Default Risk of Treasury Securities

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Abstract

The short-term paper-bill spread is studied and emphasis is put on default risk premia exclusively. An event study analysis is conducted and enhanced by independent quantitative methods. The U.S. money market is exhaustively analyzed throughout the recent global financial crisis. An extension of previous research shows how the market treats Treasury securities in severe times. Empirical results support the hypothesis of embedded default risk, albeit an anomalous "*flight to quality*" behaviour is evident in later stages of the crisis.

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Chapter 1

Introduction

My interest in what is believed to be safe investments amplified when financial turmoil broke out during the recent global financial crisis. The effects of the ubiquitous crisis are still substantial as the aftermath has been deeply rooted. The consequences of the crisis have raised some questions whether a risk-free asset actually exists. The importance of a risk-free benchmark is nevertheless not to be disregarded. Some widely renowned financial models presume the existence of a risk-free asset.

Remarkable amounts of incurred debt have raised concerns over possible defaults of troubled countries like Greece and the United States among others. If judicious actions are not enough to reverse the debt growth, printing new money or perhaps writing off debts may be the only solutions left. Figure 1.1 shows, for instance, how the total U.S. debt has escalated during the recent financial crisis.[1] A clear upward-sloping pattern has become even steeper with a distinct change during the crisis. This example also shows how the U.S. debt ceiling, which is enacted into American law, had to be raised alongside the adjacent debt, whereby an imminent default was outmanoeuvred for the time being. Incremental increases in the debt ceiling have been steady until 2008, after which increases have become more frequent and significant to cope with the rapid debt growth. Hikes in the debt ceiling, however, should not be taken for granted and the U.S. has, de facto, been close to overdraw its debt limit. Such an incident could lead to a sovereign default of the country. Meanwhile, the gross domestic product (GDP) has not had the same growth. Throughout the financial crisis the debt ceiling was raised by \$6.2 trillion from \$9.0 trillion at the beginning of 2007 to \$15.2 trillion at the end of 2011, corresponding to a total increase of 69 percent. This increase was driven by a 75 percent increase in the total public debt during the same period, according to data reported by the Council of Economic Advisers (CEA) (2012). Correspondingly, the debt-to-GDP ratio

[1] Amounts of the U.S. debt and increases in the U.S. debt ceiling as reported by Austin and Levit (2012).

rose from 64 percent to 97 percent between 2007 and 2011. The increase in total debt held by the public has been a major factor to the aggregated increase. This is also apparent in Figure 1.1. The U.S. Government has issued Treasury securities, simply known as Treasuries, as instruments to cover the debt. The Treasury securities market took a remarkable leap amid the crisis, whereby short-term Treasury securities experienced a two-folded increase in outstanding amounts, according to the CEA (2012). Short-term Treasury securities and commercial paper account for a couple of trillions of U.S. dollars in outstanding amounts and are an important part of the U.S. money market.

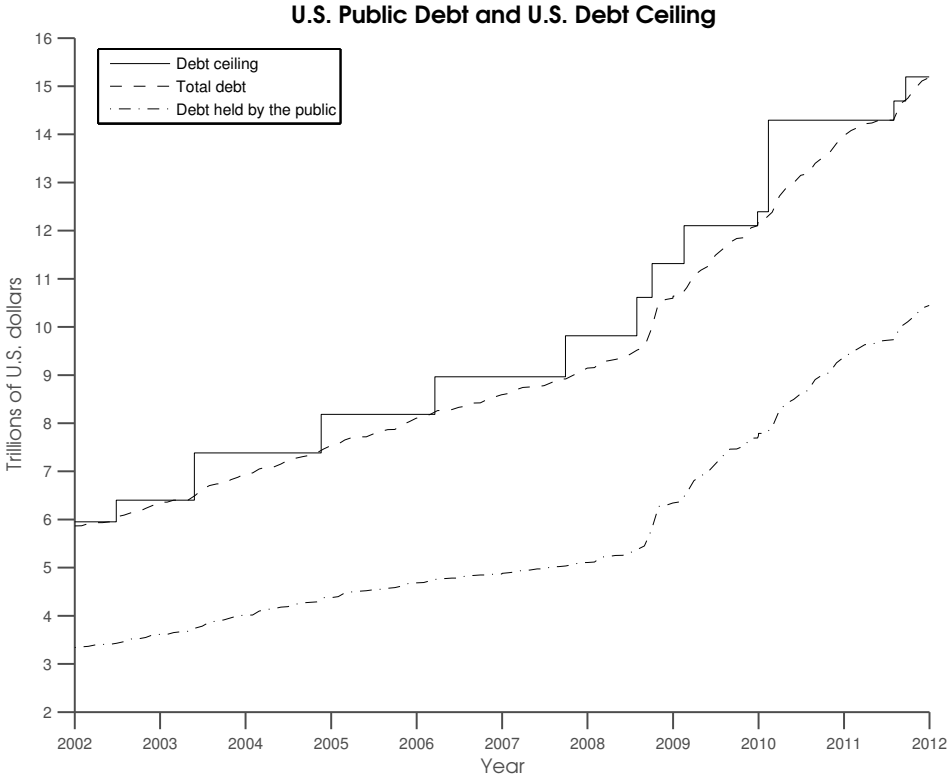

Figure 1.1: U.S. public debt, both total amounts and amounts held by the public, as well as U.S. debt limit over the past ten years.

Previous research has studied how Treasury securities have suffered from default risk exposure. Nippani et al. (2001) show that the market reacted to debt limit controversies in late 1995 and early 1996 by charging a default risk premium. That study is based upon three-month as well as six-month Treasury securities and commercial paper. Similar debt ceiling disputes reappeared a few years later. Liu et al. (2009) argue that the market once again compensated for a risk premium. The effect was however not sustained

and ceased to exist gradually. Similarly, Liu et al. (2009) use Treasury securities and commercial paper, both with three months to maturity. A recent study by Nippani and Smith (2010) finds evidence of risk premium compensation by the market due to the financial crisis. In contrast to the two earlier papers, Nippani and Smith (2010) use long-term Treasury securities with ten years to maturity together with long-term LIBOR swaps. The outline of the yield spread analysis in this thesis is in the spirit of Nippani et al. (2001) but focuses on one-month securities and is confined to the recent financial crisis.

First, the theory associated with fixed-income securities is introduced and discussed. Appropriate securities are then studied to see if any default risk is evident. The prologue to the financial crisis, as well as the crisis per se, and its repercussions are analyzed by various quantitative methods and statistical tests. Events that are believed to have the most impact on the securities, particularly in terms of default risk, are handpicked for this study. The results are finally presented and evaluated.

Chapter 2

Theoretical Framework

The size of the financial markets has become immense and this vast development has led to the emergence of new markets, assets and derivatives, all along the traditional fixed-income market that still is vital for many financial services. A theoretical framework will first be presented before light is shed on financial applications. This chapter will cover the cornerstones and principles of the financial markets by definitions and explanations. Fixed-income securities will be in focus, as will interest rates and risks associated with this type of securities. Last but not least will the fixed-income market be described and risk measurements, in particular those related to credit and default, will be prioritized.

A simple initial setup, nonetheless powerful, is to consider a financial market with two tradable assets — a *risk-free asset*, or sometimes called *riskless asset*, and a *risky asset*. A *risk-free rate* is, consequently, the rate of return of a risk-free asset. Many various financial applications use the risk-free rate as a benchmark to compare the rate of return of other investments. It is, for instance, commonly being used as discount factor and in deciding assets' risk premia. A *risk premium* is the expected difference between the return of a risky asset and the return of a benchmark, i.e. a risk-free asset. The risk-free concept is, moreover, incorporated in proverbial models like the capital asset pricing model, the arbitrage pricing theory model and the Black-Scholes option pricing model.

2.1 Risk-Free and Risky Asset

A risky asset is quite easy to identify. Any asset that bears some sort of risk or, more generally, has an uncertain cash flow, is considered to be risky. Identifying a risk-free asset, by contrast, might not be that easy because of the various types of risks that exist. What does risk-free mean? I will try to answer that question and later on give a short mathematical deduction.[1]

[1] See Björk (2009) for a more thorough disentanglement of the topic.

First, lets define the dynamics of a risk-free asset.

Definition 2.1 (Risk-Free Asset)**.** *A value process V(t) is the value of a risk-free asset if it has the dynamics*

$$dV(t) = r(t)V(t)dt \tag{2.1}$$

for any adapted function r(t).

Solving the differential equation (2.1) gives the value

$$V(t) = V(s)e^{\int_s^t r(s)ds} \tag{2.2}$$

at time $t \geq s$. By assuming that the interest rate is a deterministic constant, the solution can be written on closed-form

$$V(t) = V(s)e^{r(t-s)} \tag{2.3}$$

and, as we will see, give a clearer interpretation.

2.2 Interest Rates

A bank account is often considered to be a safe money deposit, at least when a central bank is guaranteeing bank deposits up to a given amount. Such explicit deposit insurance is stated by a central bank in order to prevent panic among the public, which in turn may lead to a bank run, and restrain withdrawals.

For a better understanding of how a risk-free asset can be interpreted, it is convenient to explain how a deposit, e.g. a bank account, and an interest rate are tied together. Money at a bank account B changes at a fixed annual interest rate r from a principal amount at time $t = s$ to a terminal amount at time $t \geq s$ such that

$$B(t) = B(s)(1 + \frac{r}{m})^{m(t-s)} \tag{2.4}$$

where m is the number of compounding periods per annum, also known as the compounding frequency. When $m = 1$, the rate is called *effective annual interest rate*, and the rate is additionally named *simple interest rate* for $m = \frac{1}{t-s}$. Rewriting equation (2.4) and taking continuous compounding gives

$$\begin{aligned} B(t) &= B(s)(1 + \frac{r}{m})^{m(t-s)} = B(s)\left((1 + \frac{r}{m})^{\frac{m}{r}}\right)^{r(t-s)} \\ &= B(s)\left((1 + \frac{1}{k})^{k}\right)^{r(t-s)} \to B(s)e^{r(t-s)} \text{ as } k \to \infty \end{aligned} \tag{2.5}$$

where the substitution $k = \frac{m}{r}$ has been utilized. In this case the rate is called *force of interest*, more generally known as *continuously compounded return*, which is equivalent to the interest rate defined for a risk-free asset, cf. equation (2.3). The value process of a continuously compounded bank account is equivalent to the value process of a risk-free asset, which infers that a bank account is indeed risk-free to some extent. N.B. that no constraints are given to the fixed interest rate r and that a negative interest rate is possible, yet validating the rate being risk-free.

