ERASMUS UNIVERSITY ROTTERDAM
ERASMUS SCHOOL OF ECONOMICS
MSc Economics & Business
Master Specialization Financial Economics

Liquidity and credit risk in sovereign yield spreads

An empirical research on the Economic and Monetary Union

Abstract

This thesis studies the relative importance of liquidity risk compared to credit risk for ten euro area sovereign yield spreads over various periods of time. Using a unique decomposition technique based on R^2, the findings show that credit risk dominates liquidity risk especially in peripheral countries. However, time variation in the importance of liquidity risk relative to credit risk can be observed. As such, liquidity risk has a relatively big role in the boom period considered, while credit risk is more important in the bust period that followed. Yet, no relative change is visible between different stress levels.

Keywords: sovereign bond yield, liquidity risk, credit risk, market stress, monetary policy
JEL classification: C33, E52, G12, G15, G18, G32

Author: Q.D. Zomerdijk

Student number: 409504

Supervisor: Dr. J.J.G. Lemmen

Second assessor: Prof.dr. M.A. Pieterse-Bloem

Date final version: July 2019

TABLE OF CONTENTS

TABLE OF CONTENTS ii
LIST OF TABLES iii
LIST OF FIGURES iv
CHAPTER 1 Introduction 1
CHAPTER 2 Related Literature 4
2.1 Setting 4
2.2 Determinants of the sovereign yield spread 6
2.3 Hypothesis development 8
CHAPTER 3 Data 11
3.1 The sample and the scope of the sample period 11
3.2 The sources and construction of the data 13
3.3 Summary statistics 14
CHAPTER 4 Methodology 18
CHAPTER 5 Empirical Results 22
CHAPTER 6 Robustness Checks 31
CHAPTER 7 Discussion 34
CHAPTER 8 Conclusions 37
REFERENCES 38
APPENDIX 40

LIST OF TABLES

Table 1: Sovereign yield spreads from 1999 to 2018 5
Table 2: Summary statistics on CDS and bid-ask for the lowest and highest yield quintile 15
Table 3: Spearman correlations among yield, CDS and bid-ask 16
Table 4: Spearman correlations among CDS spreads and yield spreads 23
Table 5: Relation between sovereign yield spread, credit risk, and liquidity risk 24
Table 6: Likelihood ratio test on the importance of liquidity risk relative to credit risk 26
Table 7: Credit and liquidity risk for different stress levels 29
Table 8: Credit and liquidity risk when controlling for market stress 30
Table 9: Summary statistics on CDS and volume for the lowest and highest yield quintile 31
Table 10: Robustness check on the likelihood ratio test 33
Table 11: Data summary 40
Table 12: Summary statistics on sovereign yield spreads for different yield quintiles 41
Table 13: 10 year credit default swaps and CDS spreads per country from 2008-2015 42
Table 14: 10 year bid-asks and bid-ask spreads per country from 2008-2015 42

LIST OF FIGURES

Figure 1: Factors affecting sovereign bond yields 7

Figure 2: 10 year sovereign bond yields in EMU-countries 12

Figure 3: 10 year credit default swaps in EMU-countries 12

Figure 4: The explanatory proportions of credit risk and liquidity risk 25

Figure 5: The time-varying explanatory proportions of credit and liquidity risk 28

Figure 6: Robustness check on the explanatory proportions 32

Figure 7: 10 year sovereign bond yields in EMU-countries for 1999-2019 40

Figure 8: Correlation between German liquidity and amount outstanding 43

CHAPTER 1 Introduction

After a long period of low yield spreads, the sovereign debt crisis of 2007 was the starting point of big yield differences within the euro area. Within the Economic and Monetary Union (EMU) exchange rate risk is absent for the sovereign issuers, which isolates credit risk and liquidity risk as the two main explanatory factors of sovereign yield spreads (Codogno et al., 2003). Since Merton (1974), literature explaining credit risk has expended rapidly. However, even after the LTCM crisis of May 1998 and the liquidity and solvency crisis of September 2008 the literature explaining liquidity risk lagged behind. This thesis especially aims to contribute to the literature by improving the understanding of the sudden widening of the yield spread when the sovereign debt crisis started.

Beber et al. (2009) did focus on liquidity risk and concluded there is a flight-to-liquidity in times of high market uncertainty. Therefore, market uncertainty plays an important role in determining which risk factors are important in explaining the sovereign yield spread. Sovereign bond spreads are widely considered to be an extensive measure of a country's overall risk premium. Risks such as liquidity risk and credit risk drive the spread. The difference between uncertainty and risk is important to look at. Uncertainty (an unknown information set) implies a situation where future events are unknown. Risk (a known information set) is the probability something loses value. In contrast to uncertainty, risk can be measured and is controllable.

From a policy perspective it would be good to know which risk factors drive the sovereign yield spread to implement effective regulations. Credit risk or default risk, which is the probability of a loss due to the issuer's failure to meet contractual obligations, can be reduced by focusing on actions addressing an increase in the issuer's solvency. Liquidity risk, which is the probability of a loss due to a leak of the marketability of the asset, can be reduced by focusing on measures which improve the functioning of markets. By holding until maturity a bondholder can avoid selling at a discount. He weights the proceeds from selling now against the expected value of waiting and the risk involving being forced to sell at a worse price in the near future. From an investor's perspective, disruption in market liquidity would refer to the attractiveness of a long-term investment, while for high credit risk this would not be the case (Longstaff, 2009).

This thesis looks at interactions between liquidity and credit risk within and across the sovereign bond market of ten countries in the EMU and its effect on the sovereign yield spreads. This will be done with data from the period of January 2008 till January 2016. The sample period captures the build-up, core and ending of the European sovereign debt crisis. As can be seen in Figure 2 (page 12), the yield spread is close to zero beyond the scope of 2008-2016, indicating a neglectable country's overall risk premium. This thesis will examine changes in correlation and changes in the credit to liquidity contribution ratio if market stress is at its highest compared to more normal market circumstances. Yield is divided into five quintile groups to indicate the level of market stress. The sovereign yield spread will be the summation of credit risk (the credit default swap) and liquidity risk (bid-ask and volume) taken as the difference between individual EMU-countries and Germany. The comparison with Germany will generate a country-specific analysis. In addition, a unique decomposition technique of sovereign yield spreads in terms of R^2 will be used to show the importance of liquidity risk in times of stressed markets. Finally, this thesis will examine the explanatory value of credit risk on sovereign yield spreads when controlling for the highest market stress to see if its explanatory value will increase. All in all, the abovementioned analysis serves the goal of answering the main research question of this paper, which is as follows:

Main question: What is the relative importance of liquidity risk relative to credit risk for euro area sovereign yield spreads over time?

The cross-section analysis shows credit risk dominates liquidity risk in explaining euro area sovereign yield spreads. In particular in peripheral countries credit risk is high, giving relatively less importance to liquidity risk compared to credit risk. However, time variation can be observed in the importance of liquidity risk relative to credit risk. For example, in the boom period liquidity risk plays a bigger role, while in the bust period credit risk is more important. Nevertheless, no differences are observable in the relative importance for different stress periods. Both the importance of credit risk as the importance of liquidity risk increases in times of high market stress. The high positive correlation makes it difficult to disentangle the two risk sorts. The likelihood ratio test shows liquidity risk does add value in explaining the yield spread next to credit risk.

The thesis has the following structure. In Chapter 1 an introduction in given to liquidity and credit risk in EMU sovereign yield spreads. Earlier research on this topic is discussed in Chapter 2, while formulating the hypotheses. In Chapter 3 the data is reported and in Chapter 4 the methodology is given per hypothesis. Chapter 5 describes the empirical results, while Chapter 6 presents the robustness checks. Chapter 7 discusses the hypotheses by looking at the test results. Finally, Chapter 8 draws a conclusion based on the outcomes of this thesis.

CHAPTER 2 Related Literature

The Related Literature is divided into three parts. Firstly, the setting is given, involving the introduction of the euro and the European Central Bank (ECB) as well as the sovereign debt crisis. Secondly, the determinants of the sovereign yield spread are discussed in detail. Thirdly, the development of the hypotheses is introduced and elaborated upon.

2.1 Setting

The construction of the Economic and Monetary Union (EMU) dates back to January 1st, 1999. Signs towards an economic integration can be observed many decades before. In 1929, Germany introduced the plan of a single European currency to the League of Nations as a way to stabilize the economy after the First World War. The idea of a single European currency was not taken into action. Moreover, the great depression following these words did not bring integration, but fragmentation for Europe. Consistent with this reasoning, Pieterse-Bloem et al. (2016) found multiple structural breakpoints in the financial integration process in Europe. By looking at the corporate bond market they discovered an increase in integration in times of the introduction of the EMU in July 1999 and a decrease in integration at the time of the global financial crisis in November 2007. Studies analyzing the period before the crisis usually find a high level of integration. Abad et al. (2010) is a good example, because they look at the period 1999-2008.

In the second part of the 19th century economic integration got more attention than in the first half of the century. This led to the decision in 1969 to make an Economic and Monetary Union as an official objective during a summit in The Hague. The integration would not only include the introduction of a European currency, but also full liberalization of capital flows and the final fixing of countries. In 1979, the European Monetary System (EMS) was introduced in which the nations of the European Economic Community (EEC) linked their currency to stabilize variability in their exchange rate. Besides the conversion in currencies, a unification of economic and fiscal policies was introduced. This happened in the form of an independent institution known as the European Central Bank (ECB), launched in 1999.

Galati and Tsatsaronis (2003) showed that as the launch date of the euro approached, the yield curves of the founding nations of the EMU converged. The resulting narrowing of the yield spread was assumed to be caused by vanishing currency risk premiums and the alignment of monetary policies. Moreover, Galati and Tsatsaronis (2003) showed an increased liquidity after the introduction of the euro in 1999, by using the proxy transaction volume. As can be seen in Table 1, the diminishment of factors driving the sovereign yield spread caused a yield spread of zero for almost all countries founding the EMU.

Table 1
Sovereign yield spreads from 1999 to 2018 based on a 10 year benchmark bond

Date	Austria	Belgium	Finland	France	Netherlands	Greece	Ireland	Italy	Portugal	Spain
1999-2008	0.152	0.190	0.131	0.353	0.089	0.521	0.079	0.162	0.210	0.152
1999	0.183	0.253	0.228	0.242	0.133	1.863	0.195	0.110	0.319	0.233
2000	0.294	0.330	0.221	0.487	0.143	0.795	0.148	0.151	0.324	0.263
2001	0.261	0.313	0.225	0.431	0.140	0.456	0.137	0.096	0.354	0.298
2002	0.176	0.198	0.193	0.350	0.102	0.271	0.115	0.144	0.185	0.170
2003	0.057	0.097	0.051	0.316	0.039	0.143	-0.009	0.106	0.059	0.040
2004	0.073	0.095	0.052	0.308	0.038	0.139	-0.141	0.169	0.050	0.046
2005	0.017	0.051	-0.027	0.274	-0.003	0.136	-0.099	0.112	-0.006	0.010
2006	0.023	0.038	0.005	0.281	0.003	0.293	-0.024	0.080	0.144	0.008
2007	0.069	0.100	0.065	0.333	0.058	0.266	0.022	0.177	0.190	0.079
2008	0.370	0.429	0.302	0.513	0.238	0.850	0.447	0.475	0.482	0.378
2009-2018	0.422	0.703	0.272	0.729	0.257	8.875	2.094	1.259	3.592	1.838
2009	0.681	0.646	0.483	0.640	0.431	1.887	1.786	0.280	0.891	0.723
2010	0.458	0.694	0.243	0.611	0.223	6.709	3.187	0.584	2.631	1.483
2011	0.672	1.586	0.358	0.931	0.342	16.219	6.699	2.243	7.728	2.793
2012	0.818	1.446	0.329	1.224	0.380	21.511	4.492	3.082	8.823	4.291
2013	0.386	0.786	0.237	0.836	0.337	8.460	2.176	1.731	4.686	2.938
2014	0.257	0.483	0.218	0.661	0.224	5.854	1.009	0.852	2.406	1.491
2015	0.214	0.308	0.192	0.543	0.159	10.094	0.461	0.655	1.773	1.203
2016	0.274	0.373	0.263	0.611	0.190	8.198	0.488	0.806	3.031	1.291
2017	0.221	0.361	0.185	0.684	0.161	5.588	0.437	0.917	2.632	1.193
2018	0.236	0.343	0.210	0.552	0.125	4.224	0.203	1.441	1.316	0.971

Notes: This table presents the yearly sovereign yield spreads of the ten countries used in this thesis. Sovereign bond yield is the interest paid on a government bond and the spread is a measure of the risk premium. It is taken as the yield of the countries relative to Germany. So, yield spread = $\text{government bond yield}_{i,t}$ - $\text{government bond yield}_{GER,t}$. In which *i* captures country *i* with *t* as the year in question. *GER* stands for Germany, which is taken as a benchmark to calculate the spread.

Table 1 also shows an increased yield spread for the period 2009-2018 compared to the period 1999-2008. This is caused by the European sovereign debt crisis, which started in 2009. Several countries in southern Europe were unable to refinance their government debt without the help of other European countries, the ECB, and the International Monetary Fund (IMF). This inability to refinance their debt resulted in higher risks of holding government bonds in countries such as Greece, Ireland, Italy, Portugal and Spain. In particular the yield of Greece was high, with an average difference in yield between Greece and Germany of 21.511 in 2012.

2.2 Determinants of the sovereign yield spread

Sovereign yield spreads are widely considered to display a country's overall risk premium. Following Dungey et al. (2000), international bond yield spreads can be decomposed into three types of risk factors, namely global factors, regional factors, and national factors (see Figure 1). In this thesis, a strict difference between global and national risk factors is made, leaving the figural grey area in between as regional risk factors.

By aggregate risk factors, the global level of instability is meant. An increase in the global level of instability is caused by higher risk aversion among investors worldwide. As such, higher investors' risk aversion implies a higher risk premium and, thus, a higher yield spread. The analysis of Caceres et al. (2010) showed global risk aversion played a significant role in explaining euro area sovereign spreads, whilst more recently country-specific factors play a more dominant role.

