest rates at which a large panel of European banks can borrow unsecured from one another and are considered as the most important reference rates in the European money market. Additional to their importance to and reflection of the European money market, we choose to include Euribor rates as they reflect market expectations about the credit risk of banks in the panel. By design interest swaps on the Euribor hence include credit risk, too. This is relevant since the CDS contracts of our sample are Euro denominated and hence will be discounted at the interest rate that the market anticipates for Euro money markets, precisely the Euribor swap rate. By using swap rates with an adequate tenor as an explanatory variable, we hence control for the effect of interest rates and discounting of expected cashflows on credit default swaps. Furthermore, in the ISDA standard model for CDS pricing discounting factors are built using rates from interest rate swaps on the Euribor 6m rate 2018.

OIS swap rate

We include the Euro overnight indexed swap (OIS) rate into our regression as a measure of the true risk-free rate within the Euro zone. In the overnight indexed swap, a fixed rate of interest, the swap rate, is exchanged for the geometric average of the Euro overnight rate (EONIA), a collateralised overnight lending rate denominated in Euro and close to the overnight rate of the ECB. Because of the daily renewal and collateralised lending, the OIS rate is widely accepted and used as a proxy for the true risk-free rate. Swaps on the OIS rate hence reflect market expectations on the future development of the risk-free rate. We therefore use OIS rates of adequate maturity as an alternative proxy for market expectations interest rates used for valuation of the CDS. A widely observed indicator of health of the financial system can be constructed by subtracting the OIS rate over 6 months from the 6 months Euribor rate. The resulting Euribor-OIS spread reflects the risk premium demanded by the market for lending unsecured to financial institutions over 6 months. In times of healthy financial markets, the spread is small. Before the global financial crisis, the Euribor-OIS spread used to be below 10 basis points (Bloomberg). In times of market distress or distrust among banks, the spread widens as the perceived risk of lending unsecured for a timespan of 6 months is high. In our analysis the Euribor-OIS spread hence serves as a barometer of health for the European financial system. Economically, we believe that high funding liquidity for banks increases the overall loan supply to the economy and thereby reduces the risk of bankruptcy due to competitive pricing of interest and the ability of firms to roll over debt and refinance quickly. Furthermore, the notion that during times of market-wide distress, the supply of risk capital is reduced across the spectrum of bonds in a manner that does not fully discriminate for credit quality, resulting in a price for bearing default risk, per unit of default risk to be borne, that is disproportionately higher for high-quality debt, could explain increased CDS spreads. Alternatively, we could use OIS rates to control for effects of the risk-free rate on CDS spreads and their changes. By taking a proxy without inherent credit risk we thereby might be able to obtain cleaner estimates and see the effects of our economic variables on debt value adjustments (DVAs), credit value adjustments(CVAs) and collateral rate adjustments (CRAs).

Inflation swap rate

We decide to include the inflation swap rate traded in financial markets as a daily measure of expected inflation in the Euro area. The zero-coupon inflation linked swap exchanges a fixed rate payment at maturity, the quoted swap rate compounded by the tenor of the swap, for an uncertain payment that is determined by the observed inflation, compounded until maturity. Referenced inflation is measured by the eurozone Harmonized Index of Consumer Prices ex tobacco (HICP).

As one of the macroeconomic variables next to GDP growth, inflation is a key driver of financial markets and asset prices. Expectations about future inflation hence should play a central role in asset pricing. Implicitly, expected inflation will be included in the nominal interest rates such as Bund yields, OIS rates or Euribor swap rates. Though, the real interest rate remains unknown. As inflation increases revenue, and under the assumption of sticky costs in the short run that can be caused by long term contracts, inflation is positive for cash flow available for debt service. This reduces the risk of default of a given company and associated reference entity. Other things equal we hence expect inflation to reduce credit spreads additional to the expected decrease following from higher risk-free interest rates. Furthermore, as the swap rate has the risk premium that investors demand for bearing inflation risk for a specified period priced in, we can analyse like-for-like the effect of inflation on credit default swap spreads without neglecting the markets tolerance for this specific type of risk.

Implied volatility

We decide to use the VSTOXX index (V2X), which measures volatility implied by options on the

Eurostoxx 50 index, as a proxy for the implied equity volatility of the most recent iTraxx CDS index constituents. Similar to the VIX index on the S&P 100 index, the VSTOXX index developed by Deutsche Boerse and Goldman Sachs is a weighted average of implied volatility from put and call options on the Eurostoxx 50 with 30-day maturity and different strike prices. Included in the forward looking implied volatility is the risk of jumps in a company?s asset value. If market participants see increased risks of sudden corrections implied volatility rises as market participants will start to hedge their positions, thereby driving implied volatility up. Theoretically, the market belief about individual firm's future volatility can be extracted from the implied volatilities of options on the firm. However, since most of the index constituents do not have publicly traded options written on them, the market for options on single stocks does not always trade very liquid, and the importance of each implied volatility varies with the CDS spread on the respective reference entity, including an exact measure for implied volatility in the set of explanatory variables proves difficult in practice. Given the diversified nature of the portfolio of iTraxx Europe constituents and assuming there are few idiosyncratic risks present in the implied volatility index, high cross correlation of implied volatility on a firm level (2018) could drive CDS spreads. We hence believe that including the VSTOXX index in our regression as a measure of aggregate volatility expectations is a sensible approach to include market expectations with regards to volatility and jump risks to our regression.

Bund yield

We decide to include the bund yield as an alternative measure of the risk-free rate and as a measure of the steepness of the yield curve. We thereby follow, Collin-Dufresn et al., 2001. Traditional sellers of credit default swaps such as banks and pension funds usually invest large parts of their portfolios in domestic bonds such as treasuries (Willis Towers Watson, 2018). A low treasury yield might therefore lead to a low credit risk spread as the return trade-off between treasury yields and risky debt becomes more favourable for credit with lower bund yields and investors can take appreciation gains from selling Bunds. Additionally, high convenience yields might also make traditional treasury buyers overthink their asset allocation and shift weights into selling less liquid, but better rewarded credit. This effect could be particularly strong in the low risk, diversified CDS portfolio of investment grade rated reference entities. Our hypothesis hence is that small term premium incentivises investors to invest in credit, thereby driving down spread levels. Vice versa a larger term premium would move the risk return relationship in favour of holding long maturity, AAA-rated, government bonds which do not have to be marked to market on the balance sheet of financial institutions.

From a macroeconomic perspective, an alternative hypothesis would be that small term spread might be a sign of market expectations about slow future growth. Based on this belief market participants could expect higher default rates as the economic environment of firms becomes less friendly for debt repayment. Alternatively, it could be argued that a small spread between 10-year yield and 2-year yield might be evidence that investors are more willing to accept risk, in this case the risk of changing interest rates, i.e. interest rate volatility.

Remaining days to maturity

We include the remaining days to maturity for CDS contracts into the set of explanatory variables to control for term effects in CDS spreads during the time the most recently issued CDS index is on-the-run. By the size of the coefficient we furthermore hope to make inference about the size and significance of added maturity for pricing CDS contracts. A large coefficient could indicate a steep increase in the term structure of CDS spreads and thereby hint at high perceived uncertainty by the markets, or aversion by markets to sell long term CDS contracts. A low and insignificant coefficient could, on the other hand, indicate that around a 5-year horizon additional time to maturity is not very costly and perceived uncertainty about future spread sizes over the 5-year tenor is relatively constant.

ECB Euro effective exchange rate

We include the European Central Bank's (ECB) nominal effective exchange rate (EER) index on the strength of the Euro versus a currency basket comprised of currencies of the 20 countries which trade most with the European Economic Region. The index is set to 100 at Q4 1999 and measures the relative strength of the Euro against this benchmark date. Primarily, we decide to include the EER to control for currency effects on firm fundamentals in our regression, as particularly European large caps operate internationally and therefore have currency risks inherent to their business. As a long-term measure we can imagine that depreciation or appreciation of the Euro vis-a-vis the currencies of Europe's largest trade partners serves as a proxy for foreign investors sentiment about prospects of the European economy as they demand or sell Euros for investing or divesting in Europe.

Index Roll

The iTraxx Europe index is rolled over semi-annually, and the investors holding the existing on-the-run index will typically try to roll into the new on-the-run index by selling the old index contract and buying a new one O'Kane, 2010. This behaviour will generally result in a P&L impact due to changes in the composition of the index and the increased maturity. The new index has a six months longer maturity than the previous index, and as credit curves tend to be upward sloping this would cause the new index spreads to be wider, ceteris paribus.

CDS Index specific variables

Eurostoxx 50

We decide to include the Eurostoxx 50 equity index as a proxy for the equity performance of iTraxx Europe index constituents. Furthermore, the Eurostoxx 50 serves as a measure for business climate and the overall state of the economy in our analysis. As such we expect the index to be negatively related to credit spreads. For the analysis of changes in CDS spreads we include the same-day return of the Eurostoxx 50 as well as the one-day lagged return of the index. This is based on previous research that has found that stock markets tend to react faster than specific parts of credit markets Blanco et al., 2005. By including lagged Equity market returns we can further control for low market activity, manifested in stale prices and efficient pricing of CDS contracts.

6.3 Single name CDS specific variables/firm-specific variables

Market capitalization

We include market capitalization to measure the equity value of the companies associated with the reference entities of the single-name CDSs that we selected. In Merton's simple structural model debt and equity are both contingent claims on the same underlying asset, the specific company, and hence closely related in their valuation. The Equity value or changes in equity value are hence predicted to coincide with the level of and changes in the debt value. On the other hand, reduced form models do not make explicit assumptions about the integration of credit and equity markets, although it is logical to model hazard rates with input from equity markets, as is done in Jarrow and Turnbull (1995). Economically, a company with high market capitalization is likely able to, at most times, retire debt by issuing new equity. We hence expect a high market capitalization to reduce CDS spreads demanded by credit markets. Besides the immediate effect we also include a lagged return variable to test for the integration of changes in credit and equity markets as formulated in Merton?s seminal work (Merton, 1974). Additionally, with the estimated lead-lag relationship of equity and credit markets we can provide further evidence for the liquidity and market depth of credit markets, as we can make inference on stale prices.

Historic volatility

We include historic volatility over the last 60 trading days to the analysis. Volatility is an integral part of Merton's structural model and has been shown by research to significant for explaining variation in credit spreads (Collin-Dufresn et al., 2001; Ericsson et al., 2009). To test for market efficiency, we distinguish between historic volatility and implied volatility. In liquid, well-functioning, markets we hence expect historic volatility to be not significant after controlling for implied volatility in the analysis. Vice versa, if historic volatility is significant in the regression this could be evidence for inefficient markets.

Total debt outstanding

We decide to include short-term debt outstanding plus long-term debt outstanding as a measure of leverage for the companies referenced by the single name CDS that we selected. Naturally, we expect high financial leverage to increase CDS spreads demanded by the market.

Time series characteristics

Over the period of 2012 to 2017 the observed spreads seem to be strongly trended, as can easily be observed from the below graph of iTraxx Europe CDS spreads. Unsurprisingly, we find that the timeseries data and the natural logarithm of the observations are integrated of order 1, i.e. they are I(1). We arrive at this conclusion as we fail to reject the null hypothesis of a unit root for both the trended and drift term version of the Augmented Dickey Fuller test.

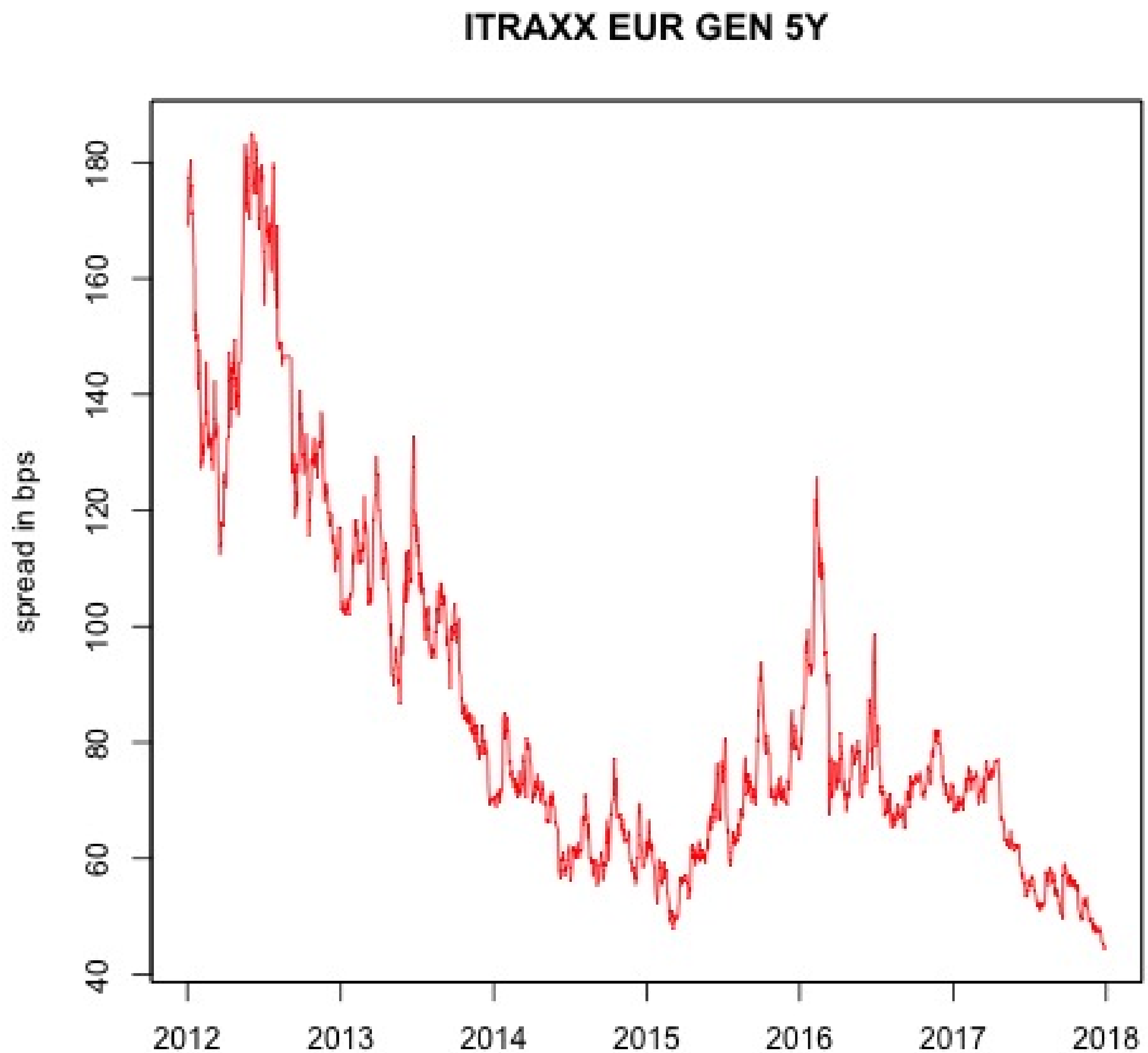


Figure: iTraxx Europe Spread levels (benchmark on-the-run 5Y mid-spread)

In fact, for any type of risky debt one would expect the credit spread to be trended, as remaining time to maturity affects the probability of survival until maturity and therefore is one of the key inputs to credit models. Ceteris paribus this term structure effect means that most of the time spreads decay as they approach the maturity date. This implies that the credit curve is concave and upward sloping, which tends to be the case for most companies, most of the time. Only distressed companies will have a credit curve that tends to be inverted, i.e. downward sloping with additional maturity. Other things equal, because of the rollover in indices and new maturity dates for single name CDSs, spreads in our sample would show a sawtooth pattern as time to maturity increases every 6 months by about 180 days. Therefore, to account for the term structure effect on CDS spreads, the number of days until maturity have been included to the regression.

