Liquidity and Credit Risk in Fixed Income Markets

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Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Objectives and Purpose

In fixed income markets, investors face at least three categories of risk: interest rate risk, credit risk, and liquidity risk. These components simultaneously affect the market prices and, thus, the yields of bonds. As two bonds typically differ in more than one dimension, their yield differences usually cannot be attributed to one of these risk factors unambiguously. Therefore, it is a non-trivial task to disentangle the contribution of the individual risk components.

The purpose of this dissertation is to study the impact of the various factors on yield differences in fixed income markets. To do so, we analyze bond markets that specifically allow us to isolate the different risk components and to gain insight into the magnitude of the respective risk premia. In particular, we focus on liquidity premia and analyze their variation for different times to maturity as well as over time. In the next two chapters of this dissertation, we investigate yield spreads that are driven by a differing liquidity only. In the subsequent chapter, we disentangle the simultaneous effects of credit risk and liquidity.

Interest rate risk and credit risk have already been studied extensively in the literature and are mostly incorporated into risk management systems and regulatory frameworks. In contrast, the measurability and the magnitude of liquidity premia are currently lively debated among practitioners such as accountants and actuaries, and regulators. In particular, these issues are discussed with regard to the implementation of Solvency II and the update of banking regulations (Basel III) in response to the recent financial crisis.

The identification of liquidity premia is particularly challenging as their impact compared to the other risk factors is typically relatively small during normal market conditions. Nevertheless, the pricing of liquidity is an important issue in fixed income markets as liquidity is especially attractive during periods of market turmoil. In particular, the recent financial crisis has shown that markets that operate smoothly under normal conditions can suddenly dry up. Moreover, the magnitude of the liquidity premium is important for investors with a long investment horizon like insurance companies or pension funds. Since they are able to lock in their investments for a long time period, buying relatively illiquid bonds with high liquidity premia offers an interesting alternative.

1.2 Concepts of Liquidity

During the last decades, a vast academic literature on liquidity capturing very different aspects has emerged. In this section, we provide a short overview of the existing concepts and clarify the notion of liquidity we consider throughout this dissertation. Moreover, we point out to which part of the literature we contribute specifically.

The literature generally distinguishes between funding liquidity and market liquidity. *Funding liquidity* concerns the access of market participants, in particular traders, to funding. Considering the liquidity of a firm, this concept is closely related to solvency. *Market liquidity* refers to the ease of trading an asset. Hence, it is determined by specific characteristics of an asset or a (homogenous) market as a whole. This liquidity concept is also called asset liquidity or trading liquidity. Most studies focus on only one of these liquidity aspects. In this dissertation, we concentrate on market liquidity. However, it is worthwhile to note that articles such as Brunnermeier and Pedersen (2009) and Fontaine and Garcia (2010) have investigated the interrelation between funding and market liquidity. They show that the liquidity concepts are linked, particularly during market crisis, and their interaction can be mutually reinforcing and may lead to a liquidity spiral.

An early definition of market liquidity goes back to Keynes (1930), p. 67, who describes an asset as more “liquid” than another, if it is “more certainly realisable at short notice without loss." This definition shows the complex nature of liquidity as he already includes two dimensions: *price* and *time*. Other dimensions of liquidity are *magnitude* (related to the price dimension) and *regeneration* (related to the price and time dimension). In market microstructure theory, as overviewed in O'Hara (1995) and Madhavan (2000), these dimensions are rendered more precisely as *tightness* (size of bid-ask spread), *immediacy* (time between order submission and settlement), *depth* (trade impact), and *resiliency* (speed at which the trade impact dissipates). Amihud et al. (2005) discuss sources of illiquidity that may lead to costs when buying or selling a security. Rational Investors anticipate these costs of future purchases and sales which thus affect current security prices to compensate investors for bearing them. As a result, less liquid assets trade at lower prices, i.e. investors demand a price discount which depends on the *liquidity level*. In addition, assuming a time-varying liquidity, investors may also demand a compensation for their exposure to *liquidity risk*, i.e. the risk that the asset has become less liquid when it is sold.

In standard no-arbitrage asset pricing theory, assets with the same cash flows should have the same price. If assets have identical characteristics but differ with respect to their current or future liquidity, any price difference can be attributed unambiguously to liquidity differences. Such a clinical environment therefore allows to directly measure liquidity premia. Empirical studies on market liquidity typically test for the existence of a liquidity effect and, if supported, investigate its magnitude and the determinants. In particular, they often try to relate the obtained liquidity premia to liquidity proxies such as the bid-ask spread, the turnover, or return volume measures like the *ILLIQ* measure defined by Amihud (2002). In the stock market, Amihud and Mendelson (1986) are the first to study the impact of liquidity on asset prices and motivated ample further studies such as Brennan and Subrahmanyam (1996) and Hasbrouck (2009) on the level of liquidity. Recently, Chordia et al. (2000), Pástor and Stambaugh (2003), and Acharya and Pedersen (2005) study the pricing of liquidity risk in stock markets.

In contrast to stock markets, fixed income markets provide a much cleaner area for investigating the effect of liquidity on asset prices. First, promised (contractual) cash flows of straight bonds are known with certainty. Second, liquidity differences disappear at maturity. Therefore, bonds with identical promised cash flows and identical credit risk should trade at the same price except for a potential liquidity premium. Hence, yield differences between these bonds can directly be interpreted as liquidity premia or discounts. Moreover, it is important to note that liquidity premia in fixed income markets can also be assigned to specific times to maturity. This fact especially allows to study the term structure of liquidity premia.

Empirical studies on liquidity in fixed income markets can further be classified into two groups. The first one contains studies such as Houweling et al. (2005) and Goyenko et al. (2010) that attempt to directly *measure market liquidity by proxies* such as the bid-ask spread. The second group examines the *effect of illiquidity on market prices*. The studies within this dissertation belong to the second category as we analyze the effect of different liquidity in closely related markets on yield spreads. Here, it is useful to differentiate between studies which concentrate on bonds that are considered to be *default-free*, typically government bonds, and studies using *defaultable bonds* like corporate bonds. This second group of studies has to control for price or yield effects of default risk.

The studies by Amihud and Mendelson (1991), Warga (1992), Kamara (1994), Krishnamurthy (2002), and Goldreich et al. (2005) analyze the U.S. Treasury market. These studies, however, investigate either short times to maturity only or, to some extent, suffer from interpolation errors in yields related to not perfectly matched cash flows. In contrast, we are able to accurately extract a model-free term structure of liquidity premia for up to ten years in the U.S. Treasury market and the market for German government bonds.

For corporate bonds, Fisher (1959) is one of the first to study the determinants of corporate bond yield spreads relative to government bonds and relates them to the issue volume as a proxy for liquidity. Due to increased transparency in corporate bond markets, in particular due to the availability of TRACE Corporate Bond Data, a large number of studies such as Collin-Dufresne et al. (2001), Chen et al. (2007), and Dick-Nielsen et al. (2009) investigate liquidity and credit risk premia in this market. De Jong and Driessen (2007) and Acharya et al. (2010) particularly focus on liquidity risk rather than the level of liquidity. These studies, however, usually need a number of modeling assumptions to disentangle liquidity and credit risk. In contrast, we study the Pfandbrief market that allows for an intuitive stratification of Pfandbriefe into segments in which prices mainly differ by only one risk factor.

1.3 Contribution and Organization

Our main contributions to the existing literature on liquidity premia in bond markets concern the following three aspects. First, we accurately isolate model-free term structures of liquidity premia between bonds with exactly matched-maturities in the U.S. Treasury market as well as the German government bond market and study their cross-sectional and time-series behavior. Second, we show that specific securities are priced almost identically even though they considerably differ with respect to their liquidity. Third, we investigate the Pfandbrief market and show that liquidity is the most important, but not the exclusive risk factor explaining yield spreads. In addition to the literature on liquidity premia in bond markets, we extend the literature on STRIPS markets. We provide a solution for the empirical puzzle that matched-maturity principal and coupon STRIPS trade at different prices. Furthermore, we contribute to the literature on credit risk premia in bond markets by isolating the different risk components within the Pfandbrief market. In contrast to previous studies, we consider the time-variation of Pfandbrief yield spreads by investigating different market environments and we explicitly account for the issuers' default risk and the quality of the cover pool.

This dissertation is organized in three self-contained chapters. A more detailed discussion of the contribution to the relevant literature is given at the beginning of each chapter. In the following, we give a short summary of the different approaches and the most important findings.

In **Chapter 2**, we isolate model-free and maturity-dependent liquidity premia within the U.S. Treasury market. The issuing policy of the U.S. Treasury provides us with a clinical environment to test for liquidity effects between Treasury notes and Treasury STRIPS. We analyze the differences between directly observed yields from coupon and principal STRIPS and synthetic yields obtained via bootstrapping Treasury notes. These yields reflect the liquidity of the coupon and principal STRIPS and the liquidity of the Treasury notes, respectively. As the maturities of the observed STRIPS yields exactly match the coupon and maturity dates of Treasury notes, we can directly compare them and no interpolation is required. Since we control for potential effects due to an asynchronous taxation, the differences directly measure the effect of the differential liquidity.

The main results of this study are as follows. First, we isolate an average liquidity premium between coupon STRIPS and Treasury notes of up to 13.7 bp during normal market conditions and up to 28.6 bp during the recent financial crisis. More importantly, the term structure of liquidity premia between coupon STRIPS and Treasury notes has a different sign for short and long maturities. This effect is surprisingly stable over time and can be attributed to the higher liquidity of coupon STRIPS for short maturities as measured by their outstanding amount and their stripping activity. Second, for principal STRIPS, we find that their yields basically coincide with synthetic yields. This result can be related to the principal STRIPS' unique reconstitution feature. Third, we show that principal STRIPS typically trade at a lower yield than otherwise identical coupon STRIPS. These empirically observed yield differences can be related to the liquidity premia between the coupon STRIPS market and the Treasury notes market and any direct liquidity effect between the matched-maturity STRIPS is of minor importance.

In **Chapter 3**, we investigate liquidity premia in the German government bond market. The methodology to isolate the liquidity premia is similar to the approach presented in Chapter 2. The results, however, show some striking differences on the one hand, and important similarities on the other. In contrast to the results for the U.S. Treasury market, German coupon STRIPS nearly always trade at a liquidity premium compared to synthetic zero-bonds obtained via bootstrapping Bunds and the premia do not show a clear maturity structure. However, the premia are rather small and economically negligible. Moreover, the yield differences significantly increase during the recent financial crisis and can to a large part be explained by liquidity related macroeconomic variables. As for the U.S. Treasury market, we find that German principal STRIPS trade in line with their corresponding synthetic zero-bonds even though they are substantially less liquid. Further, we show for the German government bond market that the positive differences between matched-maturity coupon and principal STRIPS do not stem from their relative liquidity, but can be traced back to the liquidity differences between the coupon STRIPS and the Bunds market.

In **Chapter 4**, we analyze liquidity and credit risk premia in the German Pfandbrief market. We measure individual Pfandbrief yield spreads relative to the estimated term structure of interest rates of public Jumbo Pfandbriefe. Due to the high level of standardization and the precise legal requirements, it is, in contrast to studies in the corporate bond market, relatively easy to isolate the different components of the individual Pfandbrief yield spreads.

Yield spreads between Pfandbriefe and German government bonds usually have been interpreted as pure liquidity premia. Our analysis reveals that liquidity is the most important, but not the exclusive risk factor within the Pfandbrief market. We show that the Pfandbrief yield spreads also depend on the quality of the issuer, the type of collateral, and the quality of the underlying assets. In particular, it is surprising that the issuer's default risk is priced considerably, even though Pfandbriefe are backed by high-quality mortgages or public-sector loans and no single Pfandbrief has ever defaulted. Using recently published cover pool data, we are also able to demonstrate that the quality of the cover pool assets is less relevant in a normal market environment, but important in times of financial turmoil.

Chapter 2

The Term Structure of Liquidity Premia in the U.S. Treasury Market[1]

2.1 Introduction

Bonds are ideal financial assets to study the impact of changing liquidity on prices or yields as liquidity differences cancel out at the maturity date. The natural hypothesis that more liquid bonds trade at lower yields than their less liquid, but otherwise identical counterparts, however, is difficult to test. The obvious reason is that bonds differ in various dimensions and, therefore, their yield differences cannot be traced back to liquidity effects unambiguously. Other effects are related to credit risk, specialness, tax treatment, option features, maturity and the coupon rate. Even if one restricts the analysis to a Government bond market to exclude most of the spread determinants, differences in the bonds' cash flow dates almost always remain. As a consequence, interpolation techniques are applied to control for coupon and maturity effects in liquidity studies. However, since empirically obtained yield differences are rather small, it is unclear whether these differences are caused by interpolation errors or whether the differences can be traced back to liquidity effects.

[1]This chapter is based on a working paper co-authored with Wolfgang Bühler. Cf. Bühler and Vonhoff (2010).

The purpose of this study is to carefully isolate liquidity premia within the U.S. Treasury market. The issuing policy of the U.S. Treasury has provided a clinical environment to test for liquidity effects between the Treasury notes and the Treasury STRIPS market since 2002 for two reasons. First, the coupon dates of regularly issued Treasury notes coincide and at least one Treasury note matures at every coupon date. This ladder-type structure in the maturities of traded Treasury notes allows us to perfectly obtain synthetic yields via bootstrapping.[2] These yields reflect the *liquidity of the Treasury notes* used in the bootstrapping procedure. Second, the synthetic yields can directly be compared to the observed STRIPS yields as their maturities exactly match the coupon and maturity dates of Treasury notes. The observed yields contain a *STRIPS-specific liquidity component* which depends on calender time, time to maturity, and whether the STRIPS corresponds to a coupon or principal payment.

It is well known that Treasury notes, bonds and STRIPS are direct obligations of the U.S. government and, thus, are exposed to identical credit risk. They are also exempt from both state and local taxes and do not have special contractual provisions. Therefore, the markets for Treasury notes, bonds, and STRIPS are practically homogenous, with three exceptions: *specialness, federal taxes, and liquidity.* On-the-run Treasury notes or bonds typically are special in the sense that they experience a relative excess demand, e.g. as collateral in the repo market. As a consequence, they trade at relatively lower yields.[3] The specialness of on-the-run bonds represents a specific heterogeneity in the Treasury market and it is relatively easy to control for this effect empirically. On the contrary, it is much more difficult to model and measure the impact of taxes on bond prices. In this study, we show that neither tax clientele nor tax timing effects have an impact on the observed yield differences. Therefore, any remaining yield difference can be attributed to a different liquidity.

U.S. Treasury STRIPS are obtained by stripping a Treasury note or bond into the coupon and the principal payments. Coupon STRIPS from different notes and bonds are assigned the same CUSIP number if they have the same maturity date. Therefore,

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[2]Throughout this dissertation, we use the term *synthetic yield* for the yield-to-maturities of synthetic zero-bonds obtained via the bootstrapping of coupon Treasury securities. This yield is also called the *spot rate.*

[3]See, e.g., Duffie (1996), pp. 494-496.

they are not distinguishable. On the contrary, principal STRIPS of each note and bond are unique and not interchangeable with other principal or coupon STRIPS. Hence, there is a specific heterogeneity in the STRIPS market caused by the different treatment of coupon and principal STRIPS. We analyze the consequences of this difference in our empirical study.

Our clinical sample allows us to determine *three term structures of interest rates* with exactly matched maturities. The first is obtained by bootstrapping Treasury notes, the second from coupon STRIPS, and the third from principal STRIPS. Analyzing these term structures of interest rates allows us to gain insight into maturity dependent liquidity premia between the different markets.