Papers about regional risk factors, encompassing everything between global and national factors, focus on contagion, regional institutions, and exchange rate risk. Contagion captures negative externalities diffusing from one crashing market to another. De Santis (2012) found significant spillovers from Greece to other southern-European countries, such as Spain, Italy, Ireland and Portugal from 2008 to 2011. Additionally, regional institutions form a risk factor that is important for explaining sovereign yield spreads. This factor measures the influence of institutions on the financial market and, thereby, also on sovereign bond yields. Lastly, exchange rate risk can play a role in explaining sovereign yield spreads, as well. Codogno et al. (2003) showed a steady convergence of government bond yields in the euro area as the introduction of the euro approached. The introduction of the euro took away expected exchange rate movements and, thereby, exchange rate risk.

The importance of the national factors in times of crisis was emphasized by Dotz and Fischer (2010). The increased expected loss component in their study suggests the important role of country-specific factors compared to global factors. As a drawback, they only look at the very beginning of the crisis. Codogno et al. (2003) mentioned the convergence of government bond yields to be due to harmonization of tax treatments before the start of the monetary union in 1999, while credit risk (e.g. controls on capital movements) had been removed a long time before that. This would leave only credit risk and liquidity risk as being relevant for a study on country level (as this thesis is). According to earlier research, for example by Longstaff et al. (2005), credit risk is the most prominent risk factor for explaining government yields. With credit default swaps as a proxy for credit risk they found a significant factor for all rating categories. Credit risk captures the risk that the issuer (in this case the government) is unable to meet its required payments. Liquidity risk however, refers to the event in which a security cannot be traded fast, without influencing the price on the market. Favero et al. (2010) suggested that sovereign yields are increasing in illiquidity. On the contrary, Bernoth et al. (2012) found periods in which the liquidity premium vanishes completely. This would mean there is no role for liquidity at all.

Figure 1
Factors affecting sovereign bond yields

Global Factors	Aggregate Risk
Regional Factors	Contagion Risk
	Regional Institutions Risk
	Exchange Rate Risk
National Factors	Credit Risk
	Liquidity Risk
	Tax Treatment and Control Risk

Notes: This figure shows all factors influencing international sovereign bond yields based on earlier research. Depending on the level and research type, one can zoom in on specific factors.

Based on the findings of the literature discussed in this paragraph, it is assumed that by looking at a country level and differences between countries, global and regional factors are not important. Even tax treatment and control risk are so much harmonized within the euro area that only liquidity risk and credit risk play a notifiable role in determining the yield spreads for the sample of this paper. In that sense, more recent studies, such as Beber et al. (2009), are observed for the decomposition in this paper.

2.3 Hypothesis development

For many decades a positive relation between credit risk and yield spreads has been assumed (Merton, 1974). However, the extent to which it can explain sovereign yield spreads is still a disputed part of the finance literature. Especially liquidity risk is regarded to have important explanatory value on a country level. There is consensus in earlier empirical literature on the observation that the liquidity risk premium decreases with the level of market integration. For example Bernoth et al. (2004) found a decrease in the liquidity risk premium with the introduction of the euro. Manganelli and Wolswijk (2009) discovered a higher liquidity risk premium since the start of the financial crisis in 2007. They even propose the solution of policy measures enhancing further integration to eliminate the liquidity risk premium.

Using yield quintiles as the indication for market stress within the EMU-country in question, the first hypothesis has the objective to show that credit risk is not the only factor affecting the yield spread on a county-specific level. Although indicating towards a liquidity risk premium this hypothesis at least shows that there is a non-credit risk factor explaining the yield spread in times of high market stress. Hypothesis 1 is therefore formulated as follows:

Hypothesis 1: The positive correlation between credit risk and sovereign yield spreads drops in times of high market stress.

In related literature, credit risk is considered to be the main driver of EMU yield spreads since the introduction of the euro. As such, Lemmen and Goodhart (1999) pointed to credit risk as the principal source of government debt markets in EMU. Longstaff et al. (2005) concluded that default risk accounts for more than 50% of the variation in corporate spreads.

By means of an unconditional cross-sectional decomposition of the sovereign yield spread, the dominance of credit risk in explaining the spread is pointed out. This is done numerically in the form of a credit to liquidity contribution ratio and graphically in the form of a stacked bar chart. This leads to the second hypothesis:

Hypothesis 2: Credit risk always dominates liquidity risk in explaining the sovereign yield spread.

Duffie et al. (2003) concluded that there is a significant variation of Russian sovereign yield spreads over time. They also found both credit risk and liquidity risk to be the main drivers of the Russian spread. Besides a large default component, Longstaff et al. (2005) observed systematic time variation and mean reversion in the non-default component of the corporate spread, as well.

To understand the relative importance of credit and liquidity risk, Hypothesis 3 looks at the time variation of the relative explanatory value. Following the methodology of Xiong et al. (2010) a decomposition is made of the time-series from sovereign yield spreads in terms of R^2. The third hypothesis is formulated as follows:

Hypothesis 3: There is a time variation in the significance of the importance of liquidity risk relative to credit risk.

Hypothesis 1 leads to the question: "what causes the decline in correlation between credit risk and sovereign yield spreads in the EMU?" As mentioned previously, liquidity risk has an important explanatory value to sovereign yield spreads according to earlier research. The important explanatory factor of liquidity risk is caused by investors who try to defensively rebalance their portfolio when there is an increase in market uncertainty by looking more at short-term liquidity risk (and transaction costs) and relatively less at long-term credit risk (Beber et al. 2009). Such a finding implies an important role for liquidity, especially in low credit risk countries and in times of high market uncertainty. Ericsson and Renault (2006) on the other hand, found an increase in the illiquidity component in their model when default becomes more likely. The increased illiquidity component implies a bigger role for liquidity in high credit risk countries.

To measure market stress, five groups of yield level have been composed for the first hypothesis. The cross-sectional credit to liquidity ratio from the second hypothesis can now be used to see whether there are differences in this ratio between different groups. This way the forth hypothesis is tested.

Hypothesis 4: The role of liquidity risk increases in times of market stress relative to credit risk.

Assuming that the correlation between liquidity and the sovereign yield spread is positive, the estimator in a simple linear regression of sovereign yield spread on credit risk would be too high, representing a positive bias. In the paper *asset pricing with liquidity risk*, Acharya and Pederson (2005) expanded their regression model by using a liquidity-adjusted capital asset pricing model (CAPM). Likewise, a liquidity factor can be added to the simple linear regression of sovereign yield spread on credit spread. This gives a regression of sovereign yield spreads onto credit spread and liquidity spread. From this regression a credit to liquidity contribution ratio can be calculated for different EMU-countries. By comparing the credit to liquidity contribution ratio for different stress levels, the preferences for liquidity can be calculated per EMU-country. This can be used as an additional explanation to Hypothesis 2.

If liquidity risk is taken into account when market stress is at its highest, excluding market stress would increase the explanatory value of credit risk on sovereign yield spreads. This increase would underline the trade-off effect between credit risk and liquidity risk when explaining sovereign yield spreads. Hypothesis 5 controls for the quintile of highest yield to proxy times of greatest market stress.

Hypothesis 5: By controlling for the quintile of greatest market stress, the explanatory value of credit risk on sovereign yield spreads increases.

Hypothesis 5 would be especially of importance for research only looking at credit risk. By controlling for liquidity risk the upward bias in the simple regression of sovereign yield spread on credit risk is removed. The argumentation could be raised that by controlling for market uncertainty the data is not representative anymore. However, using data with and without controlling for the greatest market stress solves this problem.

CHAPTER 3 Data

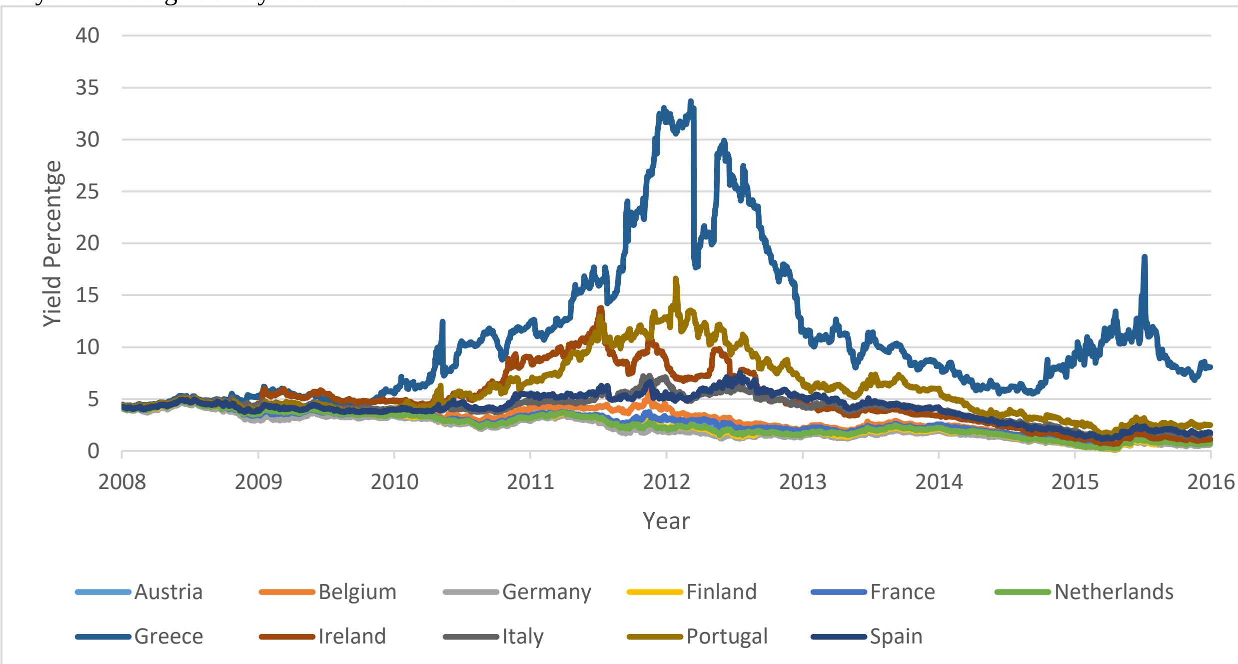
The Data Chapter is split into two parts. The first part looks at the sample and the scope of the sample period for this thesis. The second part discusses the sources and construction of the data. This involves the construction of the liquidity measure, which needed to be aggregated to country and daily level to correspond with the other variables.

3.1 The sample and the scope of the sample period

In this empirical research, a sample consisting of 11 countries within the Economic and Monetary Union (EMU) is used. These countries are Austria, Belgium, Finland, France, Greece, Germany, Ireland, Italy, the Netherlands, Portugal, and Spain. The sample period is January 2008 until January 2016 and is used in order to give a balanced panel dataset. In other time periods, the sovereign yield spread in EMU-countries is close to zero, making it an uninteresting time period for a decomposing of yield spreads. The chosen time period includes instances of great uncertainty, for example the global financial crisis of 2008 and the European sovereign debt crisis. In Figure 2, the evolution of 10 year sovereign yields are represented graphically. The sample period captures at least the European sovereign debt crisis. After a stable period, a time of uncertainty for European sovereign states started in 2009, followed by a rapid increase of yields in 2010 and 2011. Most government yields started to show a decline in 2012, which is mostly due to the implementation of structural reforms in the peripheral countries (Karanikolos et al., 2013). Following the words of Mario Dragi from November 2014, the crisis ended in the second quarter of 2013. However, he also mentioned some real factors remained weak: “The euro area exited recession in the second quarter of 2013, but underlying growth momentum remains weak. Unemployment is only falling very slowly. And confidence in our overall economic prospects is fragile and easily disrupted, feeding into low investments.” This refers to the peripheral countries within the EMU. The countries within the dataset can be grouped into two categories based on sovereign bond yields. By using Figure 2, a difference is made between core counties, including Austria, Belgium, Finland, France, Germany, and the Netherlands and the more peripheral counties, including Greece, Ireland, Italy, Portugal, and Spain.[1] A clear difference between the two groups can be seen when comparing the corresponding yields.

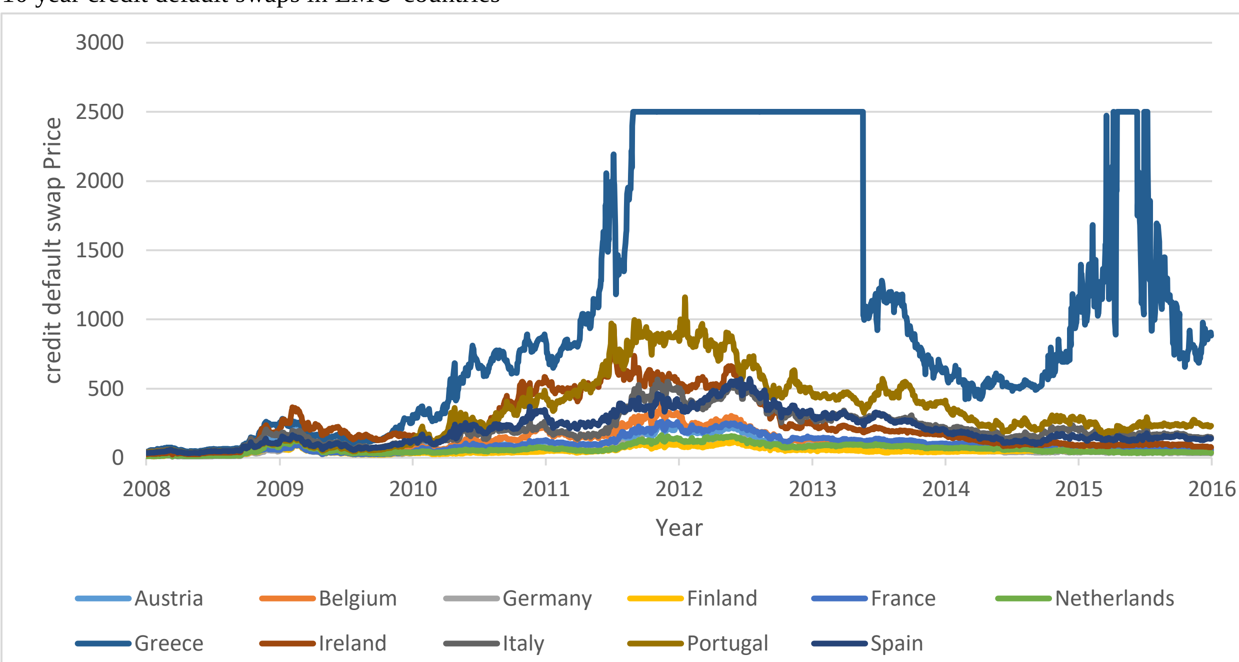
[1] The peripheral counties are also known under the abbreviations southern- or GIIPS-countries.