We also find non-stationarity amongst the set of explanatory variables. Specifically, we find that the logarithm of the Eurostoxx 50 index, Euribor 5-year swap rates, the yield slope, inflation swap rates, historic volatility and the ECB effective exchange rate index have a stochastic trend and integrated of order 1. We hence have unit root non-stationarity in both dependent and independent variables, and therefore face the risk of estimating a spurious regression in levels if selected variables do not cointegrate.

Beside first differencing or other transformation methods to reduce time series to stationarity, a more interesting and more appropriate way to analyse trending variables is cointegration. Intuitively, following Greene, 2012, if two (or more) series are integrated of order one, denoted I(1), then a linear combination of them might be stable around a constant mean. This would imply that the series share a common trend and, as a result, are drifting together at approximately the same rate. In such a case one can distinguish between a long-run relationship between the variables, and the short-run dynamics. That is, respectively, the manner in which the variables drift together, and the relationship between deviations of the variables from their individual long-run trend. Intuition suggests that the linear combination of I(1) variables does not mysteriously create a well-behaved new variable. Rather, something present in the original variables must be missing from the aggregated one. Hence, the only way variables can be cointegrated is that they have at least one common trend of some sort. Given the starting time of our timeseries, common trends present in our data could include; the normalization in credit markets following the turbulences from the global financial crisis and debt crisis; the effect of quantitative easing in all major economies on global financial markets; continuously decreasing interest rates in developed countries; low inflation in the European Union; increasing risk tolerance of investors; the slow economic recovery of Europe. All trends could be reasonably expected to be present in the dependent and explanatory variables and could potentially be the cause of non-stationarity of CDS spreads in our sample period.

If cointegration between dependent and explanatory variables is possible, then differencing the data would be counterproductive since it would remove the slow moving, long-term, trends from the data available and thereby obscure the long-run relationship between the size of credit spreads and financial or economic variables. Besides better inference about long-term trends in the data, cointegration models have one more advantage in that estimators are super-consistent as they converge faster to their true value (Greene, 2012).

On the other hand, with long term trends removed from the data, a difference regression will give a cleaner picture of short-term dynamics in credit spread changes and taken together with the level analysis allow for an estimation of the significance of long term trends for the level of credit spreads.

HAC Standard Errors

In order to account for possible autocorrelation in the residuals of the estimates, we employ Newey-West heteroscedasticity- and autocorrelation-consistent standard errors. HAC standard errors are asymptotically normal distributed and are an appropriate estimator for the asymptotic covariance matrix (Greene, 2012). Our sample consists of daily data over a 5-year period and is therefore considered to be of significant size for the estimates to be consistent, also for results where serial autocorrelation is not present.

Multicollinearity

One of the main assumptions behind linear regressions is independence between the explanatory variables. Any violation of this assumption causes multicollinearity in the regression. Interpretation of empirical regressions becomes more difficult with increased multicollinearity since the underlying effects of the additional explanatory variables overlap, and hence the individual contribution of the independent variables to the fit of the model becomes vague. In addition, multicollinearity influences the significance of the regression coefficients such that inference might be diluted. On the other hand, regressions might suffer from omitted variable bias if variables that are important for the true data generating process of the dependent variable are omitted. Thus, there exists a trade-off for regression models between suffering from multicollinearity or omitted variable bias. This encourages us to check for signs of multicollinearity in our regressions in the correlation matrices of our explanatory variables (unreported). As a rule of thumb, it is acknowledged that multicollinearity becomes a severe problem for regressions if correlations between explanatory variables exceed 0,80 (Gujarati, 2004).

For the determinants of the changes in the spreads of the iTraxx Europe indices, multicollinearity tend not to be a severe problem. The only remarkable correlation observed for these variables is between the changes in implied equity volatility and the Eurostoxx 50 return, amounting to 0.79. Nevertheless, as the significance and estimated effect of both variables is preserved when added to the multivariate regression, this multicollinearity is interpreted as insignificant.

The correlation matrices for the levels regressions, on the other hand, tend to suffer from higher multicollinearity issues. High correlation is observed between the Euribor rate and the yield slope (0.86), the yield slope and the anticipated inflation (0.82), the Eurostoxx and the Euribor-OIS spread (-0.79), and the Euribor rate and anticipated inflation (0.76). The multicollinearities for the levels regressions makes it more difficult to interpret the results, as will become evident in the next section.

The Error Correction Model

The error correction model resulting of adding the lagged residuals from the log level regression to the first difference regression of the previous section is shown below. Before adding the lagged residuals we run the augmented dickey fuller regression and use values provided by Engle and Granger in their seminal paper on cointegration and error correction (Engle and Granger, 1987). The estimated model describes the short-term variation of credit spreads around their long-run trends during the 2012 to 2017 episode.

$$\Delta ln(s_t) = \beta_0 + \beta_1 \Delta X_t + \gamma_1 * u_{t-1} \tag{7.1}$$

Empirical model

Empirical model

We specify the empirical model used for our empirical analysis of the levels of Index CDS spreads as follows:

$$ln(s_t) = \beta_0 + \beta_1 * ln(SX5E_t) + \beta_2 * Vol_{60d} + \beta_3 * ln(EER_t) + \beta_4 * EURIBOR_{5Y} + \beta_5 * EUR - OIS_t \\ + \beta_6 * YLDslope_t + \beta_7 * Infl_t + \beta_8 * V2X_t + \beta_9 * Days2Mat_t$$

That is, we regress the natural logarithm of the observed CDS spreads on the natural logarithm of the Eurostoxx 50 index, historic 60 trading day volatility, the natural logarithm of the ECB published effective exchange rate, the Euribor 5Y swap rate, the Euribor-OIS spread, the Yield slope, inflation swap rates, the V2X implied volatility index on the Eurostoxx 50, remaining days to maturity and a constant.

$$ln(s_t) = \beta_0 + \beta_1 * BAS_t + \beta_2 * leverage_t + \beta_3 * Vol_{60d} + \beta_4 * ln(EER_t) + \beta_5 * EURIBOR_{5Y} \\ + \beta_6 * EUR - OIS_t + \beta_7 * YLDslope_t + \beta_8 * Infl_t + \beta_9 * V2X_t + \beta_10 * Days2Mat_t$$

The empirical model used for empirical analysis of the levels of single name CDS spreads and payments upfront on tranches of the iTraxx Crossover is similar to the above introduced model, but includes the difference between bid and ask price to control for lower liquidity in the respective CDS markets. The model is hence specified as follows:

$$ln(s_t) = \beta_0 + \beta_1 * BAS_t + \beta_2 * ln(SX5E_t) + \beta_3 * Vol_{60d} + \beta_4 * ln(EER_t) + \beta_5 * EURIBOR_{5Y}$$
$$+\beta_6 * EUR - OIS_t + \beta_7 * YLDslope_t + \beta_8 * Infl_t + \beta_9 * V2X_t + \beta_10 * Days2Mat_t$$

The empirical model used for our empirical analysis of the changes of Index CDS spreads follows:

$$\Delta ln(s_t) = \beta_0 + \beta_1 * \Delta ln(SX5E_t) + \beta_2 * \Delta ln(SX5E_{t-1}) + \beta_3 * \Delta Vol_{60d} + \beta_4 * \Delta ln(EER_t)$$
$$+\beta_5 * \Delta EURIBOR_{5Y} + \beta_6 * \Delta EUR - OIS_t$$
$$+\beta_7 * \Delta YLDslope_t + \beta_8 * \Delta Infl_t$$
$$+\beta_9 * \Delta V2X_t + \beta_{10} * \Delta roll_t + \beta_{11} * \hat{u}_{t-1}$$

That is, we regress the natural logarithm of the observed CDS spread changes on the natural logarithm of the same-day Eurostoxx 50 returns, the one-day lagged Eurostoxx 50 return, absolute changes in last 60 trading day volatility, percentage changes in the ECB published effective exchange rate, absolute changes in the Euribor 5Y swap rate, absolute changes in the Euribor-OIS spread, absolute changes in the Yield slope, absolute changes in the inflation swap rates, absolute changes in the V2X implied volatility index on the Eurostoxx 50, a dummy variable for the index roll date, an error correction term from the log level regression and a constant.

The empirical model used for empirical analysis of the changes of single name CDS spreads and payments upfront on tranches of the iTraxx Crossover is similar to the above introduced model, but includes the absolute changes in bid-ask spreads to control for changes in liquidity in the respective CDS markets. The error correction model for changes in single name CDSs is hence specified as follows:

$$\Delta ln(s_t) = \beta_0 + \beta_1 * \Delta BAS + \beta_2 * \Delta leverage_t + \beta_3 * \Delta ln(MktCap_{t-1}) + \beta_4 * \Delta Vol_{60d}$$
$$+\beta_5 * \Delta ln(EER_t) + \beta_6 * \Delta EURIBOR_{5Y} + \beta_7 * \Delta EUR - OIS_t + \beta_8 * \Delta YLDslope_t$$
$$+\beta_9 * \Delta Infl_t + \beta_{10} * \Delta V2X_t + \beta_{11} * \Delta roll_t + \beta_{12} * \hat{u}_{t-1}$$

We chose to transform the dependent variable using the natural logarithm, while keeping the reduced form model for determining credit spreads in mind. By taking the natural logarithm of the credit spread the right-hand side is transformed to a linear combination of the logarithm of the present value of protection minus the present value of premium payments including accrued premium payments.

$$ln(s_t) = ln(Protection_t) - ln(Premium_t) \tag{8.1}$$

Variation in the linear combination of log protection leg and log premium leg is hence a linear combination of variance and covariance of the two terms which we try to estimate with a linear regression model. Transforming CDS spreads with the natural logarithm, furthermore, provides us with interesting properties for the interpretation of the estimated coefficients and accommodates for the non-linear relationship of variables in the model.

By taking a pragmatic approach to transforming explanatory variables we end up with a set of explanatory variables that is mixed log level and level. Similarly, the set of explanatory variables for the difference regression consists of mixed log differenced and differenced variables based on the level explanatory dataset.

Empirical Results and Analysis

9.1 Regression results for the log levels

	ITRAXX EUR GEN									
										Robust SE
SX5E	-2.226^{***}									-1.815^{***}
60d std.dev		29.377^{***}								1.612
EER			-2.664^{***}							-2.696^{***}
EURIBOR5Y				0.438^{***}						-0.116^{*}
EURIBOR-OIS					1.720^{***}					-0.163
YLDslope						0.475^{***}				0.458^{***}
Infl							0.546^{***}			-0.011
V2X								0.029^{***}		0.010^{***}
Days2Mat									0.0003	0.0004^{*}
Constant	22.227^{***}	4.046^{***}	16.899^{***}	4.131^{***}	3.968^{***}	3.848^{***}	3.713^{***}	3.788^{***}	3.917^{***}	30.316^{***}
Observations	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504
Adjusted R^2	0.864	0.118	0.077	0.399	0.588	0.262	0.347	0.227	0.001	0.956

Note: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

The estimated parameters suggest that long-term changes in credit spreads are indeed driven by both financial and economic expectations. Particularly, using heteroskedasticity and autocorrelation (HAC) robust standard errors, the variables significant at the 5% level for explaining the long-term variation in the observed spreads are estimated to be the Eurostoxx 50 return, the effective exchange rate, the 5-year Euribor swap rate, the slope of the yield curve, implied equity volatility and the remaining days to maturity.

iTraxx Europe spreads inversely depend on the Eurostoxx 50 level. Specifically, if the Eurostoxx 50 index increases by 1%, the iTraxx Europe spread is predicted to decrease by 1.82%. It is striking that the sensitivity of credit spreads to changes in the equity value is larger than one. In Merton's simple structural credit risk model risky debt has a sensitivity to equity returns larger than one if the contingent claim's delta (sensitivity of equity to changes in the asset value) is less than 0.5. Merton's model allows for this if a company is highly levered. Hence, a possible explanation for this high sensitivity could be the size of leverage that European large caps are deploying. Indeed, adjusted for leases, the average market debt to equity ratio of a large set of European publicly listed companies, including financials, is reported as 88.9% by Aswath Damodaran from New York University's Stern school of Business (2018) for January 2018. Under the assumption that iTraxx Europe constituents sustain similar debt levels, leverage could be a plausible explanation for the size of the estimated coefficient and testimony for some degree of integration between equity and credit markets.

Effective exchange rate is negatively related to the CDS index spreads, where a 1% appreciation of the Euro is expected to decrease the iTraxx Europe spread by 2.4%. Under the assumption that foreign exchange rates are driven by economic fundamentals and interest rates over the long-term, an appreciation of the Euro would be a sign of investor confidence in the European economy and market expectations of growth in the real economy, which would make credit less risky as an asset class and therefore reduce CDS spreads.

Significant at the 5% level, the interest rate variable in our empirical model, given by the Euribor 5-year swap rate, is inversely related to iTraxx Europe CDS spreads. If the 5-year Euribor interest swap rate increases by 100 basis point, this is expected to decrease the level of the index CDS spreads by 11.6%. From a Merton model perspective CDS spreads decrease with rising risk-free rates as the underlying assets drift term increases and the asset is hence less likely to face default. However, from the univariate regression, the Euribor rate is estimated to have a positive effect on the spreads. Given that the slope of the yield curve and the Euribor rate have relatively high correlation, and that the estimated effect of the slope of the yield curve is persistent in both regressions, multicollinearity could mean that the true influence of the risk-free interest rate is in fact positive and to a large extent captured by the yield slope coefficient.

An increase of 100 basis points in the slope of the yield curve is predicted to increase the level of CDS spreads by 57.46%. This estimated effect differs from that predicted by credit risk models for investment grade debt, where the yield slope is inversely related to credit spreads. As the yield curve steepens expected future cash flows are discounted more. With upward sloping default risk curves, this means that the value of protection decreases proportionally more than a risky annuity payment over the same period. Hence, other things equal, the spread demanded by the market should decrease. Payments upfront, as they were introduced for CDSs in Europe with ISDA's small bang protocol, would not change this dynamic as they merely are the difference in net present value of fixed coupon payments and running spreads. One interpretation of the coefficient could therefore be that the level of credit default swap spreads is largely determined by supply and demand for CDS contracts. As traditional sellers of protection such as insurance companies, pension funds or banks are required by regulation to hold high quality and liquid assets, such as government bonds, they often position themselves at the long end of the maturity spectrum in order to reap a term premium Stark, 2014. As the term premium diminishes and asset-liability management (ALM) becomes challenging, banks, insurances and pension funds might be enticed to seek higher yield and take on additional, unfunded, exposure to credit risk by selling more CDS contracts. From a mathematical perspective, under the assumption of an increasing credit term structure the present value of protection would, ceteris paribus, be more sensitive to a steeper yield curve than the present value of the premium leg. An increase in the yield slope would hence decrease the present value of protection more and thereby lead to lower cost of protection.

The implied equity volatility and the iTraxx Europe spreads are positively related. In particular, if the level of the implied volatility increases by 100 basis points, the credit spread is expected to widen by 1%. This estimate confirms our former intuition about the effect of expected systemic equity volatility on credit spread levels.

One additional day to maturity increases the expected credit spread by 0.04% and, vice versa, every day less to maturity decreases the expected credit spread by 0.04%. This implies that, ceteris paribus, through the term structure effect between a time to maturity of 5.25 years at issuance of the latest on-the-run series and a time to maturity of 4.75 years, the credit spread decreases by 6.95%.