Our study is related to three important strands of literature. The first identifies liquidity premia in Treasury bills, notes and bonds. Amihud and Mendelson (1991) and Kamara (1994) study yield differences between Treasury bills and Treasury notes with maturities below six months. They find significant liquidity premia in the yields of notes compared to bills. A couple of studies analyze the on-the-run phenomenon, e.g., Warga (1992), Krishnamurthy (2002), Goldreich et al. (2005), and Pasquariello and Vega (2009). These studies find that most recently issued government bonds have lower holding-period returns or trade at lower yields than previously issued bonds maturing on similar dates. They attribute this effect to a higher liquidity of the recently issued bonds. Elton and Green (1998) compare portfolios of Treasury securities with approximately the same cash flows but different liquidity (as proxied by trading volume) and find that a higher liquidity leads to lower yields. Longstaff (2004) investigates price differences between Treasury STRIPS and stripped Refcorp bonds and relates them to flight-to-liquidity proxies. All these studies, however, suffer to some extent from interpolation errors related to not perfectly matched cash flows or they econometrically have to control for differences in the coupons or maturities. As the yield differences are typically small, e.g. only up to 1.5 bp on average in the study by Goldreich et al. (2005), it cannot be excluded that a larger part of these differences are introduced by matching methods. This critique does not apply to the studies by Fleming (2002) and Strebulaev (2002). In contrast to our study, however, these studies have to restrict their sample to bills and notes with less than six months prior to maturity to obtain exactly matched cash flows. Recently, Goyenko et al. (2010) study bond market liquidity by analyzing time-series of quoted bid-ask spreads for different maturities over an extended period of time. While this study analyzes three broad maturity classes, we provide a in-depth analysis with 20 maturity classes.

The second strand of literature deals with the impact of taxation on bond prices. One of the major problems is the existence of tax clienteles which was first studied by Schaefer (1982) and Litzenberger and Rolfo (1984b). Using the typical approach for estimating implied tax rates of the marginal investor, Green and Ødegaard (1997), Elton and Green (1998), and Liu et al. (2007) find support for the absence of tax clientele effects in the U.S. Treasury market for periods after the Tax Reform Act of 1986. Based on buy-and-hold strategies, our results support the findings of these authors that the marginal investor is tax-exempt and taxes do not substantially impact government bond prices. A second problem is the existence of tax timing options. Constantinides and Ingersoll (1984) theoretically derive the value of these options. Empirically, Litzenberger and Rolfo (1984a), Jordan and Jordan (1991), and Elton and Green (1998) determine their value by using bond "triplets" and find evidence for their existence. Regarding the yield differences between Treasury STRIPS and Treasury notes, however, we deduce that tax timing effects do not impact our results.

The third strand of literature specifically deals with Treasury STRIPS and consists of two groups. The first group primarily focusses on arbitrage opportunities between coupon bonds and the replicating portfolio consisting of STRIPS. Most studies, e.g. Lim and Livingston (1995), Grinblatt and Longstaff (2000), Jordan et al. (2000), and Sack (2000), find that arbitrage opportunities are rare and cannot be exploited successfully once transaction costs are considered. Grinblatt and Longstaff (2000) show that observed price differences between the portfolios can partially be explained by liquidity-related factors. Contrary to our study, these studies analyze price differences only on a portfolio basis and, therefore, do not allow the isolation of liquidity effects in the term structure of interest rates. The second group of studies investigates observed price and yield differences between matched-maturity coupon and principal STRIPS.[4] Daves and Ehrhardt (1993) find that principal STRIPS typically trade at a lower

[4]Other studies of U.S. Treasury STRIPS examine motives for stripping and rebundling (Grinblatt and Longstaff (2000)), term structure estimation (Sack (2000)), and cointegration (Kung and Carverhill (2005)).

yield than otherwise identical coupon STRIPS. They attribute the difference to a reconstitution option embedded in principal STRIPS and to liquidity differences. Jordan et al. (2000) obtain a similar result. They observe, however, that principal STRIPS sometimes trade at lower yields and attribute these yield differences to the richness of the underlying note or bond. We contribute to this strand of literature by showing that these differences can be ascribed to the liquidity differences between coupon STRIPS and the Treasury note corresponding to the principal STRIPS.

The main results of our study are the following. First, we find that coupon STRIPS yields significantly differ from synthetic yields obtained via bootstrapping Treasury notes. We provide evidence that these differences cannot be explained by tax clientele or tax timing effects. Thus, we empirically isolate an average liquidity premium of up to 14 bp during normal market conditions, and up to 29 bp during the recent financial crisis. More importantly, the term structure of liquidity premia between coupon STRIPS and Treasury notes has a different sign for short and for long maturities. This effect is surprisingly stable over time and can be attributed to the higher liquidity of coupon STRIPS for short maturities. The well-known on-the-run effect is of minor importance. For principal STRIPS, on the contrary, we find that their yields basically coincide with the synthetic yields. This result can be reasoned by the principal STRIPS' unique reconstitution feature and no distinct liquidity premium can be isolated.

Second, we analyze the maturity structure of yield differences between different coupon and principal STRIPS maturing on the same day. For short maturities (below two years), we find lower yields for coupon STRIPS than for principal STRIPS. For long maturities (7-10 years) we find higher yields. This result extends the finding of Daves and Ehrhardt (1993) and Jordan et al. (2000) that, on average over all maturities, coupon STRIPS trade at higher yields than otherwise identical principal STRIPS. Since matched-maturity STRIPS are taxed synchronously, taxation obviously cannot explain these differences. In this study, we show that the empirically observed yield differences between coupon and principal STRIPS can be traced back to the liquidity premia between coupon STRIPS and Treasury notes. Extending this approach, we show that yield differences between different principal STRIPS maturing on the same day can be ascribed to the fact that they differ with respect to their underlying instrument, either a Treasury note or a Treasury bond. Hence, the liquidity differences between Treasury notes and bonds transmit to the STRIPS market and any direct liquidity effect between the STRIPS is of minor importance.

Finally, our analysis shows that liquidity premia between coupon STRIPS and Treasury notes significantly increase during the recent financial crisis. To capture the time variation of liquidity premia, we relate the observed yield differences to macroeconomic variables that are associated with a flight-to-liquidity. The results suggest that short-term coupon STRIPS and long-term notes can be regarded as a "safe haven" with regard to liquidity risk in times of higher uncertainty.

The remainder of this chapter is structured as follows. In Section 2.2, we carefully describe the institutional details of the STRIPS program and discuss potential effects on the yield differences. In addition, this section presents the empirical design. In Section 2.3, we provide and discuss the empirical results. Section 2.4 concludes.

2.2 Design of the Study

Subsequently, we recall some well-known institutional features of the U.S. Treasury STRIPS program as far as they are relevant for our study.[5] We further render the calculation of observed and synthetic yields more precisely. Moreover, we discuss the potential impact of liquidity, taxation, and the unique reconstitution feature on our results. Finally, we present the empirical design of our study.

2.2.1 Institutional Details

The Separate Trading of Registered Interest and Principal Securities (STRIPS) programm was set up by the U.S. Treasury in 1985. Since October 1997 almost all newly issued notes and bonds have been eligible for stripping. STRIPS are direct obligations of the U.S. government and are obtained by delivering a Treasury note or bond to the Federal Reserve in exchange for a bundle of zero-bonds corresponding to the coupon and principal payments. As notes and bonds are held in book-entry form

[5] A detailed description of the Treasury STRIPS program can be found, e.g., in Grinblatt and Longstaff (2000) and Jordan et al. (2000).

the transaction can be executed at little cost.[6]

STRIPS are identified by whether they are created from a coupon or a principal payment. Coupon STRIPS that are due on the same day are assigned the same CUSIP number, even if they originally come from a different note or bond. Contrarily, the principal STRIPS of each note and bond are assigned a unique CUSIP number and they are not interchangeable with other principal or coupon STRIPS. To reconstitute a previously stripped note or bond, the appropriate proportions of the component STRIPS must be delivered to the Federal Reserve. For the principal payment, the principal STRIPS must have been derived from the note or bond being reconstituted. For the coupon payments, however, matched-maturity coupon STRIPS from arbitrary notes or bonds can be used.

For our analysis, we first determine the observed and synthetic yields on a pre-tax basis. According to market convention, we compute the annual (or bond-equivalent) yield of a STRIPS by simply doubling the yield-to-maturity, calculated in units of coupon periods, of Treasury notes and bonds (semiannual coupon payments). These yields are determined from directly observed prices and, therefore, denoted as observed yields in contrast to synthetic yields obtained via the bootstrapping of Treasury notes and bonds. We adjust the difference if the maturity date falls on a weekend or a public holiday to consider the cash flows exactly. We denote the annualized yield of a coupon STRIPS by y^C and the annualized yield of a principal STRIPS by y^P.

For extracting synthetic yields we use the standard bootstrapping procedure. In this procedure, the observed dirty price of a coupon bond is defined as the sum of discounted future cash flows. The discount factors or, equivalently, the synthetic yields are unknown. Given observed prices of coupon bonds with identical coupon dates, and given that at every coupon date up to some date exactly one bond matures, we can recursively obtain the synthetic yields. We pay regard to using the same day count conventions and adjustments as for STRIPS.[7] We denote $r(T)$ the *final synthetic yield* of a coupon bond with maturity T. If there is more than one note or bond maturing on the same coupon date, their final synthetic yields should be the same. However, small

[6] Further details are given in Sack (2000).

[7] As is common in the secondary market, we apply the "street" convention, i.e. we compound interest until the next coupon date.

yield differences are typically observed.[8] We discuss the potential bias when presenting our data.

For tax purposes, STRIPS are treated as originally issued discount (OID) instruments and taxed according to the constant yield method. Therefore, the annually accrued interest on STRIPS is taxed even though no interest is paid, leading to negative cash flows for taxable entities prior to maturity. It is important to note that the after-tax yield cannot simply be calculated from its pre-tax yield multiplied with (1 – tax rate). This approach disregards the obligatory intermediate tax payments during the maturity of the STRIPS. Instead, a bootstrapping-type procedure is applied to the after-tax cash-flows.[9]

Considering the current U.S. tax law we are also able to calculate the synthetic after-tax yields for Treasury notes. We assume that the investors' tax rates do not change over time and that they choose the optimal amortization rule, i.e. deferring market discount amortization to maturity and amortizing market premium by the constant yield method.[10] Then, the synthetic after-tax yields can be calculated by using the bootstrapping procedure with after-tax cash flows.[11]

2.2.2 Potential Effects on Observed and Synthetic Yields

(1) Liquidity

Typical proxies for the liquidity of a fixed income security include trading activity, the outstanding amount, the bid-ask spread, and the age.[12] Only the first two proxies need a clarification for the STRIPS market and are defined as follows:

Trading activity is typically measured by the number of trades, the trading volume, the time period between trades, or by the full order book. As none of these variables are available for STRIPS we use the stripping activity as the best available proxy. We define the stripping activity $SA^P(T)$ of a principal STRIPS with maturity T by the face value of the underlying note or bond being stripped within a given time

[8] See, e.g., Warga (1992), Duffie (1996), and Krishnamurthy (2002).

[9] The difference between these after-tax yield calculations is discussed in Daves and Ehrhardt (2008).

[10] We abstract from the case that the amortization of a market discount may be optimal if the investor expects an increasing tax rate.

[11] For a theoretical derivation confer, e.g., to the appendix of Green and Ødegaard (1997).

[12] See, e.g., Fleming (2003).

interval (one month). For coupon STRIPS with a certain maturity T, we define the monthly stripping activity $SA^C(T)$ by the sum of matched-maturity coupon STRIPS being obtained via stripping notes or bonds with equal or longer maturities within a given time interval, i.e.

$$SA^C(T) = \sum_{s \geq T} \frac{C_s}{100} \cdot SA^P(s), \tag{2.1}$$

where C_s is the corresponding semiannual coupon payable at T. This definition reflects the fact that matched-maturity coupon STRIPS are interchangeable (are assigned the same CUSIP number). As a consequence, the stripping activity of coupon STRIPS increases if the remaining time to maturity decreases. Stripping activity is positively related to trading volume as the incentive to strip typically comes from retail. This fact was previously stated by Stigum (1990), p. 696, and reconfirmed by recent conversations with traders. The STRIPS trader initiates the stripping procedure with the Federal Reserve and sells coupon or principal STRIPS to the customers.[13]

The outstanding amount of a security provides information about the absolute supply of this security. The actually outstanding amount of a specific note or bond at a given point in time is the total outstanding volume minus the amount held in stripped form. Analogously, the outstanding amount $OA^P(T)$ of a specific principal STRIPS with maturity T equals the total outstanding volume of the underlying note or bond held in stripped form. For coupon STRIPS with a specific maturity date T, the outstanding amount $OA^C(T)$ equals the total coupon volume of all notes and bonds that mature at or after this specific maturity date and are held in stripped form, i.e.

$$OA^C(T) = \sum_{s \geq T} \frac{C_s}{100} \cdot OA^P(s). \tag{2.2}$$

Treasury notes and bonds clearly differ from Treasury STRIPS with respect to their outstanding amount. Shortly after an issuance of a note or bond, typically hardly any STRIPS related to this issue exist. As pointed out above, the outstanding amount of coupon STRIPS maturing on the same day but coming originally from different

[13]Reconstitution activity could also be used as a proxy for trading activity, however, as it is highly positively correlated to stripping activity we do not consider it.

issues add up due to the fungibility. Therefore, $OA^C(T)$ increases with decreasing time to maturity and it is possible that this amount exceeds the outstanding amount of the note or bond.[14] A similar relationship holds between the outstanding amounts of coupon and principal STRIPS.[15]

Besides these liquidity proxies we also consider the well-known on-the-run effect. Ample empirical studies have found that most recently issued notes trade at lower yields and are more liquid than older ones.[16] We control for this specific effect by including a dummy variable with value one if the note trades on-the-run, and zero otherwise.

(2) Taxation

The differential federal taxation between coupon Treasury securities and Treasury STRIPS may affect the observed and synthetic yields calculated as in Section 2.2.1. Therefore, we analyze potential tax clientele and tax timing effects. First, we empirically investigate whether different tax clienteles may have an impact on the yield differences between these markets. Second, we derive that tax timing effects do not influence our results.

Considering buy-and-hold investors, a clear-cut tax advantage or disadvantage of one of these markets does not exist. In particular, the feedback effect between the prices of notes or STRIPS and their taxation leads to non-linear tax effects with respect to various factors. The direction of the tax effect in a buy-and-hold setting depends on the maturity time, the shape of the term structure of interest rates, and whether a note trades below or above par.[17] For obtaining the direction of a potential tax effect we now assume that investors value Treasury notes and STRIPS using identical after-tax yields. If taxes play a role in the Treasury market, prices (and therefore pre-tax yields) have to adjust to meet this requirement. In the following, we discuss the potential effects for any marginal tax rate greater than zero.

Discount notes obtain a tax advantage relative to STRIPS that is increasing in

[14] In December 2004, e.g., the outstanding amount of the 12% Treasury Bond maturing on 15 May 2005 was USD 1,957 million whereas the outstanding amount of corresponding coupon STRIPS was USD 3,684 million.

[15] Daves and Ehrhardt (1993), p. 319, provide an example of this effect.

[16] See, e.g., Krishnamurthy (2002), Goldreich et al. (2005), and Pasquariello and Vega (2009).

[17] Gregory and Livingston (1989) analyze tax differences between a note and a pre-tax cash-flow matching portfolio of STRIPS for different tax scenarios in detail.

its market discount. In contrast to the discount of STRIPS, the market discount of a coupon bond trading below par does not have to be amortized until maturity. This rule leads to a tax deferral compared to STRIPS, and the advantage will appear in a lower final pre-tax yield required for discount bonds compared to STRIPS. Thus, we expect the synthetic final pre-tax yield of the note to be lower the higher its discount, leading to a higher pre-tax yield difference between Treasury STRIPS and notes.