Figure 2
10 year sovereign bond yields in EMU-countries



Notes: This figure shows evolution of the sovereign bond yields with 10 years to maturity. The yield is taken from an index of generic yields. The yield is the net realized return/principal amount for a bond, with the government as issuer.

Figure 3
10 year credit default swaps in EMU-countries



Notes: This figure shows the evolution of credit default swaps on government bonds with 10 years to maturity. The CDS is a derivative contract enabling market participants to swap credit risk with other market participants. In this figure the price of the CDS can be seen. The CDS of Greece has been winsorized at a level of 2500.

3.2 The sources and construction of the data

As represented in Table 1, the sample consists of a great variety of data. The most important of which are the sovereign bond yields and the proxies for liquidity risk and credit risk, which are the three liquidity measures based on trade and quote information and the credit default swaps respectively. Further there are some bond characteristics mentioned, which have been used for the aggregation of the variables to daily and country level.

The sovereign bond yields represented graphically above are taken from the database Bloomberg. These are the historical, generic yields of an index from Markit with a daily frequency. As can be seen in Table 1, the dataset contains of a wide range of time intervals for the bonds looked at, consisting of a o maturity form one year up until and including 20 years. The sovereign yield spreads are constructed on country level by subtracting the sovereign yields of the country in question by the sovereign yields of Germany. The yield of Germany is taken as a benchmark, because the risk on these bonds are usually neglectable. This gives five yield spreads for core countries and five yield spreads for peripheral countries.

The data of the credit default swaps, which proxies credit risk, is taken from Bloomberg. These are again ex-post prices, this time from Ice Norge AS with a daily frequency. The bond characteristics of the credit default swaps are by construction similar to the sovereign yields, mentioned in the last paragraph. As so, the time to maturity, 10 years, corresponds with other data used and again Germany is used as a benchmark. In Figure 3 can be seen that Germany has the lowest CDS, making them a relevant benchmark. As a drawback, however, there is counterparty risk included, because the CDS are issued by banks. Especially in the time period of the global financial crisis of 2008 this could lead to biased estimates. Nevertheless, Rodrigues et al. (2018) showed over the time period 2005-2016 that the CDS spreads had the ability to predict sovereign crisis, while credit ratings had no predictive ability. This means that CDS would be the best credit risk measure according to earlier research. What also can be seen from Figure 3 is that the CDS of Greece is winsorized at a level of 2500, because it affects the data too much if it would jump to a level over 20,000 (what it did).

The data for the liquidity measures are taken from the Mercato telematico dei Titoli di Stato (MTS) interdealer platform, which are observed at an intra-day frequency. On the MTS platform, all sovereign debt securities are quoted in the order book data, allowing to create quote based liquidity measures. For measuring the tightness of liquidity, in this research two common types of liquidity measures are being used, namely: the bid-ask, and the depth of the liquidity based on the quoted volume. Both measures are constructed in such a way that it gives the level of illiquidity. Therefore, a higher value indicates more liquidity risk. The bid-ask and the depth of the liquidity only look to a single dimension: price and volume, respectively. Nevertheless, both of these measures are of importance. In the exceptional case of a tight spread and no tradable volume or a large spread and a generous volume the measures would contradict. In the main text of this thesis the bid-ask spread is used. This leaves the quoted volume as liquidity measure for the robustness checks of Chapter 6.

Both liquidity measures have been aggregated to daily level and country level for 10 years to maturities to match the sovereign yields and the credit default swap data. Another frequently used dimension is seasonedness (e.g. how recently a security was issued). Since this dataset consists only of on-the-run securities this dimension would not add anything. The aggregation of the high intra-day frequency to a daily level has been done in correspondence with Boyd Buis, following his paper (Buis et al., 2018)[2]. A value-weighted liquidity measure holds a bias, because liquidity is increasing in issue size (Pellizzon et al., 2013).[3] Therefore, the aggregation to country level has been done equally-weighted. An allowance of 10% in the time to maturity has been accepted to make the country level aggregation per maturity to make buckets of them (e.g. a maturity between nine and eleven for ten years to maturity et cetera).

3.3 Summary statistics

Credit risk is captured by credit default swaps, while liquidity risk is captured by an equally-weighted bid-ask spread within the Empirical Results of this paper. The summary statistics of

[2] Nonetheless, this thesis contributes a lot to existing literature such as Buis et al. (2018) by making a decomposition based on R^2 and using different yield quintiles as a proxy for market stress.

[3] One can argue equal weights generates a bias (e.g. a lower liquidity measure) as well in the case of a small, illiquid bond in their maturity bucket. However, Figure 8 (page 42) shows there are no outliers, resulting in the fact that the bias is neglectable in this research.

these two measures are represented in Table 2, where Panel A analyses days at which the 20% highest yield was denoted and Panel B analysis days at which the 20% lowest yield was denoted. These two quintiles give an indication whether the data is about periods of high stress or low stress. Panel A overall gives higher values for the for credit default swaps and the bid-ask spread than Panel B. For the CDS these higher values can only be observed for the GIIPS-countries. The core countries, on the contrary, show a decrease of CDS in stressed periods. The bid-ask spread increases for all countries except Germany in stressed periods of high yield.

Thus, periods of higher stress are associated with high credit risk and liquidity risk for most countries. This gives preliminary information about the movements of the two risk types. Despite these absolute observations, no conclusions can be drawn based on Table 2. In the next chapter the methodology for relative measurements is discussed.

Table 2
Summary statistics on CDS and bid-ask for the lowest and highest yield quintile

Panel A: Highest quintile										
	credit default swap					**bid-ask**				
Variable	**Mean**	**Median**	**Std. dev.**	**Min.**	**Max.**	**Mean**	**Median**	**Std. dev.**	**Min.**	**Max.**
Germany	25.953	24.790	17.294	7.600	70.895	0.066	0.059	0.028	0.032	0.200
Austria	73.728	68.500	63.282	10.500	260.140	0.416	0.269	0.356	0.070	1.936
Belgium	132.526	142.250	102.364	21.200	400.000	0.292	0.214	0.261	0.048	2.298
Finland	33.313	28.390	21.771	9.900	94.150	0.299	0.160	0.367	0.025	5.657
France	38.941	27.795	36.568	9.600	260.330	0.169	0.106	0.142	0.030	0.773
Netherlands	43.028	33.500	34.541	9.600	126.330	0.163	0.155	0.117	0.030	1.532
Greece	2320.324	2500.000	412.176	935.410	2500.000	1.542	1.371	0.885	0.094	7.205
Ireland	550.783	539.020	81.009	371.260	952.770	0.400	0.323	0.296	0.079	2.419
Italy	364.890	405.520	144.337	35.000	566.195	2.809	2.512	1.160	0.738	7.232
Portugal	737.464	778.130	156.228	423.480	1161.100	4.794	3.903	2.602	1.176	12.834
Spain	371.442	362.280	92.432	208.440	570.510	0.540	0.444	0.327	0.145	2.245
Panel B: Lowest quintile										
	credit default swap					**bid-ask**				
Variable	**Mean**	**Median**	**Std. dev.**	**Min.**	**Max.**	**Mean**	**Median**	**Std. dev.**	**Min.**	**Max.**
Germany	41.834	38.375	15.378	30.500	137.510	0.070	0.066	0.022	0.028	0.196
Austria	52.526	51.000	5.777	40.720	77.025	0.092	0.060	0.152	0.027	1.693
Belgium	82.225	81.010	6.556	66.845	170.010	0.064	0.040	0.123	0.025	1.215
Finland	48.480	49.000	2.826	39.920	63.105	0.062	0.050	0.075	0.021	0.996
France	79.428	78.010	13.542	37.470	131.295	0.055	0.048	0.032	0.027	0.332
Netherlands	46.303	43.000	10.421	32.500	95.000	0.045	0.029	0.079	0.017	1.432
Greece	111.294	109.550	58.160	41.800	261.700	0.313	0.227	0.333	0.047	3.215
Ireland	94.027	95.000	7.254	75.665	115.820	0.114	0.088	0.122	0.028	1.851
Italy	169.357	165.000	21.054	133.970	235.060	0.246	0.220	0.213	0.079	4.034
Portugal	235.373	234.000	28.030	173.715	308.330	0.365	0.295	0.275	0.077	2.520
Spain	137.830	138.000	15.740	97.005	176.990	0.187	0.157	0.142	0.064	1.998

Notes: This table reports a comparison of both credit default swap and the bid-ask between periods of high yield and periods of low yield. High yield is classified as the 20% highest yield and low yield as the 20% lowest yield. Both are based on a daily sample of eight years generating 2079 observations per country.

Table 3
Spearman correlations among yield, CDS and bid-ask

Germany		*1*	*2*	*3*	**Austria**		*1*	*2*	*3*	**Belgium**		*1*	*2*	*3*
yield	*1*	X	X	X	yield	*1*	X	X	X	yield	*1*	X	X	X
CDS	*2*	-0.28	X	X	CDS	*2*	0.23	X	X	CDS	*2*	0.00	X	X
		(0.00)					(0.00)					(0.88)		
bid-ask	*3*	0.00	0.21	X	bid-ask	*3*	0.59	0.68	X	bid-ask	*3*	0.68	0.43	X
		(0.95)	(0.00)				(0.00)	(0.00)				(0.00)	(0.00)	
Finland		*1*	*2*	*3*	**France**					**Netherlands**				
yield	*1*	X	X	X	yield	*1*	X	X	X	yield	*1*	X	X	X
CDS	*2*	-0.49	X	X	CDS	*2*	-0.40	X	X	CDS	*2*	-0.24	X	X
		(0.00)					(0.00)					(0.00)		
bid-ask	*3*	0.51	0.24	X	bid-ask	*3*	0.54	0.16	X	bid-ask	*3*	0.51	0.30	X
		(0.00)	(0.00)				(0.00)	(0.00)				(0.00)	(0.00)	
Greece		*1*	*2*	*3*	**Ireland**		*1*	*2*	*3*	**Italy**		*1*	*2*	*3*
yield	*1*	X	X	X	yield	*1*	X	X	X	yield	*1*	X	X	X
CDS	*2*	0.92	X	X	CDS	*2*	0.79	X	X	CDS	*2*	0.36	X	X
		(0.00)					(0.00)					(0.00)		
bid-ask	*3*	0.69	0.65	X	bid-ask	*3*	0.71	0.80	X	bid-ask	*3*	0.65	0.33	X
		(0.00)	(0.00)				(0.00)	(0.00)				(0.00)	(0.00)	
Portugal		*1*	*2*	*3*	**Spain**									
yield	*1*	X	X	X	yield	*1*	X	X	X					
CDS	*2*	0.74	X	X	CDS	*2*	0.62	X	X					
		(0.00)					(0.00)							
bid-ask	*3*	0.80	0.83	X	bid-ask	*3*	0.54	0.64	X					
		(0.00)	(0.00)				(0.00)	(0.00)						

Notes: This table presents the Spearman correlations between yield, CDS and bid-ask for all 11 countries. Pearson's correlation coefficient is not used because it assumes a normal distribution, linear relation, and the absence of outliers. The rank correlation coefficient of Spearman only assumes a monotonic relationship. P-values are noted in parentheses.

Table 3 presents the Spearman correlations among yield, CDS and bid-ask. The relation between liquidity measure bid-ask and yield resembles Table 2. For all countries there is a significant positive relation, except for Germany. The relationship between liquidity risk and yield is insignificant in Germany. The relationship between CDS's and yield is more various. While the GIIPS-countries all show a strong positive relationship, most core countries show a negative relationship. Exceptions are Belgium (no relation) and Austria (a positive significant relationship). More troublesome is the positive relation between credit risk and liquidity risk. This positive relation underlines the need to decompose the yield and look at differences in stress level.

CHAPTER 4 Methodology

The Methodology discusses the method employed for this thesis with respect to evaluating the five hypotheses. Although the proxies are already mentioned in the Data (as displayed in the Data Summary of Table 2) and the hypotheses are developed in the Related Literature, the construction of the variables is described below. After the Methodology, only spreads are used, as opposed to the chapters before the Methodology where Germany is not yet used as a benchmark. The tests used in this research follow in this chapter ordered per hypothesis.

Hypothesis 1: The positive correlation between credit risk and sovereign yield spreads drops in times of high market stress.

For Hypothesis 1, yield is scaled into five quintiles as a proxy for the level of market stress. Per country, the daily level of yield is put in one of the five baskets. The correlation between CDS spreads for sovereign yield spreads on that day is measured and is put in that basket/quintile. Then, an average correlation is calculated and differences in correlation between credit risk and yield can be observed per stress level (e.g. per quintile/basket). If the correlation decreases when looking at a higher quintile, Hypothesis 1 is accepted.

As a first step towards Hypothesis 2, a simple linear regression equation is used to regress sovereign yield spread onto credit risk. The formula is as follows:

$$Y_{i,t} - Y_{GER,t} = \alpha + \beta_i \, (CDS_{i,t} - \, CDS_{GER,t}) + \varepsilon_{i,t} \qquad (1)$$

In the formula the sovereign yield spread is given for county *i* on time *t* as the dependent variable with Germany as benchmark. The difference between the credit default swap of country *i* on time *t* and the credit default swap of Germany on time *t* is used as a proxy for credit risk, which is the independent variable. Beta gives the sensitivity of the sovereign yield spread when the credit risk changes for country *i*. Alpha displays the amount of the sovereign yield spread that cannot be explained by the credit risk and epsilon gives the white random error component of country *i* on time *t*.

Hypothesis 2: Credit risk dominates liquidity risk in explaining the sovereign yield spread.