As mentioned earlier, deposited money at a bank account is expected to vary over time at some interest rate. A bank deposit giving a negative interest rate is exceptional and not coveted, because there is an expectation that an investment should yield a positive outcome in the future. Otherwise the investment would not be attractive, unless the future outlook is pessimistic. Such demand for a monetary compensation implies a demand for a future value that is greater than the present value. In other words, an amount of money is considered to be worth more to today than in the future and to abstain from it today means that, in the future, a greater amount of money is required in return. This is usually referred to as *intertemporal choice*.[2]

2.3 Fixed-Income Securities

A bank account is an example of how money grows on a fixed-income basis. It can, in its essence, be extended to a wider assortment of financial assets, as an asset class categorized as *fixed-income securities*. A typical fixed-income security is a *bond*.

2.3.1 Bonds and Bond Yields

A *coupon bond* is a bond that gives the holder of the security predetermined payments at some intermediary points in time between issuance date and maturity date. Given a bond's cash flow, the price of a bond is determined by the *yield to maturity*.

Definition 2.2 (Yield to Maturity)**.** *The yield to maturity of a fixed-income security is the effective annual interest rate at which all cash flows are discounted such that the nominal amount equals the price of the fixed-income security.*

Bond markets conventionally quote bonds in yields rather than prices, though prices can be expressed explicitly with yields. The price of a coupon bond is

$$P = \sum_{i=1}^{n} \frac{C_i}{(1+y)^i} \tag{2.6}$$

[2]See Chapter 10 Intertemporal Choice in Varian (2010) for further details.

where y is the yield to maturity or simply yield, and C_i is the cash flow

$$C_i = c_i + N\delta_{in} = c_i + \begin{cases} N, & \text{if } i = n \\ 0, & \text{if } i \neq n \end{cases} \tag{2.7}$$

at time i, where c is the size of a coupon payment, N is the nominal amount, and δ denotes the Kronecker delta. The difference between two bond yields is called *yield spread*.

A *zero-coupon bond* is a special case of a coupon bond since it does not provide any coupon payments, which means that $c_i = 0$ for all i. The price of a zero-coupon bond is then

$$P = \frac{N}{(1+y)^n} \tag{2.8}$$

which is equivalent to equation (2.4) when the compounding frequency is $m = 1$ and $s = 0$, which in turn means that a zero-coupon bond is a risk-free asset in the same manner as a bank account. Governments and central banks typically issue zero-coupon bonds on primary markets, for instance through auctioning. A bond issued in this way is often called *government bond* or *treasury bond* and can be traded on a secondary market. A treasury bond is also called *treasury bill* (t-bill) if its time to maturity is one year or less. A corresponding bond emitted by a corporation is called corporate bond, where *commercial paper* is a special case of a corporate bond. Commercial paper is unsecured promissory notes used in short-term financing to raise short-term funds or in bridge financing as an interim loan awaiting a long-term, lower-cost alternative.

Securities are constrained by legislation. For instance, securities in the U.S. are regulated by the Securities Act of 1933, which requires securities to be registered with the Securities and Exchange Commission (SEC) to make issuance of such securities legal. Section 3 of the Securities Act of 1933 states which securities are exempt from registration. Section 3(a)(3) requires that the time to maturity of some securities must not exceed 270 days in order to become exempt. This means that time to maturity of commercial paper seldom exceeds 270 days. Another important criterion of the time to maturity is whether it makes the security eligible for the discount window regulated by the Federal Reserve System, that is the central bank of the U.S. Securities with a time to maturity of 90 days or less are eligible for the discount window, making such securities traded at lower costs than securities not eligible for the discount window. The time to maturity is hence typically less than 90 days.

Both treasury bonds and commercial paper are traded on the money market, which is an over-the-counter (OTC) market containing short-term instruments with a time to maturity typically inferior or equal to one year. Trades in OTC markets are established through bilateral contracts, wherein

two parties agree on how future agreements should be settled. Covenants of this kind are usually sold for relatively huge amounts, though smaller investors can participate in this market through mutual funds. The yield calculation, or more precisely the price quotation and compounding frequency, for money market instruments differs in various countries. Martellini et al. (2003) clarify that yield calculations have different conventions. Prices are quoted on a discount basis or a money market basis. One year is treated as 360 days in the U.S., whilst 365 days is the basis in the UK.

2.4 Risk and Uncertainty

Risk is one of the foundations of finance. An asset that is considered to be risk-free by academia does not necessarily have to be risk-free in reality since there might be some discrepancies between theory and practice. Over the past few decades a very own asset class has emerged, namely credit, wherein one of the key elements has been classification of asset quality. Needless to say, how risk is treated is an important aspect in both theory and practice and in order to understand its impact it is essential to understand its characteristics. A common taxonomy to separate risk from uncertainty is to view uncertainty as the lack of certain determination of a state, whereas risk is a state of uncertainty with undesired outcome. Risks can be divided into different types. I will try to cover the most important types of risks that are associated with fixed-income securities by following the work of Fabozzi and Mann (2005).

2.4.1 Types of Risks

Fixed-income securities are chiefly exposed to *market risk*. The market risk of fixed-income markets is called *interest rate risk* and is the risk that interest rates may change. As interest rates increase prices of fixed-income securities will fall and vice versa, ceteris paribus. The exposure to interest rate risk is obvious if one considers to trade a fixed-income security before it reaches its maturity date. Interest rate risk is often measured by duration and modified duration. Immunization is a method — usually built upon zero-coupon bonds — to neutralize interest rate risk as it ensures a fixed rate of return over a predetermined horizon, all other risks omitted.

Credit risk is the risk of delinquency. The value of a fixed-income security will decline if the issuer of the security does not provide payments as promised. If the debtor is unable to fulfill its obligations in full the risk is referred to as *default risk*, that is the risk that the borrower will default on its obligations. Another name for credit risk is *counterparty risk*. There are different ways of measuring credit risk. One can quantify credit risk by, for instance, calculating the expected loss and unexpected loss using approaches that include default probability, value-at-risk or expected shortfall. As we

will see, there are even specialized companies having their own models for calculating and rating credit risk. Even though credit risk is a peculiar risk, it is an asset class that is tradable in some cases since securitization has enabled an emerging credit market to offer a wide range of derivatives. One example is a *credit default swap* (CDS) which is a contract that enables to hedge credit risk. It is similar to insurance since a swap premium has to be paid to enter a CDS contract.

Liquidity risk is conjoined with how liquid a market is. The easier it is to trade an asset to its recent value, the higher market liquidity. A small bid-ask spread and small transaction costs are characteristic properties of a liquid market. Under such circumstances solicitation of an asset should be in parity with its most recent market value. Both Fabozzi and Mann (2005) and Martellini et al. (2003) notice that the U.S. Treasury securities market is extremely liquid.

Another important risk to take into consideration is *refinancing risk*, or *roll-over risk*. Given an investment strategy, the real outcome may not equal the expected outcome as investment conditions tend to change over time. If an initial strategy, for example, has a time horizon of two years but only one-year contracts are traded on the market, then there is uncertainty of not knowing what the future cash flow will be if a one-year contract is invested in the first year and reinvested in the second year. A coupon bond has a refinancing risk since it is not clear at what rate a coupon payment might be reinvested. These problems are possible to solve by immunization, for instance by purchasing a futures contract or, for a special purpose, a forward contract.

Systemic risk is the risk of a market meltdown. The risk is possible due to interdependencies in one or several markets. One example of systemic risk is a bank run with cascading effects on other financial companies due to interbank linkages. This has led to idioms like "*too big to fail*" and "*too many to fail*". The former means that a company or an institution is too valuable for a country to let it default on its debts, whereby the government will try to bail out the company or institution in question. As Saunders and Allen (2010) propose, the latter idiom creates incentives for a herding behaviour of banks that exacerbate systemic risk. If sufficiently many banks are widely exposed to a collapse of the market then there is, at least short-term, incentives ex post for a bailout of all the banks. One suggestion to deal with systemic risk is, as Varian (2010) mentions, to have a lender of last resort, which is typically a central bank. Systemic risk is not to be erroneously referred to as *systematic risk*, which is, in contrast to idiosyncratic risk, non-diversifiable risk.

The risk that the purchasing power will decline because cash flows generated by an asset are inferior to the inflation is called *inflation risk*.

A peculiar risk is the risk that models are built on wrong assumptions and perceived as egregious. This risk is sometimes referred to as *neglected*

risk. For the sake of an example consider Titanic; a "*AAA-rated ship*" no one could imagine would sink and yet it did.

The aforementioned risks are some types of financial risks. Other risks, however, might have bigger impact on fixed-income markets then pure financial risks. *Political risk* is one of those risks affecting markets and their mechanisms. Regulatory frameworks affect financial markets in a crucial way and are necessary to mitigate future financial contagions. Debt ceiling issues are one example of political risk.

2.4.2 Credit Risk Measurements

Credit risk can, as mentioned earlier, be measured in different ways. In this section, however, scoring systems are discussed exclusively. Credit ratings play an important role in determining how creditworthy a country or corporation is. A credit rating is, as Byström (2010) points out, a relative measure based on both qualitative and quantitative information of the creditworthiness of a debtor. Potential creditors primarily recognize credit rating agencies' rankings. Nationally recognized statistical rating organizations (NRSROs) rate issuers and securities in the U.S. A potential investor of a security is permitted by the SEC to use a NRSRO's credit rating for certain regulatory purposes. There are three credit rating agencies standing out above all the other, namely the Big Three: Moody's Investors Service, Standard & Poor's and Fitch Group. Their rating scales are very similar, but most importantly, the rankings distinguish between investment grade and speculative grade; the former is considered less risky than the latter. Credit ratings are divided into short-term and long-term creditworthiness based on the investment horizon. The Big Three have around twenty tiers and use appropriate ratings to distinguish between short-term debt and long-term debt. A credit rating agency monitors a credit quality and changes its rating if necessary. Before an upgrade or downgrade is imminent, a credit rating agency usually lists its potential change of an obligor on a list, sometimes called credit watch list, though an immediate change in the rating is possible if the credit rating agency has misjudged the creditworthiness of the debtor in question. Regardless, credit watch lists serve as forecasts for future rating changes. According to Martellini et al. (2003), a decision, whether to adjust a rating or not, is usually made within three months after a credit watch announcement, whilst an outlook is an announcement giving a longer-term forecast typically in the span of six months to two years.

A substantial part of the criticism of the credit rating system is that ratings are based on historical information and credit might hence be incorrectly assessed and support skewed ratings. Another critique that Byström (2010) mentions is the credit rating agencies' tardiness in reassessing their credit ratings and actually reassigning them sooner rather than later. Saunders and Allen (2010) also note how some rating services are in a conflict

of interest since they both receive fees from issuers and investors. Some published ratings are explicitly requested, whilst others are unsolicited.

Nevertheless are the agencies of importance as their ratings more or less decide in what debt certain institutional investors may invest. Many American institutions and money market funds are permitted by law to only invest in investment grade debt or to hold minimum weights in different tiers. Besides, a credit rating may also inflict at what interest rate an obligor is able to borrow money. Higher rated issuers are privileged with lower interest rates. This is closely related to historical levels of default rates for each tier as well as rating transition probabilities.