For premium notes the result is ambiguous and the direction of the tax effect may slightly depend, among others, on the shape of the term structure.[18] The premium of coupon bonds, however, can be amortized by applying the constant yield method. Since STRIPS are also taxed by the constant yield method, there is virtually no difference in the after-tax yields. Therefore, we cannot establish a general relationship, as for the case of notes trading at a discount.

These effects are in line with the analysis of Gregory and Livingston (1989) for the current U.S. tax law. In contrast to the findings of Kamara (1994), our setting differs in two respects: First, Kamara (1994) analyzes maturities of less then six month such that the taxation is identical regardless of whether one is buying a note, a bill or STRIPS. Second, we do not consider the sellers' point of view as their tax strategy highly depends on the time of the purchase and whether the note was bought at a premium or at a discount.

In contrast to this potential tax clientele effect, we do not expect tax timing options to have an impact on the yield differences. Obviously, one could argue that a STRIPS portfolio has more tax timing options than the corresponding Treasury note, leading ceteris paribus to a higher value of the STRIPS portfolio. However, as tax timing opportunities arise, the note can immediately be stripped and some STRIPS can separately be sold in the market, possibly leading to advantageous capital gains or losses.[19] Hence, the tax timing options in the coupon Treasury market should not differ from the tax timing options in the STRIPS market. This result is in line with Grinblatt and Longstaff (2000) who discuss the effect of tax timing on the relative pricing of Treasury notes and STRIPS.

[18]Precisely, the effect depends on the pre-tax and after-tax yields for all payment dates $t < T$.

[19]Section 1286 of the Internal Revenue Code states that the basis of the stripped Treasury note or bond shall be allocated with respect to the fair market values to the corresponding STRIPS.

Fortunately, for an important part of our study potential tax differences do not matter. The yields of matched-maturity coupon and principal STRIPS are affected identically by taxation.[20] Hence, the yield differences between these STRIPS can exclusively be traced back to liquidity differences and specific reconstitution features. The size of these differences also allows us to control for tax effects in the differences between observed STRIPS yields and synthetic yields obtained from Treasury notes and bonds by the bootstrapping procedure.

(3) Reconstitution

An important effect that may lead to yield differences between coupon and principal STRIPS is that matched-maturity coupon and principal STRIPS are not perfect substitutes. When reconstituting a note or bond, one has to deliver exactly those principal STRIPS originally derived from the note or bond that is being reconstituted. Therefore, an "option to reconstitute" is implicitly embedded in principal STRIPS and can be assumed to have a positive value.[21] On the one hand, considering the reconstitution effect only, principal STRIPS should have a lower yield than matched-maturity coupon STRIPS. On the other hand, due to their fungibility, coupon STRIPS may have a larger outstanding amount, especially for short maturities. Assuming that a larger outstanding amount is related to a better liquidity and lower yields, two opposite effects on the difference between coupon and principal STRIPS exist. It is not obvious which effect dominates. In Section 2.3.3 we empirically investigate this problem.

Another interesting question refers to the yield differences between matched-maturity principal STRIPS derived from Treasury notes and Treasury bonds, respectively. Our sample allows us to measure the relative richness of the two coupon Treasury securities in a clean way.[22] It is sufficient to compare the final synthetic yields of the respective Treasury note or bond. For example, the Treasury note is rich compared to the Treasury bond if and only if its final synthetic yield is lower than that

[20] Daves and Ehrhardt (1993), p. 317, note that until the tax reform of 1989 there have been tax advantages for Japanese investors buying principal STRIPS instead of coupon STRIPS. This benefit was supposed by Stigum (1990), p. 695, to explain yield differences between coupon and principal STRIPS. Nowadays, however, coupon and principal STRIPS are treated equally in terms of taxation issues.

[21] See, e.g., Daves and Ehrhardt (1993), p. 325.

[22] Contrary to the richness and cheapness as defined by Jordan et al. (2000), our measure does not depend on a spline-based estimation procedure.

of the Treasury bond. Using this measure we are able to study the effect of relative richness of Treasury securities on yields in the STRIPS market. Section 2.3.5 is devoted to this question.

2.2.3 Empirical Design

Our sample period covers the time span from February 2002 until November 2008 on a daily basis. This period is determined by the ability to compute synthetic yields via bootstrapping. We divide our sample into two sub-samples. The first sample period covers the time span prior to the financial crisis and ranges from 15 February 2002 until 29 June 2007. The second sample period starts in July 2007. We consider this month as the first month of the financial crisis as two hedge funds managed by Bear Stearns almost collapsed at the end of June 2007. Comparing these two periods gives us insights whether the financial crisis has an impact on liquidity premia within the Treasury market.

For our analysis, we need prices of coupon bonds with identical coupon dates and, ideally, with exactly one coupon bond maturing at every coupon date. U.S. Treasury notes and bonds are usually auctioned quarterly with semi-annual coupon payments in February/August and May/November. The coupons and the redemptions are always paid on the 15th of a corresponding month.[23] Being issued on a regular basis, these series are adequate to perform our study. Moreover, these series are representative for the whole treasury market as they capture approximately 60% of the issues, and 59% of the total outstanding volume, of all marketable Treasury notes and bonds.[24]

Our observation period starts in February 2002. Prior to this month, the exact bootstrapping methodology is not applicable because no Treasury note or bond with maturity on 15 February 2002 exists. Hence, it is the natural starting date for the February/August series. Similarly, we start on 15 May 2003 with the May/November series. We consider all Treasury notes and bonds from the two series for which we are able to compute the final synthetic yields during our observation period. This restricts

[23]If this day coincides with a weekend or public holiday, the payment is made on the next trading day.

[24]This ratio is as of December 2007 and calculated using data from the *Monthly Statement of the Public Debt of the United States*.

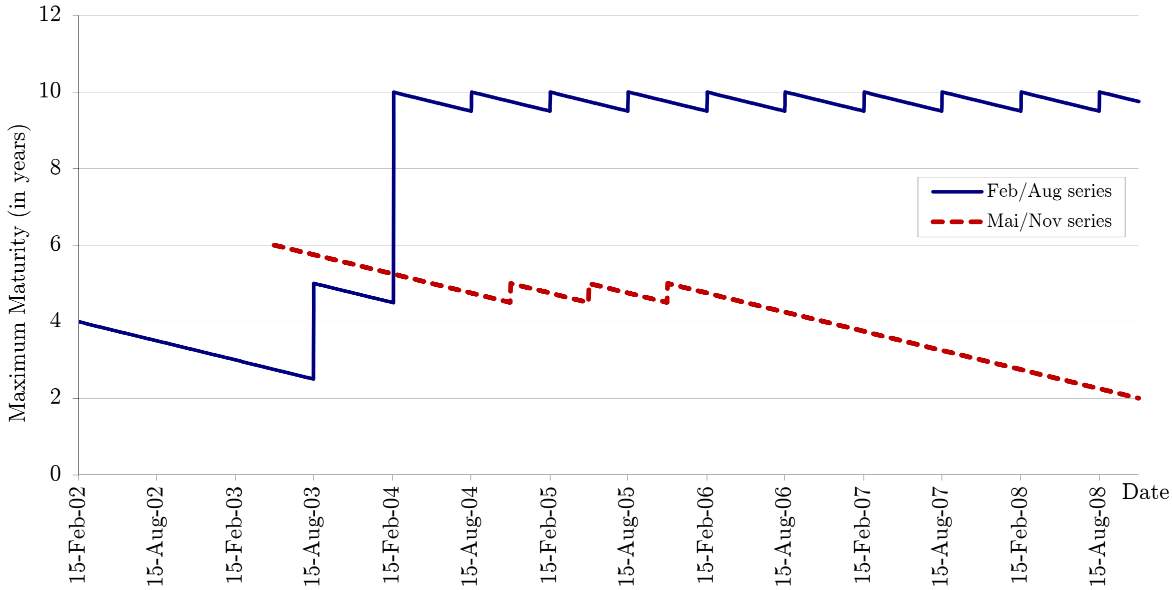

Figure 2.1: Maximum Maturity for Synthetic Yields of U.S. Treasury Notes
This figure shows the maximum maturity for the different series up to which we are able to exactly determine synthetic yields via bootstrapping U.S. Treasury notes.

our sample to notes and bonds with maturities until August 2018. The maximum maturity up to which we are able to exactly determine the synthetic yields for the different series is depicted in Figure 2.1. From 17 February 2004 on, we are able to determine synthetic yields up to ten years for the February/August series. For the May/November series, however, due to a missing maturity of a note or bond on 15 May 2011 we are able to compute the synthetic yields for up to six years only.

Following these refinements, our total sample consists of 48 Treasury notes and 6 Treasury bonds of the February/August series, and 32 Treasury notes and 2 Treasury bonds of the May/November series. These notes and bonds have fixed coupons and do not have any embedded option. For each Treasury note and bond we consider the corresponding principal STRIPS. We further consider all 48 coupon STRIPS maturing at a coupon date of a note or bond in our sample. From this data we determine three discrete term structures of interest rates for synthetic yields, coupon STRIPS and principal STRIPS on a daily basis. In the first part of the empirical study we further reduce our sample by considering Treasury notes only. They typically differ from Treasury bonds by their outstanding amount, their age and potentially by an on-the-run feature. Later, we also include Treasury bonds to measure effects of yield differences between matched-maturity Treasury notes and bonds on their corresponding matched-maturity principal STRIPS.

Frequently, two or three Treasury notes mature on the same date. Thus, the bootstrapping procedure may lead to two or three final synthetic yields for a given maturity. We treat these yields as separate observations. However, we have to decide the appropriate yield for discounting the coupons of notes with longer maturities. Since the differences between the final synthetic yields of those notes are very small in our data set, we simply take the arithmetic mean when proceeding with the bootstrapping. As an alternative we have used the smallest and largest final synthetic yield. This robustness check shows that the potential absolute error being introduced is 0.02 bp on average with a maximum of 0.26 bp. Therefore, averaging does not significantly affect our results.

We obtain daily price data for Treasury notes and bonds and coupon STRIPS via Bloomberg over the whole observation period. For the corresponding principal STRIPS, daily price data are available since 27 November 2006.[25] The so-called Bloomberg Generic Prices used in this study are consensus prices calculated from the information delivered by a variety of bond dealers and financial institutions.[26] Bloomberg ensures the data quality by marking a security "not priced" if there are not at least three prices being contributed to their system. To further verify the reliability, we checked a number of prices with data from different sources and did not find significant differences.[27]

We clean our data set in the following way: we delete the observations on dates where prices are missing for several notes such that the exact bootstrapping is not applicable. Moreover, we eliminate the observations with zero returns for almost all securities.[28] Consistent with Amihud and Mendelson (1991) we exclude all securities with less than 15 days to maturity. The trading close to maturity is particularly thin and small pricing errors will convert to extreme annualized yield errors. After this data preparation, we remain with more than 63,000 synthetic yields, about 44,000 yields of

[25]Therefore, we further reduce our sample by excluding the Treasury bonds maturing prior to this date.

[26]Although the prices are recorded at the same time, actual transaction times may slightly differ or the quotes may just reflect the dealers' price evaluation. This may introduce measurement errors, but should not asynchronously effect the yields and, thus, not bias the results systematically.

[27]Moreover, other data providers such as GovPX, Markit, Thomson Datastream, and Xtracter deliver indicative end-of-day STRIPS quotes only.

[28]Mostly, these dates correspond to public holidays and the quotes just seem to be carried forward.

principal STRIPS, and about 53,000 yields of coupon STRIPS. Summary information of the data set is presented in Table 2.1.

Consistent with Bloomberg, we follow the Treasury security market convention of next-day settlement and calculate accrued interest on an actual/actual basis. We are aware of the market convention that price information for STRIPS are usually quoted as (three-digit) yields. Since Bloomberg's methodology, however, is based on consensus prices we believe in being more accurate by taking the given prices and calculating the corresponding yields. Moreover, by using price data we are consistent with our methodology for calculating the synthetic yields. The absolute differences to the yields delivered by Bloomberg are below 0.2 bp and are due to rounding differences.

We use end-of-day mid prices for calculating the synthetic yields from Treasury notes as well as the yields of coupon and principal STRIPS. Therefore, we do not take transaction costs into account. Nevertheless, when interpreting the results we analyze whether the yield differences exceed the typical bid-ask spreads. We calculate the bid and ask yields for STRIPS using bid and ask prices delivered by Bloomberg. For assessing synthetic bid and ask yields we simply add, or subtract, half of the typical bid-ask yield spread from, or to, synthetic yields.[29]

To study liquidity effects we collect monthly observations on the total outstanding volume, the amount held in stripped form, and the stripping and reconstitution activity of Treasury notes and bonds. This data covers our 82-month sample period from February 2002 to November 2008 and is obtained from the *Monthly Statement of the Public Debt of the United States* issued by the U.S. Treasury. Furthermore, for analyzing the flight-to-liquidity premium, we obtain monthly observations of the federal funds rate (*FED*) from the Federal Reserve Bank of St. Louis, and monthly observations of the Chicago Board Options Exchange Volatility Index (*VIX*) via the Bloomberg system. This data also covers our sample period from February 2002 to November 2008.

[29] The Bloomberg methodology usually assumes a representative bid-ask spread of 1/16 in terms of prices for notes and bonds (1/32 for maturities up to 1 year and on-the-run issues). For STRIPS they assume a representative bid-ask spread of 0.02% or 2 bp in terms of annual yields. These values are in line with evidence by Elton and Green (1998), Jordan et al. (2000), and Longstaff (2004).

Table 2.1: Summary Information for U.S. Treasury Notes and Bonds and U.S. Treasury STRIPS

This table shows summary information for the U.S. Treasury securities considered in our study. The total outstanding volume, the amount held in stripped form, and the stripping activity are monthly averages given in USD million. For notes and coupon STRIPS the data is averaged across the different issues. The number of daily observations is the number of observed or synthetic yields of all issues during the whole sample period from February 2002 to November 2008. The overall statistics are based on equal weights of all observations.