According to earlier research, liquidity also plays a big role in explaining sovereign yield spreads (Acharya & Pederson, 2005). This would mean that there is an omitted variable bias in the previous regression. Using a multiple linear regression formula including both credit and liquidity risk would solve this problem. The following model is based on Beber et al. (2009):

$$Y_{i,t} - Y_{GER,t} = \alpha + \beta_i \ (CDS_{i,t} - \ CDS_{GER,t}) + \delta_i \ (LIQ_{i,t} - \ LIQ_{GER,t}) + \varepsilon_{i,t} \qquad (2)$$

The only difference is the added liquidity risk, taken as the difference between the liquidity measure of country *i* on time *t* and the liquidity measure of German on time *t*. Also, the sensitivity measure delta is added to the equation. Beta can be interpreted as the sensitivity of the sovereign yield spread to credit risk, while delta is the sensitivity to liquidity risk. If beta is bigger than delta for all countries, Hypothesis 2 can be accepted. As an addition a credit to liquidity contribution ratio is calculated for a boom and bust period per country. Figure 2 can be used to find the peak in the sovereign bond yield for each country.

To be able to interpret the regression results the natural logarithm is used for the credit default swaps and the bid-ask. The logarithmic transformation moderates the effect of extreme values. Running regressions while using absolute values would lead to biased results. The logarithmic transformation is defined as follows:

$$CDS_{i,t} = \log(cds_{i,t}) \quad \& \quad LIQ_{i,t} = \log(liq_{i,t})$$

To look at Hypothesis 2 graphically, a stacked bar chart is used to show the proportions of the credit contribution and the liquidity contribution graphically. R^2 is used to make a difference between the explained part of credit risk and liquidity risk, generating three percentages per country. The formulas below are used to calculate the credit and liquidity proportion. When adding up to 100%, the remaining part is the unexplained proportion.

$$Credit\ proportion_i = \frac{|credit\ contribution_i|}{|credit\ contribution_i| + |liquidity\ contribution_i|} * \ R^2$$

$$Liquidity\ proportion_i = \frac{|liquidity\ contribution_i|}{|credit\ contribution_i| + |liquidity\ contribution_i|} * R^2$$

$$Unexplained\ proportion_i = 1 - Credit\ contribution_i - Liquidity\ contribution_i$$

Hypothesis 3: There is a time variation in the significance of the importance of liquidity risk relative to credit risk.

In addition, a decomposition of the time-series from sovereign yield spread in terms of R^2 can be made, following the methodology of Xiong et al. (2010). Beta and delta are made time-varying using covariance and variance per country as the formulas beneath show.

$$\beta_{i,t} = \frac{Cov\ ((Y_{i,t} - Y_{GER,t}),(CDS_{i,t} - CDS_{GER,t}))}{Var(CDS_{i,t} - CDS_{GER,t})} \quad \& \quad \delta_{i,t} = \frac{Cov\ ((Y_{i,t} - Y_{GER,t}),(LIQ_{i,t} - LIQ_{GER,t}))}{Var(LIQ_{i,t} - LIQ_{GER,t})}$$

In contrast to the regression used for Hypothesis 2, beta is time-varying in this formula. Beta is given for country *i* on time *t*. Sovereign yields and credit default swaps are given for county *i* on time *t* as well with Germany as a benchmark to calculate the spread. Also, the proportions used for credit risk and liquidity risk change to time-varying variables based on Beber et al. (2009):

$$Credit\ proportion_{i,t} = \frac{|credit\ contribution_{i,t}|}{|credit\ contribution_{i,t}| + |liquidity\ contribution_{i,t}|}$$

$$Liquidity\ proportion_{i,t} = \frac{|liquidity\ contribution_{i,t}|}{|credit\ contribution_{i,t}| + |liquidity\ contribution_{i,t}|}$$

A 100% stacked area graph is used to show the time variation in the two proportions above. A half-yearly rolling window with time periods of one year is used to make the graph. To answer Hypothesis 3, a likelihood ratio test between Model 1 and Model 2 is done per years. Based on the significance of the chi-squares, a conclusion can be drawn about the added value of liquidity risk relative to credit risk. When the goodness of fit of Model 2 relative to Model 1 changes in significance, there is significant time variation in the importance of liquidity risk relative to credit risk and Hypothesis 3 is accepted.

Hypothesis 4: The role of liquidity risk increases in times of market stress relative to credit risk.

The CDS spread, liquidity spread, and yield spread based on natural logarithms utilized for Hypothesis 2, are used for Hypothesis 4, as well. Similar to the approach in Hypothesis 1, yield quintiles are used to create market stress buckets. The credit to liquidity contribution ratio is averaged per quintile. If the difference between the highest and the lowest quintile is significantly bigger than zero Hypothesis 4 can be accepted.

Hypothesis 5: By controlling for the quintile of greatest market stress, the explanatory value of credit risk on sovereign yield spreads increases.

To test Hypothesis 5, the cross-sectional regression from Hypothesis 2 is used again. When erasing the highest yield quintile from the dataset, beta (e.g. the sensitivity of the sovereign yield spread to credit risk) should increase to be able to accept Hypothesis 5.

CHAPTER 5 Empirical Results

The Empirical Results Chapter describes how the hypotheses, which were developed in Chapter 2, are tested. Each of the five hypotheses is either accepted or rejected based on the test results. These test results are represented in tables and graphs within this chapter. Differences are made between, among others, peripheral and core countries, boom and bust periods, and various stress levels.

Table 4 shows Spearman correlations among CDS spread and yield spread, which can be used to answer Hypothesis 1. The correlations are shown for different yield quintiles (Panel A) and different years (Panel B). The columns show different counties, a specific average core, and an average peripheral column. The table supports earlier literature by displaying a positive coefficient in almost all correlations. Especially the difference in total correlation between core countries and peripheral countries is notable. Where the yield spread from the former is, with an average correlation of 0.60, weakly positively related to the CDS spread, the latter shows an almost one-on-one relation between the two variables, as they have an average correlation of 0.94. The higher total correlation than the correlation in all quintiles seems counterintuitive, but can be explained by Simpson's paradox: a trend appears in the whole dataset, but gets smaller in the subsamples.

Panel A fails to depict a lower correlation between the CDS spread and the yield spread for higher yield levels. When comparing the first yield quintile and the fifth yield quintile, the correlation seems to increase per yield quintile for both core and peripheral countries. Such a finding indicates a higher correlation between the CDS spread and the yield spread, leaving less space for liquidity in high stressed markets. This goes against the flight-to-liquidity principle discussed by Beber et al. (2009). Hypothesis 1 is therefore rejected. In spite of this rejection, the average correlations of 0.44 and 0.74 in the fifth yield quintile leave enough space for the liquidity spread to have explanatory value in determining the yield spread.

Table 4
Spearman correlations among CDS spread and yield spread

Panel A: per yield quintile

Quintile	Austria	Belgium	Finland	France	Netherlands	Average Core	Greece	Ireland	Italy	Portugal	Spain	Average Peripheral
1nd	0.70	-0.46	0.57	-0.12	0.15	**0.10**	0.74	0.20	0.31	0.61	0.11	**0.39**
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	**(0.06)**	(0.00)	(0.00)	(0.00)	(0.00)	(0.03)	**(0.00)**
2nd	0.72	0.83	0.74	0.82	0.61	**0.57**	0.82	0.62	0.64	0.89	0.58	**0.71**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**
3th	0.82	0.79	0.64	0.91	0.45	**0.55**	0.77	0.94	0.88	0.73	0.92	**0.85**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**
4th	0.75	0.68	0.43	0.51	0.42	**0.42**	0.73	0.84	0.93	0.77	0.97	**0.85**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**
5th	0.89	0.55	0.14	0.00	0.83	**0.44**	0.61	0.66	0.91	0.65	0.86	**0.74**
	(0.00)	(0.00)	(0.12)	(0.99)	(0.00)	**(0.00)**	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**
total	0.84	0.89	0.72	0.83	0.57	**0.60**	0.86	0.96	0.96	0.97	0.95	**0.94**
	(0.00)	(0.0)	(0.00)	(0.00)	(0.00)	**(0.00)**	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**

Panel B: per year

Date	Austria	Belgium	Finland	France	Netherlands	Average Core	Greece	Ireland	Italy	Portugal	Spain	Average Peripheral
2008	0.84	0.83	0.81	0.41	0.77	**0.73**	0.93	0.90	0.91	0.79	0.82	**0.87**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**
2009	0.83	0.80	0.72	0.14	0.83	**0.566**	0.65	0.69	0.75	0.09	0.24	**0.48**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**
2010	0.38	0.87	0.10	0.58	0.12	**0.41**	0.89	0.96	0.92	0.86	0.92	**0.91**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)	**(0.00)**	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**
2011	0.91	0.95	0.45	0.91	0.43	**0.73**	0.87	0.69	0.96	0.92	0.86	**0.86**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**
2012	0.92	0.93	0.62	0.83	0.50	**0.76**	-0.62	0.84	0.88	0.89	0.73	**0.55**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**
2013	0.04	0.54	0.29	0.13	0.80	**0.36**	0.81	0.78	0.75	0.83	0.74	**0.78**
	(0.66)	(0.00)	(0.00)	(0.01)	(0.00)	**(0.00)**	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**
2014	0.57	-0.57	0.36	0.14	0.70	**0.24**	0.82	0.78	0.26	0.78	0.54	**0.64**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**
2015	0.77	-0.15	0.31	-0.40	-0.09	**0.09**	0.74	0.26	0.69	0.81	0.62	**0.62**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.14)	**(0.14)**	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	**(0.00)**

Notes: This table reports Spearman correlations between CDS spread and yield spread. For both variables, Germany has been taken as a benchmark. Five yield quintiles are denoted in Panel A to the show differences in correlation for different stress levels. Panel B denotes the differences in correlation per year. In addition, a difference between core countries and peripheral countries is made. The number of observations per country is 2079. P-values are denoted in parentheses.

Panel B of Table 4 shows a lower correlation in the second half of the dataset for all countries. This emphasizes the importance to look at a boom and a bust period, which is done for Hypothesis 2. In addition, the average correlation of core countries shows an important development. It gets more and more insignificant towards the end of the sovereign debt crisis. The increasing insignificance of the results can be interpreted as liquidity risk being the only driver of the yield spread in the time period after the crisis.

Table 5
The cross-sectional relation between sovereign yield spread, credit risk, and liquidity risk

Panel A: Model 1

	sovereign yield spread									
	Austria	**Belgium**	**Finland**	**France**	**Netherlands**	**Greece**	**Ireland**	**Italy**	**Portugal**	**Spain**
Constant	-0.023***	-1.550***	0.082***	0.044***	0.115***	-20.950***	-8.255***	-5.875***	-9.522***	-5.986***
	(0.006)	(0.015)	(0.009)	(0.006)	(0.008)	(0.505)	(0.166)	(0.117)	(0.197)	(0.100)
Credit risk	0.164***	0.603***	0.082***	0.135***	0.085***	4.667***	2.261***	1.596***	2.511***	1.651***
	(0.006)	0.015	(0.003)	(0.006)	(0.004)	(0.089)	(0,348)	(0.024)	(0.040)	(0.022)
Adj. R^2	0.432	0.610	0.316	0.233	0.299	0.631	0.784	0.774	0.703	0.803

Panel B: Model 2

	sovereign yield spread									
	Austria	**Belgium**	**Finland**	**France**	**Netherlands**	**Greece**	**Ireland**	**Italy**	**Portugal**	**Spain**
Constant	0.320***	-1.094***	0.208***	0.221***	0.211***	-4.846***	-4.990***	-4.255***	-4.977***	0.320***
	(0.019)	(0.048)	(0.013)	(0.019)	(0.012)	(0.757)	(0.203)	(0.104)	(0.213)	(0.106)
Credit risk	0.116***	0.054***	0.063***	0.138***	0.081***	1.653***	1.503***	1.588***	1.503***	0.116***
	(0.005)	(0.013)	(0.003)	(0.055)	(0.004)	(0.123)	(0.039)	(0.021)	(0.039)	(0.021)
Liquidity risk	0.081***	0.048***	0.040***	0.051***	0.025***	0.552***	0.151***	0.833***	0.151***	0.081***
	(0.004)	(0.005)	(0.002)	(0.004)	(0.002)	(0.110)	(0.024)	(0.008)	(0.034)	(0.011)
Adj. R^2	0.574	0.643	0.417	0.392	0.340	0.635	0.822	0.808	0.775	0.817
Boom C/L ratio	1.668	8.246	1.625	2.204	3.302	3.873	2.501	15.498	8.087	11.119
Bust C/L ratio	1.265	33.084	4.731	27.483	5.936	10.409	15.989	85.801	9.990	9.201

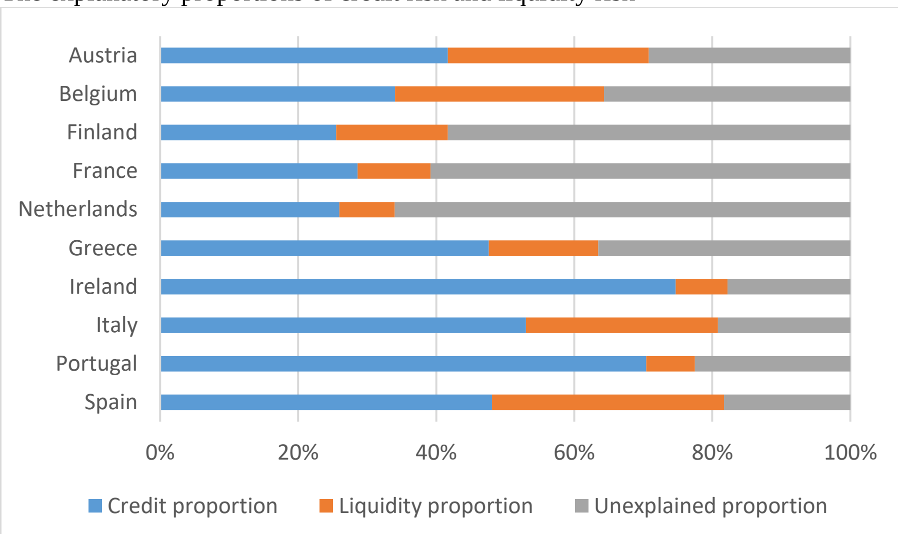
Notes: This table reports the outcomes of the regression: $Y_{i,t} - Y_{GER,t} = \alpha + \beta_i\ (CDS_{i,t} - CDS_{GER,t}) + \varepsilon_{i,t}$ for Panel A and $Y_{i,t} - Y_{GER,t} = \alpha + \beta_i\ (CDS_{i,t} - CDS_{GER,t}) + \delta_i\ (LIQ_{i,t} - LIQ_{GER,t}) + \varepsilon_{i,t}$ for Panel B. The difference in generic yield, CDS and bid-ask of country *i* at time *t* and that of Germany at time *t* is taken to calculate the spreads used in this regression. The natural logarithm is taken for the credit and liquidity measure. All coefficients are for bonds with 10 years to maturity. A significance level of 0.01 is denoted as *** and White standard errors are denoted in parentheses.