Interestingly, although the Euribor-OIS spread and the anticipated inflation does not have significant impact on the iTraxx Europe index spreads in our empirical model, they are predicted to explain large parts of the variations in these spreads when they are regressed in isolation. The main driver of the iTraxx spreads is the return on the Eurostoxx 50 index with highly significant coefficients in the univariate and the multivariate regressions, as well as an adjusted R^2 of 86.4%.

9.2 Regression Results for the log differences

In this section, we analyse the results from our regressions on the log differences of CDS spreads and explain the significant determinants of spread changes in the on-the-run iTraxx Europe CDS index with a maturity of 5 years over the sample period of 01.01.2012 - 31.12.2017. The regression results are presented in table below.

	ITRAXX EUR GEN 5Y												
										Robust SE		Robust SE	
SX5E r_t	-1.854^{***}										-1.509^{***}		-1.524^{***}
SX5E r_{t-1}		-0.018									-0.077		-0.081
60d std.dev			5.613^{*}								0.718		0.690
EER				0.455^{*}							-0.580^{**}		-0.638^{***}
EURIBOR5Y					-12.830^{***}						8.295^{**}		7.852^{**}
EURIBOR-OIS						6.433					12.114		9.837
YLDslope							-26.295^{***}				-5.740^{*}		-4.779
Infl								-41.275^{***}			-7.978^{**}		-7.591^{**}
V2X									1.352^{***}		0.324^{***}		0.328^{***}
roll										7.546^{***}	7.858^{***}		7.825^{***}
ECM												2.452	3.567^{***}
Constant	-0.024	-0.064	-0.062	-0.066	-0.075	-0.061	-0.074	-0.078	-0.056	-0.119	-0.075	-0.064	-0.075
Observations	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503
Adjusted R^2	0.560	-0.001	0.003	0.002	0.013	-0.0004	0.073	0.093	0.426	0.049	0.631	0.002	0.637

Note: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

As expected, stock returns and implied equity volatility are highly significant. In fact, these two variables explain most of the variation in CDS spread changes of the benchmark index, indicated by the high R^2 of the univariate regressions (56% and 43%, respectively). Furthermore, we also find statistically significant explanatory power from changes in the Euribor rate and our proxies for macroeconomic expectations such as growth or inflation.

One interesting finding is the effect of the change in interest rate. Running a univariate regression with the change in the Euribor rate as the only explanatory variable yields a highly significant negative coefficient. This is in line with theoretical arguments. However, the sign of the estimated variable in the full multivariate regression contradicts both our prediction and results from previous studies, such as that of Collin-Dufresn et al., 2001, Breitenfellner and Wagner, 2012 among others. Typically, one would expect that an increase in the interest rate would lower the risk neutral probability of default and hence the CDS spread, as in the case of the univariate regression. The observed positive sign could be explained by the fact that higher interest rates increases the cost of borrowing for borrowers of floating rate debt as well as the cost of replacing maturing debt with newly issued debt. In that way positive changes in the Euribor swap rate increase the chance of the bond issuer to default on his obligations, leading to wider CDS spreads. Furthermore, investors that sell insurances typically have positions in other fixed income securities such as treasuries. When the interest rate rises, investors get a higher risk-exposure on their long positions, making them reluctant to take on extra risk in their short (CDS) positions and, as a result, they demand higher CDS premia. One different interpretation of the change in sign after adding other explanatory variables to the regression might be explained by the effect of the changes in anticipated inflation. The change in inflation swap rates has a negative impact on the change of CDS spreads, as predicted. As inflation is also included in the nominal interest rate, changes in the Euribor rate could mostly represent the changes in the real interest rate when changes in inflation is added to the regression. With a negative influence significant on a 1% level, the inflation coefficient can be interpreted as we explained in the data description, namely that regardless of the interest rate, an increase in inflation has positive effects on revenues and cash flows such that the probability of default decreases. Hence, the effect of the changes in the Euribor rate seems to be twofold in terms of our interpretation. A positive shift in the variable increases the change in CDS spreads when the shift is caused by changes in the real interest rate, while it decreases the change in CDS spreads when the shift roots back to the changes in inflation.

Changes in the slope of the yield curve have a statistically significant influence on changes in CDS spreads. Increased steepness of the term structure could indicate an improved economic environment in the future which improves recovery rates Varma, Cantor, and Hamilton, 2004, but also be an indication of an economy with monetary tightening of credit Zhang et al., 2009. The estimated coefficient in our regression is negative, implying stronger evidence of the former argument. However, when we add the ECM factor, the estimated coefficient of the changes in the slope of the yield curve does no longer have significant impact on the CDS spread changes. This is the only variable affected by the correction model to the extent that the significance level of the coefficient is reduced.

The reason for including a lagged variable of the stock return is based on the findings in previous studies. Norden and Weber, 2009 present findings that stock markets react quicker than CDS markets due to stock markets pronounced liquidity. In contrast, our regression results show highly significant influence for the immediate stock return, but not for the lagged variable. In fact, the lagged stock return does not tend to contribute in explaining the variation in the CDS spread changes at all, which is seen in the negative R^2 of the univariate regression. This suggests that the stock market does not benefit from a reaction advantage relative to the CDS market, and this can be explained by the increased liquidity of the CDS indices. As expected, the regression coefficient of the logarithmic stock return is negative, in line with theoretical reasoning. When the Eurostoxx 50 is rising, it indicates an enhanced overall state of the economy and equity performance of the constituents. Hence, the likelihood of a company defaulting on its debt claims tightens, causing the CDS spread to narrow. The high significance of the variable, and the fact that the stock return is estimated to explain 56% of the variation in the spreads, lead us to perceive the equity and the credit market as highly integrated.

The changes in the effective exchange rate is significant and inversely related to changes in CDS spreads. According to our empirical model, after including the error correction term, a 100 basis points increase in the effective exchange rate basket (as a proxy for a 100 basis points appreciation of the Euro) reduces the credit spread by 0.64%. Controlling for interest rate and expected inflation, we interpret this finding as evidence for our initial hypothesis that exchange rate movements, as a proxy for growth expectations and foreign investor sentiment about investing in Europe, can be used to explain credit spread changes. Given the variable's significance at the 0.1% level, we see this as evidence for the intuition that anticipation of economic growth reduces credit spreads. The significance level of the coefficient and its point estimate increases when we include the ECM factor in the regression. This might indicate that the EER has a significant effects on the CDS spreads in the long term, as the ECM adjust the model to account for the long-term effects from the levels regression.

Changes in the implied equity volatility represents uncertainty in the market, since it indicates movements in the equity values. Increased volatility leads to higher probability of default, and as a result, the CDS spread increases. This positive relationship is confirmed in our regression results. While the regression coefficient is significant, its magnitude is small, indicating limited influence on the CDS spread changes.

The roll dummy is found to be highly significant, in addition to having the expected positive sign. Every time a new series is launched, the CDS spread increases significantly. This is explained by the term structure of the credit curves. The maturity of the newly launched series is six months longer, and since credit curves tend to be upward sloping for investment grade firms, the CDS spread naturally increases. In addition, the new composition of the newly launched series of constituents might include entities with higher spreads, as they are restricted by a liquidity requirement rather than spread width.

The change in the Euribor-OIS spread is not statistically significant, however, we find it intuitive to comment on the coefficient. The explanatory variable is the change in the difference between the Euribor and the OIS swap rate. This change in the difference is usually small, however explodes at time of perceived stress in the financial markets. Prior to the global financial crisis, this measure was not of big interest to investors or analytics since its magnitude was minuscule. As a measure for bank credit risk, the size of the spread increased rapidly during the crisis, as banks started to worry about default between each other. After the crisis, this measure has received increased attention from credit markets. An increase in the Euribor-OIS spread signals higher credit risk for the banks and thus exacerbates financial stability and increases in the probability of default. This widens the CDS spread. The change in the Euribor ? OIS spread could also be interpreted as a measure of funding risk in the real economy, and an increase in the variable typically indicates a credit crunch. Hence, the insignificance of the variable is not surprising, as the credit market has been in a period of normalization during our sample period.

The error correction term is highly significant. This indicates that long-term effects from the levels regression, that otherwise would have been lost as a result of taking first differences, have significantly been implemented in our regression results. Interpretation of the coefficient is that a one unit increase in the residuals of the log level regression increases credit spreads by 3.63%.

Our empirical model achieves a high adjusted R^2 of 63.1%, which provides a significantly higher predictability than previous research, such as that of Collin-Dufresn et al., 2001 and Ericsson et al., 2009. Including the lagged residual from the log levels regression given by the ECM factor, in order to correct for values that might be lost by taking first differences, improves the adjusted R^2 of our empirical model with additional 60 basis points. Hence, through our analysis, we are able to explain 63.7% of the variations in the changes of the iTraxx Europe index.

9.3 Results for the Subindices

We extend the analysis to assess the explanatory power of our selected independent variables on spread levels and changes of spread levels of the iTraxx Europe Subordinated Financials, the iTraxx Europe Senior Financials and the iTraxx Europe Crossover index, which reference a portfolio of CDS on subordinated and senior debt issued by European financial institutions and sub-investment grade rated debt issued by European non-financial companies. We do not include the Non-financials and HiVol indices as IHS Markit does not issue new series of the respective indices anymore.

The regression analysis of the different sub-indices yields, up to a certain extent, similar results as for the benchmark iTraxx Europe index. This correspondence is particularly pronounced for the Crossover index. Eurostoxx 50 returns as well as the implied volatility are empirically proven to be the main common drivers of the spread changes for all indices. In univariate regressions changes in stock returns alone explain 51%-52% of the variations in spread changes for the Crossover and the Senior Financials indices and 41% of variation of changes in the Subordinated Financials index. The corresponding adjusted R^2 for single variable regression of the indices on implied volatility is 38%-39% and 30%. Changes in inflation are significant for all indices, with a distinct effect for the Crossover index. The Euro effective exchange rate is again significantly related to CDS spread changes, however differs in significance for the financials indices being most significant for the Senior Financial index. Unsurprisingly, as in the benchmark case, the roll date effect is highly significant for the three sub-indices considered in this analysis.

In the following we want to briefly discuss differences between the indices level and difference regressions as well as to point out interesting results and possible interpretations of the estimated coefficients.

iTraxx Crossover

	ITRAXX XOVER GEN 5Y									
										Robust SE
SX5E	-2.019^{***}									-1.697^{***}
60d std.dev		33.971^{***}								2.536
EER			-3.134^{***}							-2.257^{***}
EURIBOR5Y				0.364^{***}						0.041
EURIBOR-OIS					1.604^{***}					-0.186
YLDslope						0.320^{***}				0.085
Infl							0.428^{***}			0.042
V2X								0.030^{***}		0.008^{***}
Days2Mat									0.0003^{*}	0.0004^{*}
Constant	22.019^{***}	5.445^{***}	20.558^{***}	5.623^{***}	5.447^{***}	5.470^{***}	5.307^{***}	5.206^{***}	5.210^{***}	29.042^{***}
Observations	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504
Adjusted R^2	0.862	0.192	0.130	0.332	0.621	0.144	0.258	0.308	0.003	0.952
Note:										*p<0.05; **p<0.01; ***p<0.001

In the log level regression, the log Eurostoxx 50 index, the logarithm of ECB's effective exchange rate, implied volatility and remaining days to maturity are estimated as significant at the 5% using heteroskedasticity and autocorrelation consistent standard errors. In comparison with the iTraxx Europe index it is surprising that the crossover index is less sensitive to changes in equity valuations as measured by the Eurostoxx 50 index as well as changes in the implied volatility index based on options on the Eurostoxx 50. An explanation for this could be that companies with high yield debt outstanding are not constituents of the Eurostoxx 50 and have less correlation with market returns as they often face highly idiosyncratic risks. Following this argument through, also their true anticipated volatility would consist relatively less of systematic equity volatility as measured by the V2X index but more of their company specific anticipated volatility. Hence also volatility transmission between iTraxx Crossover constituents and Eurostoxx 50 members would be low. Furthermore, the coefficient size suggests the iTraxx Crossover's dependence on long-term exchange rates is less than for the investment grade index. Finally, comparing the term structure coefficient of iTraxx Europe and iTraxx Crossover, it is interesting that both coefficients are estimated to be of the same size. This could be evidence that at the 5-year maturity level the sensitivity to added maturity for investment grade and non-investment grade debt is similar.

	ITRAXX Xover GEN 5Y												
										Robust SE		Robust SE	
SX5E r_t	-1.730^{***}										-1.400^{***}		-1.418^{***}
SX5E r_{t-1}		-0.035									-0.074		-0.081
60d std.dev			6.975^{**}								2.213		2.172
EER				0.577^{**}							-0.394^{*}		-0.444^{*}
EURIBOR5Y					-11.837^{***}						8.174^{**}		7.841^{**}
EURIBOR-OIS						10.294					16.332^{**}		14.619^{*}
YLDslope							-24.297^{***}				-4.875^{*}		-4.330^{*}
Infl								-42.189^{***}			-11.499^{***}		-10.803^{***}
V2X									1.255^{***}		0.282^{***}		0.285^{***}
roll										6.787^{***}	7.099^{**}		7.165^{**}
ECM												2.174	3.969^{***}
Constant	-0.023	-0.060	-0.058	-0.062	-0.071	-0.056	-0.070	-0.075	-0.053	-0.110	-0.068	-0.060	-0.068
Observations	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503
Adjusted R^2	0.513	-0.0005	0.005	0.004	0.011	0.00004	0.065	0.102	0.386	0.041	0.576	0.002	0.583

Note: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

In addition to the coefficients that are significant for influencing changes in the benchmark index, spread changes in the Crossover index seem to be more sensitive to factors of the term structure. Changes in the Euribor-OIS spread and in the slope of the yield curve have significant positive and negative impacts on changes in the Crossover index spreads, respectively. From an economic perspective, constituents of the crossover index are often more reliant on the availability of funding, which is why it makes sense that signs of bad health in financial markets increases CDS spreads. Similarly, from an economic perspective, a steep yield curve could be interpreted as a sign for increased growth expectations, which would benefit average debt fundamentals and thus decrease CDS spreads. From a technical point of view the negative sensitivity of the iTraxx Crossover index could hint at an aggregate hazard rate that is increasing with maturity. Given an aggregate hazard rate that is increasing with maturity, the sensitivity of the protection leg to changes in the long-term interest rate would be larger than the corresponding sensitivity of the premium leg. A change in the yield slope would hence, other things equal, lead to larger change in value of the protection leg than the premium leg and hence to a decrease in CDS spread.

iTraxx Senior Financials (Snrfin)

	ITRAXX SNRFIN GEN 5Y									
										Robust SE
SX5E	-3.144^{***}									-2.789^{***}
60d std.dev		37.949^{***}								-3.355
EER			-3.950^{***}							-4.378^{***}
EURIBOR5Y				0.627^{***}						-0.052
EURIBOR-OIS					2.439^{***}					-0.257
YLDslope						0.664^{***}				0.460^{**}
Infl							0.798^{***}			-0.039
V2X								0.037^{***}		0.005
Days2Mat									0.0004	0.0005^{*}
Constant	29.790^{***}	4.147^{***}	23.140^{***}	4.223^{***}	3.995^{***}	3.835^{***}	3.604^{***}	3.823^{***}	3.806^{***}	46.165^{***}
Observations	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504
Adjusted R^2	0.855	0.098	0.085	0.404	0.586	0.254	0.368	0.183	0.002	0.937

Note: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

In the log level regression of the iTraxx Senior Financials (Snrfin) index on the selected set of explanatory variables we find a significant (at the 5% level) relationship between Snrfin and equity valuations as measured by the log of the Eurostoxx 50 index, the Euro effective exchange rate as measured by the log of the ECB statistic, the yield slope and remaining days to maturity. In comparison with the iTraxx Europe index it is noteworthy that implied volatility and the Euribor 5-year swap rate are not significant for explaining variation in the index levels.