Notes and Principal STRIPS of Notes

Series	# Issues	Coupon	Total Outstanding	Amount Stripped	Monthly Stripping Activity	# Daily Observations	
						Notes	PSTRIPS
FebAug 3 years	8	3.625	23,507.86	270.53	30.75	5,445	2,803
FebAug 5 years	10	3.963	20,248.52	374.87	30.58	8,922	3,978
FebAug 10 years	30	5.246	22,174.71	683.35	55.09	24,604	23,074
MayNov 3 years	8	3.734	24,778.92	362.02	25.72	5,248	2,164
MayNov 5 years	15	4.342	25,759.00	647.53	60.12	11,896	5,641
MayNov 10 years	9	6.319	18,654.85	832.64	53.39	7,513	6,641
Overall	80	4.723	22,451.48	596.94	48.43	63,628	44,301

Bonds and Principal STRIPS of Bonds

Series and Coupon	Issue Date	Maturity Date	Total Outstanding	Amount Stripped	Monthly Stripping Activity	# Daily Observations	
						Bond	PSTRIPS
FebAug 11.25 %	02/15/1985	02/15/2015	10,526.79	1,792.91	392.83	1,068	1,448
FebAug 10.625 %	08/15/1985	08/15/2015	4,023.92	666.12	182.16	943	1,448
FebAug 9.25 %	02/18/1986	02/15/2016	5,433.48	293.12	157.32	813	1,448
FebAug 8.875 %	08/15/1987	08/15/2017	10,974.28	2,804.04	651.68	441	1,448
Overall			7,739.62	1,389.05	346.00	3,265	5,792

Coupon STRIPS

Series	# Issues	First Maturity	Last Maturity	Amount Stripped	Monthly Stripping Activity	# Daily Observations
FebAug	33	08/15/2002	08/15/2018	2,501.06	599.96	13,805
MayNov	15	11/15/2003	11/15/2010	3,351.41	471.28	39,281
Overall	48			2,710.32	568.29	53,205

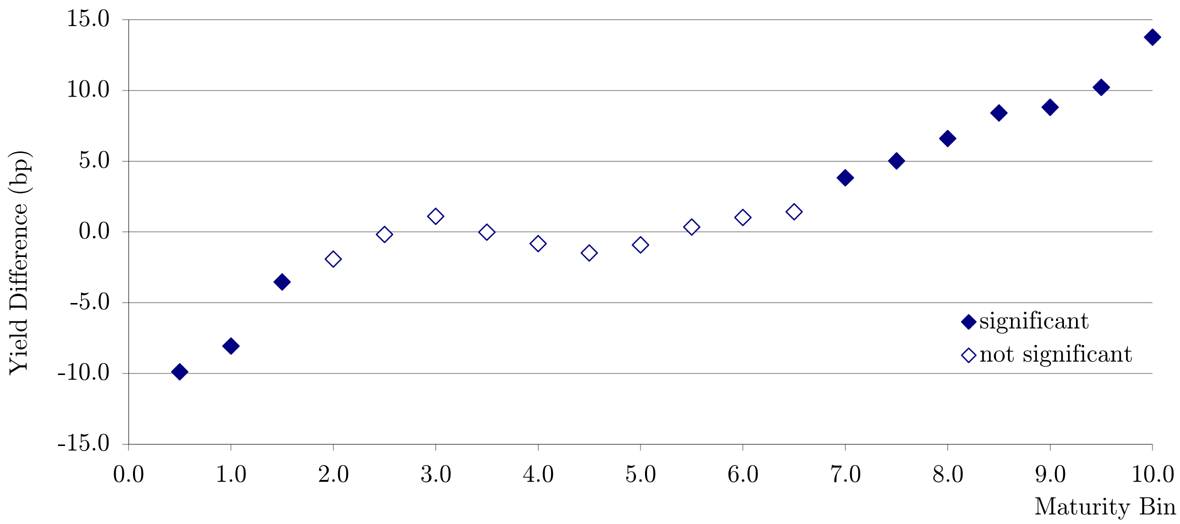

Figure 2.2: Coupon STRIPS Yields – Synthetic Yields ($y^C - r$)

This figure shows the mean difference between coupon STRIPS yields and synthetic yields for each maturity bin. For a given maturity bin, the mean is calculated over time for the period from February 2002 until June 2007. The filled (empty) rectangles represent mean yield differences that (do not) significantly exceed the typical bid-ask spread.

2.3 Empirical Results

2.3.1 Coupon STRIPS Yields vs. Synthetic Yields

We first investigate the differences between the yields of coupon STRIPS and the synthetic yields, $y^C - r$. We classify them with regard to their remaining time to maturity in half-year maturity bins. Bin T ($T = 0.5, 1.0, \dots$) consists of all yield differences for maturities in the interval $[T - 0.25; T + 0.25)$. The yield differences for a given maturity bin are averaged across notes and the descriptive statistics calculated across time.[30]

Figure 2.2 displays the mean yield difference $y^C - r$ for each maturity bin. Surprisingly, the differences tend to increase with time to maturity. For short maturities, coupon STRIPS yields are on average smaller than synthetic yields with a yield difference of up to 10 bp. This relationship reverses for maturities above five years and the differences are the largest for the maturity bin of ten years (14 bp). For interpreting the economic significance as already depicted in Figure 2.2, we take

[30] We also calculated the results by only using the exact times to maturity of 0.5, 1.0, 1.5, etc. years. The results are qualitatively in line with the results presented here. This restriction, however, would reduce our data set by more than 90%.

transaction costs into account and compare the corresponding bid and ask yields. For maturities up to 1.5 years the mean difference of $y^C_{bid} - r_{ask}$ is significantly smaller than zero. For maturities larger than seven years we observe that y^C_{ask} is on average significantly greater than r_{bid}. These differences could theoretically be exploited by buying (selling) the synthetic zero-bond and selling (buying) the coupon STRIPS. However, we do not claim that a violation can immediately be exploited as an arbitrage opportunity since the synthetic zero-bond cannot be traded directly. Nevertheless, these differences cannot be explained by a typical variation within the bid-ask spread. For maturities between two and seven years, however, the coupon STRIPS can, on average, be considered as being priced in line with the synthetic yields when taking transaction costs into account.

Table 2.2 shows the detailed summary statistics of the yield differences. Almost all mean and median differences between y^C and r are significantly different from zero. The increasing maturity structure is also evident when examining the fraction of observations greater than zero. For maturities below two years, less than 20% of all observations are negative whereas more than 70% of all observations are positive for maturities above seven years.

These results only provide evidence for the cross-sectional structure of the yield differences for the whole sample period. To examine a possible time variation, Figure 2.3 presents the mean yield differences for the two, five, and eight year maturity bin over time. It becomes evident that the yield difference for the eight year maturity bin nearly always exceeds the other yield differences, even though it is decreasing over time. The yield differences for maturities of approximately five years mainly fluctuate around zero. The two year yield differences are hardly above zero. Hence, this figure exhibits the persistence of the yield differences for the respective maturity bins over time.

Up to this point, we only have shown the existence of significant and persistent differences between observed coupon STRIPS yields and synthetic yields. Subsequently, we try to explain the cross-sectional pattern of the yield differences and their variation over time. Therefore, we relate these differences to several liquidity proxies, a proxy for a potential tax effect, and market-wide variables. The first liquidity proxies are the stripping activity of a coupon STRIPS, SA^C, and the outstanding amount of a

Table 2.2: Coupon STRIPS Yields – Synthetic Yields ($y^C - r$)

This table shows the summary statistics for the differences between coupon STRIPS yields and synthetic yields in basis points. The statistics are based on the mean yield difference at a given date for a given maturity bin and calculated over time. *** (**,*) denotes the significance at the 1% (5%, 10%) level. The significance of the mean is tested using a two-sided t-test with Newey-West HAC standard errors, the significance of the median by a non-parametric Wilcoxon signed-rank test. The significance of the differences between bid and ask yields is tested using one-sided t-tests with Newey-West HAC standard errors. N is the number of daily observations. The overall statistics are based on equal weights of all observations. The sample period ranges from February 2002 to June 2007.

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N	% > 0	$y^C_{bid} - r_{ask}$	$y^C_{ask} - r_{bid}$
0.5	-9.9***	10.2	-62.9	-8.8***	22.4	1,362	17.0%	-7.9***	-11.9
1.0	-8.1***	7.2	-37.5	-8.1***	20.8	1,365	12.3%	-6.1***	-10.1
1.5	-3.5***	4.0	-23.5	-3.0***	9.2	1,366	15.2%	-1.5***	-5.5
2.0	-1.9***	2.3	-13.8	-2.1***	5.5	1,366	19.7%	0.1	-3.9
2.5	-0.2	3.1	-12.0	-0.1	10.4	1,366	48.5%	1.8	-2.2
3.0	1.1***	4.1	-10.6	1.3***	11.9	1,366	62.4%	3.1	-0.9
3.5	0.0	4.1	-9.8	0.0	12.6	1,238	49.9%	2.0	-2.0
4.0	-0.8**	4.6	-9.7	-1.7***	10.4	1,106	38.4%	1.2	-2.8
4.5	-1.5***	5.6	-14.2	-1.6***	8.8	1,043	40.9%	0.5	-3.5
5.0	-0.9*	6.7	-18.5	-0.6***	12.9	1,043	42.2%	1.1	-2.9
5.5	0.3	7.1	-18.4	-0.5*	23.7	1,043	43.5%	2.3	-1.7
6.0	1.0***	4.0	-6.3	0.0***	14.2	919	49.7%	3.0	-1.0
6.5	1.4***	3.7	-8.9	0.8***	12.9	852	60.9%	3.4	-0.6
7.0	3.8***	5.3	-6.6	4.9***	21.5	852	70.0%	5.8	1.8***
7.5	5.0***	3.6	-2.7	5.5***	15.4	852	89.7%	7.0	3.0***
8.0	6.6***	3.4	-1.2	6.8***	15.1	852	99.1%	8.6	4.6***
8.5	8.4***	3.9	0.5	8.3***	18.0	852	100.0%	10.4	6.4***
9.0	8.8***	3.6	2.0	8.7***	18.3	852	100.0%	10.8	6.8***
9.5	10.2***	3.7	3.6	9.6***	24.6	852	100.0%	12.2	8.2***
10.0	13.8***	4.1	5.9	13.6***	22.1	460	100.0%	15.8	11.8***
Overall	0.5***	7.5	-62.9	0.3***	24.6	21,007	52.1%	2.5	-1.5

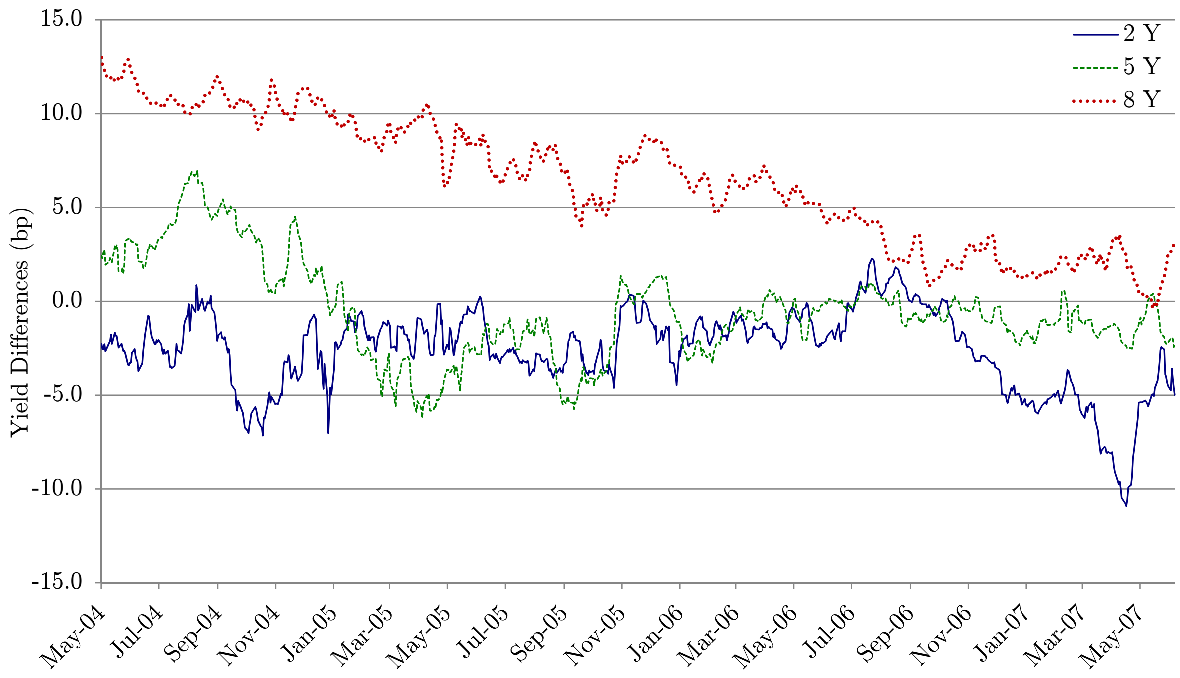

Figure 2.3: Coupon STRIPS Yields – Synthetic Yields ($y^C - r$)
This figure shows the mean differences between coupon STRIPS yields and synthetic yields for the two, five, and eight year maturity bin for the time period from May 2004 until June 2007.

coupon STRIPS, OA^C. As argued in Section 2.2.2, both variables are positively related to coupon STRIPS liquidity and we expect the yield differences to decrease with each of these proxies. The third variable we consider is the age of a note, i.e. the time since the note was issued. This variable reflects the fact that notes have the tendency to become less liquid as they age whereas this relation is ambiguous for coupon STRIPS as they come from a variety of underlying notes and bonds.[31] Hence, we expect the yield differences to be decreasing with the age of a note. Additionally, we control for the well-known on-the-run effect by including a dummy variable. We expect the yield differences to be significantly larger if the corresponding Treasury note is trading on-the-run.

To consider effects due to the asynchronous taxation of Treasury notes and STRIPS, we include the market discount in our analysis. It is measured as the amount of discount for each note assuming a face value of USD 100, $100 - P^{Note}$, and zero otherwise. As derived in Section 2.2.2, the yield difference $y^C - r$ should increase with

[31] This argument is also supported by the fact that Bloomberg's indicative bid-ask spread for notes relative to STRIPS is increasing as they age.

the market discount of a note if taxes play a role.

Yield differences between two market segments may also be influenced by the market-wide liquidity or a flight-to-liquidity effect. To test for these effects, one ideally relates the yield differences to fund flows into the respective segments. Due to lack of data, we alternatively relate the yield differences to macroeconomic variables that proxy the overall level of market liquidity. The first of these variables is the change in the effective federal funds rate ΔFED. A positive shock to the federal funds rate signals a monetary policy tightening and, therefore, should be positively related to a liquidity premium. The second variable is the Chicago Board Options Exchange Volatility Index VIX. VIX is often interpreted as an "investor fear gauge."[32] Ben-Rephael et al. (2010) and Ederington and Golubeva (2009) recently find empirical evidence that flows from equity to bond funds are positively related to changes in VIX. Hence, an increase in the index may signal that investors prefer to hold less risky assets. Therefore, they migrate to the most liquid Treasury securities which leads to an increase in the liquidity premium.

We have already shown that short-maturity coupon STRIPS persistently trade at a yield discount relative to notes and long-term coupon STRIPS trade at a premium. If the yield differences are driven by differing liquidity, and a flight-to-liquidity effect exists within the Treasury market, we should expect opposite effects of the market-wide liquidity proxies for short and long maturities. Therefore, the yield differences $y^C - r$ should decrease for short maturities and increase for long maturities when ΔFED or VIX increases. We test this effect by interacting the macroeconomic variables with a dummy for maturities below two years, and a dummy for maturities above seven years, respectively.

Stripping information is available on a monthly basis only and, therefore, we use end-of-month observations of the yield differences in our regression analysis. The augmented Dickey-Fuller tests shows that the null of non-stationary monthly yield differences can be rejected on a 1% significance level. Table 2.3 shows four regression results which differ by the inclusion of the lagged yield differences and the macroeconomic variables.

[32] See, e.g., Whaley (2009).

Table 2.3: Regression Results of Explanatory Variables for Differences between Coupon STRIPS Yields and Synthetic Yields

This table reports the estimated coefficients and the t-statistics from the regression of the difference between coupon STRIPS yields and synthetic yields with the same time to maturity. The yield differences are calculated in basis points and the stripping activity SA^C as well as the outstanding amount OA^C are denoted in billion USD. *AGE* is given in years, *DISCOUNT* in USD. *OTR* equals one if the note is on-the-run, and zero otherwise. ΔFED ($< 2.0/ > 7.0$) denotes the first differences of the federal funds rate (measured in percentage points) times a dummy variable for all maturities below two years/above seven years. *VIX* is the Chicago Board Options Exchange Volatility Index measured in basis points and interacted analogously. The t-statistic is shown below the coefficient estimates and is computed using Newey-West HAC standard errors. *** (**,*) denotes the significance at the 1% (5%, 10%) level. N is the number of monthly observations. The sample consists of monthly observations from February 2002 to June 2007.