In Table 5, a positive bias can be observed when looking at the coefficient for credit risk in the simple non-linear regression of Model 1 and the coefficient for credit risk in the multiple non-linear regression of Model 2 (except for France). The positive bias is not surprising, because liquidity risk has a positive effect on the yield spread and earlier literature found a positive correlation between credit risk and liquidity risk (Ericsson and Renault, 2006). Moreover, Table 3 shows a positive relation between bid-ask and CDS for all countries (before the spread was calculated)[4]. The adjusted R^2 reveals significant explanatory power of the models in especially peripheral countries. For example, in Ireland, credit risk and liquidity risk explain 82.2% of the variance in the country's yield spread. The adjusted R^2 is lower in Model 1 for all countries. The higher adjusted R^2 in Model 2 relative to Model 1 (as well as the positive bias) points to an important role for liquidity risk.

[4] Even the negative bias for France can be explained by Table 3, because France is the only country with a correlation between bid-ask and CDS lower than Germany.

Nevertheless, the credit to liquidity contribution ratio in the boom and the bust periods shows a bigger explanatory value for credit risk than for liquidity risk, because the ratio is bigger than 1.000 for all countries. Especially in the bust, the ratio is high: in eight out of ten counties the credit to liquidity contribution ratio is higher in the bust than in the boom. This means that in most cases credit risk dominates liquidity risk in explaining the sovereign yield spread in the period after the peak. This adds to the literature mentioning credit risk as the most important factor explaining the yield spread (Longstaff et al., 2005; Lemmen and Goodhart, 1999).

Figure 4
The explanatory proportions of credit risk and liquidity risk



Notes: This figure shows the cross-sectional proportion of credit risk and liquidity risk on the sovereign yield spread. The proportions are calculated by the following formulas: $Credit\ proportion_i = \frac{|credit\ contribution_i|}{|credit\ contribution_i|+|liquidity\ contribution_i|} * R^2$ and $Liquidity\ proportion_i = \frac{|liquidity\ contribution_i|}{|credit\ contribution_i|+|liquidity\ contribution_i|} * R^2$. When adding the three to 100%, the remaining part is the $Unexplained\ proportion_i$.

The proportions of the contributions are shown graphically in Figure 4. The unexplained part is substantial in the core countries. In their recent study, Podstawski and Velinov (2018) find an increase in credit risk for peripheral countries in times of market stress and a decrease for core countries, due to the country-specific bank exposure on sovereign risk. This could explain the higher credit risk in peripheral countries. The unexplained part is biggest in the Netherlands. This could be due to a lack of investor diversification. The Dutch government recently (May 2019) issued green bonds, partly to attract a new group of investors. The money raised through the bond issue, is used to finance sustainable projects. As a dark side, different types of bonds also bring fragmentation besides diversification.

In most countries displayed in Figure 4 credit risk accounts for less than 50% of the variation in the yield spread. Only the proportion of credit risk in Ireland, Italy and Portugal are in line with outcome of Longstaff et al. (2005) on corporate bonds, showing a credit proportion of more than 50%. Moreover, Figure 4 shows a bigger bar for credit proportion than for liquidity proportion for all ten countries. Therefore, credit risk dominates liquidity risk in all cases. Such findings indicate the importance of credit risk. Hence, Hypothesis 2 can be accepted.

Table 6
Likelihood ratio test on the importance of liquidity risk relative to credit risk

Date	Austria	Belgium	Finland	France	Netherlands	Greece	Ireland	Italy	Portugal	Spain
2008	1.59 (0,207)	25.84 (0.000)	3.93 (0.047)	44.84 (0.000)	9.86 (0.002)	13.36 (0.000)	14.86 (0.000)	21.14 (0.000)	60.73 (0.000)	57.39 (0.000)
2009	53.22 (0.000)	35.26 (0.000)	49.14 (0.000)	92.87 (0.000)	41.68 (0.000)	87.45 (0.000)	0.05 (0.815)	79.02 (0.000)	227.34 (0.000)	202.43 (0.000)
2010	6.02 (0.014)	0.38 (0.536)	7.14 (0.008)	0.56 (0.454)	1.53 (0.216)	12.70 (0.000)	35.44 (0.000)	21.11 (0.000)	1.17 (0.279)	22.29 (0.000)
2011	84.42 (0.000)	31.80 (0.000)	5.38 (0.020)	12.55 (0.000)	15.37 (0.000)	2.43 (0.119)	43.98 (0.000)	24.14 (0.000)	67.81 (0.000)	23.12 (0.000)
2012	1.19 (0.275)	19.20 (0.000)	4.43 (0.035)	8.78 (0.003)	0.79 (0.375)	0.58 (0.446)	20.17 (0.000)	0.10 (0.746)	14.61 (0.000)	1.09 (0.297)
2013	34.21 (0.000)	3.82 (0.051)	1.21 (0.271)	0.89 (0.345)	0.20 (0.652)	2.99 (0.084)	97.74 (0.000)	76.89 (0.000)	33.31 (0.000)	121.35 (0.000)
2014	2.43 (0.119)	42.43 (0.000)	9.10 (0.003)	13.27 (0.000)	0.09 (0.770)	8.61 (0.003)	8.28 (0.004)	16.81 (0.000)	6.20 (0.013)	0.74 (0.391)
2015	7.27 (0.007)	12.98 (0.000)	13.26 (0.000)	0.22 (0.643)	3.67 (0.055)	6.65 (0.010)	2.01 (0.156)	48.75 (0.000)	62.12 (0.000)	3.52 (0.061)

Notes: This table presents the chi-squares from the likelihood ratio test of the following models: $Y_{i,t} - Y_{GER,t} = \alpha + \beta_i (CDS_{i,t} - CDS_{GER,t}) + \varepsilon_{i,t}$ & $Y_{i,t} - Y_{GER,t} = \alpha + \beta_i (CDS_{i,t} - CDS_{GER,t}) + \delta_i (LIQ_{i,t} - LIQ_{GER,t}) + \varepsilon_{i,t}$. The former is nested in the latter, giving one degree of freedom. The difference in generic yield, CDS, and bid-ask of country *i* at time *t* and that of Germany at time *t* is taken to calculate the spreads used in this regression. P-values are denoted in parentheses. 260 observations are used per year.

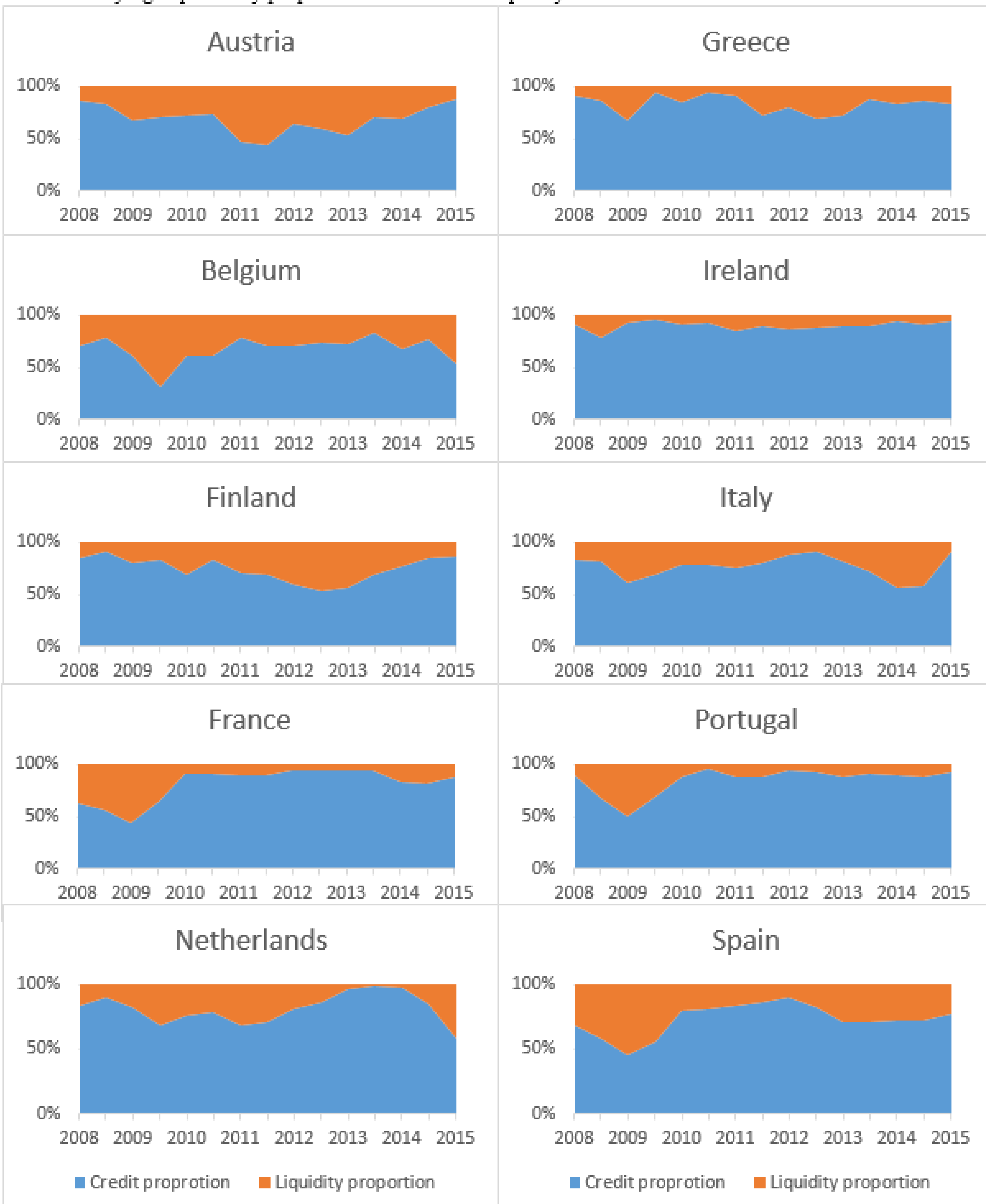
Table 6 denotes an insignificant added value of liquidity to the relation of credit risk on the sovereign yield spread in every country for at least one year[5]. In the Netherlands even five of the eight chi-squares show an insignificant outcome at a 0.05 significance level. Although Figure 4 shows a small liquidity proportion in the Netherlands, it is relatively big compared to the credit proportion. Nevertheless, in most cases the extended model has a significant better fit than the simple regression has. So, in most cases restricting liquidity risk to zero would significantly reduce the fit of the model.

Hypothesis 3 deals with the time variation of the importance of liquidity risk relative to credit risk. The chi-squares in Table 6 undergo large changes over time. Based on the fact that each country has both a significant and an insignificant chi-square over eight years, the hypothesis that there is significant time variation can be accepted.

Figure 5 shows the time variation in the credit and liquidity proportion based on the yearly variance and co-variance. In correspondence with Figure 4, Austria, Belgium and Spain have the biggest liquidity. Furthermore, credit risk seems to grow relative to liquidity risk after 2009. A clear example can be found in the data of France, where liquidity is relatively high in 2008 and 2009, while credit risk is relatively high in 2010 until 2013. This example translates to a high chi-squares for France in 2008 and 2009 (44.84 and 92.87 respectively). The cause is intuitively understandable: in a period when securities are more difficult to sell, a period of capital constraints will follow, resulting in a higher probability of default. This corresponds with the finding of Beber et al. (2009), because investors try to defensively rebalance their portfolio in times of increasing market uncertainty by looking at liquidity.

[5] The addition of one variable to the model, namely liquidity risk, gives all chi-squares in Table 6 the property of one degree of freedom.

Figure 5
The time-varying explanatory proportions of credit and liquidity risk



Notes: This figure shows the rolling window time series proportion of credit and liquidity risk on the yield spread. The contributions are calculated by the following formulas: $\beta_{i,t} = \frac{Cov\,((Y_{i,t}-Y_{GER,t}),(CDS_{i,t}-CDS_{GER,t}))}{Var(CDS_{i,t}-CDS_{GER,t})}$ & $\delta_{i,t} = \frac{Cov\,((Y_{i,t}-Y_{GER,t}),(LIQ_{i,t}-LIQ_{GER,t}))}{Var(LIQ_{i,t}-LIQ_{GER,t})}$. 260 observations are used in the 15 semi-annual rolling windows per country.

Table 7 denotes the multiple regression analysis used in Table 5 Panel B as well, but than for different yield quintiles. Interestingly, the adjusted R^2 is bigger in periods of high stress than in low stress for nine out of the ten considered countries. The six insignificant results based on a 0.05 significance level in the regression can be explained by the high White standard error, pointing to outliers caused by the low number of observations. Supporting the result drawn for Hypothesis 2, credit risk dominates liquidity risk based on all credit to liquidity contribution ratio's (C/L ratio's) in Table 7 (displaying a value bigger than 1.000). The C/L ratio is smaller in the highest quintile compared to the lowest quintile in six out of ten countries. The results are, however, not enough to conclude that liquidity risk increases relative to credit risk in times of high market stress. Therefore, Hypothesis 4 cannot be accepted.