Chapter 3

Methodological Approach

The aim of this study is to examine if there is any so called risk-free rate by examining if any risk is inherent in the risk-free asset, i.e. the financial benchmark. Admittedly, treasury securities have served as a bellwether of the risk-free rate for both the academia and financial sector for quite some time. The turmoil in the financial markets over the recent years, however, has raised some questions of the existence of a benchmark. To find out if this doubt has been well-founded, U.S. Treasury securities are taken as the benchmark. The U.S. debt has — until recently, when it was downgraded on August 5, 2011, by S&P — always been in the Big Three's top tiers. The downgrade was controversial to say the least as it was the first time ever that any of the Big Three had given the U.S. debt anything but the highest AAA rating.

3.1 Yield Spread

The yield of a security consists of a risk-free rate and a risk premium that, compared with a benchmark yield, can be divided into two main components — default risk and liquidity risk. A default risk measurement of U.S. Treasuries is necessary for a proceeded analysis. Well-known risk measures are the spread between corporate bond yields and government bond yields, the spread between T-bill yields and Eurodollar rates, called the TED spread[1], the difference between London interbank offered rates (LIBORs) and Treasury yields, and the spread between LIBORs and overnight indexed swaps (OISs), dubbed the LIBOR-OIS spread, where OIS is the geometric mean of an overnight index, e.g. an overnight interbank rate, over a given term. All these yield spreads are indicators of different types of risks. Hahn (1993) among others, describes the corporate spread, i.e. the spread between corporate bond yields and government bond yields with comparable time to

[1]Nowadays, the three-month LIBOR typically replaces the Eurodollar according to Hull (2012).

maturity, as an indicator of default risk.

Considering that the nature of the financial crisis was deep-rooted in the financial sector, it is favourable to pick securities outside its epicenter. Corporate bonds and commercial paper are therefore of special interest. Saunders and Allen (2010) argue that corporate bonds are a better proxy for the risk-free rate in lieu of government bonds. Fabozzi and Mann (2005) claim that the commercial paper yield premium consists of three principal components, where credit risk is a major factor. U.S. Treasury securities are tax-exempt, which, ipso facto, account for higher prices and thus lower yields, ceteris paribus. Commercial paper is on the other hand taxable. Liquidity is also mentioned by Fabozzi and Mann (2005) as an inferior factor. Hull (2012, p. 77) points out two main aspects that make U.S. Treasury securities a mere artificial benchmark. First, he notes that the U.S. regulation lowers government bond yields more than what otherwise would have been the case, because financial institutions are obliged to hold Treasury securities. Second, U.S. Treasuries are, as mentioned earlier, not taxed at state level. Hull (2012) therefore adheres to the fact that Treasury securities are an artificial benchmark for a risk-free asset and in lieu of Treasuries he emphasize the OIS as a better candidate, although the LIBOR served as a prominent benchmark until it soared during the financial crisis.

Various studies have tried to pinpoint the intrinsic risks in yield spreads and the two main components mentioned earlier are the most frequently discussed topics. There is a dissension concerning which element has the most impact. Chuderewicz (2002) and Gefang et al. (2011), to name a few, show that both risks are inherent but liquidity risk is primary. While Chuderewicz (2002) examines the spread between commercial paper and T-bills, Gefang et al. (2011) research the LIBOR-OIS spread and find that the events through the financial crisis featured liquidity concerns. On the other hand, Griffiths et al. (2011) and Longstaff et al. (2005), among others, argue that default risk had the most significant impact. Moreover, Longstaff et al. (2005) attest that the majority of yield spreads between corporate CDSs and the U.S. Treasury yield curve are related to default risk. Nippani and Smith (2010) notice, however, that the size of the CDS market is relatively small compared with the Treasury securities market. In addition, Griffiths et al. (2011) show that the money market was highly influenced by the financial crisis in terms of credit risk rather than liquidity risk, whilst in particular highly rated, short-term commercial paper was less sensitive to credit risk concerns than other types of commercial paper. This is in line with the goal of this thesis, namely to compare the presumed benchmark with an alternative benchmark.

There are chiefly three types of commercial paper: asset-backed, financial, and non-financial commercial paper. Liu et al. (2009) admit that non-financial commercial paper is favourable, though the lack of proper time series makes them switch to financial commercial paper. As Figure 3.1

shows, one can clearly see how the outstanding amounts of commercial paper have fluctuated over time. The total amount outstanding reached its peak in mid-2007, at over 2 trillion U.S. dollars, and has since declined. The decrease has foremost been due to asset-backed commercial paper, though financial commercial paper has been more stable but not as stable as non-financial commercial paper. Kacperczyk and Schnabl (2010) notice how the commercial paper market collapsed after the bankruptcy of Lehman Brothers and argue that the asset-backed commercial paper market suffered from illiquidity. Kacperczyk and Schnabl (2010) conclude that the asset-backed commercial paper market suffered most from the financial crisis, whilst the effect on financial commercial paper was less severe. The non-financial commercial paper market experienced least problems during the crisis. The problems the market for asset-backed commercial paper encountered make Kacperczyk and Schnabl (2010) suggest that the market lost its faith in asset-backed commercial paper, mostly because these securities turned out to be less safe than what was expected from both sides of the market. Non-

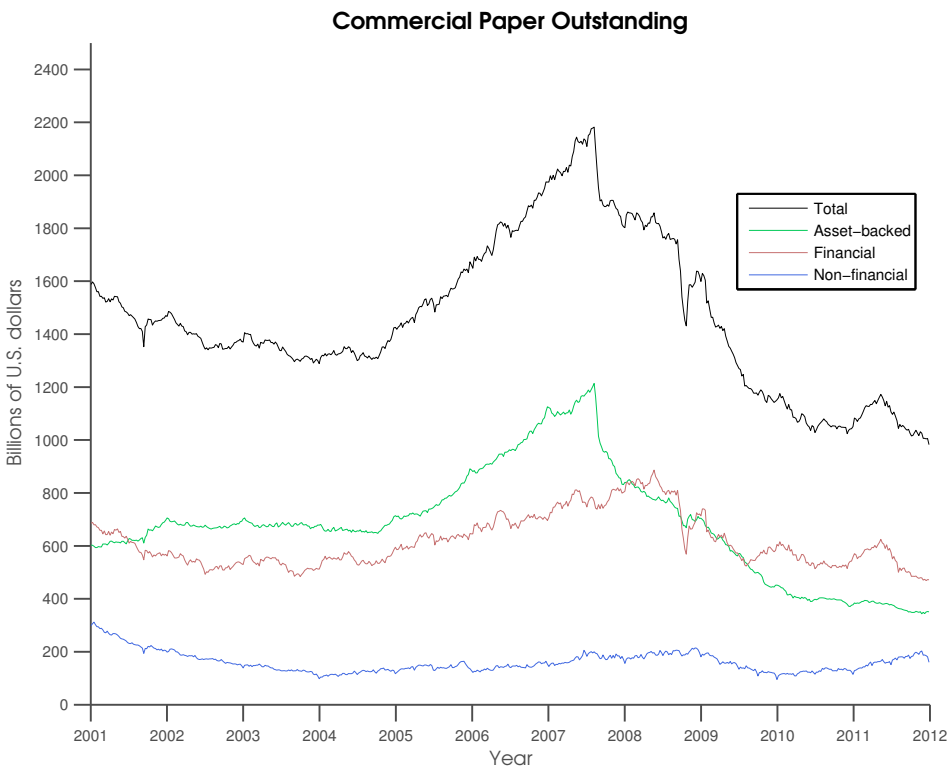

Figure 3.1: Total amounts of commercial paper outstanding as well as amounts of each type of commercial paper outstanding. The amounts are not seasonally adjusted.

financial commercial paper is desirable since this study aims to compare relatively solvent securities with each other. The sales volume of shorter-term commercial paper is higher than the sales volume of longer-term commercial paper. Higher sales volume indicates higher market liquidity. Fabozzi and Mann (2005, p. 286) also notice that the most common maturity is less than 45.

With all this in mind, I choose one-month non-financial commercial paper rated AA or higher. Assets rated AA or higher belong basically to the short-term top tier. The problem Liu et al. (2009) experience is eluded since this study compares different times to maturity than Liu et al. (2009), whose study utilizes three-month commercial paper. The benchmark is on the other hand taken as the one-month T-bill.[2] This study examines if the yield of the short-term Treasury security solely is equal to the risk-free rate or if a risk premium is embedded in the yield. The difference between one-month non-financial U.S. commercial paper yield and the one-month U.S. T-bill yield, both securities traded on the secondary market, is defined as the yield spread

$$\Delta y = y_{CP} - y_{TB}. \tag{3.1}$$

This spread is sometimes called the paper-bill spread and it will be used to analyze whether default risk premia were embedded in one-month U.S. Treasury securities. An increase in the yield spread implies that commercial paper is exposed to more risk than Treasury securities and, conversely, a reduction in the paper-bill spread means that the benchmark has suffered from more risk exposure than commercial paper. No distinction is made whether commercial paper, or Treasuries for that matter, has experienced a greater or smaller change in risk alone. A diminution in the yield spread does not necessarily mean that the T-bill yield has increased since it is possible that the commercial paper yield has decreased more than the yield of the Treasury security. The latter may even remain constant and yet enable a reduction in the yield spread. It is the yield spread in combination with events that acts as a default risk measurement. A significant increase in the yield spread at a default-related event signifies an intrinsic default risk of the benchmark.

The data, including market quotes and outstanding amounts, were obtained from the Federal Reserve Economic Data (FRED), a database managed by the Federal Reserve Bank of St. Louis. The yield spread is observed on a daily basis, though market quotes are not reported for all trading days since trading volumes for some days have not been sufficient enough to support market quotes according to the Federal Reserve. Linear interpolation is therefore used to circumvent this problem to some extent. Movements in the yield spread are shown in Figure 3.2, where one can clearly see that the

[2] One-month T-bill has an original time to maturity of four weeks, that is almost one month, and is hence sometimes called four-week T-bill.

turbulent stages of the financial crisis implied an increased volatility of the paper-bill spread. Before an analysis can be performed, a time frame has to be selected and accompanied by appropriate events.