Regression	(1)	(2)	(3)	(4)
Constant	**22.02*** **	**4.95*** **	**6.40*** **	**1.19**
	14.05	4.11	3.99	1.04
Stripping Activity SA^C	**-5.59*** **	**-1.41*** **	**-4.75*** **	**-1.59*** **
	-10.42	-4.27	-10.35	-4.80
Outstanding Amount OA^C	**-6.20*** **	**-1.43*** **	**-1.30** **	**-0.16**
	-12.85	-3.94	-2.55	-0.44
AGE	**-0.51*** **	**-0.12** **	**-0.02**	**0.02**
	-6.23	-2.33	-0.27	0.40
OTR	**2.76*** **	**1.16*** **	**1.74*** **	**0.99*** **
	2.96	2.81	2.80	2.65
DISCOUNT	**-0.09**	**-0.06**	**-0.35*** **	**-0.14*** **
	-0.74	-1.08	-3.45	-2.60
ΔFED (< 2.0)			**-14.54*** **	**-8.19*** **
			-5.61	-3.76
ΔFED (> 7.0)			**13.78*** **	**5.03*** **
			4.80	3.35
VIX (< 2.0)			**-0.29*** **	**-0.11*** **
			-9.88	-5.16
VIX (> 7.0)			**0.55*** **	**0.18*** **
			13.88	6.50
Lag-Variable		**0.74*** **		**0.65*** **
		23.69		17.73
N	2,376	2,310	2,376	2,310
Adjusted R^2	0.186	0.584	0.376	0.605

In Regressions (1) and (2), the results show a significant and negative relation between the yield differences and the liquidity proxies. A higher stripping activity is related to a lower yield difference reflecting the increasing mean yield difference for a larger time to maturity as reported in Table 2.2. The relation between the yield differences and the outstanding amount of coupon STRIPS is also significantly negative. As expected, the effect of the age of a note is always significantly negative. The results are robust to the inclusion of the lagged yield difference. The lagged yield difference is significantly positive for all regressions reflecting the fact that there is a high degree of persistence in the yield differences. The differences in the liquidity proxies can, however, to a substantial extent explain the term structure of the yield differences between coupon STRIPS and Treasury notes.[33]

The yield differences are significantly larger if the corresponding Treasury note is trading on-the-run. Compared to regressions when omitting the on-the-run dummy (not reported), however, the results for the liquidity proxies do not change substantially and the adjusted R^2 hardly improves. Therefore, the on-the-run effect seems to be of minor importance.

The market discount has a significant positive effect when considered as single explanatory variable (not reported). The adjusted R^2, however, shows that this variable hardly explains any variation of the yield differences.[34] We consider the market discount as a control variable for a potential tax effect into the liquidity regression. The coefficient, however, is not significant and the results do not substantially change. These findings suggest that taxation does not have an impact on the observed yield differences and the liquidity effect remains stable even though controlling for potential tax effects.[35]

Regressions (3) and (4) of Table 2.3 present the coefficient estimates when including the macroeconomic variables. For short maturities, ΔFED and VIX have a negative impact. For long maturities the result is vice versa. This result is consistent

[33] An analysis of the residuals reveals that the liquidity proxies nearly entirely explain the time to maturity effect.

[34] Including the lagged variable, the coefficient of the market discount is no longer significant.

[35] To further validate this conclusion, we also have analyzed the impact of various variables related to the taxation of a Treasury note or STRIPS and do not find any significant impact of an asynchronous taxation.

with the hypothesis that a movement to the most liquid segment occurs when the monetary policy tightens or uncertainty increases. Moreover, it is in line with the notion that coupon STRIPS are more liquid than notes for short maturities and less liquid for maturities above seven years.

The adjusted R^2 rises substantially compared to Regression (1) when including the macroeconomic variables. However, the coefficient estimates for the other liquidity proxies do not change substantially. Only the effect of the note's age is no longer significant and the market discount has a significant negative effect that is not in line with a potential tax effect. Moreover, the results are robust to the inclusion of the lagged yield difference. It is important to note that the coefficient of the lag variable in Regression (4) is smaller than in Regression (2) and the adjusted R^2 rises. Hence, the macroeconomic variables seem to capture a considerable part of the variation over time.

In summary, our analysis provides support that the yield differences between the market for coupon STRIPS and the market for Treasury notes are mainly driven by the differing liquidity of the particular instruments. Furthermore, the variation of the yield differences over time is maturity-dependent and shows a flight-to-liquidity behavior.

2.3.2 Principal STRIPS Yields vs. Synthetic Yields

In this section, we investigate the differences between the yields of principal STRIPS and the synthetic yields, $y^P - r$. The results are computed and illustrated in the same manner as the results in the previous section and displayed in Figure 2.4. Compared to Figure 2.2, it is striking that the yield differences $y^P - r$ do not show a clear maturity dependence. The absolute difference is below 2 bp and not significant when transaction costs are considered. Hence, taking transaction costs into account, principal STRIPS can be regarded as being priced in line with Treasury notes. Table 2.4 shows that the mean or the median is significantly positive or negative for particular maturity bins, but neither shows a maturity dependence. Moreover, an inspection of the time series provides evidence that the yield difference vary rather randomly around zero.

As in Section 2.3.1, we formally test the relationship between the obtained yield differences and liquidity proxies. Accordingly, we use the stripping activity of a principal

Table 2.4: Principal STRIPS Yields – Synthetic Yields ($y^P - r$)

This table shows the summary statistics for the differences between principal STRIPS yields and synthetic yields in basis points. The statistics are based on the mean yield difference at a given date for a given maturity bin and calculated over time. *** (**,*) denotes the significance at the 1% (5%, 10%) level. The significance of the mean is tested using a two-sided t-test with Newey-West HAC standard errors, the significance of the median by a non-parametric Wilcoxon signed-rank test. The significance of the differences between bid and ask yields is tested using one-sided t-tests with Newey-West HAC standard errors. N is the number of daily observations. The overall statistics are based on equal weights of all observations. The sample period ranges from February 2002 to June 2007.

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N	% > 0	$y^P_{bid} - r_{ask}$	$y^P_{ask} - r_{bid}$
0.5	0.2	7.3	-41.5	0.0	23.9	1,301	50.0%	2.2	-1.8
1.0	-1.5***	4.9	-24.8	-0.8***	17.9	1,302	39.2%	0.5	-3.5
1.5	-1.2***	4.7	-16.8	-0.6***	15.0	1,305	41.3%	0.8	-3.2
2.0	-0.2	3.0	-19.0	-0.2*	7.5	1,300	46.1%	1.8	-2.2
2.5	0.5**	2.9	-19.1	0.4***	11.8	1,238	57.4%	2.5	-1.5
3.0	1.1***	2.5	-11.1	0.9***	12.4	1,106	70.3%	3.1	-0.9
3.5	-0.6***	1.9	-9.3	-0.3***	5.7	1,043	40.9%	1.4	-2.6
4.0	0.1	2.3	-8.5	0.1	21.2	1,043	53.2%	2.1	-1.9
4.5	-0.3	3.1	-18.5	0.1	28.9	1,043	52.3%	1.7	-2.3
5.0	0.4**	2.5	-12.7	0.4***	21.1	1,043	63.7%	2.4	-1.6
5.5	-0.9***	3.0	-13.7	-0.1***	16.0	1,043	48.2%	1.1	-2.9
6.0	-1.9***	5.7	-34.6	0.1***	41.6	919	53.5%	0.1	-3.9
6.5	-1.2***	5.8	-26.2	-0.1***	41.3	852	49.1%	0.8	-3.2
7.0	-0.3	4.4	-10.4	-0.1***	41.5	852	47.2%	1.7	-2.3
7.5	-1.8***	7.5	-44.1	-0.3***	55.3	851	45.8%	0.2	-3.8
8.0	-1.6***	4.9	-26.6	-1.1***	40.2	844	36.4%	0.4	-3.6
8.5	-1.6***	5.4	-35.2	-1.6***	37.3	713	29.6%	0.4	-3.6
9.0	-1.0*	5.7	-31.5	-0.7	7.8	387	39.0%	1.0	-3.0
9.5	-1.4	9.2	-34.0	1.6	7.4	85	58.8%	0.6	-3.4
10.0	0.1	1.6	-2.7	0.0	7.0	26	50.0%	2.1	-1.9
Overall	-0.6***	4.6	-44.1	-0.1***	55.3	18,296	48.7%	1.4	-2.6

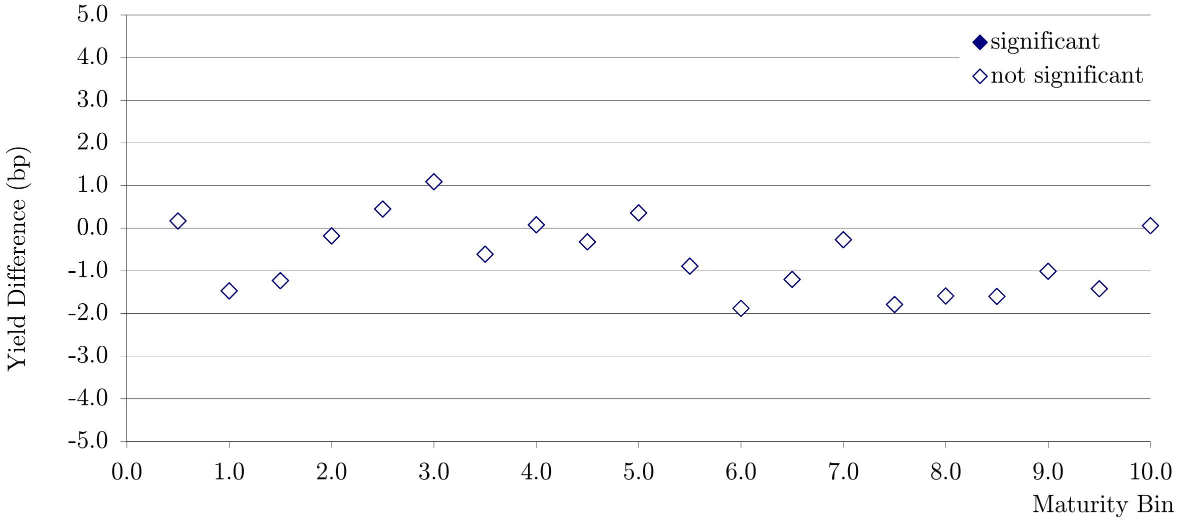

Figure 2.4: Principal STRIPS Yields – Synthetic Yields ($y^P - r$)

This figure shows the mean difference between principal STRIPS yields and synthetic yields for each maturity bin. For a given maturity bin, the mean is calculated over time for the period from February 2002 until June 2007. The filled (empty) rectangles represent mean yield differences that (do not) significantly exceed the typical bid-ask spread.

STRIPS, SA^P, its outstanding amount, OA^P, and the age of the Treasury note as explanatory variables. Further, we include an on-the-run dummy, the market discount to control for potential tax effects as well as the macroeconomic variables presented in Section 2.2.2. The results are presented in Table 2.5.

In contrast to the results for coupon STRIPS, we find no significant relationship between the yield differences and the liquidity proxies. Our findings do not considerably change when controlling for the on-the-run effect. Only the on-the-run dummy has a significantly positive effect showing that the principal STRIPS yield is significantly higher than the synthetic yield if the note is trading on-the-run. However, even with this effect, the adjusted R^2 is negligible. In an univariate regression the discount variable has a significantly negative impact at the 10% level (not reported). Including the lagged variable, however, the impact of the discount becomes insignificant. By regressing the yield differences on both the taxation and liquidity variables, we test the possibility that both effects cancel out each other. The results clearly neglect this conjecture as all parameters are statistically insignificant.

The macroeconomic variables impact the short term yield differences significantly negatively at the 10% level, but only if the lagged yield differences in not included. The lagged yield difference is significantly positive for all regressions. The coefficient,

Table 2.5: Regression Results of Explanatory Variables for Differences between Principal STRIPS Yields and Synthetic Yields

This table reports the estimated coefficients and the t-statistics from the regression of the difference between principal STRIPS yields and synthetic yields with the same time to maturity. The yield differences are calculated in basis points and the stripping activity SA^P as well as the outstanding amount OA^P are denoted in billion USD. AGE is given in years, $DISCOUNT$ in USD. OTR equals one if the note is on-the-run, and zero otherwise. ΔFED ($< 2.0/ > 7.0$) denotes the first differences of the federal funds rate (measured in percentage points) times a dummy variable for all maturities below two years/above seven years. VIX is the Chicago Board Options Exchange Volatility Index measured in basis points and interacted analogously. The t-statistic is shown below the coefficient estimates and is computed using Newey-West HAC standard errors. *** (**,*) denotes the significance at the 1% (5%, 10%) level. N is the number of monthly observations. The sample consists of monthly observations from February 2002 to June 2007.

Regression	(1)	(2)	(3)	(4)
Constant	**-0.96***	**-0.60**	**-0.65**	**-0.39**
	-1.82	-1.64	-1.23	-0.98
Stripping Activity SA^P	**1.94**	**1.99**	**1.70**	**1.92**
	0.93	0.88	0.78	0.83
Outstanding Amount OA^P	**0.08**	**0.00**	**0.16**	**0.00**
	0.33	0.00	0.59	0.01
AGE	**0.11**	**0.07**	**0.12**	**0.07**
	1.37	1.20	1.42	1.13
OTR	**4.14****	**2.29****	**3.87***	**2.27***
	1.96	2.16	1.82	1.95
$DISCOUNT$	**-0.01**	**0.02**	**0.03**	**0.06**
	-0.10	0.23	0.27	0.68
ΔFED (< 2.0)			**-6.06***	**-3.70**
			-1.76	-1.38
ΔFED (> 7.0)			**-8.95**	**0.88**
			-1.33	0.19
VIX (< 2.0)			**-0.04***	**-0.02**
			-1.66	-0.81
VIX (> 7.0)			**-0.02**	**-0.08**
			-0.24	-1.35
Lag-Variable		**0.41*****		**0.40*****
		6.07		5.97
N	1,373	1,313	1,373	1,313
Adjusted R^2	0.010	0.149	0.025	0.153

however, is relatively small and reflects a low degree of persistence in the yield differences. Moreover, the adjusted R^2 is relatively small for all regressions. In summary, the regression results support the findings presented in Table 2.4, and we conclude that principal STRIPS are on average priced in line with the synthetic yields.

This result is surprising and it allows for three preliminary conclusions. First, differences in the taxation of Treasury notes and principal STRIPS do not result in systematic yield differences. Second, there are no systematic differences in the liquidity premia between the principal STRIPS and the coupon Treasury market. Third, principal STRIPS are priced in line with Treasury notes, suggesting that the unique reconstitution feature drives the relationship. These conclusions will be tested in the next section. There, we explicitly control for tax effects by comparing the yields of coupon and principal STRIPS.

2.3.3 Coupon STRIPS vs. Principal STRIPS

Matched-maturity coupon and principal STRIPS provide exactly the same cash flows at maturity. Tax differences between these two types of STRIPS do not exist and, therefore, should have no impact on yields. Due to differing liquidity, however, they may actually trade at different prices. Moreover, principal STRIPS are unique in terms of their reconstitution feature. If this feature would be the only determinant for yield differences, the coupon STRIPS should show larger yields than principal STRIPS. If liquidity effects are the only reason for yield differences, we expect larger yields of coupon STRIPS for long maturities and vice versa for short maturities.

Figure 2.5 displays the mean differences between the observed yields of coupon and principal STRIPS.[36] In contrast to the finding of Daves and Ehrhardt (1993) that, in general, coupon STRIPS trade at a yield premium relative to principal STRIPS, we find that principal STRIPS trade at a significantly higher yield for short maturities.[37] This figure is directly comparable with Figure 2.2 and shows striking similarities: First, the yield differences tend to increase with time to maturity and change their sign at a

[36] Detailed summary statistics are given in Table A.1 in the appendix of this chapter.

[37] Carverhill (1995) also found a negative price premium of principal STRIPS over coupon STRIPS at short term to maturity.