Table 7
Credit and liquidity risk for different stress levels

	sovereign yield spread									
Panel A: Highest quintile										
	Austria	**Belgium**	**Finland**	**France**	**Netherlands**	**Greece**	**Ireland**	**Italy**	**Portugal**	**Spain**
Credit risk	0.829***	0.493***	0.115***	0.053***	0.156***	15,697***	5,533***	2,204***	5,440***	3,339***
	(0.056)	(0.020)	(0.005)	(0.012)	(0.010)	(0.548)	(0.296)	(0.050)	(0.326)	(0.112)
Liquidity risk	0.105***	0.012**	0.033***	0.048***	0.009**	-0.268	-0,102	0.110***	0,882***	0,218***
	(0.010)	0.005	(0.006)	(0.006)	(0.006)	(0.386)	(0,119)	(0.037)	(0.118)	(0.042)
Adj. R^2	0.783	0.745	0.726	0.149	0.674	0.553	0.477	0.869	0.618	0.796
C/L ratio	**7.895**	**41.083**	**3.485**	**1.104**	17.333	58.571	54.245	**20.036**	**6.168**	15.317
Panel B: Lowest quintile										
	sovereign yield spread									
	Austria	**Belgium**	**Finland**	**France**	**Netherlands**	**Greece**	**Ireland**	**Italy**	**Portugal**	**Spain**
Credit risk	0.066***	0.208***	0.055***	-0.033**	0.009**	0.880***	0.225***	0.493***	1.349***	-0.065
	(0.016)	(0.035)	(0.013)	(0.015)	(0.004)	(0.037)	(0.069)	(0.073)	(0.071)	(0.052)
Liquidity risk	0.005**	0.005	0.010**	-0.003	0.007**	0.042***	0.061***	-0.005	0.140***	-0.031***
	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.011)	(0.016)	(0.008)	(0.013)	(0.009)
Adj. R^2	0.245	0.119	0.174	0.013	0.027	0.862	0.078	0.106	0.542	0.024
C/L ratio	13.200	41.600	5.500	11.000	**1.286**	**20.952**	**3.689**	98.600	9.621	**2.097**

Notes: This table reports the outcomes of the regression: $Y_{i,t} - Y_{GER,t} = \alpha + \beta_i\ (CDS_{i,t} - CDS_{GER,t}) + \delta_i\ (LIQ_{i,t} - LIQ_{GER,t}) + \varepsilon_{i,t}$. The difference in generic yield, CDS, and bid-ask of country *i* at time *t* and that of Germany at time *t* is taken to calculate the spreads used in this regression. The natural logarithm is taken for the credit and liquidity measure. Yields are used to create stress quintiles. A significance level of 0.01 is denoted as ***, 0.05 as **, and 0.10 as *. White standard errors are denoted in parentheses. 416 observations are used per quintile.

Table 8

Credit and liquidity risk when controlling for market stress

Panel A: without controlling

	sovereign yield spread									
	Austria	**Belgium**	**Finland**	**France**	**Netherlands**	**Greece**	**Ireland**	**Italy**	**Portugal**	**Spain**
Constant	-0.023***	-1.550***	0.082***	0.044***	0.115***	-20.950***	-8.255***	-5.875***	-9.522***	-5.986***
	(0.006)	(0.015)	(0.009)	(0.006)	(0.008)	(0.505)	(0.166)	(0.117)	(0.197)	(0.100)
Credit risk	**0.164*** **	0.603***	**0.082*** **	0.135***	**0.085*** **	**4.667*** **	**2.261*** **	**1.596*** **	**2.511*** **	**1.651*** **
	(0.006)	0.015	(0.003)	(0.006)	(0.004)	(0.089)	(0,348)	(0.024)	(0.040)	(0.022)
Adj. R^2	0.432	0.610	0.316	0.233	0.299	0.631	0.784	0.774	0.703	0.803

Panel B: with controlling

	sovereign yield spread									
	Austria	**Belgium**	**Finland**	**France**	**Netherlands**	**Greece**	**Ireland**	**Italy**	**Portugal**	**Spain**
Constant	0.005	-1.860***	0.082***	-0.209***	0.154***	-13.288***	-5.099***	-3.594***	-5.315***	-5.172***
	(0.008)	(0.075)	(0.003)	(0.043)	(0.008)	(0.292)	(0.138)	(0.081)	(0.111)	(0.108)
Credit risk	0.147***	**0.675*** **	0.051***	**0.220*** **	0.057***	3.196***	1.509***	1.089***	1.564***	1.464***
	(0.023)	(0.019)	(0.010)	(0.012)	(0.004)	(0.053)	(0.032)	(0.018)	(0.025)	(0.025)
Adj. R^2	0.317	0.607	0.183	0.379	0.193	0.782	0.743	0.572	0.678	0.765

Notes: This table reports the outcomes of the regression: $Y_{i,t} - Y_{GER,t} = \alpha + \beta_i\ (CDS_{i,t} - CDS_{GER,t}) + \varepsilon_{i,t}$ for Panel A and Panel B. The difference in generic yield, CDS, and bid-ask of country *i* at time *t* and that of Germany at time *t* is taken to calculate the spreads used in this regression. The natural logarithm is taken for the credit and liquidity measure. A significance level of 0.01 is denoted as *** and White standard errors are denoted in parentheses. 2079 observations are used per country for Panel A and 1663 for Panel B.

Table 8 points out results from the regression analysis of sovereign yield spread on credit risk for the full sample (Panel A), and whilst controlling for the 20% highest yield (Panel B). In eight out of ten cases, controlling for high yield does not increase the sensitivity of the credit risk variable to the sovereign yield spread. Moreover, the adjusted R^2 does not improve in nine out of ten cases. This means that the explanatory value of credit risk on the sovereign yield spread does not improve when controlling for periods of high yield, resulting in the rejection of Hypothesis 5.

CHAPTER 6 Robustness Checks

As a robustness check, volume is used as a measure of liquidity risk instead of bid-ask, which was used in earlier chapters. Table 2 displays the summary statistics showing high values for volume. As opposed to bid-ask, volume has lower values in the highest quintile (Panel A) than the lowest quintile (Panel B). However, a low volume means high liquidity risk, while low bid-ask means low liquidity risk. This means that liquidity risk is higher in periods of high stress according to the volume measure, which is in agreement with the findings on bid-ask. The credit default swap is higher in the highest quintile and, consequently, in periods of high stress. Despite these outcomes, Table 2 only provides preliminary information. No conclusions can be drawn with respect to the hypotheses.

Table 9

Summary statistics on CDS and volume for the lowest and highest yield quintile

Panel A: Highest quintile

	credit default swap					volume				
Variable	**Mean**	**Median**	**Std. dev.**	**Min.**	**Max.**	**Mean**	**Median**	**Std. dev.**	**Min.**	**Max.**
Germany	25.953	24.790	17.294	7.600	70.895	2.10E+07	2.21E+07	4.83E+06	5.00E+06	3.08E+07
Austria	73.728	68.500	63.282	10.500	260.140	3.22E+07	3.16E+07	8.40E+06	5.00E+06	5.77E+07
Belgium	132.526	142.250	102.364	21.200	400.000	4.50E+07	4.50E+07	1.83E+07	1.19E+07	9.18E+07
Finland	33.313	28.390	21.771	9.900	94.150	2.87E+07	2.56E+07	1.02E+07	1.32E+07	6.44E+07
France	38.941	27.795	36.568	9.600	260.330	2.64E+07	2.63E+07	7.08E+06	1.27E+07	4.54E+07
Netherlands	43.028	33.500	34.541	9.600	126.330	3.74E+07	3.63E+07	7.33E+06	1.84E+07	6.67E+07
Greece	2320.324	2500.000	412.176	935.410	2500.000	3.50E+06	2.11E+06	2.64E+06	2.00E+06	1.40E+07
Ireland	550.783	539.020	81.009	371.260	952.770	2.67E+07	2.49E+07	9.20E+06	7.51E+06	5.78E+07
Italy	364.890	405.520	144.337	35.000	566.195	5.16E+07	5.16E+07	1.47E+07	1.81E+07	1.03E+08
Portugal	737.464	778.130	156.228	423.480	1161.100	2.13E+07	2.04E+07	4.49E+06	1.31E+07	3.69E+07
Spain	371.442	362.280	92.432	208.440	570.510	4.09E+07	4.01E+07	7.60E+06	1.84E+07	6.11E+07

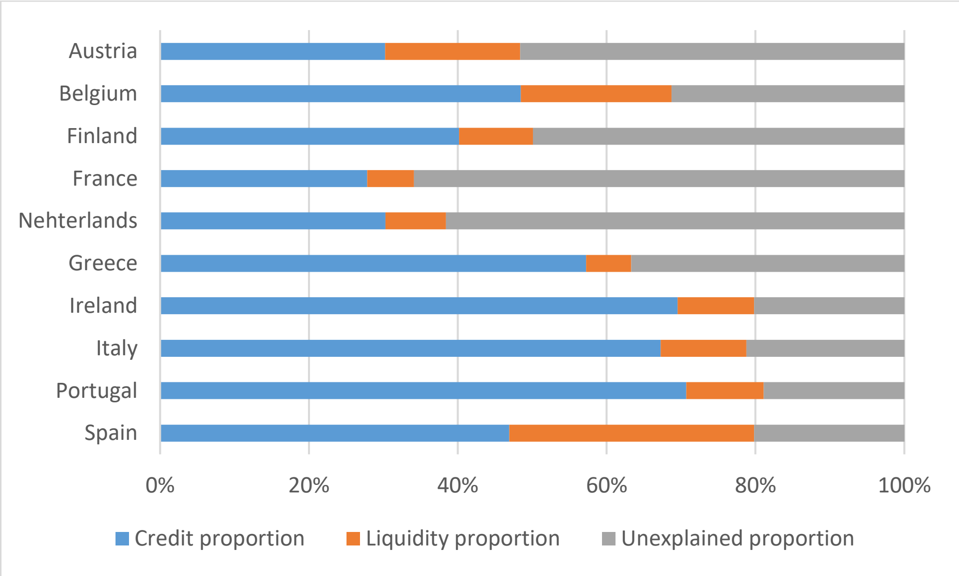
Panel B: Lowest quintile

	credit default swap					volume				
Variable	**Mean**	**Median**	**Std. dev.**	**Min.**	**Max.**	**Mean**	**Median**	**Std. dev.**	**Min.**	**Max.**
Germany	41.834	38.375	15.378	30.500	137.510	3.29E+07	3.32E+07	4.44E+06	1.76E+07	4.50E+07
Austria	52.526	51.000	5.777	40.720	77.025	3.23E+07	3.17E+07	3.88E+06	2.23E+07	4.66E+07
Belgium	82.225	81.010	6.556	66.845	170.010	8.13E+07	8.16E+07	8.85E+06	4,05E+07	1.03E+08
Finland	48.480	49.000	2.826	39.920	63.105	7.16E+07	7.19E+07	8.55E+07	3.81E+07	1.00E+08
France	79.428	78.010	13.542	37.470	131.295	3.45E+07	3.35E+07	4.87E+06	1.91E+07	5.31E+07
Netherlands	46.303	43.000	10.421	32.500	95.000	5.42E+07	5.27E+07	1.09E+07	3.67E+07	1.08E+08
Greece	111.294	109.550	58.160	41.800	261.700	3.46E+07	3.30E+07	1.03E+07	9.32E+06	6.73E+07
Ireland	94.027	95.000	7.254	75.665	115.820	6.67E+07	6.37E+07	1.49E+07	3.16E+07	1.15E+08
Italy	169.357	165.000	21.054	133.970	235.060	7.82E+07	8.02E+07	1.45E+07	1.22E+07	1.08E+08
Portugal	235.373	234.000	28.030	173.715	308.330	6.59E+07	6.26E+07	3.33E+07	1.00E+07	1.55E+08
Spain	137.830	138.000	15.740	97.005	176.990	5.75E+07	5.67E+07	8.17E+06	2.40E+07	9.03E+07

Notes: This table reports a comparison of both credit default swap and the volume between periods of high yield and periods of low yield. High yield is classified as the 20% highest yield and low yield as the 20% lowest yield. Both are based on a daily sample of eight years generating 2079 observations per country.

The proportions of the contributions from the credit default swap spread (credit proportion) and the volume spread (liquidity proportion) on the sovereign yield spread are shown in Figure 6. The proportion of the volume spread is comparable to the bid-ask spread in Figure 4 liquidity measure. Nonetheless, the volume spread proportion is slightly smaller for all countries. Based on Figure 6, four peripheral countries (Greece, Ireland, Italy, and Portugal) are in line with the results of Longstaff et al. (2005), displaying a credit proportion of more than 50%. The blue bar, representing the credit proportion, is bigger than the orange bar for all countries. Based on this observation, credit risk dominates liquidity risk in explaining the sovereign yield spread. Therefore, Hypothesis 2 can be accepted. This result is in line with the findings in the Empirical Result Chapter.

Figure 6
Robustness check on the explanatory proportions



Notes: This figure shows the cross-sectional proportion of credit risk and liquidity risk on the sovereign yield spread. The proportions are calculated by the following formulas: $Credit\ proportion_i = \frac{|credit\ contribution_i|}{|credit\ contribution_i|+|liquidity\ contribution_i|} * R^2$ and $Liquidity\ proportion_i = \frac{|liquidity\ contribution_i|}{|credit\ contribution_i|+|liquidity\ contribution_i|} * R^2$. When adding the three to 100%, the remaining part is the $Unexplained\ proportion_i$.