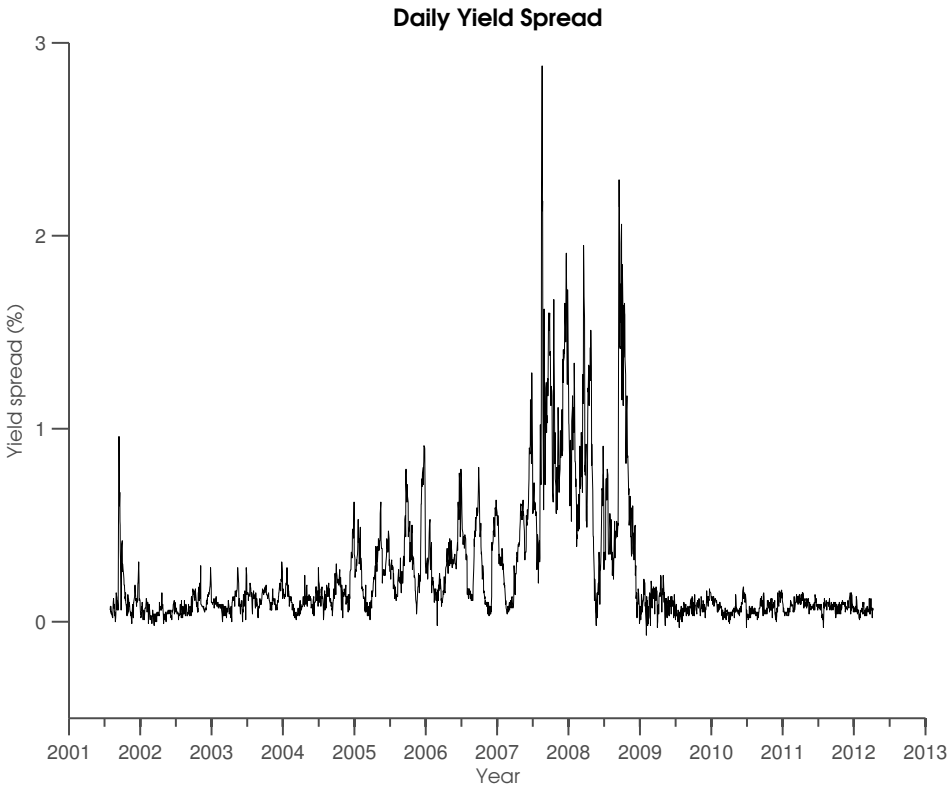

Figure 3.2: Daily yield spread from July 2001 to April 2012.

3.2 Chain of Events

The time period of choice is narrowed down to include the prelude to the financial crisis, as well as the crisis itself and its aftermath. The outbreak of the financial crisis is ambiguous as its starting date is quite vague. Some signs were at least revealed in 2007. Kacperczyk and Schnabl (2010) confirm that the first clear signs could be ferreted out in the summer of 2007, although subprime mortgages were rising tremendously already in 2006. An important hint was revealed on June 1, 2007, when Moody's and S&P downgraded over 100 bonds backed by subprime mortgages. The time period between this event and one trading day after the downgrade of the U.S. debt is taken as the *main-event period*, i.e. the period from June 1, 2007, to August 8, 2011. Events within this window are of special interest and emphasis is

put on certain events that are expected to have a strong relationship with the yield spread. There is a myriad of events that occurred during the financial crisis, hence a delimitation is necessary. Events affecting a possible default of the U.S. debt are indispensable. Recall how the debt ceiling has changed over the past few years, cf. Figure 1.1. Such hikes in combination with debt ceiling controversies are signs of an approaching sovereign bankruptcy. Other examples of events are money market interventions and of course key happenings of the financial crisis. All in all, 76 events are picked out for an event study analysis. The entire list of events can be found in Table B.1. Press releases as well as articles in major financial newspapers confirm all events.

3.3 Comparisons of Events

To ensure that effects of an event are captured, an *event window* is defined as the date the event was reported and the following trading day. This approach is also advocated by Campbell et al. (1997). If an event is issued on a day without any trading then the following trading day is taken to be the event window. Similar, adjoining events are arranged into an *event group*. As a result, 49 events groups are formed. Table B.1 indicates with parentheses which event group each event belongs to. A comparison period is needed to determine if an event group has any impact on the yield spread. A *pre-event period* is used for this purpose. This period has the same number of trading days as the main-event period but occurs before the main-event period. The pre-event window is obtained by shifting the main-event window five years backwards, such that the two periods are not overlapping. This approach avoids possible confounding of calendar effects according to Nippani et al. (2001). More precisely, the pre-event period starts on June 3, 2002, which is five years before the first event, and ends on August 8, 2006, which is five years prior to the last event window. Both periods consist of 1091 trading days.

Yield spreads of each event group are collected and used to compare the mean of each event group with the mean of the pre-event period. The null hypothesis states that each difference should be zero and it is tested against non-zero differences. See Appendix A.1 for details regarding statistical theory. A two-sided, two-sample t-test is carried out for each of the differences to test whether the differences are significant or not.

The main-event period and the mean of the pre-event period are illustrated in Figure 3.3. The yield spread took some great leaps during the first stages of the crisis but then shrank through the crisis. The spread did not only revert to its mean, but it rather established a lower level than ex ante. The figure also showcase that the mean of the pre-event period is not an accurate a priori estimate of the future yield spread and therefore the afore-

mentioned method will not serve its purpose good enough. In order to pull off better results another pre-event comparison period is applied. A more suitable method to detect effects of an event is to consider a *time-shifting window* which is equal to the 30 most recent trading days preceding the starting date of an event group.

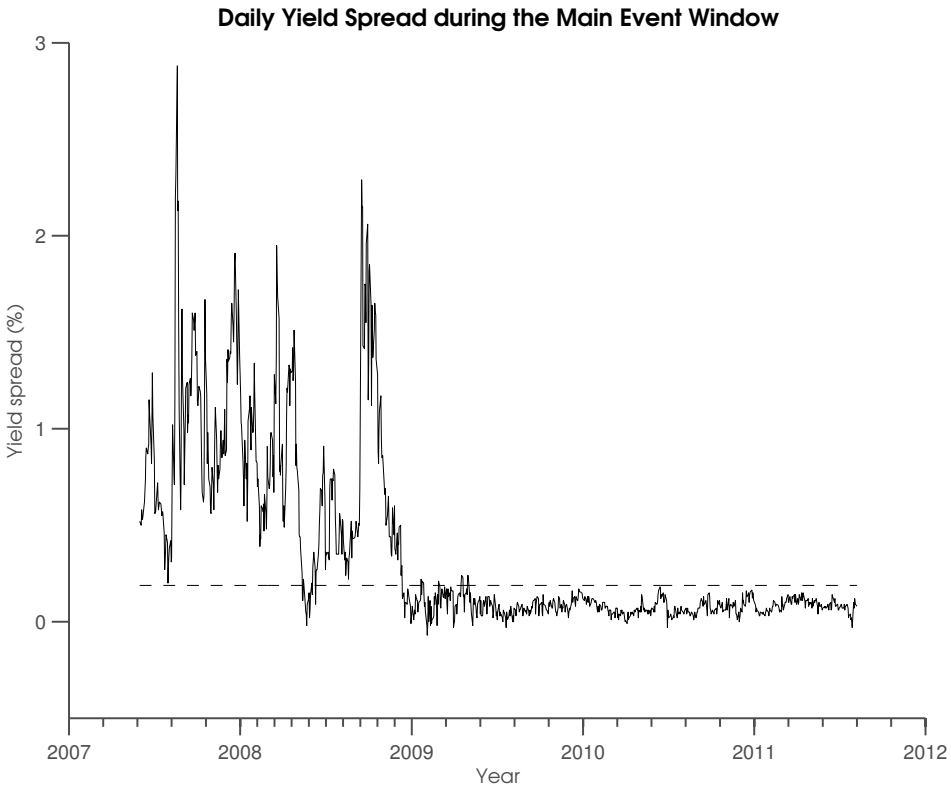

Figure 3.3: Daily yield spread during the main-event period and the mean of the yield spread during the pre-event comparison period.

The robustness of the results of the aforesaid methods is resolved by non-parametric tests. A sign test is first and foremost undertaken. The number of positive signs, as well as the total number of signs, is computed by subtracting the mean of the time-shifting window from each event group. The null hypothesis states that the number of positive and the number of negative signs are equal, which implies that no effect is evident on the yield spread. The number of positive signs and the number of negative signs should be different under the alternative hypothesis. Campbell et al. (1997) point out the possible weakness of the sign test if the data are on daily basis and suggest rank-based tests as complements to the sign test. Both a Wilcoxon signed-rank test and a Wilcoxon rank-based test — two tests introduced by Wilcoxon (1945) — are done in addition to the sign test. All

non-parametric tests are carried out with the time-shifting window, except for the tests for the entire main-event period, which is compared with the pre-event period. Both the sign test and the Wilcoxon signed-rank test compare each event group with the mean of each comparison period, whilst the Wilcoxon rank-sum test compares each event group with each comparison period. Two-sided tests resulting in corresponding p-values conclude this part of the analysis.

All the above tests require that an event group stretch over a minimum of two days, otherwise the tests will not be complete. With that being said, an event group that does not fulfill the prerequisite is extended to include the subsequent trading day for consistency.

To test for preserved effects beyond the main-event window, the aforementioned tests are reiterated for slightly different comparison periods. Consequently, a *post-event period* is chosen along with a corresponding pre-event period. The post-event window starts on August 9, 2011, directly after the main-event window ends, continues for six consecutive months, and ends on February 9, 2012. The corresponding pre-event period takes place between August 9, 2010, and February 9, 2011, i.e. to avoid a possible confounding of calendar effects, the pre-event comparison period is the post-event period shifted one year backwards. Both windows have a length of 132 trading days.

3.4 Regression Model

The previous methods have some shortcomings as they are crude proxies that neither handle external parameters nor timing of releases of information. A construction of a regression model that controls for the aforementioned drawbacks provides further examination of the yield spread. Bernanke (1990) mentions that the paper-bill spread is closely related to economic activities and the inflation rate. I let the value-weighted equity index S&P 500 measure the economic activities in the U.S. economy, where value-weighted signifies that the weights of the stocks in the portfolio are proportional to their market capitalizations. The inflation parameter is modeled as the daily London gold fixing p.m. denominated in U.S. dollars, i.e. the gold price per troy ounce determined by the London Bullion Market Association (LBMA) in the afternoon. Morris and Walter (1993) describe how certificates of deposit charge Treasury bills of comparable maturity with a premium and give examples of how the TED spread, i.e. the spread between Eurodollar deposits and U.S. Treasury securities, is affected by default risk. Eurodollar certificates of deposit are time deposits denominated in U.S. dollars at banks outside the U.S. One-month Eurodollar deposit rates denominated in U.S. dollars are therefore taken as an explanatory variable for the paper-bill spread. The time series of the predictor variables were collected from

the FRED, except for the gold price, which was obtained from the LBMA. Considering that the yield spread is believed to be dependent on the three explanatory variables mentioned above as well as the event groups mentioned earlier, the yield spread at time t is modeled as follows

$$\Delta y(t) = \theta_0 + \theta_{XAU} x_{XAU}(t) + \theta_{SI} x_{SI}(t) + \theta_{ED} x_{ED}(t) + \sum_{i=1}^{n} \theta_{E_i} \mathbb{1}_{E_i}(t) + \varepsilon(t) \quad (3.2)$$

where x_{XAU} is the gold fix, x_{SI} corresponds to the S&P 500 stock index, x_{ED} is the Eurodollar deposit rate, and $\mathbb{1}_{E_i}(t)$ denotes the indicator function that is equal to one if event group E_i occurs at time t, and zero otherwise. This model is a generalization of n event groups. Notice that the θ_0 term indicates that an intercept is included in the model and that ε denotes the error term. The multiple linear regression model is summarized by

$$Y_\Delta = X\Theta + \epsilon \quad (3.3)$$

where the regressand Y_Δ is the yield spread vector, X is the matrix of the panel data, wherein the first column of the regressor is a vector of ones corresponding to the intercept, Θ is the parameter vector, and ϵ corresponds to the residual vector. Effects of an event are measured by modeling an event group as a dummy variable. In order to interpret the effects of an event group the corresponding parameter estimate is analyzed to see if it is statistically significant or not. The parameter estimates are derived using ordinary least squares (OLS), cf. Appendix A.2, whereupon t-statistics are computed. A t-test is done for each and every parameter coefficient to test the null hypothesis, under which a coefficient is equal to zero. The alternative hypothesis states that a coefficient is different from zero, thus making the t-test a two-sided test.