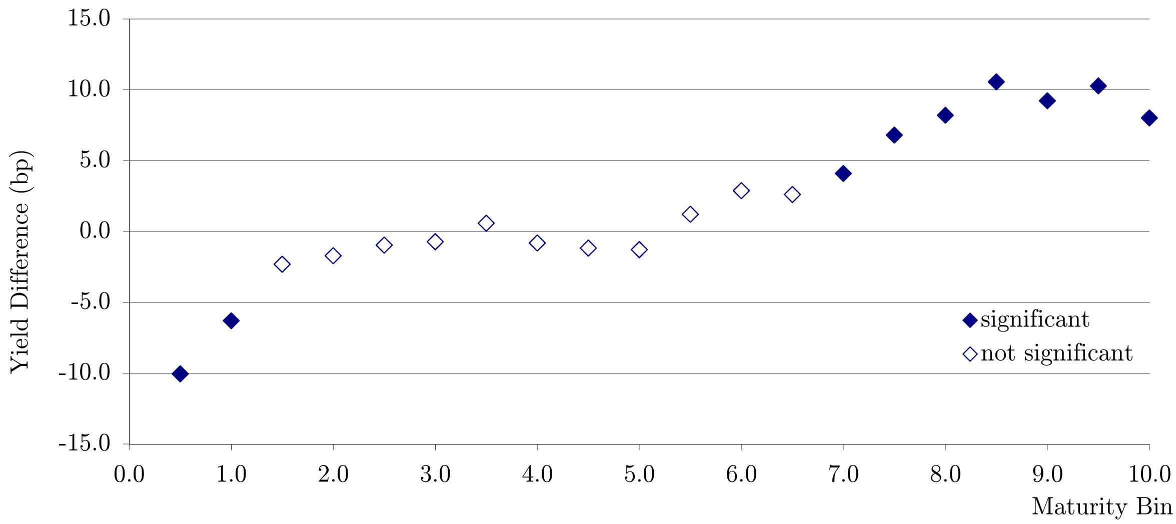

Figure 2.5: Coupon STRIPS Yields – Principal STRIPS Yields ($y^P - y^C$)
This figure shows the mean difference between coupon STRIPS yields and principal STRIPS yields for each maturity bin. For a given maturity bin, the mean is calculated over time for the period from February 2002 until June 2007. The filled (empty) rectangles represent mean yield differences that (do not) significantly exceed the typical bid-ask spread.

maturity of approximately five years. Second, including transaction costs, for maturities larger than seven years we observe that y^C_{ask} is on average significantly greater than y^P_{bid}. Since we previously have found that principal STRIPS are usually priced according to the synthetic yields, the liquidity premia between coupon STRIPS and Treasury notes seem to just pass through.

Similar to the previous sections, we formally test the relationship between the observed yield differences and liquidity proxies. Since the endogenous variable is the difference between coupon and principal STRIPS yields, we now use the difference of the stripping activities, $SA^C - SA^P$, and the difference of the outstanding amounts, $OA^C - OA^P$, as explanatory variables. Furthermore, we include the age of the principal STRIPS which coincides with the age of the underlying note, as well as the macroeconomic variables. Table 2.6 presents the four regression results which differ by the inclusion of the macroeconomic variables and the lagged yield differences.

As expected, a significantly negative relation between the yield differences and the difference in the stripping activity exists. The coefficient of the difference in the outstanding amount is not significant in Regression (2). Age has a significantly negative impact. This effect can be reasoned by the fact that principal STRIPS tend to vanish in the investors' portfolios similar to their underlying notes whereas there are always

Table 2.6: Regression Results of Explanatory Variables for Yield Differences between Coupon STRIPS and Principal STRIPS

This table reports the estimated coefficients and the t-statistics from the regression of the difference between coupon STRIPS and principal STRIPS yields with the same time to maturity. The yield differences are calculated in basis points and the stripping activity *SA* as well as the outstanding amount *OA* are denoted in billion USD. *AGE* is given in years. The t-statistic is computed using Newey-West HAC standard errors. *** (**,*) denotes the significance at the 1% (5%, 10%) level. N is the number of monthly observations. The sample consists of monthly observations from February 2002 to June 2007.

Regression	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	**1.14**	**0.55**	**-3.30*** **	**-0.65**	**1.19**	**1.03** **	**0.11**	**0.75**
	0.81	0.83	-2.62	-0.96	1.49	2.14	0.14	1.56
$SA^C - SA^P$	**-5.77*** **	**-1.52*** **	**-5.00*** **	**-1.77*** **	**-1.64*** **	**-0.68*** **	**-1.78*** **	**-0.73*** **
	-7.57	-4.24	-8.37	-5.01	-4.30	-3.03	-4.80	-3.15
$OA^C - OA^P$	**2.10*** **	**0.27**	**1.75*** **	**0.31***	**0.32**	**-0.16**	**0.39** **	**-0.13**
	5.41	1.42	4.89	1.66	1.59	-1.17	1.98	-0.97
AGE	**-0.67*** **	**-0.14*** **	**0.31*** **	**0.14** **	**-0.19*** **	**-0.07**	**-0.05**	**-0.05**
	-5.99	-2.60	2.74	2.19	-2.59	-1.56	-0.66	-0.82
ΔFED (< 2.0)			**-5.40**	**-4.79**			**3.64**	**1.04**
			-1.18	-1.42			1.07	0.39
ΔFED (> 7.0)			**24.70*** **	**7.10** **			**14.51** **	**1.35**
			5.15	2.06			2.44	0.36
VIX (< 2.0)			**-0.30*** **	**-0.12*** **			**-0.03**	**0.00**
			-7.55	-4.63			-1.22	-0.01
VIX (> 7.0)			**0.57*** **	**0.17*** **			**0.10**	**0.04**
			10.04	3.73			1.36	0.85
$y^C - r$					**0.87*** **	**0.53*** **	**0.81*** **	**0.53*** **
					21.33	10.26	16.92	9.78
Lag-Variable		**0.79*** **		**0.70*** **		**0.48*** **		**0.47*** **
		33.05		23.89		11.26		11.00
N	1,497	1,428	1,497	1,428	1,399	1,343	1,399	1,343
Adjusted R^2	0.173	0.660	0.391	0.678	0.687	0.811	0.698	0.811

active short-maturity coupon STRIPS in the market. The macroeconomic variables have the same impact as on the difference between coupon STRIPS and Treasury notes, $y^C - r$. The lagged yield difference is significantly positive for all regressions reflecting the fact that there is a high degree of persistence in the yield differences.

In addition to these variables, we also include the yield difference $y^C - r$ as a measure for the liquidity differences between the coupon STRIPS and the coupon Treasury market. Thereby, we test the conjecture that, due to the unique reconstitution feature, the liquidity differences transmit to the STRIPS market. Regressions (5)–(8) of Table 2.6 show the significantly positive impact of the liquidity difference $y^C - r$ on the observed yield differences between coupon and principal STRIPS. Comparing the adjusted R^2 from Regressions (2) and (4) to Regressions (5) and (7) it is striking that the liquidity difference $y^C - r$ explains even more of the variation compared to the lagged yield difference. This result is in line with the finding of Jordan et al. (2000) that yield differences between matched-maturity coupon and principal STRIPS can be explained by the richness or cheapness of the note or bond that is underlying the principal STRIPS.

In summary, these results show that the observed yield differences between coupon and principal STRIPS can be explained, at least partially, by the liquidity premia between coupon STRIPS and Treasury notes. Due to the unique reconstitution feature of principal STRIPS, the liquidity premia just pass through and affect the yield differences between coupon and principal STRIPS. Direct liquidity differences between coupon and principal STRIPS are of minor importance.

2.3.4 Financial Crisis

In this section, we analyze the yield differences during the period of the financial crisis. This time period is apparently related to a change in the bond market liquidity, whereas the institutional features of the stripping program as well as the taxation remain unchanged. Also, U.S. Treasury securities still do not contain significant default risk. Any observed difference to the previous sections should therefore be related to a different liquidity premium.

Figure 2.6 presents the mean yield differences for the time periods before and after

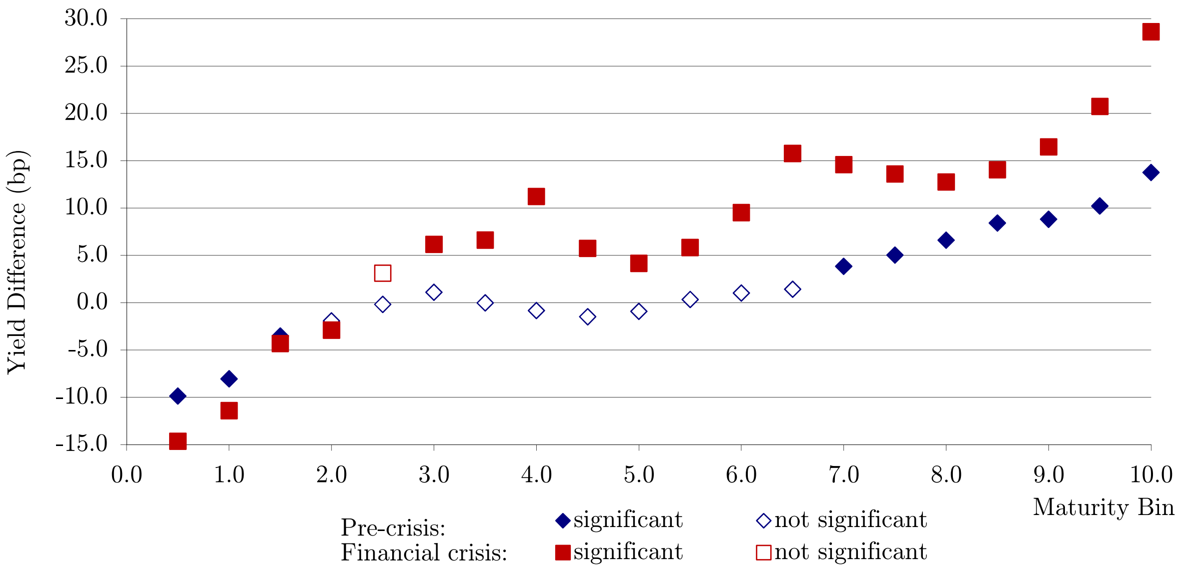

Figure 2.6: Coupon STRIPS Yields – Synthetic Yields ($y^C - r$)

This figure shows the mean difference between coupon STRIPS yields and synthetic yields for each maturity bin. For a given maturity bin, the mean is calculated over time for the periods from February 2002 until June 2007 (pre-crisis) and from July 2007 until November 2008 (financial crisis). The filled (empty) rectangles represent mean yield differences that (do not) significantly exceed the typical bid-ask spread.

July 2007. The results do not change qualitatively, but are more pronounced compared to the pre-crisis period. We can still observe that y^C is significantly smaller than r for shorter maturities and vice versa for longer maturities. Considering transaction costs we find that the coupon STRIPS ask yield y^C_{ask} is significantly greater than the synthetic bid yield r_{bid} for maturities larger than three years already. Moreover, the yield differences $y^C - r$ for maturities larger than two years significantly increase compared to the pre-crisis period. This finding provides an indication that medium- and long-term coupon STRIPS are traded with a significant liquidity premium compared to notes during the financial crisis.[38] Our calculations also show that the two sub-samples differ with respect to the observed volatility.[39] As expected, the standard deviation of the yield differences during the financial crisis is, for each maturity bin, considerably greater than during normal market conditions. This finding suggests that a greater uncertainty in times of financial turbulence can also be seen in a higher variation of the liquidity premia.

[38]These results are even more pronounced when investigating the subsample for the period after the beginning of 2008.

[39]Detailed summary statistics are given in Table A.2 in the appendix of this chapter.

Table 2.7: Regression Results of Explanatory Variables for Differences between Coupon STRIPS Yields and Synthetic Yields during the Financial Crisis

This table reports the estimated coefficients and the t-statistics from the regression of the difference between coupon STRIPS yields and synthetic yields with the same time to maturity. The yield differences are calculated in basis points and the stripping activity SA^C as well as the outstanding amount OA^C are denoted in billion USD. AGE is given in years, $DISCOUNT$ in USD. OTR equals one if the note is on-the-run, and zero otherwise. ΔFED ($< 2.0/ > 7.0$) denotes the first differences of the federal funds rate (measured in percentage points) times a dummy variable for all maturities below two years/above seven years. VIX is the Chicago Board Options Exchange Volatility Index measured in basis points and interacted analogously. The t-statistic is shown below the coefficient estimates and is computed using Newey-West HAC standard errors. *** (**,*) denotes the significance at the 1% (5%, 10%) level. N is the number of monthly observations. The sample consists of monthly observations from June 2007 to October 2008.

Regression	(1)	(2)	(3)	(4)
Constant	**69.60*** **	**25.29*** **	**34.67*** **	**7.82***
	12.79	4.90	5.33	1.66
Stripping Activity SA^C	**-17.20*** **	**-9.39*** **	**-17.28*** **	**-5.19*** **
	-5.92	-3.82	-7.20	-2.61
Outstanding Amount OA^C	**-18.63*** **	**-5.85*** **	**-5.50*** **	**-1.17**
	-11.19	-4.28	-2.79	-0.89
AGE	**-0.24**	**0.16**	**0.38**	**0.36**
	-0.71	0.68	1.13	1.53
OTR	**14.75*** **	**5.28**	**7.94** **	**2.39**
	3.60	1.53	2.31	0.90
$DISCOUNT$	**0.50**	**0.50**	**-1.02**	**-0.33**
	0.45	0.70	-1.25	-0.54
ΔFED (< 2.0)			**-3.99**	**-22.69*** **
			-0.72	-4.13
ΔFED (> 7.0)			**16.50*** **	**8.00*** **
			5.07	2.68
VIX (< 2.0)			**-0.51*** **	**-0.34*** **
			-5.30	-4.47
VIX (> 7.0)			**0.65*** **	**0.31*** **
			6.30	3.21
Lag-Variable		**0.88*** **		**0.91*** **
		15.03		16.19
N	655	652	655	652
Adjusted R^2	0.222	0.579	0.355	0.625

In such periods, flights-to-quality and flights-to-liquidity are widely observed, i.e. investors prefer to have less exposure to credit risk and to hold more liquid securities.[40] Hence, we expect to observe stronger effects when performing regressions analogously to the pre-crisis period (Section 2.3.1). Table 2.7 presents the regression results for the period of the financial crisis. The coefficient estimates are in line with our expectations whenever significant. The stripping activity and the outstanding amount have a negative impact that is much stronger during the period of the financial crisis. The on-the-run effect is significantly positive and greater than in the pre-crisis period. Moreover, the macroeconomic variables ΔFED and VIX also have the expected signs and a stronger impact compared to the pre-crisis period. Therefore, our results are consistent and even more pronounced during the period of financial turmoil.

In contrast to the results for coupon STRIPS, the absolute size of the differences between principal STRIPS and Treasury notes approximately stays the same during the financial crisis.[41] Again, considering transaction costs, the differences are not significant. For the observed yield difference between coupon STRIPS and principal STRIPS, we again find the striking similarity to the differences between y^C and the synthetic yield r. Hence, also during the financial crisis, the differences between coupon and principal STRIPS are essentially driven by the liquidity premia between coupon STRIPS and Treasury notes.

2.3.5 Notes vs. Bonds

So far we have analyzed yield differences using only Treasury notes and their corresponding STRIPS. Jordan et al. (2000) have shown that matched-maturity principal STRIPS coming from different underlying notes and bonds may trade at different prices even if they provide exactly the same cash flows at maturity. We now investigate these yield differences and relate them to differences in the final synthetic yields of the corresponding Treasury notes and bonds. The latter differences are due to characteristics such as a differing outstanding amount or the on-the-run feature and should, due to the unique reconstitution feature, translate into yield differences of the

[40] See, e.g., Beber et al. (2009).