	ITRAXX SNRFIN GEN 5Y												
										Robust SE		Robust SE	
SX5E r_t	-2.115^{***}										-1.805^{***}		-1.824^{***}
SX5E r_{t-1}		-0.084									-0.162^{**}		-0.167^{**}
60d std.dev			6.391^{*}								0.716		0.674
EER				0.465							-0.686^{**}		-0.740^{***}
EURIBOR5Y					-18.944^{***}						6.908		6.911
EURIBOR-OIS						17.764					21.062		19.958
YLDslope							-32.943^{***}				-8.609^{**}		-8.231^{**}
Infl								-47.239^{***}			-7.631^{*}		-7.585^{*}
V2X									1.507^{***}		0.267^{*}		0.263^{*}
roll										8.262^{***}	8.594^{***}		8.548^{***}
ECM												1.091	2.052^{***}
Constant	-0.055	-0.100	-0.099	-0.103	-0.118	-0.094	-0.114	-0.117	-0.093	-0.162	-0.108	-0.101	-0.107
Observations	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503
Adjusted R^2	0.518	0.0002	0.002	0.001	0.020	0.001	0.081	0.087	0.376	0.042	0.579	0.001	0.583

Note: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

The regression results for changes in the Senior Financials index differs from the benchmark and the Crossover index by their estimated coefficients on the lagged Eurostoxx 50 returns and the change in the Euribor rate. First, the lagged stock return is predicted by the model to have highly significant influence on the credit spread changes. Intuitively, this could be evidence that the Eurostoxx 50 index leads the Snrfin index or, more simply, that the senior financials index is not that liquidly traded such that end of day prices do not reflect all information available on a specific day. Testament for this hypothesis could be seen in the low transaction volume of Snrfin indices [1] and comparatively high bid-ask spreads with the effect that inefficient pricing is not arbitraged away quick. In comparison with the level regression, it is noticeable that changes in the V2X index are significant, albeit with a small coefficient, for explaining short-term variation in Snrfin CDS spreads, while over the long-term the V2X index is deemed not significant. A possible explanation for this conundrum could be that financial institutions often act as intermediaries, take on low operating risk and hence remain relatively neutral to equity market volatility over the long term for which low unlevered betas are testament (see e.g. 2018). Senior debt for financial institutions may thus be expected to have low sensitivity to shifts in equity volatility over the long term, which we may not be able to distinguish from noise over the time period observed.

iTraxx Subordinated Financials (Subfin)

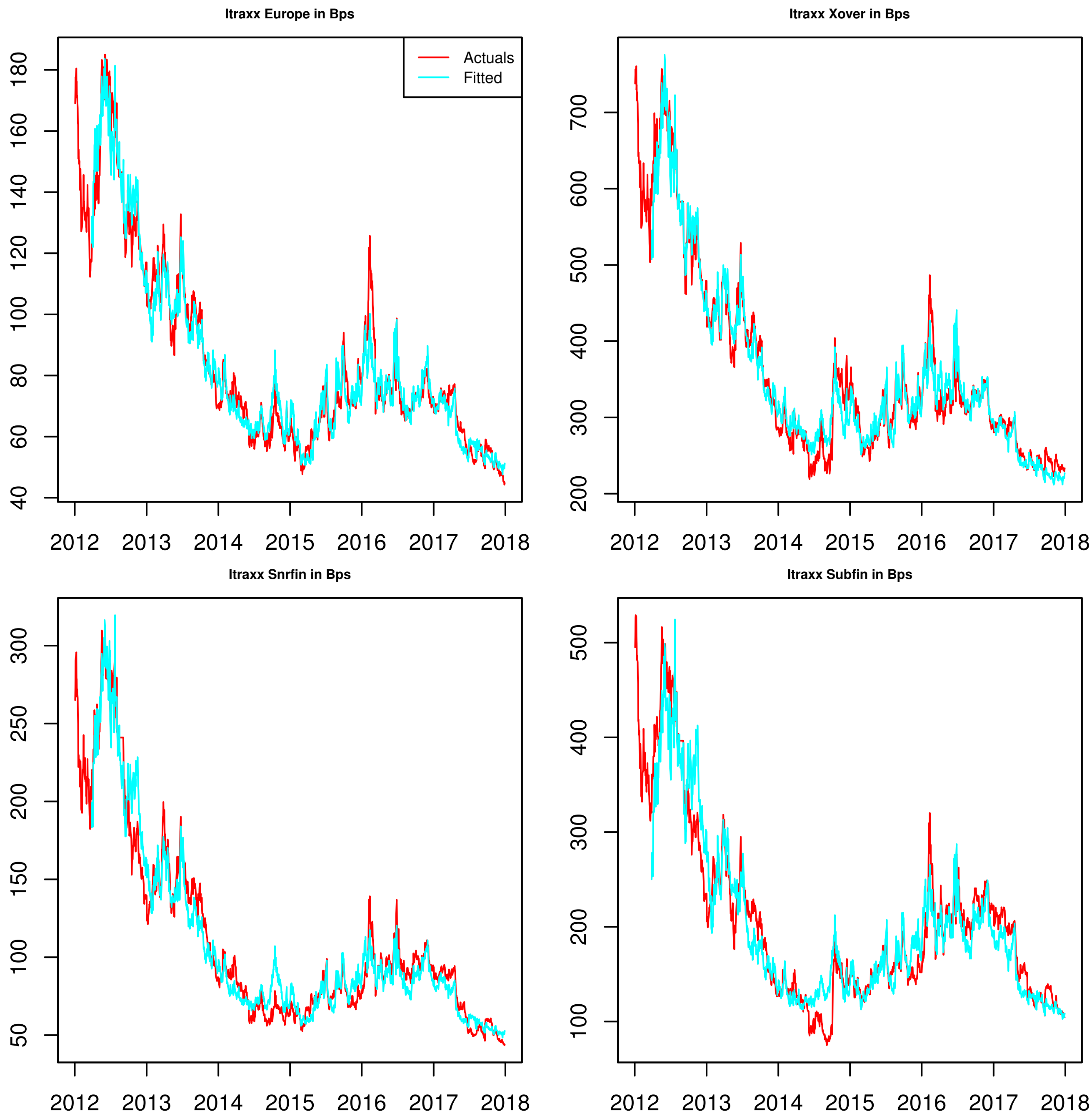
[1] See DTCC http://www.dtcc.com/repository-otc-data)

					ITRAXX SUBFIN GEN 5Y					
										Robust SE
SX5E	-2.439^{***}									-2.678^{***}
60d std.dev		40.904^{***}								-5.132
EER			-5.317^{***}							-4.860^{***}
EURIBOR5Y				0.289^{***}						-0.439^{***}
EURIBOR-OIS					1.789^{***}					-0.274
YLDslope						0.277^{***}				0.497^{**}
Infl							0.489^{***}			0.051
V2X								0.038^{***}		0.010^{*}
Days2Mat									0.001^{**}	0.001
Constant	24.780^{***}	4.757^{***}	30.213^{***}	5.054^{***}	4.792^{***}	4.907^{***}	4.621^{***}	4.447^{***}	4.164^{***}	47.959^{***}
Observations	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504
Adjusted R^2	0.673	0.149	0.201	0.112	0.413	0.057	0.180	0.253	0.005	0.869
Note:										$^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

In the log level regression of the iTraxx Subordinated Financials (Subfin) index on the selected set of explanatory variables we find a significant relationship between Subfin and equity valuations as measured by the log of the Eurostoxx 50 index, the Euro effective exchange rate as measured by the log of the ECB statistic, the Euribor 5-year swap rate, the yield slope and volatility implied by options on the Eurostoxx 50 index. In comparison with the iTraxx Europe index it is noteworthy that remaining time to maturity is not significant for explaining variation in the index levels. An explanation for this finding could be that the time effect on Subfin CDS spreads is small and not distinguishable from white noise over the observed period. The Euribor 5-year swap rate coefficient is smaller than the ITraxx Europe coefficient, providing testament to the interest rate risk bourn by financial institutions. Given the subordinate nature of the referenced debt claim, the Subfin's long-term sensitivity to changes in the Euribor 5-year swap rate should not come as a surprise.

							ITRAXX SUBFIN GEN 5Y						
										Robust SE		Robust SE	
SX5E r_t	-2.014^{***}										-1.678^{***}		-1.696^{***}
SX5E r_{t-1}		-0.162^{*}									-0.224^{***}		-0.233^{***}
60d std.dev			5.431								-0.355		-0.430
EER				0.503							-0.659^{**}		-0.706^{**}
EURIBOR5Y					-16.346^{***}						7.938		7.416
EURIBOR-OIS						19.444					24.435^{*}		22.613
YLDslope							-29.667^{***}				-6.334^{*}		-5.869^{*}
Infl								-49.430^{***}			-12.524^{*}		-12.455^{*}
V2X									1.448^{***}		0.290^{**}		0.291^{**}
roll										7.933^{***}	8.260^{***}		8.274^{***}
ECM												0.469	1.723^{**}
Constant	-0.031	-0.071	-0.073	-0.076	-0.089	-0.066	-0.086	-0.091	-0.066	-0.133	-0.079	-0.074	-0.079
Observations	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503
Adjusted R^2	0.410	0.002	0.001	0.001	0.013	0.001	0.057	0.083	0.303	0.033	0.464	-0.0003	0.468
Note:													$^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

The regression results for the Subordinated Financials index differs from the benchmark and the Crossover index by their estimated coefficients on the one-day lagged Eurostoxx 50 returns and the change in the Euribor rate. First, the lagged stock return is predicted by the model to have highly significant influence on CDS spread changes. Intuitively, this could indicate that the stock market leads the CDS market for subordinated debt from the financial sector, or that the Subfin index is not that liquidly traded which, such that information available at closing of the market is not fully priced in quoted spreads. Evidence for this hypothesis could be seen in the low notional value of Subfin indices traded (DTCC) and comparatively high bid-ask spreads with the effect that inefficient pricing is not arbitraged away quick. Second, the change in the Euribor spread is not affecting short-term spread changes of the sub-index on subordinated financial debt.



Overall, the results from the analysis of the sub-indices further underline the explanatory performance of our model, achieving an adjusted R^2 of 47% for changes in the Subordinated Financials index, and 58% for changes in the Senior Financials index and Crossover indices.

9.4 Single Name Results

We run similar regressions on four single-name constituents of the iTraxx Europe index to examine the determinants of single-name CDS spread levels and changes. The constituents are chosen randomly from the major sectors that constitutes the index, with the intention to interpret differences between the drivers of the CDS spread levels and changes of the different industries. For the single-name regressions, we also include the additional firm-specific variables presented in the data description.

AXA

	CDS AXA 5Y										
										Robust SE	
Bid-Ask spread	0.143^{***}										0.009^{*}
Leverage		7.214^{***}									5.868^{***}
60d std.dev			0.450^{***}								0.117^{*}
EER				-4.509^{***}							-3.429^{***}
EURIBOR5Y					0.974^{***}						0.181
EURIBOR-OIS						3.314^{***}					-0.739^{***}
YLDslope							1.014^{***}				0.396^{*}
Infl								1.169^{***}			-0.111
V2X									0.041^{***}		0.016^{***}
Days2Mat										0.0002	0.0002
Constant	3.684^{***}	2.757^{***}	3.644^{***}	25.610^{***}	3.870^{***}	3.628^{***}	3.286^{***}	2.995^{***}	3.579^{***}	4.019^{***}	17.984^{***}
Observations	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504
Adjusted R^2	0.339	0.894	0.185	0.064	0.565	0.626	0.343	0.456	0.131	-0.0003	0.952

Note: *p<0.05; **p<0.01; ***p<0.001

The log levels regression for AXA shows that seven out of the ten independent variables in our model have significant influence on the CDS spread. This yields the highest number of significant estimates in our sample of single names. Furthermore, we are able to explain 95% of the variation in the CDS spreads, given by the adjusted R^2. On the 5% level, these include the Bid-Ask spread, leverage, 60 days volatility, effective exchange rate, the Euribor-OIS spread, the yield slope and the implied equity volatility. Seen in isolation, in the univariate regressions, most of the variables are able to explain a large part of the variation in the spreads, where leverage alone explains 89%. The Euribor-OIS spread and the Euribor rate also have high explanatory power with adjusted R^2 of 62.6% and 56.5%, respectively. Interestingly, while the Euribor-OIS spread has a significantly positive effect on the CDS spreads in the univariate regression, as well as in the multivariate regressions for the other constituents, this spread is significantly inversely related to the CDS spread for AXA.

	AXA CDS 5Y													
												Robust SE		Robust SE
Bid-Ask	0.046											0.048		0.058
Leverage		473.590***										209.180***		211.989***
Equity r_{t-1}			−0.262***									−0.263***		−0.263***
60d std.dev				6.459***								1.780		1.943
EER					0.772**							0.065		0.048
EURIBOR5Y						−10.348**						11.368**		11.154**
EURIBOR-OIS							19.226					30.821*		27.735*
YLDslope								−23.718***				−8.312*		−7.586*
Infl									−41.983***			−11.871**		−11.798**
V2X										1.346***		0.988***		0.996***
roll											2.907***	3.298***		3.286***
ECM													1.792	2.330***
Constant	−0.129	−0.066	−0.117	−0.123	−0.132	−0.138	−0.120	−0.138	−0.143	−0.121	−0.173*	−0.116	−0.129	−0.116
Observations	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503
Adjusted R^2	0.0001	0.236	0.019	0.008	0.005	0.006	0.001	0.044	0.071	0.313	0.011	0.398	0.004	0.405

Note: *p<0.05; **p<0.01; ***p<0.001

Changes in the CDS spread of AXA are significantly driven by changes in leverage, lagged equity return (market cap changes), changes in the Euribor rate, changes in the Euribor-OIS spread, changes in the slope of the yield curve, changes in anticipated inflation, changes in implied equity volatility, and the Roll Dates. In the univariate regression results, it is evident that the changes in the implied equity volatility and the changes in leverage are the main variables to explain the variations in the changes of the CDS spreads. Corresponding to the log levels regression, our empirical model is able to explain the highest amount of the variations in the CDS spread changes for AXA relative to the other constituents, given by an adjusted R^2 of 40.5%. Intuitively, this can indicate that our estimated model is well fitted to explain the CDS spreads of financials.

BASF

	CDS BASF 5Y										
										Robust SE	
Bid-Ask spread	−0.015*										0.038**
Leverage		4.392***									3.585*
60d std.dev			0.335***								−0.007
EER				−1.357***							−0.676
EURIBOR5Y					0.386***						−0.144
EURIBOR-OIS						1.675***					0.997***
YLDslope							0.429***				0.453**
Infl								0.424***			0.211
V2X									0.027***		0.016***
Days2Mat										−0.00002	0.0001
Constant	3.805***	2.945***	3.300***	10.121***	3.527***	3.345***	3.264***	3.227***	3.199***	3.772***	4.627
Observations	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504
Adjusted R^2	0.002	0.060	0.125	0.021	0.335	0.605	0.233	0.227	0.211	-0.001	0.771

Note: *p<0.05; **p<0.01; ***p<0.001

For the log levels of BASF, we are only able to explain 77% of the variations in the CDS spreads ? the lowest of the constituents in levels. Bid-Ask spread, leverage, the Euribor-OIS spread, the yield slope and the implied equity volatility are all significant at the 5% level. Again, the Euribor-OIS spread is able to explain a substantial part of the variation in the CDS spreads, with and adjusted R^2 of 60.5% from the single regression.