A statistical phenomenon when dealing with regression models is the existence of multicollinearity, which infers that explanatory variables in a model are highly correlated. The method derived by Newey and West (1987) is used to overcome this problem as it adjusts for both autocorrelation and heteroskedasticity.

The regression analysis is performed on 1354 days, starting on December 1, 2006, and ending on February 9, 2012, thus covering the period from six months prior to the first event to six months after the last event window.

Chapter 4

Empirical Results

4.1 Comparisons of Events

The results of the t-tests with t-statistics as well as p-values for the difference between the mean of each event group and the mean of the pre-event comparison period using both fixed and time-shifting windows can be found in Table B.2. The entire main-event period denoted "*Main*" is significant compared with the pre-event period. The mean of the pre-event window and the mean of the main-event window are 0.19 and 0.36, respectively. The majority of the event groups are significant using the fixed window approach. One-sided t-tests, though not reported in any table, showed that the first twenty or so event groups had a significant increase in the yield spread, whilst the remaining event groups did not show any significant impact. The turning point occurred when the National Bureau of Economic Research (NBER) announced that the U.S. economy was in a recession combined with a new record-low target for the federal funds rate a few days later. These results are more or less to be expected by looking at Figure 3.3.

The results of utilizing a time-shifting window show, more interestingly, that 21 of 49 event groups are significant at the 95% confidence level. Significant decreases in the yield spread were also observed by looking at the left tail of the Student's t-distribution. One-sided t-tests showed that the rush on Northern Rock shrank the yield spread, as did access to TARP funding covered by event group 20. The announcement by the NBER that the U.S. economy was in a recession and record-low federal funds rates, cf. event group 22, were impacting the yield spread as well. Lowered outlooks for both the U.S. debt and the UK debt had an increasing effect on default risk of the T-bills. Event group 29 and 43 capture these effects. Huge annual losses reported by Fannie Mae and Freddie Mac are significant for the paper-bill spread. Event group 41, 46, and 47 show typical characteristics of an imminent sovereign default and were perceived significantly by the market as risk premia were charged on all these occurrences. A total of 16 event

groups implied an embedded default risk premium in the short-term Treasury securities, given a 95% confidence level using a time-shifting window. The U.S. debt ceiling controversies in mid-2011 and the following downgrade of the U.S. debt by S&P from AAA to AA+ were expected to reduce the yield spread, but notably a diametrical effect is evident.

The results of the non-parametric tests are reported in Table B.3, which shows the number of positive signs and the total number of signs as well as p-values of the three non-parametric tests. Calculated z-statistics of the sign tests are in addition also presented. The results do not show the same number of significant event groups as the t-tests. The Wilcoxon rank-sum test performs best in the sense that it delivers the highest number of significant event groups, namely 14. The sign test, on the other hand, only shows that 9 event groups are significant, whilst the Wilcoxon signed-rank test only captures 4 event groups at a 95% confidence level. However, two of the three tests manage to detect similar event groups and compared with the previous method they also capture event group 6, 10, 19, 20, 22, 39 and 47, of which some are closely related to default risk. As a result, it seems that these event groups in particular expressed default risk premia of Treasury securities. One drawback of the non-parametric tests is the size of the event groups as most event groups consist of very few days.

The paper-bill spread for the post-event window and the mean of the pre-event window are shown in Figure 4.1. The trend seems to be quite volatile with the spread moving around the mean of the pre-event period. The results of the comparison between the mean of the post-event period, which is equal to 0.079, and the mean of the pre-event period, which is equal to 0.072, are provided in Table B.4. The t-test gives a significant result at the 90% confidence level. All the non-parametric tests are significant at the 95% confidence level. Moreover, the sign test and Wilcoxon rank-sum test are even significant at the 99% confidence level. The results show that the turbulence around the increase in the debt ceiling followed by the downgrade of the U.S. by S&P had an effect for the post-event period and that the effect sustained after the main-event period had ended.

4.2 Regression Analysis

The aforementioned tests have some drawbacks, however, and in order to overcome those shortcomings new tests are achieved with a regression model, cf. equation 3.3. The R^2-statistic and the $\bar{R}^2$-statistic of the regression model are 0.62 and 0.60, respectively. Computed t-statistics adjusted with the Newey-West method are, besides regular t-statistics, presented in Table B.5. Two-sided p-values of the t-statistics and coefficients of the predictor variables complete the table. The results show that the intercept and, more interestingly, the gold fix as well as the S&P 500 equity index do not have

any significant impact. The Eurodollar deposit rate, on the other hand, has a significant impact at the 99% confidence level. 30 of the 49 event groups have a significant impact on the yield spread, given a 95% confidence level. Not to mention, 22 of these events are even significant at the 99% confidence level. Strikingly, the majority of these events are located in the first half of the event groups. Only 7 events from the second half of the event groups are significant at the 95% level. These are event group 28, 31, 32, 34, 35, 37 and 40.

The number of event groups that are significant under both the crude comparisons of events and the regression model is, however, surprisingly low. Given a 95% confidence level, only 6 event groups, namely event group 2, 13, 18, 19, 20 and 22, that had significant diminishing effects on the yield spread under the time-shifting window are significant using the regression model. When S&P placed 612 bonds on their credit watch list, as well as when large automaker and life insurance companies sought TARP funding, it seemingly had a decreasing effect on the yield spread. The same effect is evident when the NBER announced that the U.S. was in a recession, which was followed by a record-low target for the federal funds rate. As a result,

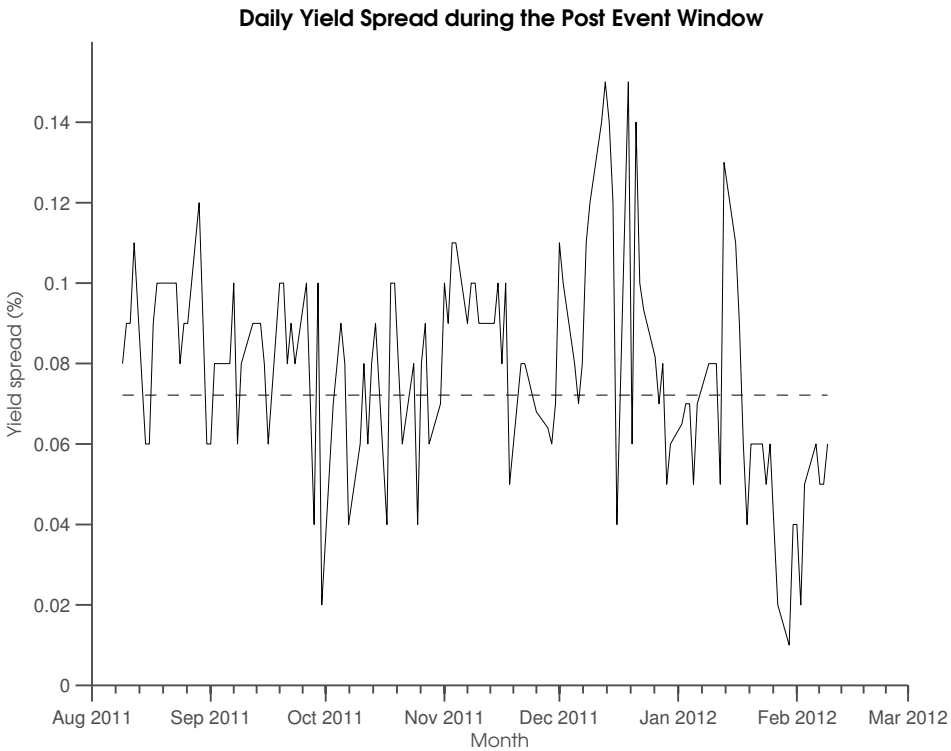

Figure 4.1: Daily yield spread during the post-event period and the mean of the yield spread during the pre-event comparison period.

the market priced Treasury securities with a default risk premium. This finding is consistent with Hahn (1993), which mentions that a default risk premium is indeed charged by the market during economic recessions.

Overall, the empirical results suggest that a majority of the events during the later stages of the crisis did not have any significant impact on the paper-bill spread. Part of this can probably be explained by a "*flight to safety*" behaviour. That is, safer investments are coveted in severe times due to greater uncertainty in the market. Despite all this, there is evidence, although mostly pretty weak, that some debt limit controversies and negative credit rating announcements, among other events, increased the default risk of Treasury securities.

Chapter 5

Conclusion

This thesis finds empirical evidence that the U.S. money market did charge T-bills with a default risk premium, but as the crisis progressed it seems that the risk premium diminished. An increase in default risk is evident three months after the bankruptcy of Lehman Brothers, when the NBER announced that the U.S. economy was in a recession in combination with record-low federal funds rates. This finding is consistent with Hahn (1993). Other evidence, albeit not as strong as the above, also shows that negative credit rating announcements and debt ceiling controversies, among other events, did embed a risk premium.

Although the U.S. has suffered from increased risk exposure the low yield levels remain a puzzle. The phenomenon of low yields is usually referred to as the risk-free rate puzzle coined by Weil (1989); if the market is risk-averse to intertemporal choice then the yields should be higher than they are. Whether the low yields are related to a temporary shift in risk aversion or a slow protracted economic growth is hard to tell. The appearance of a "*flight to quality*" behaviour may be one reason for an increased demand for Treasury securities. This could also explain the empirical results in the later stages of the crisis.

The Federal Reserve has reported that it will hold interest rates at exceptionally low levels for years to come. Nobel laureate economist Paul Krugman believes that this explains the low government bond yields better and points out that the U.S. has adopted a zero interest rate policy similar to Japan. A dubious future outlook might be the reason that Treasury securities are almost traded at par. In fact, Treasury inflation-protected securities have recently even been traded below par.