[41] The results for the financial crisis are depicted in the appendix of this chapter.

corresponding principal STRIPS.

For lack of traded short-maturity Treasury bonds, we are not able to apply the exact bootstrapping procedure with Treasury bonds only. Therefore, we compute their final synthetic yields by discounting their coupon payments using the synthetic yields obtained by bootstrapping Treasury notes. The payments, however, occur at exactly the same dates so that we do not have any time distortion. Using this procedure, we are able to measure the relative richness or cheapness of a Treasury bond compared to Treasury notes accurately.

The notes examined in this section have an initial time to maturity of ten years and the bonds have an initial time to maturity of 30 years.[42] Our data allows us to analyze four matched-maturity notes and bonds and their corresponding principal STRIPS on a daily basis starting on 27 November 2006. Panel A of Table 2.8 shows that synthetic yields of bonds are significantly larger than synthetic yields of notes. In fact, the difference is positive for almost all observations. Surprisingly, the same finding can be observed when comparing the corresponding principal STRIPS. Furthermore, the average difference is similar for matched-maturity synthetic yields and for principal STRIPS yields and amounts to about 10 bp for maturities in 2015 and 2016 and to more than 20 bp for the maturity in 2017.

For the synthetic yields we observe the typical on-the-run phenomenon. The positive yield differences can be reasoned by the fact that notes are traded more actively than clearly off-the-run bonds which have already existed for approximately 20 years. Therefore, these differences reflect a liquidity yield premium for the aged bonds. Regarding the different magnitude of the yield differences one should consider that the notes maturing in 2015 and 2016 are not the most recently issued during our observation period, whereas the note maturing in 2017 is trading on-the-run for a sizable fraction of our observation period. Thus, the different magnitude can be explained by a liquidity yield discount for recently issued notes.

Next, we focus on explaining the yield differences between the matched-maturity principal STRIPS corresponding to notes and bonds, respectively. There are two effects that should affect the yield differences in opposite directions. First, the principal

[42]See Panel B of Table 2.1 for details on the bonds considered.

STRIPS have differing liquidity in terms of stripping activity and outstanding amount. There is a huge amount of bonds held in stripped form and the notes are rarely stripped since they are recently issued.[43] Moreover, there is reasonable stripping activity for the bonds and only sparse stripping activity for the notes. This observation suggests a higher trading activity for the principal STRIPS of bonds compared to notes. Therefore, the liquidity effect should lead to a negative yield difference between principal STRIPS of bonds and principal STRIPS of notes.

Second, having the required amount of coupon STRIPS, the principal STRIPS of notes and bonds allow the owner to reconstitute a note or a bond, respectively. Hence, a specific principal STRIPS is unambiguously connected to the underlying note or bond. If the underlying bond is trading at a premium compared to a note, the principal STRIPS of a bond should also trade at a premium compared to a principal STRIPS of a note. Thus, the reconstitution effect should result in the concordance of the yield differences between the principal STRIPS and the yield differences between the underlying notes and bonds.

Our results in Panel A of Table 2.8 clearly indicate that the second effect is prevalent. We formally test this result by regressing the yield differences between the principal STRIPS on the yield differences between the synthetic yields. The regression results are shown in Panel B of Table 2.8. As already suggested by interpreting the summary statistics of the yield differences, we find a positive and highly significant relation between the observed yield differences $y^{P,bond} - y^{P,note}$ and the synthetic yield differences $r^{bond} - r^{note}$ for all pairs of notes and bonds. The estimated slope coefficient is between 0.74 and 0.89 and the adjusted R^2 is above 82%. This finding suggests that the empirically observed yield differences between matched-maturity principal STRIPS can, to a large extent, be explained by the differences of the corresponding synthetic yields. Any direct liquidity effect between the different principal STRIPS is of minor importance.

[43] The percentage held in stripped form of the four bonds is on average 16% and the maximum is at 36%.

Table 2.8: Summary Statistics and Regression Results for Yield Differences between Matched-Maturity Principal STRIPS

PANEL A: Yield Differences between Principal STRIPS and Yield Differences between Synthetic Yields (Same Maturity)

This table shows the summary statistics for the differences between principal STRIPS yields from matched-maturity notes and bonds as well as the differences between the corresponding synthetic yields. The notes have an initial time to maturity of ten years whereas the bonds have an initial time to maturity of 30 years. *** (**,*) denotes the significance at the 1% (5%, 10%) level. The significance of the mean is tested using a two-sided t-test with Newey-West HAC standard errors, the significance of the median is assessed by a non-parametric Wilcoxon signed-rank test. N is the number of daily observations. The sample consists of daily observations from November 2006 to November 2008.

Yields Bonds – Yields Notes (in basis points) **Sample: 11/27/06 - 11/13/08**

Maturity		Mean	Std. Dev.	Min.	Median	Max.	N	% > 0
02/15/2015	PSTRIPS	11.7***	13.5	-0.9	9.0***	88.9	483	97.1%
	synthetic	13.6***	14.9	0.1	10.8***	102.4	483	100.0%
08/15/2015	PSTRIPS	9.1***	9.9	-4.5	6.1***	69.5	476	98.9%
	synthetic	10.5***	11.6	-2.0	7.5***	78.3	476	97.1%
02/15/2016	PSTRIPS	9.0***	7.3	0.6	6.9***	66.7	480	100.0%
	synthetic	9.5***	8.8	0.6	7.4***	78.4	480	100.0%
08/15/2017	PSTRIPS	20.9***	10.2	2.4	20.4***	84.7	306	100.0%
	synthetic	23.7***	10.8	11.8	23.1***	86.0	306	100.0%

PANEL B: Regression Results for Differences between Principal STRIPS Yields on Differences between Synthetic Yields

This table reports the coefficient estimates and the t-statistics from the regression of the yield difference between matched-maturity principal STRIPS on the corresponding difference between synthetic yields. The specific model is:

$$y_t^{P,bond}(T) - y_t^{P,note}(T) = \beta_0 + \beta_1 \cdot (r_t^{bond}(T) - r_t^{note}(T)) + \varepsilon_t(T)$$

The yield differences are calculated in basis points. The t-statistic is computed using Newey-West HAC standard errors. *** (**,*) denotes the significance at the 1% (5%, 10%) level. N is the number of daily observations. The sample consists of daily observations from November 2006 to November 2008.

Sample: 11/27/06 - 11/13/08

Maturity	β_0	t-stat	β_1	t-stat	N	Adj. R^2
02/15/2015	-0.3723	-1.98**	0.8875	60.55***	483	0.958
08/15/2015	0.6007	3.60***	0.8048	41.25***	476	0.902
02/15/2016	1.9519	7.58***	0.7485	28.14***	480	0.823
08/15/2017	0.4024	0.62	0.8649	31.59***	306	0.833
Pooled	0.5605	3.52***	0.8438	66.07***	1,745	0.916

2.4 Summary and Conclusion

In this chapter we investigate matched-maturity yield differences in the U.S. Treasury market. We find significant differences by comparing the yields of coupon STRIPS with synthetic yields obtained from Treasury notes via bootstrapping. For longer maturities, coupon STRIPS trade at higher yields and for short maturities, Treasury notes trade at a premium. These differences cannot be explained by a differential taxation. We rationalize that the observed yield differences can be attributed to a different liquidity that is changing with respect to time to maturity due to the fungibility of coupon STRIPS. Moreover, the liquidity premium is increasing during the financial turmoil of 2007/2008. This premium can be related to macroeconomic variables that proxy a flight-to-liquidity effect.

The results show that the fungibility of coupon STRIPS was successful to create a rather liquid market for Treasury zero-bonds, primarily for maturities up to three years. In particular, this finding has been proven during the recent financial crisis. Therefore, we can conclude that short-term coupon STRIPS can be regarded as a “safe haven” with regard to credit and liquidity risk.

Even though principal STRIPS and Treasury notes clearly differ with respect to their liquidity, we cannot isolate a distinct liquidity premium between these markets. Our findings rather suggest that the uniqueness of principal STRIPS with regard to reconstitution leads the investors to price principal STRIPS in line with their corresponding Treasury notes.

We gain new insights in explaining the empirically observed yield differences between coupon and principal STRIPS as well as between principal STRIPS having the same maturity. In contrast to previous studies, our findings have made discernible that the yield differences between matched-maturity coupon and principal STRIPS can be traced back to the liquidity differences between coupon STRIPS and Treasury notes. Comparing matched-maturity principal STRIPS, the yield differences can be ascribed to the synthetic yield differences of the corresponding notes and bonds. Hence, the liquidity differences within the STRIPS market are of minor importance and, due to the unique reconstitution feature, any yield difference between matched-maturity STRIPS is directly affected by the corresponding synthetic yield difference.

These results are important for academics and market practitioners when considering STRIPS instead of coupon bonds in empirical studies. Sack (2000) and Steeley (2008), for example, advise to use STRIPS data for estimating zero-coupon yield curves. However, one has to decide whether to use coupon or principal STRIPS for such empirical studies. Our findings directly imply that, due to their unique link via reconstitution, principal STRIPS are the superior choice when measuring effects compared to other coupon bonds. Due to their fungibility, coupon STRIPS do not contain idiosyncratic effects of coupon bonds and are the appropriate choice for comparison with other zero-bonds. Certainly, in any empirical investigation with STRIPS one should always consider possible distortions due to the liquidity effects shown in this study.

A Appendix to Chapter 2

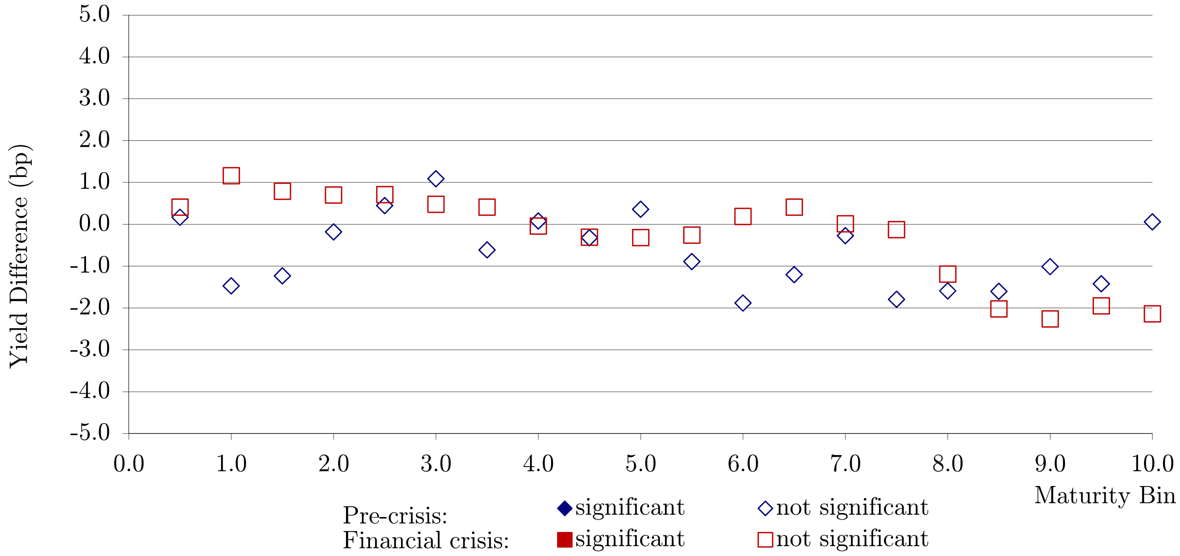

Figure A.1: Principal STRIPS Yields – Synthetic Yields $(y^P - r)$

This figure shows the mean difference between principal STRIPS yields and synthetic yields for each maturity bin. For a given maturity bin, the mean is calculated over time for the periods from February 2002 until June 2007 (pre-crisis) and from July 2007 until November 2008 (financial crisis). The empty rectangles represent mean yield differences that do not significantly exceed the typical bid-ask spread.

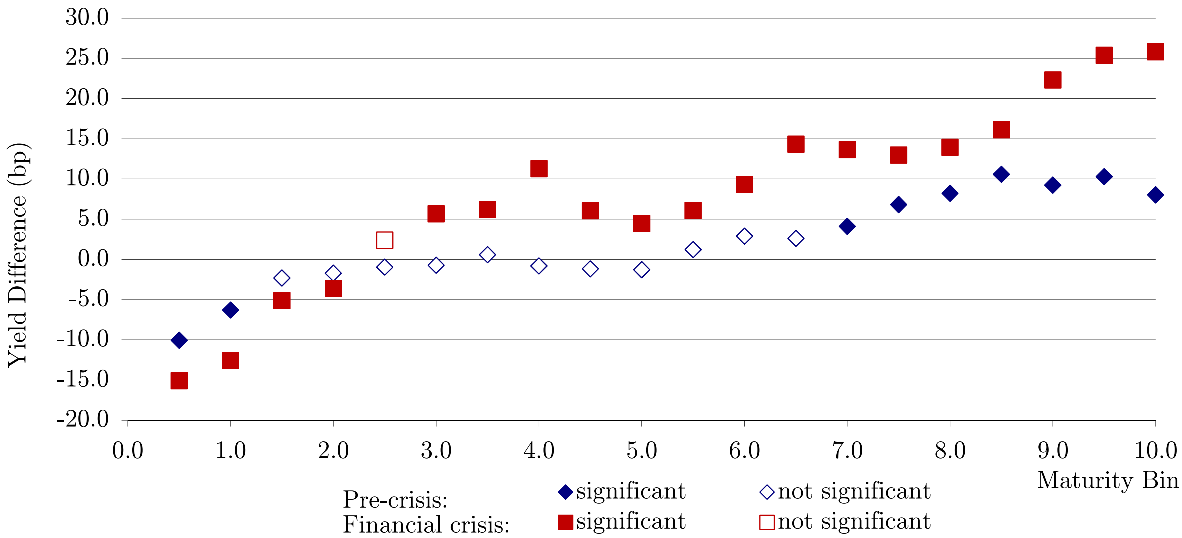

Figure A.2: Coupon STRIPS Yields – Principal STRIPS Yields $(y^C - y^P)$

This figure shows the mean difference between coupon STRIPS yields and principal STRIPS yields for each maturity bin. For a given maturity bin, the mean is calculated over time for the periods from February 2002 until June 2007 (pre-crisis) and from July 2007 until November 2008 (financial crisis). The filled (empty) rectangles represent mean yield differences that (do not) significantly exceed the typical bid-ask spread.

Table A.1: Coupon STRIPS Yields – Principal STRIPS Yields ($y^C - y^P$)

This table shows the summary statistics for the yield differences between coupon and principal STRIPS in basis points. The statistics are based on the mean yield difference at a given date for a given maturity bin and calculated over time. *** (**,*) denotes the significance at the 1% (5%, 10%) level. The significance of the mean is tested using a two-sided t-test with Newey-West HAC standard errors, the significance of the median by a non-parametric Wilcoxon signed-rank test. The significance of the differences between bid and ask yields is tested using one-sided t-tests with Newey-West HAC standard errors. N is the number of daily observations. The overall statistics are based on equal weights of all observations. The sample period ranges from February 2002 to June 2007.