								BASF CDS 5Y						
												Robust SE		Robust SE
Bid-Ask	−0.135											−0.159		−0.135
Leverage		234.242***										70.944		76.771
Equity r_{t-1}			−0.331***									−0.272		−0.283***
60d std.dev				3.060								−0.710		−0.454
EER					0.139							−0.429		−0.440
EURIBOR5Y						−2.329						9.006*		8.631
EURIBOR-OIS							13.288					21.024		21.583
YLDslope								−9.502***				−4.229		−3.773
Infl									−27.174***			−16.293***		−15.966***
V2X										0.604***		0.470***		0.476***
roll											2.491***	2.581**		2.548**
ECM													0.763	1.246**
Constant	−0.062	−0.060	−0.055	−0.061	−0.063	−0.064	−0.056	−0.066	−0.071	−0.058	−0.100	−0.081	−0.062	−0.080
Observations	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503
Adjusted R^2	0.001	0.039	0.023	0.0002	-0.0004	-0.0002	0.0005	0.009	0.041	0.086	0.011	0.135	0.001	0.138
Note:														*p<0.05; **p<0.01; ***p<0.001

According to our empirical model, the changes in the CDS spreads for BASF are driven by the changes in the Euribor rate, changes in anticipated inflation, the changes in implied equity volatility and the Roll Dates. However, when including the ECM, the changes in the Euribor rate are no longer significant, while the inverse relation between the lagged equity return and the changes in the CDS spreads become significant at the 0.1% level. Unfortunately, our model is only able to explain 13.8% of the variations in the changes of the CDS spreads, which is more in line with previous results, such as those of Collin-Dufresn et al., 2001 and Ericsson et al., 2009.

EDF

							CDS EDF 5Y				
										Robust SE	
Bid-Ask spread	0.070***										0.009
Leverage		1.907***									3.185***
60d std.dev			0.124***								−0.019
EER				−3.702***							−0.943
EURIBOR5Y					0.144***						0.378**
EURIBOR-OIS						1.247***					0.700***
YLDslope							0.166***				0.047
Infl								0.295***			−0.122
V2X									0.028***		0.009*
Days2Mat										0.0003	0.0004
Constant	3.985***	3.092***	4.074***	21.720***	4.233***	4.019***	4.130***	3.956***	3.734***	3.809***	5.522
Observations	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504
Adjusted R^2	0.089	0.284	0.085	0.165	0.047	0.339	0.034	0.110	0.244	0.002	0.875
Note:											*p<0.05; **p<0.01; ***p<0.001

For the log levels of the CDS spread in the case of EDF, significant variables on the 5% level is given by leverage, the Euribor rate, the Euribor-OIS spread and the implied equity volatility. Although the significant variables are few in numbers, they are able to explain as much as 87.5% of the variations in the levels of the CDS spread. Once again, the Euribor-OIS spread yields the highest adjusted R^2 in the univariate regression, explaining 34% of the variations. In contrast to the other single names, Bid-Ask spread does not have a significant effect on the CDS spreads, implying that EDF is less sensitive to trading-liquidity.

	EDF CDS 5Y													
											Robust SE		Robust SE
Bid-Ask	−0.024											−0.019		−0.014
Leverage		151.346***										73.194***		74.819***
Equity r_{t-1}			−0.152***									−0.141***		−0.143***
60d std.dev				1.347								0.879		0.788
EER					0.088							−0.355		−0.345
EURIBOR5Y						−5.445*						9.282*		9.358*
EURIBOR-OIS							26.506**					32.090*		32.025*
YLDslope								−12.429***				−6.390*		−6.120*
Infl									−27.538***			−14.214***		−13.944***
V2X										0.719***		0.564***		0.571***
roll											3.049***	3.306***		3.343***
ECM													0.553	1.321*
Constant	−0.038	−0.045	−0.039	−0.039	−0.038	−0.043	−0.026	−0.043	−0.047	−0.034	−0.085	−0.074	−0.038	−0.074
Observations	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503
Adjusted R^2	-0.001	0.083	0.016	0.001	-0.001	0.003	0.006	0.022	0.058	0.169	0.023	0.253	-0.0001	0.256
Note:														*p<0.05; **p<0.01; ***p<0.001

For the changes in the CDS spreads of EDF, changes in leverage, lagged equity return, changes in the Euribor rate, changes in the Euribor-OIS spread, the changes in the slope of the yield curve, changes in anticipated inflation, changes in implied equity volatility, and the Roll Dates, are significant at the 5% level. Implied volatility is estimated with the highest adjusted R^2 in the univariate regressions, indicating its prominent role in explaining the variations of the CDS spread changes. After including the ECM variables, we are able to explain 25.6% of the variation in the changes of the CDS spreads.

Telenor

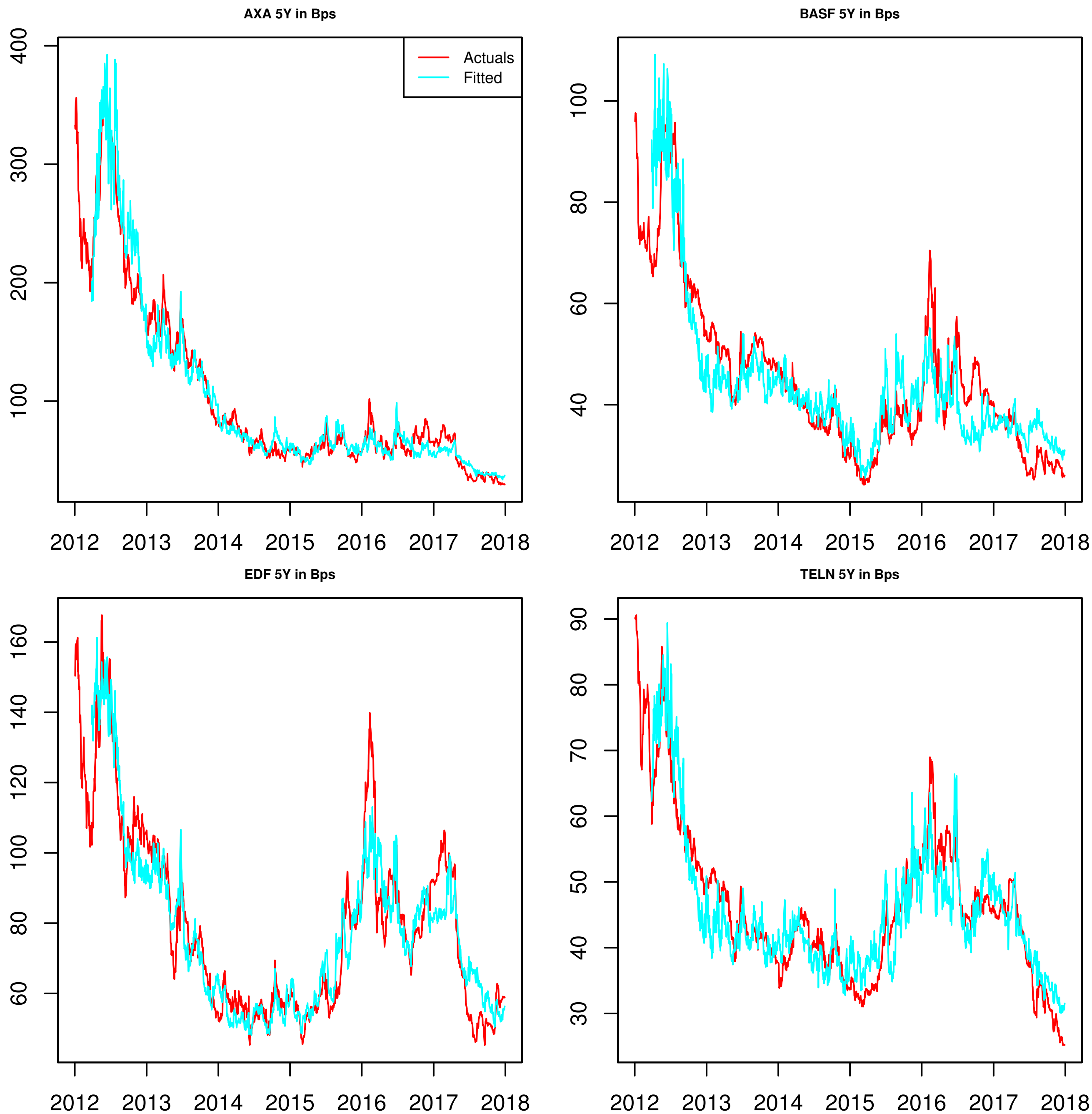
	CDS TELN 5Y										
										Robust SE	
Bid-Ask spread	0.046***										0.037**
Leverage		0.563***									2.520***
60d std.dev			0.262***								0.047
EER				−2.516***							−0.814
EURIBOR5Y					0.111***						−0.022
EURIBOR-OIS						1.049***					0.697***
YLDslope							0.096***				0.211
Infl								0.129***			0.139
V2X									0.025***		0.018***
Days2Mat										0.0003**	0.001*
Constant	3.582***	3.661***	3.448***	15.619***	3.731***	3.545***	3.686***	3.637***	3.276***	3.181***	4.915
Observations	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504	1,504
Adjusted R^2	0.070	0.007	0.125	0.141	0.052	0.444	0.021	0.038	0.358	0.006	0.800
Note:											*p<0.05; **p<0.01; ***p<0.001

In the log levels regression for Telenor the Bid-Ask spread, leverage, the Euribor-OIS spread, implied equity volatility and the remaining days to maturity, have significant influence on the CDS spreads. Adjusted R^2 of the multivariate regression indicates that our model is able to explain 80% of the variations in the spreads. Corresponding to the rest of the single names, the Euribor-OIS spread achieves the highest R^2 of the univariate regressions, followed by the implied equity volatility. In contrast to the rest of the single name sample, the coefficient for the remaining days to maturity is significant. However, the point estimate is small, indicating that this outlier effect might not be of great importance.

	TELN CDS 5Y													
												Robust SE		Robust SE
Bid-Ask	0.249***											0.276**		0.295**
Leverage		98.812***										44.606*		46.420*
Equity r_{t-1}			−0.203***									−0.194***		−0.197***
60d std.dev				1.137								0.289		0.259
EER					0.425**							0.031		0.019
EURIBOR5Y						0.824						7.365*		7.174*
EURIBOR-OIS							−1.650					5.261		5.231
YLDslope								−6.249***				−2.932		−2.605
Infl									−19.544***			−11.072***		−10.575***
V2X										0.506***		0.447***		0.457***
roll											2.586***	2.734***		2.744***
ECM													0.158	1.066*
Constant	−0.060	−0.066	−0.054	−0.060	−0.062	−0.059	−0.061	−0.063	−0.067	−0.057	−0.100	−0.092*	−0.060	−0.092*
Observations	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503	1,503
Adjusted R^2	0.007	0.022	0.016	-0.0002	0.004	-0.001	-0.001	0.007	0.039	0.112	0.022	0.179	-0.001	0.181

Note: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Changes in the CDS spreads of Telenor are, according to our empirical model, significantly driven by the changes in the Bid-Ask spread, changes in leverage, the lagged equity return, changes in the Euribor rate, changes in anticipated inflation, changes in implied equity volatility, and the effects of the Rolls Dates. When including the ECM factor, our model achieves an adjusted R^2 of 18.1%. This is mostly driven by the changes in the implied equity volatility, according to the univariate regressions. In contrast to the other constituents, changes in the CDS spreads of Telenor are highly significantly affected by changes in the Bid-Ask spreads.



Leverage changes are significant for three out of the four single-names included in the analysis, while the coefficient for leverage in the levels regressions prove significant for all. The leverage of a company has previously been theoretically and empirically proved to affect its credit risk and hence the CDS spread (Collin-Dufresn et al., 2001 ; Ericsson et al., 2009). Essentially, the higher the leverage, the smaller the debt increase before the company defaults on its debt obligations. Hence, a positive correlation between the leverage factors and the CDS spreads was expected, and further confirmed by our results. However, the point estimates and significance levels of the coefficients vary a lot between the entities. As mentioned under data description, we have chosen to use the total debt outstanding over the sum of total debt outstanding and market capitalization as a proxy for leverage. Looking at the univariate regressions for both levels and changes, also these estimated coefficients are highly significant for all firms, increasing the viability of our results and further supports our interpretations.

Market capitalization is used as a proxy for the equity value of the entities. According to our empirical model, the lagged equity return proves highly significant for all four single-names and inversely related to the CDS spread changes, as expected. The strong effect of this factor might go beyond explaining only the change in equity value. Compared to the equity value of a firm, its market capitalization is almost always higher, and changes on a daily basis. This is because the variable also reflects perception of the investors, who take into account additional factors such as sales, earning and market trends. As a result, the effect of this variable might be interpreted, in addition to changes in equity value, as implied market view of the company and its performance.

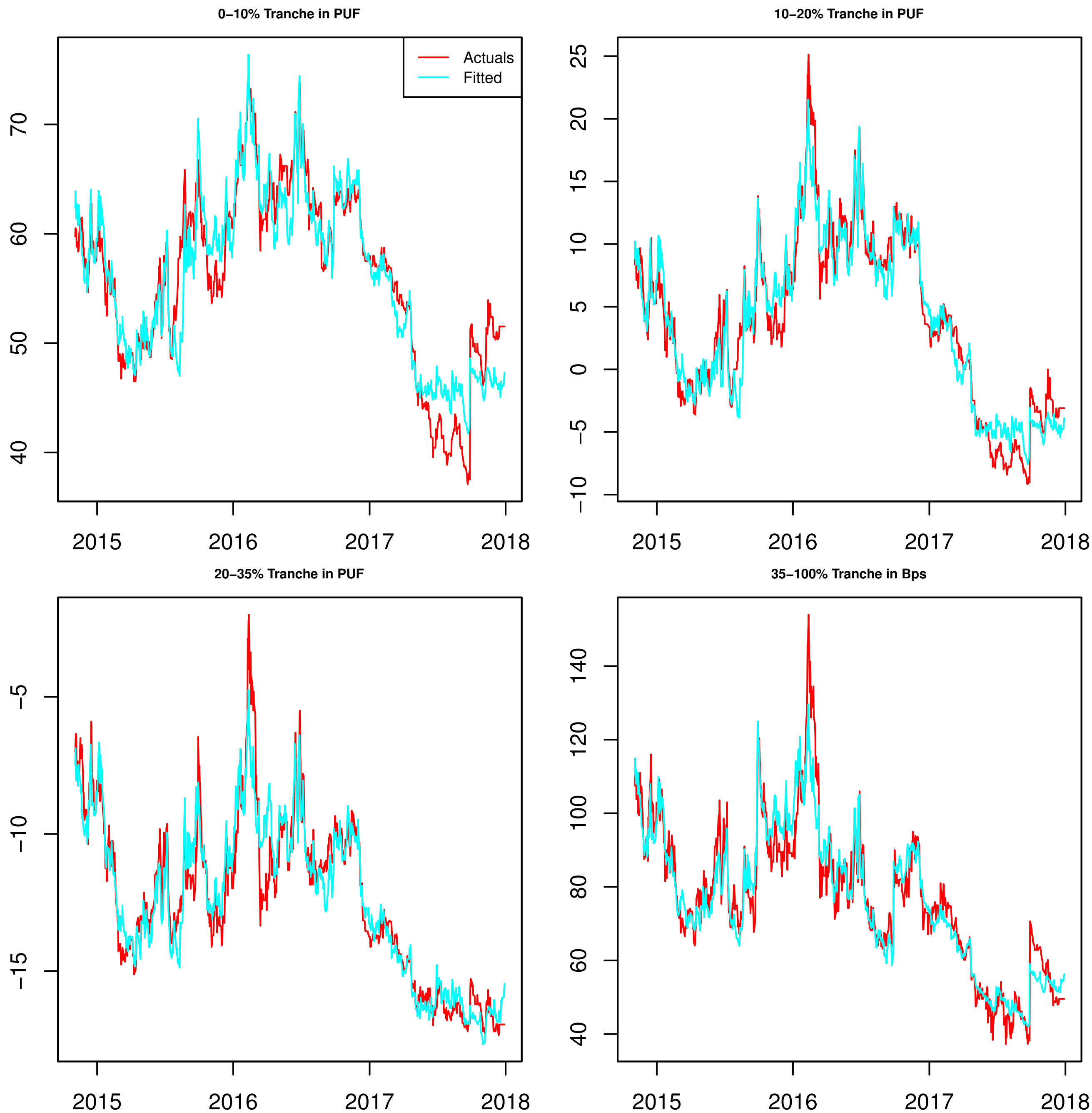
Changes in the Bid-Ask spreads for the single names do not tend to have a significant effect on the changes in the single name CDS spreads. As a measure of liquidity, this result is not surprising, since the constituents of the iTraxx Europe index are the most liquid CDS single names in the market. Despite this, the changes in Bid-Ask spread is significant at 1% level for the changes in CDS spreads for Telenor. This result could indicate that Telenor is more sensitive to changes in liquidity. However, with the argument against liquidity issues of the constituents, this result is likely to be based on other explanations.