Finally, this thesis concludes that short-term U.S. Treasury securities are not to be expected as free of default, though questions remain whether U.S. Treasury bonds are to be treated as a bellwether of the financial benchmark. Treasury securities are tax-exempt, which, ipso facto, make them an artificial benchmark.

Appendix A

Statistical Theory

A.1 Statistical Inference

In statistics, analysis of a sample is a crucial approach in order to draw conclusions about the relationship between the sample itself and its population. A sample is a subset of a population, which contains all possible outcomes. *Hypothesis testing* is a method that can be used to draw conclusions about a sample. A *null hypothesis* H_0 is usually tested against an *alternative hypothesis* H_1. The purpose of a hypothesis test is to see if a null hypothesis can be rejected or not. If a parameter specified by a null hypothesis is included in an acceptance region, then the null hypothesis cannot be rejected. On the other hand, a null hypothesis can be rejected if a parameter specified by it is a part of a rejection region, i.e. the complement to an acceptance region. The construction of the hypotheses decides if a rejection region is located in either a specific tail or in both tails of a distribution and as a consequence determines if a test is a *one-sided* or *two-sided* test.

A *test statistic* $t(y)$ is a function of a sample $\{y_i\}_{i=1}^n$ and is often used in statistics to conduct a hypothesis test. The choice of test statistic is usually based upon the underlying distribution of a population. Since a test statistic, per se, only is an arbitrary function of a sample, a more standardized interpretation is to use a *probability value*, better known as *p-value*, defined as

$$p(y) = P(t(Y) \geq t(y)|H_0) \tag{A.1}$$

which states the probability of observing a value of the test statistic that is at least as large as the actually observed value of the test statistic, given the null hypothesis. Put differently, a p-value is the lowest *significance level* α at which a null hypothesis can be rejected. The significance level is, ergo, the probability of incorrectly rejecting a true null hypothesis. $1 - \alpha$ is called the *confidence level*. In this context a test statistic is said to be *statistically significant* if a null hypothesis can be rejected.

A.1.1 Statistical Tests

A test statistic is used to summarize information in a sample and thus often consists of a single datum. A value of a test statistic can be obtained by normalizing a datum with respect to a location and a scale. In this way a statistical error can be tested whether it is significant or not. The composition of a test statistic may then answer questions about the relationship between a sample and a population or the relationship between samples. A test statistic may, depending on what is pertinent to test, be expanded to deal with more information than just a location and a scale, albeit this is a basic approach ushering in how to conduct a test. Sampling assumptions decide the nature of a test; whether it is a parametric or non-parametric test. The former assumes that a sample belongs to a particular distribution, whilst the latter makes no such assumption.

When the location and scale factors are known, one can obtain the *z-statistic* by normalizing a datum with respect to a location μ and a scale σ resulting in the normalized value

$$z = \frac{\bar{X} - \mu}{\sigma} \tag{A.2}$$

where $\bar{X}$ is a statistic, e.g. the mean, of the random variable X, μ is the known expected value of X and σ is the known standard deviation of X. A test based upon this test statistic is usually called a *z-test*. If X belongs to a Gaussian distribution, i.e. $X \sim \mathcal{N}(\mu, \sigma^2)$, then z is a standard normal variable.

Another well-known test is the *t-test*. The *t-statistic* is defined as

$$t = \frac{\bar{X} - Y}{s_X/\sqrt{n}} \tag{A.3}$$

where $\bar{X}$ is the sample mean and s_X is the sample standard deviation. The test statistic follows a Student's t-distribution under the null hypothesis. Unlike the z-test, the t-test is used when at least the scale factor is an estimate. There are many possible ways of constructing this test. A one-sample t-test is eligible if one wants to test whether the sample mean is supported by the specified value $Y = \mu_0$ in a null hypothesis. In order to find a p-value and complete a t-test, one needs the degrees of freedom ν, which correspond to the number of statistical values that are free to vary. In this case $\nu = n - 1$. Other constructions of the t-test consist of two samples, where Y for example is a sample mean of a second sample, and examine if the difference between two sample means is significant. Notice that the sample variance may change due to the possibility of unequal sample sizes and unequal variances, and that the sample variance as well as the degrees of freedom will have to be weighted accordingly.

Both the z-test and t-test are commonly used to test equality of two means, whilst the *sign test*, which is a binomial test, and the *Wilcoxon signed-rank test* as well as the *Wilcoxon rank-sum test*, which are two rank-based tests initially proposed by Wilcoxon (1945), are examples of non-parametric tests for equality of two medians. A sign test examines whether a statistic belongs to a binomial distribution. That is, a random variable X that has two possible outcomes for each trial and is repeated for n independent trials belongs to a binomial distribution, i.e. $X \sim B(n, p)$, where p is the success rate of one of the outcomes in a trial. The expected value and variance of X are then $E[X] = np$ and $V(X) = np(1-p)$. A sign test is constructed to take differences between pairs of samples, $\{(x_i, y_i)\}_{i=1}^n$, and count the number of positive differences, $N^+ = \sum_{i=1}^n \mathbb{1}_{x_i > y_i}(x_i, y_i)$, and the number of non-zero differences, $N = \sum_{i=1}^n |\text{sgn}(x_i - y_i)|$, where $\mathbb{1}$ and sgn denote the indicator function and the signum function, respectively. In fact, a sign test can be interpreted as a z-test if a variable, e.g. the number of positive signs, is approximated with the normal distribution. The z-statistic of a sign test is then

$$z^+ = \frac{N^+ - Np}{\sqrt{Np(1-p)}}. \tag{A.4}$$

A.2 Regression Analysis

The idea behind linear regression analysis is to examine a linear relationship between n dependent observations in Y and p explanatory variables in X for each observation expressed by a parameter vector Θ. Since the parameter vector only approximates the linear relationship, a residual term ε is included for each observation. The following theorem shows how the unknown parameters can be estimated.

Theorem A.1. *For a multiple linear regression on the form*

$$Y = X\Theta + \epsilon \tag{A.5}$$

the parameter estimates given by ordinary least squares (OLS) are

$$\hat{\Theta} = (X^T X)^{-1} X^T Y. \tag{A.6}$$

Proof. The parameter vector is

$$\begin{aligned}\hat{\Theta} &= \arg\min_{\Theta} \|Y - X\Theta\|^2 = \arg\min_{\Theta} \epsilon^T \epsilon = \arg\min_{\Theta} (Y - X\Theta)^T (Y - X\Theta) \\ &= \arg\min_{\Theta} Y^T Y - 2\Theta^T X^T Y + \Theta^T X^T X \Theta \end{aligned} \tag{A.7}$$

and the partial derivatives are thus

$$\frac{\partial \hat{\Theta}}{\partial \Theta} = -2X^T Y + 2X^T X \Theta \tag{A.8}$$

which, set to zero, finally gives

$$\hat{\Theta} = (X^T X)^{-1} X^T Y \tag{A.9}$$

if $(X^T X)^{-1}$ is invertible. □

A useful statistic in regression analysis is the R^2*-statistic*. It is defined as

$$R^2 = 1 - \frac{\sum_{i=1}^{n} \varepsilon_i^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2} \tag{A.10}$$

where $\bar{y}$ is the arithmetic mean of $\{y_1, \ldots, y_n\}$. The higher the R^2, the better the model fits the variability in the data. The adjusted R^2-statistic, denoted $\bar{R}^2$, is intimately related to the ordinary R^2-statistic as it can be written as

$$\bar{R}^2 = 1 - (1 - R^2)\frac{n-1}{n-p-1} = 1 - \frac{\sum_{i=1}^{n} \varepsilon_i^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2} \frac{n-1}{n-p-1}. \tag{A.11}$$

The $\bar{R}^2$-statistic only increases if an additional explanatory variable improves the model more than what would be expected by chance.

Appendix B

Tables

Table B.1: Chain of Events Impacting the Yield Spread.

1. 2007-06-01	Moody's and S&P downgrade over 100 bonds backed by second-lien subprime mortgages.	(1)
2. 2007-07-11	S&P places 612 securities backed by subprime residential mortgages on a credit watch list.	(2)
3. 2007-08-17	The Federal Reserve Board votes to reduce the primary credit rate by 50 basis points to 5.75 percent. It also increases the maximum maturity of primary credit loans to 30 days.	(3)
4. 2007-09-14	United Kingdom's fifth-largest mortgage lender is provided with liquidity support by the Bank of England after suffering a bank run.	(4)
5. 2007-09-18	The Federal Reserve Board votes to reduce the primary credit rate by 50 basis points to 5.25 percent and the Federal Open Market Committee (FOMC) votes to reduce its target for the federal funds rate by 50 basis points to 4.75 percent.	(4)
6. 2007-09-29	The U.S. debt ceiling is increased by $850 billion to $9,815 billion.	(5)
7. 2007-10-31	The Federal Reserve Board votes to reduce the primary credit rate by 25 basis points to 5.00 percent and the FOMC votes to reduce its target for the federal funds rate by 25 basis points to 4.50 percent.	(6)
8. 2007-12-11	The Federal Reserve Board votes to reduce the primary credit rate by 25 basis points to 4.75 percent and the FOMC votes to reduce its target for the federal funds rate by 25 basis points to 4.25 percent.	(7)
9. 2007-12-12	The Federal Reserve Board announces the creation of the Term Auction Facility (TAF). The FOMC authorizes temporary reciprocal currency arrangements, known as swap lines, with the European Central Bank and the Swiss National Bank.	(7)
10. 2008-01-22	The Federal Reserve Board votes to reduce the primary credit rate by 75 basis points to 4.00 percent and the FOMC votes to reduce its target for the federal funds rate by 75 basis points to 3.50 percent.	(8)
11. 2008-01-30	The Federal Reserve Board votes to reduce the primary credit rate by 50 basis points to 3.50 percent and the FOMC votes to reduce its target for the federal funds rate by 50 basis points to 3.00 percent.	(9)
12. 2008-02-13	The President of the U.S. signs the Economic Stimulus Act of 2008 into law.	(10)
13. 2008-02-17	Northern Rock is overtaken by the HM Treasury of the UK.	(10)

See next page for continuation.

Table B.1: Chain of Events Impacting the Yield Spread – Continued from previous page.