Table 10
Robustness check on the likelihood ratio test

Date	Austria	Belgium	Finland	France	Netherlands	Greece	Ireland	Italy	Portugal	Spain
2008	0.12 (0,733)	54.31 (0.000)	0.04 (0.047)	13.10 (0.000)	1.24 (0.265)	0.08 (0.771)	59.41 (0.000)	12.53 (0.000)	82.08 (0.000)	16.48 (0.000)
2009	5.21 (0.022)	122.09 (0.000)	9.24 (0.002)	2.45 (0.117)	23.25 (0.000)	0.01 (0.941)	4.64 (0.031)	62.28 (0.000)	168.04 (0.000)	162.90 (0.000)
2010	0.80 (0.370)	42.49 (0.000)	5.04 (0.025)	6.84 (0.009)	0.20 (0.656)	10.50 (0.001)	5.52 (0.019)	7.94 (0.048)	2.82 (0.093)	4.12 (0.042)
2011	41.70 (0.000)	2.85 (0.009)	55.14 (0.000)	0.00 (0.975)	17.82 (0.000)	9.54 (0.000)	11.80 (0.001)	4.24 (0.040)	30.04 (0.000)	24.11 (0.000)
2012	15.63 (0.000)	25.03 (0.000)	29.72 (0.035)	5.42 (0.020)	5.84 (0.016)	18.81 (0.000)	0.04 (0.850)	2.24 (0.135)	0.46 (0.498)	120.85 (0.000)
2013	6.23 (0.013)	4.26 (0.039)	2.92 (0.088)	4.88 (0.027)	1.10 (0.295)	0.01 (0.905)	25.33 (0.000)	48.52 (0.000)	0.10 (0.755)	6.67 (0.010)
2014	30.20 (0.000)	17.50 (0.000)	12.46 (0.000)	2.46 (0.116)	89.41 (0.000)	3.83 (0.050)	54.63 (0.000)	75.07 (0.000)	0.41 (0.522)	10.92 (0.001)
2015	0.11 (0.745)	1.64 (0.200)	31.19 (0.000)	0.07 (0.798)	0.03 (0.864)	25.96 (0.000)	41.47 (0.000)	55.38 (0.000)	31.92 (0.000)	0.18 (0.669)

Notes: This table presents the chi-squares from the likelihood ratio test of the following models: $Y_{i,t} - Y_{GER,t} = \alpha + \beta_i (CDS_{i,t} - CDS_{GER,t}) + \varepsilon_{i,t}$ & $Y_{i,t} - Y_{GER,t} = \alpha + \beta_i (CDS_{i,t} - CDS_{GER,t}) + \delta_i (LIQ_{i,t} - LIQ_{GER,t}) + \varepsilon_{i,t}$. The former is nested in the latter, giving one degree of freedom. The difference in generic yield, CDS, and volume of country *i* at time *t* and that of Germany at time *t* is taken to calculate the spreads used in this regression. P-values are denoted in parentheses. 260 observations are used per year.

Table 10 shows the likelihood ratio test denoting the added value of the volume spread (liquidity risk) on the credit default swap spread (credit risk) on the sovereign yield spread. The chi-squares of the volume spread is slightly smaller than those of the bid-ask spread shown in Table 6, indicating a lower added value to the simple regression. Nevertheless, every country has both significant and insignificant chi-squares. These outcomes suggest time variation in the importance of liquidity risk relative to credit risk. In correspondence with the results in Chapter 5, Hypothesis 3 can be accepted.

CHAPTER 7 Discussion

In this chapter the five hypotheses used in this paper will be discussed based on the test results of this thesis and earlier research. In addition, limitations and suggestions for further research will be mentioned here. The discussion will be structured per hypothesis, starting with Hypothesis 1:

Hypothesis 1: The positive correlation between credit risk and sovereign yield spreads drops in times of high market stress.

Hypothesis 1 indicates, the yield spread is increasing in liquidity risk by showing that at least there is a non-credit factor influencing the yield spread in times of high market stress. However, the outcomes show that credit risk increases in times of high market stress. The hypothesis is therefore rejected. While Beber et al. (2009) found a flight to liquidity in times of market uncertainty, credit risk still plays an important role. Nonetheless, still a significant non-credit factor could be found. The summary statistics show that credit and liquidity risk are positively correlated. It can therefore still be true that the correlation between liquidity risk and the sovereign yield spread increases, as well, in times of high market stress. This, however, is captured by Hypothesis 4.

The rejection of Hypothesis 1 confirms the findings of Merton (1974), who concluded that there is a positive correlation between credit risk and the yield spread. This positive correlation underlines the importance of credit risk in explaining the sovereign yield spread on which the following hypothesis is based.

Hypothesis 2: Credit risk always dominates liquidity risk in explaining the sovereign yield spread.

Hypothesis 2 is accepted based on the fact that higher credit risk makes a higher contribution to explaining the sovereign yield spread for all ten countries. Especially in peripheral countries the credit component is high which could be due to the effect of country-specific bank exposure on sovereign risk, as Podstawski and Velinov (2018) suggested. Besides, banks are usually the protection sellers in a CDS agreement, generating counterparty risk when selling the CDS. This is a limitation of the credit risk measure used in this thesis. As a mitigation, Rodrigues et al. (2018)

found CDS spreads could predict the European sovereign debt crisis, while credit rating had no predicting power at all.

The domination of credit risk in explaining the sovereign yield spread supports work of Lemmen and Goodhart (1999) as well as Longstaff et al. (2005), who both showed the importance of credit risk earlier on. This thesis, however, also shows the significant importance of liquidity risk in especially the boom period, while credit risk is relatively more important in the bust period. Because of this shift in importance, regulators should focus less on liquidity instruments and more on solvency instruments, such as financial leverage. The findings also denote an unexplained proportion based on R^2. The unexplained proportion leaves an interesting topic for further research. Possibilities are risk aversion as mentioned by Dungey et al. (2000) or contagion as mentioned by De Santis (2012).

Another addition for further research would be to use the limit order book slope (LOS) as a measure for liquidity risk. Wuyts (2008) found this to be a superior measure to bid-ask and volume, because it combines the two measures. Such a measure would give a higher quality of liquidity measuring as he finds the LOS-measure to be significantly better than the other two measures. In addition, different maturities can be used in the decomposition used to answer Hypothesis 2. Ericsson and Renault (2006) found a downward-sloping term structure of liquidity spreads. Whether this influences the decomposition can be sought out.

Hypothesis 3: There is a time variation in the significance of the importance of liquidity risk relative to credit risk.

Based on the likelihood ratio test, Hypothesis 3 is accepted. The likelihood ratio test tests if liquidity risk adds significant value to the regression of credit risk on the sovereign yield spread per year. Because every country has significant and insignificant chi-squares, there is time variation in the significance of the importance of liquidity risk relative to credit risk. This finding supports work of Longstaff et al. (2005), who found significant time variation in the non-default component of the yield spread. It is also important in explaining why Duffie et al. (2003) found a significant variation in yield spreads. Hence, it can be concluded that liquidity risk explains at least a part of the variation in the yield spread over time.

Hypothesis 4: The role of liquidity risk increases in times of market stress relative to credit risk.

Hypothesis 4 is rejected based on the yield quintiles approach in this thesis. Even so, the approach of comparing the highest and lowest yield quintile is a unique addition to the literature on this topic. The approach is for example completely different than the fund flow approach of Beber et al. (2009).Whilst investigating Hypothesis 1, an important role for credit risk can be observed in times of high market stress. As such, the rejection of Hypothesis 4 does not come as a complete surprise. Nevertheless, many significant liquidity factors are found. Especially in the boom period, liquidity risk plays an important role compared to credit risk. While the rejection of Hypothesis 1 suggests a more important role for credit risk in times of high market stress, the results of Hypothesis 4 do not do so for liquidity risk. Moreover, the stress level does not seem to influence the effect from liquidity risk on the sovereign yield spread at all.

In further research, more observations could be used to increase the significance of the results. By collecting high frequency CDS and yield data, the data can be aggregated to a higher frequency than the daily level in this research. A technique such as the Nelson-Siegel structure can be used as it parsimoniously model yield curves to match times to maturity at a high frequency (Nelson and Siegel, 1987).

Hypothesis 5: By controlling for the quintile of greatest market stress, the explanatory value of credit risk on sovereign yield spreads increases.

In line with the results from Hypothesis 1, Hypothesis 5 needs to be rejected, too. As can be seen in the correlations from Hypothesis 1, the positive correlation between credit risk and the sovereign yield spread increases in times of high market stress. Based on this finding, controlling for the quintile of greatest market stress would result in a decrease in the explanatory value of credit risk on sovereign yield spreads. The outcomes from Hypothesis 5 indeed show a decrease in this explanatory value after controlling.

CHAPTER 8 Conclusions

This thesis examines the relative importance of liquidity risk compared to credit risk for euro area sovereign yield spreads in different time periods as the main question. By using R^2 in the decomposition and comparing different yield quintiles as a proxy for market stress, this thesis contributes to earlier research on this topic, such as Buis et al. (2018) and Beber et al. (2009). While the findings show that both liquidity and credit risk are increasing in periods of high market stress, no significant difference in the relative importance of liquidity risk compared to credit risk can be found for different stress levels. Disentangling credit risk and liquidity risk is difficult because they move together very tightly. The correlation between them is positive in all countries observed.

Even though credit risk dominates liquidity risk in all ten countries examined, liquidity risk has a significant explanatory value on the sovereign yield spread. This significance supports Favero et al. (2010) in the discussion within the literature about liquidity risk. Especially in the boom period liquidity risk is relatively high. Credit risk takes a more important role in the bust period of the crisis compared to liquidity risk. From a policy perspective, this means regulators such as bank supervisors should focus less on liquidity instruments. More important is the credit risk that follows liquidity risk. Therefore, solvency instruments would be a better choice when the crisis passed its peak.

The importance of liquidity risk is thus smaller than credit risk when explaining the euro area sovereign yield spread over time. Especially in peripheral countries credit risk is high, giving relatively less important role to liquidity risk compared to credit risk. Because credit and liquidity risk show the same patterns over time, they are arduous to unravel. Nonetheless, time variation can be observed in the relative importance of the two, supporting earlier research (e.g. Longstaff et al., 2005). As such, liquidity risk is more important in a boom period than in a bust period. No changes in the relative importance of liquidity risk relative to credit risk could be found based on the comparison of the highest and the lowest quintile (e.g. market stress). Both risks increase with similar proportions in times of high market stress.

REFERENCES

Abad, P., Chulia, H., & Gomez-Puig, M. (2010). EMU and European government bond market integration. *Journal of Banking & Finance (34) 12*, 2851-2860.

Acharya, V. V., & Pederson, L. H. (2005). Asset pricing with liquidity risk. *Journal of Financial Economics 77 (2)*, 375-410.

Beber, A., Brandt, M. W., & Kavajecz, K. A. (2009). Flight-to-quality or flight-to-liquidity? Evidence from the euro-area bond market. *Review of Financial Studies 22 (3)*, 925-957.

Bernoth, K., Von Hagen, J., & Schukecht, L. (2012). Sovereign risk premium in the European Sovereign Bond Market. *Journal of Inernatonal Money and Finance 31 (5)*, 975-995.

Buis, B., Pieterse-Bloem, M. A., Verschoor, W. F., & Zwinkels, R. (2018). Expected Issuance Fees and Market Liquidity. *SSRN Working Paper No. 508*.

Codogno, L., Favero, C., & Missale, A. (2003). Yield spreads on EMU government bonds. *Economic Policy 37 (1)*, 503-532.

De Santis, R. (2012). The Euro area sovereign debt crisis: save haven, credit rating agencies and the spread of the fever from Greece, Ireland and Portugal. *SSRN ECB Working Paper No. 1419*.

Duffie, D., Pedersen, L., & Singleton, K. (2003). Modeling sovereign yield spreads: A case study of Russian debt. *The Journal of Finance 58 (1)*, 119-159.

Dungey, M., Martin, V., & Pagan, A. (2000). A multivariant latent factor decomposition of international bond yield spreads. *Jounnal of Applied Econmetrics 15 (6)*, 697-715.

Ericsson, J., & Renault, O. (2006). Liquidity and credit risk. *Journal of Finance 61 (5)*, 2219-2250.

Favero, C., Pagano, M., & Von Thadden, E. (2010). How does liquidity affect government bond yields? *Journal of Financial and Quantitative Analysis 45 (1)*, 107-134.

Fischer, C., & Dotz, N. (2010). What can EMU countries' sovereign bond spreads tell us about market perception of default probabilities during the recent financial crisis. *Deutsche Bundesbank Discussion Paper No. 11/2010*.

Galati, G., & Tsatsaronis, K. (2003). The impact of the euro on Europe's financial markets. *Financial Markets, Institutions and Instruments 12 (3)*, 165-222.

Karaniolos, M., Mladovsky, P., Cylus, J., Thomson, S., Basu, S., Stuckler, D., . . . McKee, M. (2013). Financial crisis, Austerity, and health in Europe. *The Lancet 381 (9874)*, 1323-1331.

Lemmen, J., & Goodhart, C. (1999). Credit risk and european goverment bond markets: a panel data econometric analysis. *Eastern Economic Review 25 (1)*, 77-107.

Longstaff, F. (2009). Portfolio claustrophobia: asset pricing in markets with illiquid assets. *American Economic Review 99 (4)*, 1119-1144.

Longstaff, F., Mithal, S., & Neis, E. (2005). Corporate yield spreads: default risk or liquidity? New evidence from the credit default swap market. *The Journal of Finance 60 (5)*, 2213-2253.

Manganelli, S., & Wolswijk, G. (2009). What drives spreads in the Euro area governement bond market? *Economic Policy 24 (58)*, 191-240.

Merton, R. C. (1974). On The Pricing Of Corporate Debt: The Risk Structure Of Interest Rates. *The Journal of Finance 29 (2)*, 449-470.

Nelson, C., & Siegel, A. (1987). Parsimonious modeling of yield curves. *The Journal of Business 60 (4)*, 473-478.

Pellizzon, L., Subrahmanyam, M., Tomio, D., & Uno, J. (2013). The microstructure of the European sovereign bond market: A study of the Euro-zone crisis. *Working Paper New York University No. 113*.

Pieterse-Bloem, M., Qian, Z., Verschoor, W., & Zwinkels, R. (2016). Time-varying importance of country and industry factors in European corporate bonds. *Journal of Empirical Finance 38 (A)*, 429-448.

Podstawski, M., & Velinov, A. (2018). The state dependant impact of bank exposure on sovereign risk. *Journal of Banking and Finance 88 (1)*, 63-75.

Rodriquez, I., Dandapani, K., & Lawrence, E. (2018). Measuring sovereign risk: Are CDS spreads better than sovereign credit ratings? *Financial Management 48 (1)*, 229-256.

Wuyts, G. (2008). The impact of liquidity shocks through the limit order book. *CFS Working Paper No. 53*.

Xiong, J. X., Ibbotson, R. G., Idzorek, T. M., & Chen, P. (2010). The equal importance of asset allocation and active management. *Financial Analysts Journal 66 (2)*, 22-30.