Corresponding to the case of the iTraxx Europe index difference regression, the coefficients for the changes in the Euribor rate, the inflation swap changes and the implied equity volatility changes are all significant, with the same signs. From the discussions above this gives intuitive meaning, since all these variables are related to the economic environment and the expectations of it, which should influence individual companies to the same (relative) extent as the aggregated CDS market. Furthermore, the effect of the Roll Dates has the same, highly significant influence on all the single name CDS spread changes as for the iTraxx Europe index spread changes, with the corresponding interpretation. One interesting observation in these difference regressions is the similarities between AXA and EDF. The CDS spread changes of the two constituents are almost equally significantly driven by the same factors, although the determinants in our model is able to explain a relatively higher amount of the variation in the spread changes for AXA.

Throughout the analysis for the single names, we identify varying predictability of the models in terms of adjusted R^2. This indicate that determinants for both levels and changes of CDS spreads tend to be sector specific. Although the explanatory power of the different variables does not change much between the analysed constituents, representing different sectors, the overall explanatory ability of the model to identify variations in the levels and changes of the spreads vary between sectors (based on R^2). Our regression results indicate that our empirical model predicts the levels and changes in CDS spreads well for the financial sector and relatively well for the energy sector, while the model has reduced explanatory power for the TMT and the industrials sectors. Furthermore, changes in implied volatility, changes in anticipated inflation and changes in leverage tend to be the major drivers of the changes in single name CDS spreads, while for the levels the main driver of the spreads is the Euribor-OIS spread.

9.5 iTraxx Europe Crossover Tranches

For a period between November 2014 and December 2017 we furthermore observe market prices for tranches on the iTraxx Crossover index. From the observed data we construct a generic index that is rolled over yearly in September, thereby maintaining a relatively constant maturity of between 5.25 and 4.25 years. We regress each of the four tranches in log levels and log difference on the familiar two sets of explanatory variables plus an error correction term. By comparing the coefficients for the different tranches, we hope to be able to give further inference on the explanatory power of our economic and financial variables for different parts of the portfolio risk. Further, we compare the estimated coefficients with the coefficients from the iTraxx Crossover model estimated over the same sub-period. We furthermore include bid-ask spreads to the regressions as a measure to control for market liquidity and changes in market liquidity. In the observed prices there is some evidence for low trading volume as for each tranche more than 10% of the sample period prices have been stale when compared to previous trading day prices.



The amount of the variation our model is able to explain in the tranche spreads are lowest for the senior (35-100%) and equity (0-10%) tranches, with R^2 of 22% and 26.5% after including the error correction term, respectively.

iTraxx Crossover during the subperiod

	ScdoXover GEN 5Y									
										Robust SE
SX5E	−1.535***									−1.589***
60d std.dev		22.466***								−3.956*
EER			−1.031***							−1.296***
EURIBOR5Y				−0.164***						0.182**
EURIBOR-OIS					1.997***					0.365
YLDslope						−0.283***				0.123**
Infl							−0.501***			−0.111*
V2X								0.020***		0.004*
Days2Mat									−0.0002	0.0001
Constant	18.127***	5.437***	10.536***	5.728***	5.369***	5.941***	6.194***	5.273***	6.050***	24.282***
Observations	825	825	825	825	825	825	825	825	825	825
Adjusted R^2	0.667	0.447	0.046	0.034	0.541	0.179	0.577	0.639	0.003	0.913
Note:										*p<0.05; **p<0.01; ***p<0.001

Over the observed period the regression model for the iTraxx Crossover reference index has slightly different coefficients than for the full sample period. Most strikingly, inflation, yield slope, historic equity market volatility and the 5 year Euribor swap rate are significant at the 5% level in the sub sample, while remaining days to maturity are only significant at the 10% level. The sign of the estimated coefficients remains the same, though.

	ScdoXover GEN 5Y												
											Robust SE		Robust SE
SX5E r_t	−1.696***										−1.458***		−1.492***
SX5E r_{t-1}		−0.094									−0.088		−0.094
60d std.dev			9.051***								2.563		2.090
EER				1.268***							−0.351		−0.398*
EURIBOR5Y					−13.792**						8.156		8.807*
EURIBOR-OIS						31.365					26.439		27.355
YLDslope							−18.780***				−3.634		−3.265
Infl								−42.826***			−9.966***		−8.885**
V2X									1.174***		0.187*		0.182*
roll										2.956**	3.366		3.444
ECM												4.143*	6.400***
Constant	−0.026	−0.051	−0.045	−0.059	−0.055	−0.047	−0.049	−0.030	−0.041	−0.074	−0.035	−0.052	−0.036
Observations	824	824	824	824	824	824	824	824	824	824	824	824	824
Adjusted R^2	0.613	0.001	0.012	0.032	0.011	0.003	0.047	0.133	0.451	0.008	0.638	0.003	0.649
Note:													*p<0.05; **p<0.01; ***p<0.001

Over the subperiod, again, the log of the Eurostoxx 50 index seems to contribute most to explaining variations in credit spreads, as the single variable regression R^2 is high. Second, the implied volatility index on the Eurostoxx index explains 63.9% of the variation in a single variable regression. Moreover, inflation, the Euribor-OIS spread, historic volatility and the yield slope all explain sizeable parts of the variation of iTraxx Crossover spreads in a single variable regression.

Similarly, the subperiod model for changes in the iTraxx Crossover spreads has different coefficients and significant variables at the 5% level than the model for the full sample period. Specifically, the Euribor-OIS spread, yield slope and the roll dummy variable cease to be significant at the 5% level.

0-10% Equity tranche

	SCDO010 GEN 5Y										
											Robust SE
Bid-Ask spread	0.033^{***}										0.0003
SX5E		-0.546^{***}									-0.494^{***}
60d std.dev			6.963^{***}								1.499
EER				-0.248^{***}							-0.431^{*}
EURIBOR5Y					-0.112^{***}						-0.018
EURIBOR-OIS						0.623^{***}					-0.021
YLDslope							-0.100^{***}				0.020
Infl								-0.157^{***}			0.016
V2X									0.006^{***}		0.002^{***}
Days2Mat										0.0001^{***}	0.0001^{**}
Constant	5.002^{***}	9.470^{***}	4.968^{***}	6.213^{***}	5.070^{***}	4.947^{***}	5.136^{***}	5.205^{***}	4.924^{***}	4.851^{***}	10.777^{***}
Observations	825	825	825	825	825	825	825	825	825	825	825
Adjusted R^2	0.124	0.699	0.356	0.021	0.134	0.436	0.187	0.472	0.460	0.054	0.862
Note:											$^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

For the log level of payment upfront for the equity tranche the Eurostoxx 50, the effective exchange rate, implied volatility and remaining time to maturity are significant at the 5% level. In contrast, in a single variable regression, the log Eurostoxx 50 index, the inflation swap rate, implied volatility, the Euribor-OIS spread and historic volatility explain the variation in the log payment upfront well. The difference in significance between single variable regression and multivariate regression could be explained by shared components of the explanatory variables, such as market wide risk tolerance, real interest rate levels or market wide high trading activity in times of uncertainty. Evidence for market-wide shared components and similar variations could be seen in the moderate degree of correlation between our explanatory variables. In the final regression model however only the variables that explain variation in log credit spreads best remain significant. Comparing significant variables and their coefficients with the regression model of the underlying iTraxx Crossover generic 5-year index, it is striking that the generic equity tranche seems to be driven more by factors that are present in the Euro effective exchange rate, the Eurostoxx 50 level, implied volatility and remaining time to maturity, while being independent of interest rate measures and inflation. During the time between roll dates it is estimated that the payment upfront decreases by 358 basis points and 3.58% of the PUF on the roll date due to the term structure effect. Perhaps unsurprisingly, the equity tranche payment upfront is more sensitive to the level of implied volatility by options on the Eurostoxx 50. A long-term one unit increase in the V2X index is predicted to increase cost of protection for the equity tranche by 20 basis points plus 0.2% of the previously quoted payment upfront. Hence, an equity tranche that is deemed risky and therefore requires high upfront payment is more sensitive to implied volatility than an equity tranche with low payment upfront. A 1% increase in the Eurostoxx 50 index decreases the PUF by 49 bps and 0.49% of the previous PUF, which tends to be higher than the iTraxx Crossover sensitivity of -1.5% of the ceteris paribus cost of protection, measured in basis points par spread. A Possible explanation for this finding could be that the Equity tranche aggregates idiosyncratic risk of the most default risky companies present in the sub investment grade Crossover index and is therefore traded by highly speculative investors. For them changes in market value, lower volatility, less time to maturity and investor confidence is more important than systemic macroeconomic variables. Additionally, the insignificance of historic volatility and bid-ask spread could hint at that the most speculative tranche is liquidly traded in financial markets.

	SCDO010 GEN 5Y													
												Robust SE		Robust SE
Bid-Ask spread	0.108*											0.100		0.097
SX5E r_t		−0.190***										−0.066		−0.088**
SX5E r_{t-1}			−0.237***									−0.228***		−0.230***
60d std.dev				−0.516								−1.331		−1.446
EER					0.418***							0.144		0.118
EURIBOR5Y						−2.584*						−0.555		−0.773
EURIBOR-OIS							7.160					2.032		1.920
YLDslope								−2.533**				−0.446		−0.183
Infl									−6.564***			−1.645		−1.404
V2X										0.157***		0.097***		0.096***
roll											0.736	0.629		0.882
ECM													3.196*	5.709***
Constant	−0.006	−0.003	−0.003	−0.007	−0.009	−0.007	−0.005	−0.006	−0.003	−0.005	−0.009	−0.004	−0.006	−0.005
Observations	824	824	824	824	824	824	824	824	824	824	824	824	824	824
Adjusted R^2	0.004	0.091	0.142	-0.001	0.042	0.004	0.001	0.009	0.036	0.095	0.002	0.256	0.005	0.274

Note: *p<0.05; **p<0.01; ***p<0.001

Changes in the payment up-front for the equity tranche are, according to the empirical model, driven by returns on the Eurostoxx 50, lagged returns on the Eurostoxx 50, changes in implied volatility and the one-day-lagged difference between the level payment up-front predicted by the initial model and the observed payment-up front. The regression of changes in the equity tranche payment upfront has an adjusted R^2 of 27.1%

In univariate regressions, one day lagged Eurostoxx 50 returns, changes in implied volatility and Eurostoxx 50 returns explain the largest part of the variation in upfront payment changes over the given timeframe when compared to the other explanatory variables included to the regression. In comparison with the iTraxx Crossover subperiod model it is striking that changes in the Euro effective exchange rate, the Euribor swap rate and inflation are not significant for explaining variation in the Crossover equity tranche price, while one-day lagged Eurostoxx 50 returns are significant in the regression. Interestingly the coefficient of the lagged Eurostoxx return is larger (in absolute value) than the same-day coefficient. We interpret this as further testament next to stale prices for thin markets and low liquidity. A short-term spike in the implied volatility index increases cost of protection for the equity tranche by 9.6 basis points plus 0.096% of the previously quoted PUF, which is lower than in the log level regression and could be evidence that the equity tranche is not very sensitive to short term changes in 30-day implied volatility. Similarly, the equity tranche's short-term sensitivity to the Eurostoxx 50 equity index is smaller than the long-term sensitivity. Aggregating same-day and one-day lagged sensitivities gives a short-term sensitivity of ?39 bps and 0.388% of the previous PUF quote. When comparing the log level model with the log difference model, it is also noteworthy that in the former model there is a significant constant while in the latter model the constant term is not significant.

In summary, evidence from the log level and log difference regressions suggest that over the observed period, while controlling for the term structure effect, the equity tranche on the iTraxx Crossover was primarily driven by components that also moved equity markets and influenced volatility expectations.

10-20% Junior Mezzanine tranche

	SCDO1020 GEN 5Y										
											Robust SE
Bid-Ask spread	0.038***										−0.004**
SX5E		−0.715***									−0.657***
60d std.dev			8.869***								0.402
EER				−0.305***							−0.508***
EURIBOR5Y					−0.162***						−0.028***
EURIBOR-OIS						0.817***					0.114***
YLDslope							−0.142***				0.014**
Infl								−0.208***			0.014
V2X									0.007***		0.001***
Days2Mat										0.0001***	0.0001***
Constant	4.599***	10.430***	4.538***	6.072***	4.672***	4.507***	4.763***	4.847***	4.485***	4.416***	12.060***
Observations	825	825	825	825	825	825	825	825	825	825	825
Adjusted R^2	0.078	0.776	0.373	0.021	0.182	0.486	0.242	0.532	0.465	0.045	0.923
Note:											*p<0.05; **p<0.01; ***p<0.001

For the log payment-up-front of the junior mezzanine tranche, the Eurostoxx 50 index, effective Euro exchange rate, the Euribor 5-year swap rate, Euribor-OIS spread, yield slope, implied volatility and time to maturity are significant at the 5% level. In single variable regressions, the log level of the Eurostoxx 50 index, inflation, implied volatility, the Euribor-OIS spread, the yield slope and historic volatility explain sizeable parts of the payment upfront variation of the junior mezzanine tranche.

Comparing significant variables and their coefficients with the regression model of the underlying iTraxx Crossover generic 5-year index, it is striking that besides common significant variables with the iTraxx Crossover regression the generic junior mezzanine tranche seems not to be driven by components present in historic volatility and inflation expectations, but in the Euribor-OIS spread.