14.	2008-03-07	The Federal Reserve Board announces forthcoming TAF auctions worth $50 billion. (11)
15.	2008-03-11	The Federal Reserve Board announces the creation of the Term Securities Lending Facility (TSLF). The 28-day facility will lend up to $200 billion of Treasury securities. (11)
16.	2008-03-16	The Federal Reserve Board announces the creation of the Primary Dealer Credit Facility (PDCF). The Federal Reserve Board also votes to reduce the primary credit rate by 25 basis points to 3.25 percent and to increase the maximum primary credit borrowing term to 90 days. (12)
17.	2008-03-18	The Federal Reserve Board votes to reduce the primary credit rate by 75 basis points to 2.50 percent and the FOMC votes to reduce its target for the federal funds rate by 75 basis points to 2.25 percent. (12)
18.	2008-04-30	The Federal Reserve Board votes to reduce the primary credit rate by 25 basis points to 2.25 percent and the FOMC votes to reduce its target for the federal funds rate by 25 basis points to 2.00 percent. (13)
19.	2008-07-30	The U.S. debt ceiling is increased by $800 billion to $10,615 billion. (14)
20.	2008-08-01	The U.S. mortgage lender Independent National Mortgage Corporation, more known as IndyMac, files for Chapter 7 bankruptcy. (14)
21.	2008-09-07	The Federal National Mortgage Association known as Fannie Mae and the Federal Home Loan Mortgage Corporation known as Freddie Mac are placed in government conservatorship by the Federal Housing Finance Agency (FHFA). (15)
22.	2008-09-15	The U.S. financial services firm Lehman Brothers Holdings Inc. files for Chapter 11 bankruptcy protection. (16)
23.	2008-09-16	The Federal Reserve Board authorizes the Federal Reserve Bank of New York to lend up to $85 billion to the American International Group (AIG). The net asset value of shares in the Reserve Primary Money Fund falls bellow $1 due to the losses of Lehman Brothers securities. (16)
24.	2008-09-17	The U.S. Treasury Department announces a Supplementary Financing Program including issues of Treasury bills to provide cash for the Federal Reserve. (16)
25.	2008-09-19	The Federal Reserve Board establishes the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF). The Federal Reserve Board also announces its intentions to purchase short-term debt obligations issued by Fannie Mae and Freddie Mac. (16)
26.	2008-10-03	The President of the U.S. signs the Emergency Economic Stabilization Act of 2008 into law. The public law creates the Troubled Asset Relief Program (TARP) worth $700 billion. The U.S. debt ceiling is also increased by $700 billion to $11,315 billion. (17)
27.	2008-10-07	The Federal Reserve Board establishes the Commercial Paper Funding Facility (CPFF). (17)
28.	2008-10-08	The Federal Reserve Board authorizes the Federal Reserve Bank of New York to borrow up to $37.8 billion in investment grade, fixed-income securities from AIG in return for cash collateral. The Federal Reserve Board also votes to reduce the primary credit rate by 50 basis points to 1.75 percent and the FOMC votes to reduce its target for the federal funds rate by 50 basis points to 1.50 percent. (17)

See next page for continuation.

Table B.1: Chain of Events Impacting the Yield Spread – Continued from previous page.

29.	2008-10-14	The U.S. Treasury Department announces that the TARP has $250 billion at its disposal which it will spend to purchase capital in financial institutions. (17)
30.	2008-10-21	The Federal Reserve Board announces the creation of the Money Market Investor Funding Facility (MMIFF). (18)
31.	2008-10-29	The Federal Reserve Board votes to reduce the primary credit rate by 50 basis points to 1.25 percent and the FOMC votes to reduce its target for the federal funds rate by 50 basis points to 1.00 percent. (19)
32.	2008-11-17	Three large U.S. life insurance companies, namely Lincoln National, Hartford Financial Services Group and Genworth Financial, seek TARP funding. (20)
33.	2008-11-18	Ford, General Motors and Chrysler, three large U.S. automaker companies, seek TARP funding. (20)
34.	2008-11-25	The Federal Reserve Board announces the creation of the Term Asset-Backed Securities Lending Facility (TALF). The U.S. Government backs up to $306 billion in Citigroup's loans and securities and directly invests $20 billion in the company. (21)
35.	2008-12-11	The National Bureau of Economic Research (NBER) announces that the U.S. economic activity reached its peak in December 2007 and that it has since been in a recession. (22)
36.	2008-12-16	The Federal Reserve Board votes to reduce the primary credit rate by 75 basis points to 0.50 percent and the FOMC votes to reduce its target for the federal funds rate to a record-low range of 0 to 0.25 percent. (22)
37.	2009-01-29	The U.S. House of Representatives passes the American Recovery and Reinvestment Act of 2009, which is an economic stimulus package worth roughly $800 billion. (23)
38.	2009-02-10	The U.S. Senate passes the American Recovery and Reinvestment Act of 2009. The Federal Reserve Board announces an expansion of the TALF to as much as $1 trillion. (24)
39.	2009-02-17	The U.S. debt ceiling is increased by $789 billion to $12,104 billion. (25)
40.	2009-02-23	The U.S. Treasury Department and the Federal Reserve Board announce a joint statement together with other federal agencies that the U.S. Government stands firmly behind the banking system and will provide the credit necessary to restore the economic growth. (26)
41.	2009-02-25	The Federal Reserve Board, together with other federal agencies, announces that forthcoming stress tests of eligible U.S. bank holding companies will be conducted. (26)
42.	2009-03-02	AIG reports a fourth quarter 2008 loss of over $60 billion and a loss of almost $100 billion for all of 2008. The U.S. Treasury Department and the Federal Reserve Board announce a restructuring of the government's assistance to AIG. (26)
43.	2009-03-03	The U.S. Treasury Department and the Federal Reserve announce the launch of the TALF. (26)
44.	2009-03-18	The FOMC increases the size of the Federal Reserve's balance sheet by purchasing $750 billion agency mortgage-backed securities, $100 billion agency debt, and $300 billion long-term Treasury securities. The Federal Reserve Bank of New York announces its plan to purchase Treasury securities. (27)

See next page for continuation.

Table B.1: Chain of Events Impacting the Yield Spread – Continued from previous page.

45.	2009-03-19	OneWest Bank acquires IndyMac. Total estimated loss to the Deposit Insurance Fund of the Federal Deposit Insurance Corporation (FDIC) is over $10 billion. (27)
46.	2009-03-23	The U.S. Treasury Department and the Federal Reserve announce a joint statement on their roles during the financial crisis and into the future, as well as necessary steps to preserve monetary stability. They agree to improve the credit markets and state that the Federal Reserve should avoid credit risk. (27)
47.	2009-05-07	The Federal Reserve presents the results of its stress tests of the 19 largest U.S. bank holding companies. During 2009 and 2010 the 19 firms may lose $600 billion. (28)
48.	2009-05-21	S&P lowers its outlook for the UK Government debt from stable to negative. (29)
49.	2009-06-24	The SEC proposes a regulatory framework for money market funds. (30)
50.	2009-06-25	AIG announces that the debt it owes the Federal Reserve Bank of New York has been cut by $25 billion. (30)
51.	2009-09-18	The U.S. Treasury Department announces the expiration of the Guarantee Program for Money Market Funds, which has generated approximately $1.2 billion in participation fees. (31)
52.	2009-11-01	CIT Group Inc. files for Chapter 11 bankruptcy protection. Its shareholders', including the U.S. Government's, equity stakes are expected to wipe out. (32)
53.	2009-11-17	The Federal Reserve Board announces that it will reduce the maximum maturity of primary credit loans from 90 days to 28 days. (33)
54.	2009-12-11	The U.S. House of Representatives passes legislation to create a Financial Stability Council. (34)
55.	2009-12-14	Citigroup announces that it will repay $20 billion that it owes the U.S. Government. (34)
56.	2009-12-28	The U.S. debt ceiling is increased by $290 billion to $12,394 billion. (35)
57.	2010-02-01	The AMLF, CPFF, PDCF and TSLF expire. (36)
58.	2010-02-12	The President of the U.S. signs the increase in the U.S. debt ceiling by $1.9 trillion to $14.3 trillion into law after it has been passed by the U.S. Congress. (37)
59.	2010-02-18	The Federal Reserve Board votes to increase the primary credit rate by 25 basis points to 0.75 percent and to shorten the maximum maturity of primary credit loans to overnight. (38)
60.	2010-02-24	Freddie Mac reports a net loss of $21.6 billion for 2009. (39)
61.	2010-02-26	Fannie Mae reports a full-year 2009 loss of $72.0 billion. (39)
62.	2010-07-21	The President of the U.S. signs the Dodd-Frank Wall Street Reform and Consumer Protection Act into law. (40)
63.	2011-01-06	The U.S. Secretary of the Treasury requests an increase in the debt ceiling. (41)
64.	2011-01-14	The Federal Reserve Bank of New York announces that its assistance to AIG is terminated. (42)
65.	2011-01-28	Moody's warns of a negative outlook for the U.S. debt. (43)
66.	2011-04-04	The U.S. Secretary of the Treasury requests an increase in the debt ceiling. (44)

See next page for continuation.

Table B.1: Chain of Events Impacting the Yield Spread – Continued from previous page.

67. 2011-04-18	S&P issues a negative outlook for the U.S.'s AAA rating for the first time since the rating agency was established in 1860.	(45)
68. 2011-05-02	The U.S. Secretary of the Treasury requests an increase in the debt ceiling.	(46)
69. 2011-05-31	The U.S. House of Representatives rejects a bill that would have raised the debt ceiling by $2.4 trillion.	(47)
70. 2011-06-02	Moody's warns of a downgrade of the U.S. credit rating.	(47)
71. 2011-07-14	S&P puts the U.S. debt on a 90-day credit watch list.	(48)
72. 2011-07-16	Egon-Jones Rating Company is the first NRSRO to downgrade the U.S. debt from AAA to AA+.	(48)
73. 2011-07-31	The President of the U.S. and the Speaker of the U.S. House of Representatives announce, separately, that an agreement increasing the debt limit, entitled the Budget Control Act, has been reached.	(49)
74. 2011-08-01	The U.S. House of Representatives passes the Budget Control Act.	(49)
75. 2011-08-02	The U.S. Senate passes the Budget Control Act and the act is signed into law by the President of the U.S.	(49)
76. 2011-08-05	S&P announces its first-ever downgrade of the U.S. debt from AAA to AA+.	(49)

Table B.2: t-Tests for Event Groups and Pre-Event Windows.