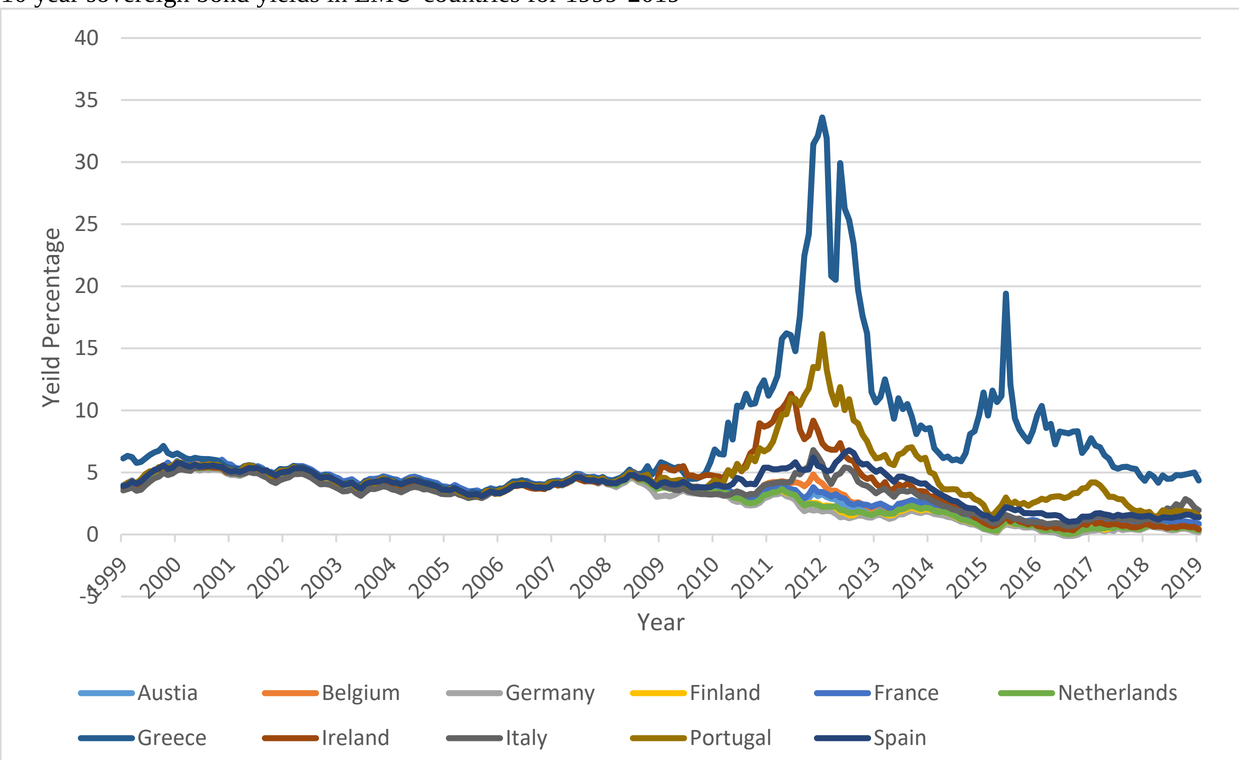
APPENDIX

Table 11
Data summary

Variable name	Proxy	Source	Database	Frequency
Yield spread	Sovereign yields	Markit	Bloomberg	daily
Credit risk	CDS and credit ratings	Ice Norge, S&P, Fitch and Moody	Bloomberg	daily
Liquidity risk	Bid-ask spread and price volume	MTS Markets	MTS Platform	daily
Issue size	-	Markit	Bloomberg	daily
Years to maturity	-	Markit	Bloomberg	daily

Notes: This table presents the proxy, source, database and frequency used for the different variables used in this paper. The table can be used for relevant proxies for further research. It also points to independent data sources with high quality and high frequency.

Figure 7
10 year sovereign bond yields in EMU-countries for 1999-2019



Notes: This figure shows the evolution of the 10 year sovereign bond yields for the 11 EMU-countries this paper looks at. It is the same data used for Figure 2, only this figure is zoomed out to the period 1999-2019. This shows that the yield spread is nearly always zero except for the sample period chosen for this paper.

Table 12

Summary statistics on sovereign yield spreads for different yield quintiles

Panel A: Highest quintile

	sovereign yield spread				
Variable	**Mean**	**Median**	**Std. dev.**	**Min.**	**Max.**
Germany	3.773	3.760	0.420	3.235	4.681
Austria	4.243	4.200	0.277	3.725	4.921
Belgium	4.346	4.286	0.284	3.615	5.814
Finland	4.074	4.043	0.309	3.585	4.863
France	4.042	3.996	0.352	3.609	4.844
Netherlands	4.096	4.045	0.323	3.523	4.856
Greece	22.770	22.287	5.721	14.727	33.702
Ireland	9.169	9.058	1.287	7.224	13.786
Italy	5.608	5.571	0.601	4.876	7.244
Portugal	10.844	10.885	1.557	7.964	16.605
Spain	5.791	5.601	0.506	5.178	7.566

Panel B: Lowest quintile

	sovereign yield spread				
Variable	**Mean**	**Median**	**Std. dev.**	**Min.**	**Max.**
Germany	0.603	0.665	0.287	0.074	1.243
Austria	0.908	0.904	0.345	0.195	1.595
Belgium	1.029	0.972	0.356	0.340	1.966
Finland	0.824	0.850	0.319	0.139	1.468
France	1.035	0.989	0.339	0.351	1.754
Netherlands	0.863	0.831	0.333	0.223	1.584
Greece	4.825	4.846	0.309	4.215	5.362
Ireland	1.431	1.298	0.458	0.647	2.604
Italy	1.991	1.892	0.473	1.125	2.945
Portugal	2.728	2.654	0.524	1.546	3.672
Spain	1.939	1.935	0.410	1.141	2.859

Notes: This table reports a comparison of sovereign yield spreads between periods of high yield and periods of low yield. High yield is classified as the 20% highest yield and low yield as the 20% lowest yield. Both are based on a daily sample of eight years generating 2079 observations per country.

Table 13
10 year credit default swaps and the CDS spreads per country from 2008-2015

Panel A: Core countries

	CDS					Benchmark	CDS spread				
Date	**Austria**	**Belgium**	**Finland**	**France**	**Netherlands**	**Germany**	**Austria**	**Belgium**	**Finland**	**France**	**Netherlands**
2008	39.848	40.039	24.364	25.092	28.131	19.012	20.835	21.027	5.352	6.080	9.119
2009	108.129	67.561	39.528	42.881	56.621	39.176	68.953	28.385	0.352	3.705	17.445
2010	85.508	118.600	35.912	80.567	52.081	48.378	37.130	70.222	-12.466	32.189	3.703
2011	128.827	218.379	66.164	151.150	85.254	87.371	41.456	131.008	-21.207	63.779	-2.117
2012	150.828	206.041	81.137	187.481	114.121	101.734	49.094	104.306	-20.597	85.747	12.387
2013	70.289	110.375	48.412	123.977	85.184	64.886	5.403	45.488	-16.474	59.091	20.298
2014	63.015	86.370	47.927	90.793	59.733	44.583	18.432	41.787	3.343	46.210	15.149
2015	50.164	80.593	47.478	73.799	40.464	37.018	13.145	43.575	10.460	36.780	3.446

Panel B: Peripheral countries

	CDS					Benchmark	CDS spread				
Date	**Greece**	**Ireland**	**Italy**	**Portugal**	**Spain**	**Germany**	**Greece**	**Ireland**	**Italy**	**Portugal**	**Spain**
2008	93.247	66.442	72.805	58.604	58.444	19.012	74.235	47.430	53.793	39.592	39.431
2009	174.189	195.561	109.458	82.686	96.353	39.176	135.013	156.385	70.282	43.510	57.177
2010	595.296	287.790	171.706	276.253	207.494	48.378	546.918	239.412	123.328	227.875	159.116
2011	1631.131	568.861	305.700	674.031	313.190	87.371	1543.760	481.490	218.329	586.659	225.818
2012	2500.000	436.556	398.588	688.854	419.492	101.734	2398.266	334.822	296.853	587.120	317.757
2013	1529.807	198.787	278.079	439.514	269.234	64.886	1464.921	133.901	213.193	374.628	204.348
2014	593.962	110.706	182.543	261.061	144.148	44.583	549.378	66.123	137.960	216.478	99.565
2015	1416.451	92.385	165.727	230.604	141.717	37.018	1379.433	55.367	128.708	193.585	104.699

Notes: This table reports the CDS spread as a measure for credit risk. The CDS spread is calculated with Germany as benchmark as represented by the formula in the Methodology: $(CDS_{i.t} - CDS_{GER.t})$. The CDS's in this table are aggregated to a yearly level by taking the average of the end of trading day observations of CDS. A sample is used consisting of 2079 observations per country (e.g. daily level for 8 years).

Table 14
10 year bid-asks and the bid-ask spreads per country from 2008-2015

Panel A: Core countries

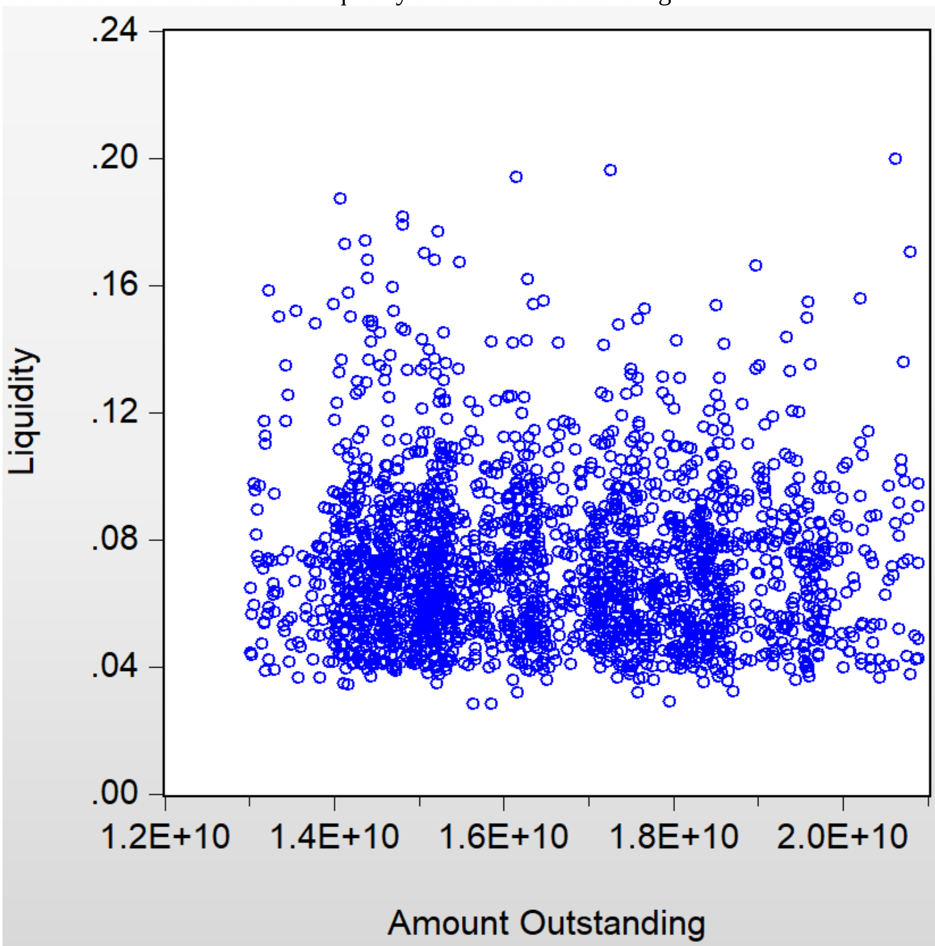
	bid-ask					Benchmark	bid-ask spread				
Date	**Austria**	**Belgium**	**Finland**	**France**	**Netherlands**	**Germany**	**Austria**	**Belgium**	**Finland**	**France**	**Netherlands**
2008	0.323	0.206	0.262	0.224	0.148	0.058	0.265	0.149	0.205	0.166	0.091
2009	0.447	0.138	0.264	0.134	0.154	0.083	0.364	0.056	0.181	0.051	0.071
2010	0.305	0.193	0.103	0.104	0.101	0.085	0.220	0.108	0.019	0.020	0.016
2011	0.350	0.393	0.252	0.175	0.134	0.087	0.263	0.306	0.166	0.088	0.047
2012	0.304	0.186	0.145	0.139	0.140	0.082	0.223	0.104	0.064	0.058	0.059
2013	0.114	0.067	0.070	0.067	0.054	0.054	0.060	0.013	0.015	0.013	-0.001
2014	0.088	0.045	0.053	0.056	0.047	0.058	0.030	-0.014	-0.005	-0.002	-0.011
2015	0.089	0.074	0.063	0.056	0.037	0.076	0.014	-0.001	-0.013	-0.020	-0.038

Panel B: Peripheral countries

	bid-ask					Benchmark	bid-ask spread				
Date	**Greece**	**Ireland**	**Italy**	**Portugal**	**Spain**	**Germany**	**Greece**	**Ireland**	**Italy**	**Portugal**	**Spain**
2008	0.325	0.491	0.232	0.346	0.215	0.058	0.268	0.434	0.174	0.288	0.157
2009	0.436	0.416	0.191	0.313	0.237	0.083	0.354	0.333	0.108	0.230	0.154
2010	1.117	0.977	0.161	1.339	0.288	0.085	1.033	0.892	0.077	1.254	0.203
2011	1.629	2.758	0.412	3.674	0.489	0.087	1.542	2.672	0.326	3.587	0.402
2012	1.436	2.764	0.294	5.052	0.603	0.082	1.354	2.683	0.212	4.970	0.521
2013	1.078	0.547	0.108	1.342	0.302	0.054	1.024	0.493	0.053	1.288	0.247
2014	0.746	0.258	0.075	0.464	0.205	0.058	0.688	0.200	0.017	0.406	0.147
2015	1.070	0.227	0.131	0.315	0.186	0.076	0.994	0.152	0.056	0.240	0.111

Notes: This table reports the bid-ask spread as a measure for liquidity risk. The bid-ask spread is calculated with Germany as benchmark as represented by the formula in the Methodology: $(\text{LIQ}_{i.t} - LIQ_{GER.t})$. The bid-asks in this table are aggregated to a yearly level by taking the average of the equally-weighted observations of bid-ask. A sample is used consisting of 2079 observations per country (e.g. a daily level for 8 years).

Figure 8
Correlation between German liquidity and amount outstanding



Notes: This figure shows the amount outstanding of the 10 year sovereign bonds for Germany. It is meant to show there are no outliers with respect to amount outstanding and liquidity, indicating an equally-weighted liquidity measure would contain no biases.