A long-term appreciation of the Euro against a basket of 20 currencies reduces the PUF by 50.8 bps and makes protection by 0.51% cheaper than the ceteris paribus quoted PUF. This tends to be less than the iTraxx Crossover's sensitivity to the Euro effective exchange rate. During the time between roll dates it is estimated that the payment upfront decreases by 358 basis points and 3.58% of the PUF on the roll date due to the term structure effect. The junior mezzanine tranche payment upfront is less sensitive to the level of implied volatility by options on the Eurostoxx 50 than the equity tranche. A long-term one unit increase in the V2X index is predicted to increase cost of protection for the equity tranche by 10 basis points plus 0.1% of the ceteris paribus quoted payment upfront. Again, a tranche that is deemed risky and therefore requires high upfront payment is more sensitive to implied volatility than an equity tranche with low payment upfront. A 1% increase in the Eurostoxx 50 index decreases the PUF by 66 bps and 0.66% of the previous PUF, which is higher than the sensitivity of the equity tranche. A Possible explanation for this finding could be that the junior mezzanine tranche is less exposed to idiosyncratic risk of the most default risky companies present in the sub investment grade Crossover index. The most default risky companies are likely not included in the Eurostoxx 50 index, which serves as the equity benchmark in this regression, and hence, by design, will covary less with the benchmark. Furthermore, those companies in distress will be affected more by idiosyncratic factors which is why market returns will be less correlated with changes in their equity value Altman, 1998. Hence the risk inherent to the junior mezzanine tranche originates more from companies that are currently not in distress and therefore more correlated with market returns. It is furthermore striking that the log level of the junior mezzanine tranche is partly driven by the level of the Euribor-OIS spread. This makes sense as commercial and investment banks are market makers for synthetic CDO tranches and thus represent major parts of counterparty risk. If there is doubt about financial integrity market makers might demand higher upfront payments to be less dependent on counterparty risk. The yield slope contributes to explaining observed variation in PUF demanded by the market for taking on a position in the junior mezzanine tranche. Specifically, a steeper slope of the yield curve is predicted to increase the price of protection demanded by the market. A technical explanation for the estimated coefficient could be found in the loss expectations of the market. As the junior mezzanine tranche might expect losses early in the lifetime of the tranche while premium payments are constant and paid in fixed intervals over the tranche's tenor. Other things equal, under this assumption the present value of protection might be less sensitive to changes in the long-term interest rate than the present value of the premium leg. As a result, under a steeper yield curve the present value of the premium leg decreases relatively faster than the present value of protection. Hence a higher payment upfront is necessary to balance present values at the inception of the transaction.

	SCDO1020 GEN 5Y													
												Robust SE		Robust SE
Bid-Ask spread	0.132											0.113		0.084
SX5E r_t		-0.298^{***}										-0.161^{***}		-0.226^{***}
SX5E r_{t-1}			-0.353^{***}									-0.343^{***}		-0.350^{***}
60d std.dev				-0.955								-2.274^{*}		-2.397^{*}
EER					0.606^{***}							0.175		0.124
EURIBOR5Y						-3.442^{*}						-0.416		-0.767
EURIBOR-OIS							8.575					2.427		3.174
YLDslope								-3.710^{**}				-0.715		-0.400
Infl									-9.439^{***}			-1.973		-1.395
V2X										0.232^{***}		0.104^{**}		0.097^{**}
roll											1.937^{***}	1.819^{*}		2.188^{**}
ECM													3.678	11.361^{***}
Constant	-0.013	-0.009	-0.008	-0.014	-0.017	-0.014	-0.012	-0.013	-0.009	-0.011	-0.021	-0.013	-0.014	-0.013
Observations	824	824	824	824	824	824	824	824	824	824	824	824	824	824
Adjusted R^2	0.003	0.125	0.176	-0.0002	0.050	0.004	0.001	0.011	0.042	0.116	0.012	0.329	0.003	0.363

Note: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Changes in the payment up-front for the junior mezzanine tranche are, according to the empirical model, driven by returns on the Eurostoxx 50, lagged returns on the Eurostoxx 50, changes in historical volatility, implied volatility, the roll date and the one-day-lagged difference between the level payment up-front predicted by the initial model and the observed payment-up front. In univariate regressions, the variation in the log difference of payments upfront for the junior mezzanine tranche is well explained by one trading day lagged returns of the Eurostoxx 50, Eurostoxx 50 returns and implied volatility.

Comparing the variable that are significant for explaining changes in the PUF with explanatory variable significant for explaining changes in the iTraxx Crossover CDS spread it is interesting that changes in the effective exchange rate, changes in the Euribor 5-year rate and the inflation rate are not significant for changes in the junior mezzanine tranche, while changes in historic volatility and one-day lagged Eurostoxx 50 returns are significant. Additionally, the coefficient of historic volatility is puzzling: an increase in historic volatility is predicted to reduce the payment upfront. Mathematically that means that volatility that enters the 60 trading-day moving average is larger than volatility that leaves the average. Historic volatility hence rises in periods of increasing volatility in equity markets.

In comparison with the log level model it is striking that in the short-term changes in the payment upfront are indeed driven by changes in equity prices and implied volatility. Over the long-term the level of payment upfront for the junior mezzanine tranche on the Crossover index is driven by both financial and economic variables.

20-35% Mezzanine tranche

	SCDO2035 GEN 5Y										
Bid-Ask spread	−0.015***										0.004
SX5E		−0.340***									−0.382***
60d std.dev			5.141***								−0.687
EER				−0.225***							−0.135*
EURIBOR5Y					−0.030***						0.067***
EURIBOR-OIS						0.477***					0.139
YLDslope							−0.082***				−0.023*
Infl								−0.119***			0.003
V2X									0.004***		0.001
Days2Mat										0.0001***	0.00002
Constant	4.477***	7.223***	4.413***	5.529***	4.479***	4.395***	4.544***	4.591***	4.380***	4.385***	8.139***
Observations	825	825	825	825	825	825	825	825	825	825	825
Adjusted R^2	0.136	0.628	0.450	0.042	0.022	0.594	0.291	0.626	0.590	0.024	0.906

Note: *p<0.05; **p<0.01; ***p<0.001

For the log payment upfront of the mezzanine tranche, bid-ask spreads, the Eurostoxx 50 index, the Euribor 5-year swap rate and the yield slope are significant at the 5% level. In a regression of the log payment upfront on the individual explanatory variables the log level of the Eurostoxx 50, inflation, implied volatility, historic volatility and the Euribor-OIS spread explain large parts of the variance in the log PUF. In comparison with the underlying iTraxx Crossover index and other tranches it is striking that implied volatility and remaining time to maturity are not significant at the 5% level. Furthermore, in comparison with the junior mezzanine tranche and the subperiod model it is interesting that the yield curve slope coefficient switched signs, predicting reduced cost of protection on the mezzanine tranche under a steeper yield curve. This could be due to the fact the mezzanine tranche will only serve as protection once 20% of the underlying portfolio of loans have defaulted. As we consider newly created index tranches, it seems reasonable to assume that loss expectation by market participants for the tranche are relatively to the two junior tranches more distant in the future. Hence as the yield curve steepens, expected loss is discounted more (as it has a higher duration) than the premium leg which is distributed over time and hence has a low duration. Thus, by a technical argument, cost of protection decreases as the present value of protection decreases more rapidly than the present value of premiums under a steeper yield curve. From an economic perspective a steeper yield curve could be a sign of market expectations on high future GDP growth, which would benefit the economy, thereby improve debt fundamentals for high-yield obligations, which would make the mezzanine tranche more secure and hence reduce required cost of protection, i.e. the payment upfront.

	SCDO2035 GEN 5Y													
											Robust SE		Robust SE	
Bid-Ask spread	0.129											0.091		0.105
SX5E r_t		-0.184^{***}										-0.108^{***}		-0.155^{***}
SX5E r_{t-1}			-0.221^{***}									-0.210^{***}		-0.218^{***}
60d std.dev				-0.682								-1.598^{*}		-1.758^{*}
EER					0.421^{***}							0.144^{*}		0.121
EURIBOR5Y						-1.276						0.962		1.794
EURIBOR-OIS							7.683					6.264		8.223^{*}
YLDslope								-1.741^{*}				-0.318		-0.584
Infl									-5.955^{***}			-1.451		-0.949
V2X										0.140^{***}		0.056^{*}		0.050^{*}
roll											0.959^{**}	0.872		0.923
ECM													3.202	13.119^{***}
Constant	-0.014	-0.011	-0.010	-0.014	-0.016	-0.014	-0.012	-0.013	-0.011	-0.012	-0.017	-0.011	-0.014	-0.011
Observations	824	824	824	824	824	824	824	824	824	824	824	824	824	824
Adjusted R^2	0.003	0.127	0.185	0.0001	0.064	0.001	0.003	0.006	0.045	0.113	0.007	0.340	0.002	0.381

Note: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

Changes in the payment up-front for the mezzanine tranche are, according to the empirical model, driven by returns on the Eurostoxx 50, lagged returns on the Eurostoxx 50, changes in historical volatility, changes in the Euribor-OIS spread, changes of implied volatility and the one-day-lagged difference between the level payment up-front predicted by the initial model and the observed payment-up front. In a regression of the log difference of the mezzanine payment upfront one day lagged Eurostoxx 50 returns, same day Eurostoxx 50 returns and changes in implied volatility have the highest individual explanatory power of the selected explanatory variables. In comparison with changes in the Crossover index it is remarkable that the Mezzanine tranche sensitivity to Eurostoxx 50 returns is about the same size as in the level regression. Opposed to the iTraxx Crossover model there is a dependence between Euribor-OIS spreads and the mezzanine tranche. Again, there is a negative relationship between changes in historical volatility and the payment upfront demanded for protection on the mezzanine tranche.

35-100% senior tranche

	SCDO35100 GEN 5Y										
Bid-Ask spread	0.032^{***}										-0.001
SX5E		-1.944^{***}									-2.002^{***}
60d std.dev			38.854^{***}								1.739
EER				-3.507^{***}							-2.422^{***}
EURIBOR5Y					0.083						0.432^{***}
EURIBOR-OIS						3.965^{***}					1.463^{**}
YLDslope							-0.524^{***}				0.045
Infl								-0.788^{***}			0.092
V2X									0.034^{***}		0.007^{**}
Days2Mat										0.001^{***}	0.001^{***}
Constant	4.030^{***}	20.058^{***}	3.861^{***}	20.770^{***}	4.295^{***}	3.661^{***}	4.764^{***}	5.092^{***}	3.600^{***}	2.595^{***}	29.731^{***}
Observations	825	825	825	825	825	825	825	825	825	825	825
Adjusted R^2	0.125	0.330	0.413	0.167	0.002	0.659	0.190	0.440	0.557	0.153	0.915

Note: $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$

For the log spreads of the senior tranche, the Eurostoxx 50 index, the effective exchange rate, the Euribor 5-year swap rate, the difference between Euribor and OIS rate, the level of implied volatility and remaining time to maturity are significant at the 5% level. In a single variable regression of the log level of the senior tranche spread the Euribor-OIS spread, implied volatility, inflation, historic volatility and the log level of the Eurostoxx 50 index have relatively large individual explanatory power of the variation in log spreads. In comparison with the underlying iTraxx Crossover estimated coefficients, it is interesting that the senior tranche is more sensitive to Eurostoxx 50 returns as well as implied volatility from options on the Eruostoxx 50. In comparison to the mezzanine tranche the Euribor coefficient increases in size. In comparison with other regression models the term structure effect is more pronounced. Again, the Euribor-OIS spread explains significant parts of the variation in spreads on the senior tranche.

							SCDO35100 GEN 5Y							
											Robust SE		Robust SE	
Bid-Ask spread	−0.118											−0.148		−0.153
SX5E r_t		−1.284***										−0.656**		−1.167***
SX5E r_{t-1}			−1.367***									−1.280***		−1.321***
60d std.dev				−4.367								−10.459*		−10.736
EER					3.314***							1.600**		1.088*
EURIBOR5Y						−5.653						5.305		12.902
EURIBOR-OIS							40.148					30.089		51.745
YLDslope								−10.654				−1.518		−2.447
Infl									−35.459***			−3.271		1.010
V2X										1.010***		0.484**		0.382*
roll											15.724***	15.318		19.585**
ECM													13.427***	21.556***
Constant	−0.095	−0.074	−0.073	−0.098	−0.112	−0.095	−0.087	−0.092	−0.075	−0.084	−0.151	−0.126	−0.095	−0.129
Observations	824	824	824	824	824	824	824	824	824	824	824	824	824	824
Adjusted R^2	0.001	0.076	0.087	-0.001	0.049	-0.001	0.0002	0.002	0.019	0.073	0.028	0.207	0.033	0.287

Note: *p<0.05; **p<0.01; ***p<0.001

Changes in quoted spreads of the senior tranche are, according to the empirical model, driven by returns on the Eurostoxx 50, lagged returns on the Eurostoxx 50, changes in the effective exchange rate, changes in the Euribor-OIS spread, changes of implied volatility, the roll date and the one-day-lagged difference between the level CDS spread predicted by the initial model and the observed payment-up front. In a univariate regression changes in the log spread are well explained individually by the one-day-lagged Eurostoxx 50 return, the same-day Eurostoxx 50 return and changes in implied volatility. Comparison of the estimated model for changes in spreads with the model for the underlying reference CDS index, the log level model and other tranches reiterates the surprisingly high sensitivity of the senior tranche's CDS spreads to equity variables such as the Eurostoxx 50 return and implied volatility from options on the Eurostoxx 50. A possible explanation for this observed pattern might be that the senior tranche aggregates systematic risk and hence covaries over the long- and short-term more with market wide factors that also drive returns of the benchmark index, the Eurostoxx 50. A puzzling result for short term variation is observed with the Euro effective exchange rate. Over the short term the model suggests that Euro appreciation against a currency basket of 20 foreign currencies increases credit spreads on the tranche, while over the long-term exchange rate appreciation reduces the tranche spread. One possible explanation of this result might be given with the overshooting hypothesis of exchange rates. Under the assumption that good's prices are slow to change in the short run, prices of currencies flexible, no arbitrage via the uncovered interest parity holds and that expectations about the exchange rate are rational, the hypothesis predicts that upon a change of an exogenous variable the short-term effect of the variable change on a currency's price can be larger than the long-term effect of the change. From a company perspective a positive external shock to the economy could therefore mean, that in the short-term currency appreciation hurts the company's exports as the exchange rate overshoots depressing revenues and hence cash flow available for debt service with other things equal. Over the long term as the currency price decreases from the overshooting level (but possibly remains higher than ex ante) and as the positive external shock materialises in the economy company fundamentals benefit and the company's debt servicing ability could increase.