		Fixed Window		Time-Shifting Window	
Event Group	Mean	t-Statistic	p-Value	t-Statistic	p-Value
1	0.51	29.24	0.01	1.44	0.17
2	0.59	36.51	0.00	-3.74	0.00
3	2.59	8.44	0.07	6.85	0.08
4	1.22	53.56	0.00	0.56	0.58
5	1.27	8.32	0.08	-0.37	0.75
6	0.61	7.74	0.08	-6.34	0.00
7	1.45	21.60	0.00	7.35	0.00
8	1.09	11.26	0.06	-1.16	0.33
9	1.23	9.01	0.07	0.80	0.52
10	0.52	7.37	0.00	-6.28	0.00
11	0.88	13.63	0.00	1.95	0.08
12	1.49	5.35	0.03	3.17	0.08
13	0.86	11.17	0.06	-2.73	0.04
14	0.50	9.98	0.00	-1.27	0.22
15	0.45	17.01	0.02	2.15	0.09
16	1.88	10.82	0.00	9.29	0.00
17	1.54	19.54	0.00	3.23	0.00
18	0.85	18.89	0.03	-6.83	0.00
19	0.85	143.61	0.00	-9.52	0.00
20	0.38	5.87	0.03	-8.20	0.00
21	0.49	2.74	0.22	-2.54	0.13
22	0.14	-1.17	0.30	-6.97	0.00
23	0.07	-4.45	0.13	-0.98	0.47
24	0.03	-3.15	0.19	-0.94	0.50
25	0.08	-2.15	0.27	0.06	0.96
26	0.11	-3.19	0.01	0.89	0.39
27	0.12	-2.98	0.04	1.01	0.35
28	0.06	-6.24	0.08	-2.92	0.10
29	0.10	-13.68	0.00	-2.42	0.02
30	0.10	-3.05	0.09	0.38	0.74
31	0.12	-10.74	0.00	8.36	0.01
32	0.09	-6.57	0.07	0.03	0.98
33	0.07	-7.84	0.06	-1.03	0.46
34	0.12	-7.17	0.00	3.30	0.03
35	0.15	-7.70	0.00	7.74	0.00
36	0.07	-7.84	0.06	-3.62	0.15
37	0.10	-19.10	0.00	0.36	0.72
38	0.08	-16.62	0.00	-3.05	0.06
39	0.05	-16.35	0.00	-4.87	0.00
40	0.04	-5.63	0.10	-1.32	0.36
41	0.07	-18.09	0.00	-3.08	0.01
42	0.05	-26.80	0.00	-6.69	0.00
43	0.06	-19.56	0.00	-2.81	0.02
44	0.11	-5.29	0.09	0.31	0.80
45	0.11	-10.74	0.00	-0.22	0.85
46	0.10	-13.68	0.00	-2.96	0.07
47	0.07	-20.78	0.00	-3.47	0.00
48	0.08	-18.41	0.00	-0.13	0.90
49	0.09	-11.13	0.00	2.93	0.01
Main	0.36	11.50	0.00	–	–

Table B.3: Non-Parametric Tests for Event Groups and Pre-Event Windows.

Event Group	N^+	N	Sign Test p-Value[1]	Signed-Rank p-Value	Rank-Sum p-Value
1	2.00	2.00	0.16 (1.41)	0.50	1.00
2	0.00	2.00	0.16 (-1.41)	0.50	0.53
3	2.00	2.00	0.16 (1.41)	0.50	0.02
4	4.00	4.00	0.05 (2.00)	0.12	0.30
5	1.00	1.00	0.32 (1.00)	1.00	0.61
6	0.00	2.00	0.16 (-1.41)	0.50	0.04
7	3.00	3.00	0.08 (1.73)	0.25	0.01
8	0.00	2.00	0.16 (-1.41)	0.50	0.56
9	1.00	2.00	1.00 (0.00)	1.00	0.51
10	0.00	4.00	0.05 (-2.00)	0.12	0.00
11	3.00	4.00	0.32 (1.00)	0.25	0.16
12	3.00	3.00	0.08 (1.73)	0.25	0.01
13	0.00	2.00	0.16 (-1.41)	0.50	0.37
14	1.00	4.00	0.32 (-1.00)	0.25	0.57
15	1.00	1.00	0.32 (1.00)	1.00	0.70
16	6.00	6.00	0.01 (2.45)	0.03	0.00
17	9.00	9.00	0.00 (3.00)	0.00	0.11
18	0.00	2.00	0.16 (-1.41)	0.50	0.09
19	0.00	2.00	0.16 (-1.41)	0.50	0.03
20	0.00	3.00	0.08 (-1.73)	0.25	0.01
21	0.00	2.00	0.16 (-1.41)	0.50	0.19
22	0.00	5.00	0.03 (-2.24)	0.06	0.00
23	0.00	2.00	0.16 (-1.41)	0.50	0.44
24	1.00	2.00	1.00 (0.00)	1.00	0.29
25	1.00	2.00	1.00 (0.00)	1.00	0.91
26	5.00	8.00	0.48 (0.71)	0.38	0.55
27	4.00	5.00	0.18 (1.34)	0.31	0.40
28	0.00	2.00	0.16 (-1.41)	0.50	0.14
29	0.00	2.00	0.16 (-1.41)	0.50	0.37
30	2.00	3.00	0.56 (0.58)	0.75	0.40
31	2.00	2.00	0.16 (1.41)	0.50	0.02
32	1.00	1.00	0.32 (1.00)	1.00	0.50
33	0.00	2.00	0.16 (-1.41)	0.50	0.44
34	3.00	3.00	0.08 (1.73)	0.25	0.06
35	2.00	2.00	0.16 (1.41)	0.50	0.09
36	0.00	2.00	0.16 (-1.41)	0.50	0.02
37	2.00	2.00	0.16 (1.41)	0.50	0.97
38	0.00	2.00	0.16 (-1.41)	0.50	0.27
39	0.00	4.00	0.05 (-2.00)	0.12	0.01
40	0.00	2.00	0.16 (-1.41)	0.50	0.31
41	0.00	2.00	0.16 (-1.41)	0.50	0.33
42	0.00	2.00	0.16 (-1.41)	0.50	0.09
43	0.00	2.00	0.16 (-1.41)	0.50	0.85
44	1.00	2.00	1.00 (0.00)	1.00	0.70
45	1.00	2.00	1.00 (0.00)	1.00	0.91
46	0.00	2.00	0.16 (-1.41)	0.50	0.16
47	0.00	4.00	0.05 (-2.00)	0.12	0.05
48	1.00	3.00	0.56 (-0.58)	1.00	0.73
49	6.00	6.00	0.01 (2.45)	0.03	0.05
Main	395.00	1092.00	0.00 (-9.14)	0.00	0.38

[1] z-statistics in parentheses.

Table B.4: Tests for Preserved Effects.

Panel A: t-Test	
Mean of the Pre-Event Window	0.07
Mean of the Post-Event Window	0.08
t-Statistic	1.75
p-Value	0.08

Panel B: Non-Parametric Tests

	Sign Test	Wilcoxon Signed-Rank Test	Wilcoxon Rank-Sum Test
z-Statistic	3.07	-2.45	2.69
p-Value	0.00	0.01	0.01
N^+	83		
N	130		

Table B.5: Regression Analysis of the Yield Spread.

		Ordinary		Newey-West	
Variable	Coefficient	t-Statistic	p-Value	t-Statistic	p-Value
θ_0	0.00	0.04	0.97	0.02	0.98
θ_{XAU}	0.00	3.86	0.00	1.81	0.07
θ_{SI}	-0.00	-2.59	0.01	-1.02	0.31
θ_{ED}	0.17	16.45	0.00	5.69	0.00
θ_{E_1}	-0.23	-1.20	0.23	-3.45	0.00
θ_{E_2}	-0.15	-0.78	0.44	-2.24	0.03
θ_{E_3}	1.80	9.36	0.00	18.51	0.00
θ_{E_4}	0.46	3.33	0.00	6.75	0.00
θ_{E_5}	0.67	2.45	0.01	10.13	0.00
θ_{E_6}	-0.04	-0.23	0.82	-0.73	0.47
θ_{E_7}	0.69	4.35	0.00	9.58	0.00
θ_{E_8}	0.57	2.95	0.00	13.13	0.00
θ_{E_9}	0.76	3.96	0.00	15.51	0.00
$\theta_{E_{10}}$	0.06	0.47	0.64	1.47	0.14
$\theta_{E_{11}}$	0.44	3.25	0.00	11.20	0.00
$\theta_{E_{12}}$	1.09	6.97	0.00	10.88	0.00
$\theta_{E_{13}}$	0.46	2.41	0.02	10.83	0.00
$\theta_{E_{14}}$	0.12	0.85	0.40	3.78	0.00
$\theta_{E_{15}}$	0.07	0.27	0.79	2.27	0.02
$\theta_{E_{16}}$	1.20	10.63	0.00	5.79	0.00
$\theta_{E_{17}}$	0.54	5.20	0.00	3.65	0.00
$\theta_{E_{18}}$	0.23	1.18	0.24	2.66	0.01
$\theta_{E_{19}}$	0.29	1.49	0.14	3.91	0.00
$\theta_{E_{20}}$	0.09	0.54	0.59	2.03	0.04
$\theta_{E_{21}}$	0.16	0.82	0.41	3.02	0.00
$\theta_{E_{22}}$	-0.11	-0.91	0.36	-3.11	0.00
$\theta_{E_{23}}$	-0.07	-0.36	0.72	-2.29	0.02
$\theta_{E_{24}}$	-0.12	-0.61	0.54	-3.52	0.00
$\theta_{E_{25}}$	-0.09	-0.46	0.65	-2.03	0.04
$\theta_{E_{26}}$	-0.07	-0.75	0.46	-1.41	0.16
$\theta_{E_{27}}$	-0.08	-0.64	0.52	-1.78	0.07
$\theta_{E_{28}}$	-0.07	-0.36	0.72	-3.67	0.00
$\theta_{E_{29}}$	-0.03	-0.16	0.87	-1.36	0.17
$\theta_{E_{30}}$	-0.02	-0.14	0.89	-0.99	0.32
$\theta_{E_{31}}$	0.05	0.28	0.78	2.48	0.01
$\theta_{E_{32}}$	0.04	0.15	0.88	2.47	0.01
$\theta_{E_{33}}$	0.00	0.01	0.99	0.15	0.88
$\theta_{E_{34}}$	0.05	0.34	0.73	2.91	0.00
$\theta_{E_{35}}$	0.09	0.35	0.73	4.19	0.00
$\theta_{E_{36}}$	0.01	0.06	0.95	0.57	0.57
$\theta_{E_{37}}$	0.05	0.23	0.81	2.43	0.02
$\theta_{E_{38}}$	0.02	0.11	0.92	1.02	0.31
$\theta_{E_{39}}$	-0.00	-0.02	0.98	-0.13	0.90
$\theta_{E_{40}}$	-0.06	-0.30	0.76	-5.04	0.00
$\theta_{E_{41}}$	-0.01	-0.07	0.95	-0.60	0.55
$\theta_{E_{42}}$	-0.03	-0.14	0.89	-1.01	0.31
$\theta_{E_{43}}$	-0.01	-0.07	0.95	-0.49	0.63
$\theta_{E_{44}}$	0.03	0.16	0.87	1.12	0.26
$\theta_{E_{45}}$	0.03	0.17	0.87	1.64	0.10
$\theta_{E_{46}}$	0.01	0.02	0.98	0.22	0.82
$\theta_{E_{47}}$	-0.02	-0.12	0.91	-0.90	0.37
$\theta_{E_{48}}$	-0.01	-0.06	0.95	-0.60	0.55
$\theta_{E_{49}}$	-0.03	-0.28	0.78	-1.44	0.15

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