High adjusted R^2

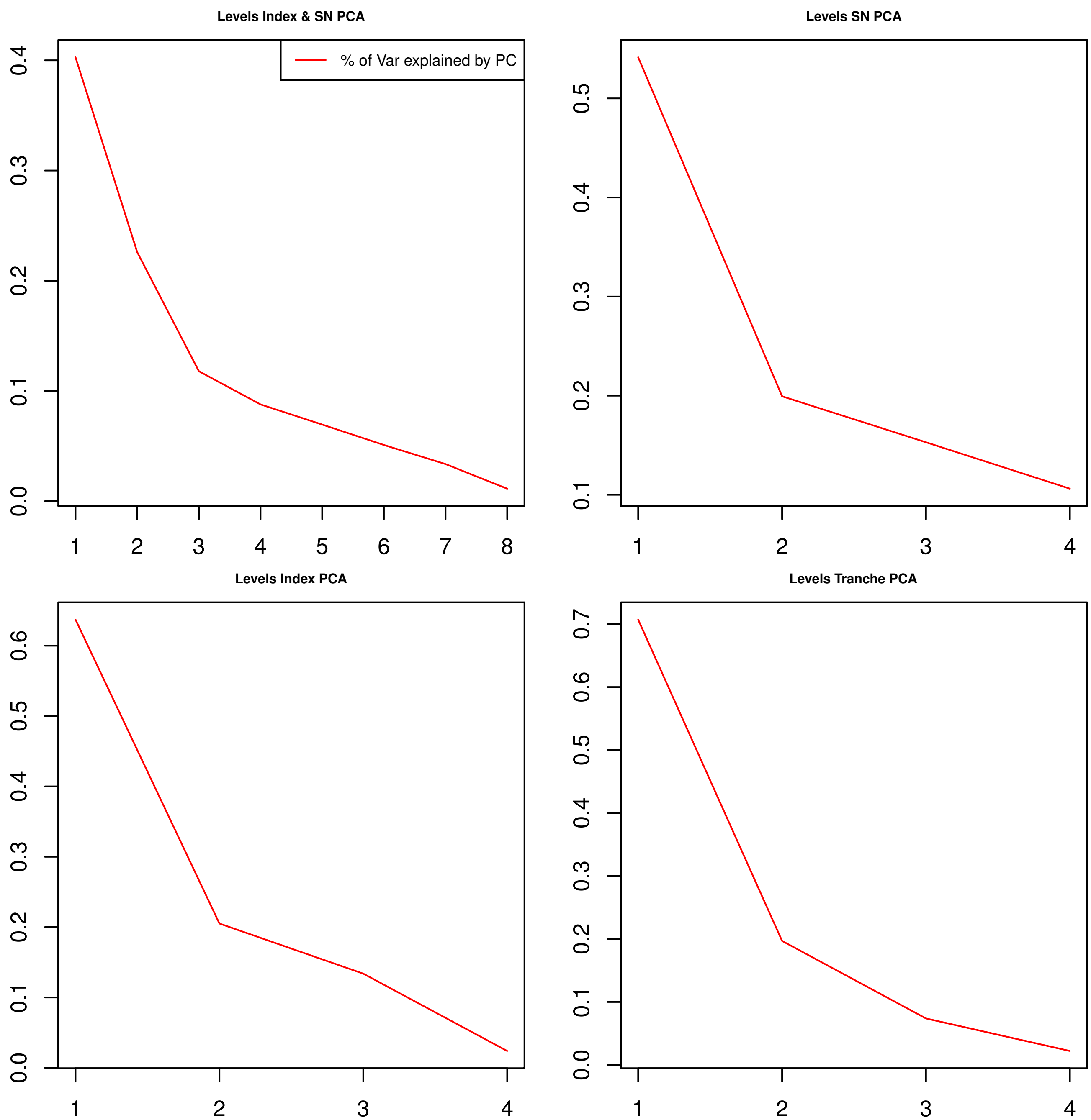
Principal Component Analysis

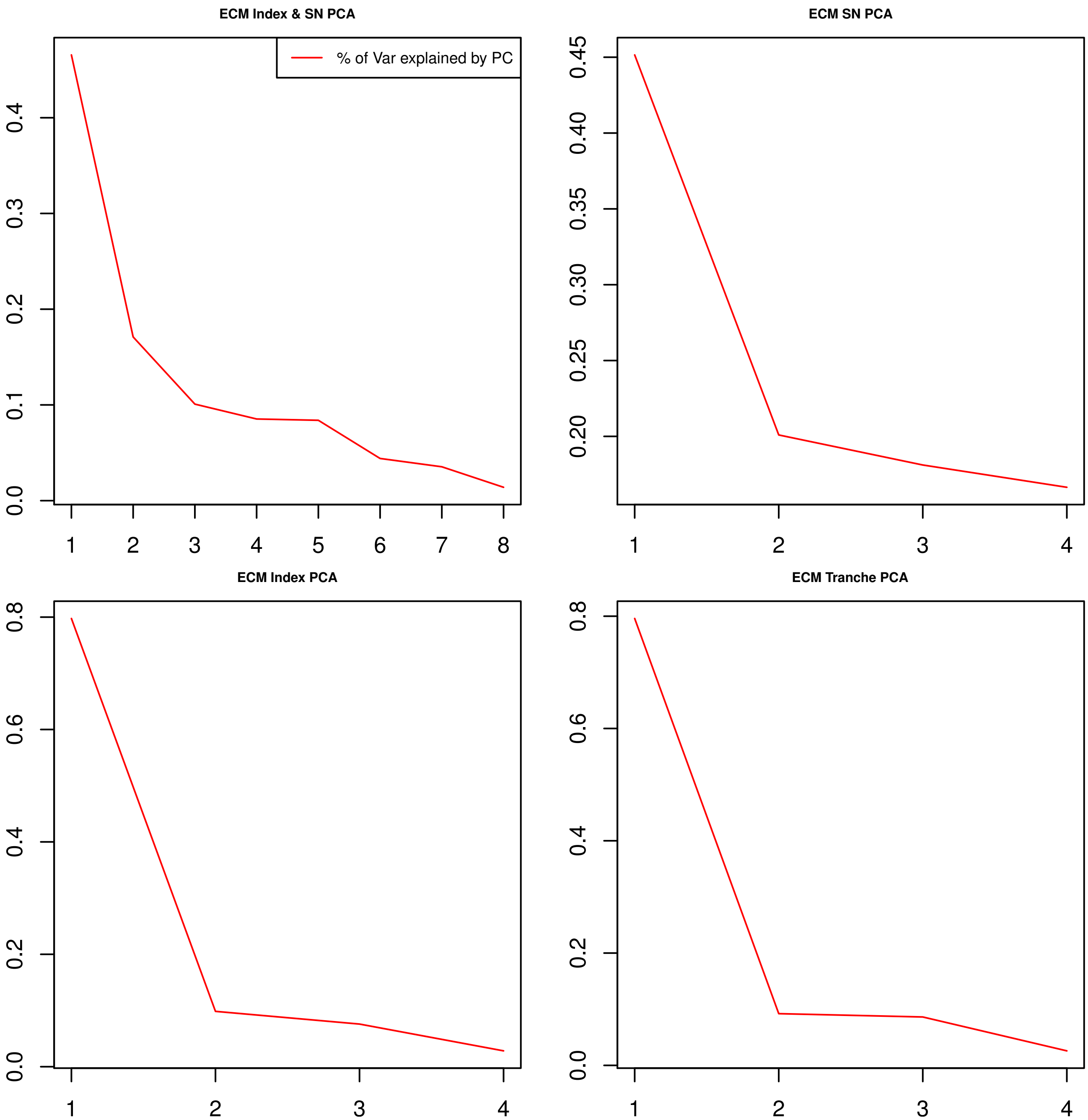
To understand the structure of the remaining variation in our data we analyse the regression residuals from the cointegration model as well as from the error correction model by investigating the principal components of the residual's normalised covariance matrices. We thereby follow a similar approach as Collin-Dufresn et al., 2001 and Ericsson et al., 2009. Suggested procedure allows us to investigate whether there exists a common factor that explains a large part of the cross-sectional variation of spreads and spread changes that have not been explained by the respective set of explanatory variables. By conducting a principal component analysis, we hence investigate whether there have been credit market specific factors driving spreads and their changes during the sample period.

We find that the residuals of index and single name level regressions share a relatively large principal component, explaining 40.3% of the variation in the 8 model's residuals. For single name CDSs the largest principal component explains 54.2%, for the iTraxx Indices 63.7% and for the tranches on the iTraxx Crossover 70.7% of variation of the residuals from the respective cointegration model.

For residuals from the error correction model we find that the first principal component of index and single name residuals explains 46.6% of variation in the residuals. On a stand-alone basis the first principal component explains 45.2% of variation for single name CDSs, for the iTraxx Indices 79.8% and for the tranches on the iTraxx Crossover 79.6% of variation of the residuals from the respective error correction model.

The relatively large first principal components indicate that there remains a shared factor in the residuals that explains large part of the variation in CDS spread levels and changes and is not related to foreign exchange, rates or equity markets. We therefore interpret the large common principal component as a credit market specific factor. This specific factor could be evidence for some degree of segmentation between credit markets and other financial markets.




ECM Index & SN PCA
% of Var explained by PC
0.0
0.1
0.2
0.3
0.4
1
2
3
4
5
6
7
8
ECM SN PCA
0.20
0.25
0.30
0.35
0.40
0.45
1
2
3
4
ECM Index PCA
0.0
0.2
0.4
0.6
0.8
1
2
3
4
ECM Tranche PCA
0.0
0.2
0.4
0.6
0.8
1
2
3
4

Equity and Credit Market (lead-lag analysis)

To understand the level of integration between credit and equity markets better we test for granger causality between changes of the iTraxx Indices' spreads and Eurostoxx 50 returns as well as for changes in selected single name CDS spreads and their reference entity's market capitalisation.

Surprisingly, we find that in the conditional distribution of current Eurostoxx 50 returns, one-day-lagged changes in the spread of iTraxx indices add information for the explanation of current Eurostoxx 50 returns. Vice versa, one-day-lagged Eurostoxx 50 returns add no information for explaining changes in the iTraxx CDS index swaps. Over the observed period it hence seems that there is a unidirectional dynamic relationship and that iTraxx CDS indices were faster in pricing new information than the Eurostoxx 50.

For the selection of single name credit derivatives, we find the opposite to be true. Changes in the respective CDS spreads do not add information for the explanation of concurrent changes in market capitalisation of the reference entity. Vice versa, one-day lagged changes in market capitalisation add information for the explanation of changes in the respective CDS spread. It hence seems that there is a unidirectional dynamic relationship and that stockholders process new information quicker, trade on that information and thereby affect the stock price than credit investors do.

A possible explanation for this finding could be a similar argument as in Grossman and Stiglitz, 1980. The authors let investors split into "informed" and "uninformed" investors as there is a cost for information but also a reward in the form of higher returns to being "informed". Given that mainly professional investors are active in credit markets, it seems fair to assume that they have low cost of information and can process information quickly such that prices reflect new information fast. In equity markets, there are relatively, fewer professional investors, hence new information could be reflected slower in prices.

Discussion of Results

If the list of factors that we considered for explaining levels and changes of CDS spreads was comprehensive, the selected modelling approach adequate and our data without bias, then our results would suggest that CDS markets share common trends with Equity, FX and rates markets as well as that efficient pricing depends on the liquidity of the respective markets. That is, the CDS market would to a large extent seem to be driven by different aggregate risk factors than suggested by structural models. If this conclusion holds then using traditional models of credit risk for the pricing and hedging of CDSs would be flawed. A different possibility, of course, is that we have omitted important systemic variables from our analysis, use data that is biased for our inference or employ faulty models.

To check for omitted variable bias additional explanatory variables could be included to the regression of log levels and log difference of CDS spreads. Natural choices could include quadratic and cross terms of existing explanatory variables in order to check if enforced linearity does not spuriously generate the observed results, daily transaction data on prices and volume of trades to better understand market dynamics and sensitivity of actual transactions to the chosen set of explanatory variables, a variance measure for volatility in CDS prices, volatility implied by options on CDS indices to account for expected variance of returns - including implied default correlation in CDS indices or SMB and HML factors to account for size and value effects of reference entities in credit markets. Furthermore, our analysis may be repeated for subperiods to gain further insight on the changes in importance of explanatory variables in explaining variation in CDS spreads. This approach could be complemented by considering an extended timeframe which is then tested for breaks in the true data generating process. We imagine that including the global financial crisis to the dataset and analysing the effect of small bang and big bang protocols while controlling for our (extended) set of explanatory variables could be an interesting direction of further research. A different, potentially interesting, direction of further research could include an investigation of volatility of observed CDS prices and arch effects. A further next step could be to estimate a cointegrated VAR model with variables from the potentially extended dataset and to use the residuals for building a VECM for changes in CDS spreads.

A source of bias in our selected set of explanatory variables could be that we only observe the subset of quoted prices that are reported by Bloomberg. We hence fail to control for effects of trades and market activity measured in trade sizes, notional outstanding and frequency of trades per day and include potentially distorted closing prices in our Analysis. Access to a full dataset of trades and long record market activity could hence lead to different estimation results. A long record of market activity would furthermore alleviate the problem of noise in the data due to the low liquidity of most CDS markets.

In the cointegration model it is safe to use ordinary least squares for the estimation of coefficients on non-stationary variables. In fact, OLS regression will produce super-consistent estimators Greene, 2012 and coefficients will be consistent in the presence of simultaneity. However, residuals tend to be serially correlated which is why we use Newey and West's heteroskedasticity and autocorrelation consistent (HAC) standard errors, which will only asymptotically be correct for inference Jin, Phillips, and Sun, 2006. Hence our inference about the significance of the estimated coefficients might be a source of error. This potential source of error will however not influence results obtained from the ECM regression, as found by Phillips, 1991. Overall, we are hence confident about the results and inference obtained from the cointegration and error correction model.

Conclusion

We investigate the levels of spreads and changes in spreads for generic CDS indices, a selection of single name CDSs and generic CDS index tranches. Several interesting results are obtained.

First, we find evidence of pockets in the CDS market that are inefficiently priced. That is, in the prices for protection at close on a given trading day, not all current information seems to be included in single name CDS prices, tranches. Interestingly enough we find that, on the other hand, granger causality between lagged changes in the spread of iTraxx CDS indices provides additional information for explaining returns of the Eurostoxx 50. iTraxx Indices hence seem to price new information quicker than the Eurostoxx 50. This finding is in conflict with Chakravarty and Sarkar, 1999, Schultz, 2001 and Hotchkiss and Ronen, 2002 who find that stock and bond markets are equally adept at efficiently incorporating new information into prices, that is they price efficiently.

Second, we find evidence that the long-term CDS spread moves with long-term market factors that are present in foreign exchange markets, rate markets, the bund yield term structure and equity valuation. In a cointegration model we are able to explain large parts of the variation in CDS spread levels. In addition, we find evidence in principal components of regression residuals that there is a credit market specific factor present in both short-term changes of spreads and long-term spread levels. We are hence able to find similar findings as **collin2001determinants** and Ericsson et al., 2009.

Third, we find that long-term spread levels are mostly explained by equity valuations for CDS indices and non-firm specific variables for single name CDSs, while short-term changes in CDS spreads are largely driven by changes in implied volatility. With an error correction model that includes the lagged residuals of the respective levels regression we are able to explain up to 63.7% of the variance in changes of CDS Index spreads and at least 13.8% for changes in less liquid single name CDSs.

Finally, we find significant explanatory power of the relative strength of the Euro and changes in the inflation swap rate for explaining variation in CDS spread changes. Given that we control for financial variables in the regression, we interpret this effect as evidence that investors in CDS markets price fundamental beliefs about the economy into CDS spreads.

A natural explanation for our findings is some degree of segmentation of credit from foreign exchange, equity and rates markets. If markets are segmented to some degree and different types of investors trade in credit, stocks, foreign exchange and rate markets, then prices in those markets could be driven by differing demand and supply shocks. Hence, while over the long-term credit, equity, foreign exchange and rates markets would share some common trends, over the short-term significant variation from the equilibrium model exists.

A different explanation could be imperfections in the data that we use on CDS markets. So potentially an aggregate factor driving liquidity in credit markets could explain the common factor that we are detecting. The measures that we use to control for liquidity might simply be inadequate at capturing this factor. However, the fact that we find similar results in liquid CDS index markets as well as in illiquid markets for CDS single names and tranches on the iTraxx Crossover gives us confidence that the credit specific factor is not due to liquidity.

Our findings hence again shed light on a shortcoming of theoretical models for credit risk. Besides risk-free interest rates credit risk models predict that largely firm specific variables predict the cost of protection for a certain reference entity. However, we find that large part of spread levels and changes in spreads are driven by systemic factors and a credit market specific factor. Therefore, our paper suggests the need for further work on equilibrium models of credit pricing.

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