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N	% > 0	$y^C_{bid} - y^P_{ask}$	$y^C_{ask} - y^P_{bid}$
0.5	-10.1***	10.7	-66.6	-10.3***	21.8	1,297	24.0%	-8.1***	-12.1
1.0	-6.3***	7.6	-31.9	-6.3***	10.8	1,301	25.9%	-4.3***	-8.3
1.5	-2.3***	5.8	-19.8	-2.6***	12.8	1,305	29.1%	-0.3	-4.3
2.0	-1.7***	3.5	-9.1	-1.8***	20.1	1,300	22.2%	0.3	-3.7
2.5	-1.0***	3.6	-10.5	-0.6***	17.4	1,238	37.2%	1.0	-3.0
3.0	-0.7**	3.9	-13.1	-0.1***	13.0	1,106	48.7%	1.3	-2.7
3.5	0.6*	4.4	-9.9	1.0***	17.8	1,043	57.8%	2.6	-1.4
4.0	-0.8**	5.1	-12.8	-1.3***	11.5	1,043	44.9%	1.2	-2.8
4.5	-1.2**	7.0	-26.5	-2.3***	27.3	1,043	38.6%	0.8	-3.2
5.0	-1.3**	6.5	-16.9	-1.5***	13.9	1,043	33.9%	0.7	-3.3
5.5	1.2**	7.6	-17.8	-0.4*	31.3	1,043	45.1%	3.2	-0.8
6.0	2.9***	7.3	-27.4	0.1***	37.2	919	50.5%	4.9	0.9
6.5	2.6***	6.9	-35.7	0.7***	27.9	852	56.6%	4.6	0.6
7.0	4.1***	6.4	-32.3	5.3***	21.2	852	64.7%	6.1	2.1***
7.5	6.8***	8.8	-49.7	6.7***	51.0	851	81.6%	8.8	4.8***
8.0	8.2***	6.3	-31.8	10.5***	33.4	844	94.2%	10.2	6.2***
8.5	10.6***	7.5	-24.3	11.1***	49.8	713	97.3%	12.6	8.6***
9.0	9.2***	6.5	2.4	6.2***	44.8	387	100.0%	11.2	7.2***
9.5	10.3***	7.8	2.6	6.3***	38.2	85	100.0%	12.3	8.3***
10.0	8.0***	1.9	1.1	8.4***	11.1	26	100.0%	10.0	6.0***
Overall	0.2	8.3	-66.6	-0.2	51.0	18,291	48.1%	2.2	-1.8

Table A.2: Coupon STRIPS Yields – Synthetic Yields ($y^C - r$) during the Financial Crisis

This table shows the summary statistics for the differences between coupon STRIPS yields and synthetic yields in basis points. The statistics are based on the mean yield difference at a given date for a given maturity bin and calculated over time. *** (**,*) denotes the significance at the 1% (5%, 10%) level. The significance of the mean is tested using a two-sided t-test with Newey-West HAC standard errors, the significance of the median by a non-parametric Wilcoxon signed-rank test. The significance of the differences between bid and ask yields is tested using one-sided t-tests with Newey-West HAC standard errors. N is the number of daily observations. The overall statistics are based on equal weights of all observations. The sample period ranges from July 2007 to November 2008.

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N	% > 0	$y^C_{bid} - r_{ask}$	$y^C_{ask} - r_{bid}$
0.5	-14.7***	21.4	-83.6	-15.9***	39.7	343	21.0%	-12.7***	-16.7
1.0	-11.4***	11.7	-42.1	-12.8***	17.5	343	18.4%	-9.4***	-13.4
1.5	-4.3***	5.8	-16.4	-4.6***	6.4	343	29.7%	-2.3***	-6.3
2.0	-2.9***	3.8	-12.4	-3.0***	8.1	343	24.5%	-0.9***	-4.9
2.5	3.1***	9.0	-10.7	1.9***	37.4	343	57.7%	5.1	1.1
3.0	6.2***	9.6	-7.0	4.1***	42.1	343	58.9%	8.2	4.2***
3.5	6.6***	10.2	-7.7	5.8***	52.8	343	79.6%	8.6	4.6***
4.0	11.2***	13.6	-10.5	12.3***	62.5	343	77.8%	13.2	9.2***
4.5	5.7***	6.8	-3.9	5.3***	41.9	343	86.0%	7.7	3.7***
5.0	4.2***	4.3	-7.2	4.9***	12.3	343	82.2%	6.1	2.1***
5.5	5.8***	6.5	-6.2	4.8***	21.7	343	74.3%	7.8	3.8***
6.0	9.5***	8.2	-6.9	11.3***	31.2	343	75.5%	11.5	7.5***
6.5	15.8***	17.1	-0.4	11.8***	91.8	343	99.4%	17.8	13.8***
7.0	14.6***	12.9	-2.2	14.2***	74.8	343	95.9%	16.6	12.6***
7.5	13.6***	9.4	1.8	12.3***	70.5	343	100.0%	15.6	11.6***
8.0	12.8***	8.4	0.3	12.7***	56.4	343	100.0%	14.8	10.8***
8.5	14.0***	11.2	1.9	9.3***	63.8	343	100.0%	16.0	12.0***
9.0	16.5***	12.8	0.8	18.2***	72.4	343	100.0%	18.5	14.5***
9.5	20.7***	14.7	3.6	16.3***	86.8	343	100.0%	22.7	18.7***
10.0	28.6***	14.7	9.9	29.2***	76.6	205	100.0%	30.6	26.6***
Overall	7.4***	15.0	-83.6	6.7***	91.8	6,722	73.5%	9.4	5.4***

Table A.3: Principal STRIPS Yields - Synthetic Yields ($y^P - r$) during the Financial Crisis

This table shows the summary statistics for the differences between principal STRIPS yields and synthetic yields in basis points. The statistics are based on the mean yield difference at a given date for a given maturity bin and calculated over time. *** (**,*) denotes the significance at the 1% (5%, 10%) level. The significance of the mean is tested using a two-sided t-test with Newey-West HAC standard errors, the significance of the median by a non-parametric Wilcoxon signed-rank test. The significance of the differences between bid and ask yields is tested using one-sided t-tests with Newey-West HAC standard errors. N is the number of daily observations. The overall statistics are based on equal weights of all observations. The sample period ranges from July 2007 to November 2008.

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N	% > 0	$y^P_{bid} - r_{ask}$	$y^P_{ask} - r_{bid}$
0.5	0.2	7.3	-41.5	0.0	23.9	1,301	50.0%	2.2	-1.8
1.0	-1.5***	4.9	-24.8	-0.8***	17.9	1,302	39.2%	0.5	-3.5
1.5	-1.2***	4.7	-16.8	-0.6***	15.0	1,305	41.3%	0.8	-3.2
2.0	-0.2	3.0	-19.0	-0.2*	7.5	1,300	46.1%	1.8	-2.2
2.5	0.5**	2.9	-19.1	0.4***	11.8	1,238	57.4%	2.5	-1.5
3.0	1.1***	2.5	-11.1	0.9***	12.4	1,106	70.3%	3.1	-0.9
3.5	-0.6***	1.9	-9.3	-0.3***	5.7	1,043	40.9%	1.4	-2.6
4.0	0.1	2.3	-8.5	0.1	21.2	1,043	53.2%	2.1	-1.9
4.5	-0.3	3.1	-18.5	0.1	28.9	1,043	52.3%	1.7	-2.3
5.0	0.4**	2.5	-12.7	0.4***	21.1	1,043	63.7%	2.4	-1.6
5.5	-0.9***	3.0	-13.7	-0.1***	16.0	1,043	48.2%	1.1	-2.9
6.0	-1.9***	5.7	-34.6	0.1***	41.6	919	53.5%	0.1	-3.9
6.5	-1.2***	5.8	-26.2	-0.1***	41.3	852	49.1%	0.8	-3.2
7.0	-0.3	4.4	-10.4	-0.1***	41.5	852	47.2%	1.7	-2.3
7.5	-1.8***	7.5	-44.1	-0.3***	55.3	851	45.8%	0.2	-3.8
8.0	-1.6***	4.9	-26.6	-1.1***	40.2	844	36.4%	0.4	-3.6
8.5	-1.6***	5.4	-35.2	-1.6***	37.3	713	29.6%	0.4	-3.6
9.0	-1.0*	5.7	-31.5	-0.7	7.8	387	39.0%	1.0	-3.0
9.5	-1.4	9.2	-34.0	1.6	7.4	85	58.8%	0.6	-3.4
10.0	0.1	1.6	-2.7	0.0	7.0	26	50.0%	2.1	-1.9
Overall	-0.6***	4.6	-44.1	-0.07	55.3	18,296	48.7%	1.4	-2.6

Table A.4: Coupon STRIPS Yields – Principal STRIPS Yields ($y^C - y^P$) during the Financial Crisis

This table shows the summary statistics for the yield differences between coupon and principal STRIPS in basis points. The statistics are based on the mean yield difference at a given date for a given maturity bin and calculated over time. *** (**,*) denotes the significance at the 1% (5%, 10%) level. The significance of the mean is tested using a two-sided t-test with Newey-West HAC standard errors, the significance of the median by a non-parametric Wilcoxon signed-rank test. The significance of the differences between bid and ask yields is tested using one-sided t-tests with Newey-West HAC standard errors. N is the number of daily observations. The overall statistics are based on equal weights of all observations. The sample period ranges from July 2007 to November 2008.

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N	% > 0	$y^C_{bid} - y^P_{ask}$	$y^C_{ask} - y^P_{bid}$
0.5	-15.1***	19.8	-67.8	-16.9***	38.4	343	18.4%	-13.1***	-17.1
1.0	-12.6***	11.7	-44.9	-14.1***	15.6	343	13.4%	-10.6***	-14.6
1.5	-5.1***	5.9	-22.1	-4.4***	5.3	343	22.7%	-3.1***	-7.1
2.0	-3.6***	4.2	-15.2	-4.0***	10.4	343	22.7%	-1.6***	-5.6
2.5	2.4**	8.9	-12.1	1.5***	44.9	343	56.9%	4.4	0.4
3.0	5.7***	9.6	-7.5	3.0***	43.0	343	57.7%	7.7	3.7***
3.5	6.2***	10.6	-11.8	5.7***	55.0	343	75.8%	8.2	4.2***
4.0	11.3***	13.9	-13.8	12.6***	66.5	343	77.8%	13.3	9.3***
4.5	6.1***	7.2	-10.4	5.5***	42.9	343	83.1%	8.0	4.0***
5.0	4.5***	5.0	-8.6	5.2***	17.7	343	79.9%	6.5	2.5***
5.5	6.1***	7.0	-9.5	5.6***	25.7	343	73.5%	8.1	4.1***
6.0	9.3***	8.9	-7.2	11.4***	35.0	343	72.6%	11.3	7.3***
6.5	14.3***	16.3	-1.6	10.5***	92.2	337	97.3%	16.3	12.3***
7.0	13.6***	12.4	-3.5	13.1***	79.0	333	93.7%	15.6	11.6***
7.5	13.0***	9.4	-0.3	11.8***	76.6	331	99.4%	15.0	11.0***
8.0	13.9***	10.1	-1.0	13.6***	67.5	339	98.8%	15.9	11.9***
8.5	16.1***	13.0	1.2	11.5***	77.8	340	100.0%	18.1	14.1***
9.0	22.3***	6.6	3.2	24.6***	38.7	162	100.0%	24.3	20.3***
9.5	25.4***	11.5	2.8	27.6***	81.0	248	100.0%	27.4	23.4***
10.0	25.8***	10.2	9.7	29.6***	44.0	160	100.0%	27.8	23.8***
Overall	6.8***	15.0	-67.8	6.3***	92.2	6,366	70.0%	8.8	4.8***

Chapter 3

Liquidity Premia in the Market for German Bunds and STRIPS

3.1 Introduction

In the previous chapter, we investigate yield differences between U.S. Treasury STRIPS and synthetic zero-bonds obtained from bootstrapping U.S. Treasury notes. In the following, we perform this approach with data for German government securities. As in the U.S. Treasury market, the ideal maturity structure of German government bonds (Bunds) allows us to isolate yields of synthetic zero-bonds and to compare them to traded yields of their corresponding STRIPS. Even though the formalities for stripping and reconstitution are similar in Germany and the United States, we find substantially different results.

The German STRIPS program has been developed to adapt the German government debt management to international standards and, thus, to enhance the attractiveness of Bunds in the background of the start of the European monetary union. Therefore, the German STRIPS program is very similar to the STRIPS program of the U.S. Treasury and to other countries that already had introduced the facility to strip government bonds. In contrast to the United States, however, the STRIPS program differs in three important aspects. First, the minimum nominal amount for stripping a Bund is EUR 50,000 compared to only USD 100 in the U.S. Treasury market. Second, only banks are allowed to reconstitute a previously stripped Bund. Third, private investors may have a tax driven incentive to invest in STRIPS as taxes are deferred until STRIPS are sold or redeemed. In this chapter, we analyze whether these differences lead to different results in the German Bunds and STRIPS market compared to the U.S. Treasury market. We apply the same methods as in the previous chapter such that the results are directly comparable.

Besides these institutional details, the study for the German market further differs in two aspects. First, except for two maturities, there is only one Bund maturing at every coupon date. Hence, we do not have to average final synthetic yields when continuing with the bootstrapping. As in the U.S. Treasury market often two or three Treasury notes mature on the same day, German data provides a much cleaner sample. Second, the amount held in stripped form is much lower in Germany compared to the United States. Whereas the outstanding STRIPS amount may even exceed the outstanding amount of a corresponding Treasury note, the percentage held in stripped form in Germany never exceeds 3.6% during our sample period. As we expect observed and synthetic yields to contain the liquidity of the respective market, this effect should also impact the observed yield differences.

The main results of our study are the following. First, in contrast to the results for the U.S. Treasury market, coupon STRIPS nearly always trade at a liquidity premium compared to Bunds and the premia do not show a clear maturity structure. However, the premia are rather small and economically negligible. Second, these yield differences significantly increase during the recent financial crisis and can be partly explained by liquidity related macroeconomic variables. Third, we find that principal STRIPS trade in line with synthetic zero-bonds obtained by bootstrapping Bunds even though principal STRIPS are substantially less liquid. Fourth, in line with the results for the U.S. Treasury market, we show that the positive differences between matched-maturity coupon and principal STRIPS do not stem from their different relative liquidity, but can be traced back to the liquidity premia between coupon STRIPS and Bunds.

Our study is related to several important strands of literature. First, we contribute to the extensive literate on liquidity premia and taxation in government bond markets as already presented in Section 2.1. Second, we particularly complement the literature on liquidity premia in the German government bond market. Third, we gain new insights into yield differences between coupon and principal STRIPS in Europe and the United States.

The German government bond market usually serves as the risk-free benchmark for European Government securities. Most studies investigating sovereign risk premia in Europe, such as Codogno et al. (2003), Geyer et al. (2004), and Bernoth et al. (2004), calculate yield spreads relative to German Bunds. However, only few studies investigate liquidity premia within the German government bond market. Kempf and Uhrig-Homburg (2000) find that German government bonds with lower liquidity trade at a significant liquidity yield premium that increases with time to maturity. Their sample, however, is only broadly classified into either liquid or illiquid bonds. Kempf et al. (2010) and Koziol and Sauerbier (2007) investigate maturity-dependent yield spreads between German government bonds and Pfandbriefe and argue that these two markets only differ with respect to their liquidity. However, Pfandbriefe are issued by banks and may trade at a significant default risk premium.[1] In contrast to these studies, German STRIPS and Bunds have exactly the same default risk as they are direct obligations of the German government. Therefore, these instruments only differ with respect to their liquidity and taxation and we are able to isolate these premia. Moreover, we contribute to this strand of literature by investigating the full term structure of liquidity premia of up to ten years.

In contrast to a large number of studies on U.S. Treasury STRIPS that are presented in Section 2.1, studies investigating the European STRIPS markets are scarce. To our knowledge, Huij et al. (2010) is the only empirical study on European coupon and principal STRIPS.[2] They investigate price differences between matched-maturity STRIPS for France, Germany, Spain, and Italy and find that potential switching profits are economically small. In addition to this study, we provide an explanation that yield differences between coupon and principal STRIPS are mainly driven by the liquidity between coupon STRIPS and the Bunds market.

The remainder of this chapter is structured as follows. In Section 3.2, we carefully describe the institutional details of the German STRIPS program and discuss potential effects on the yield differences. Further, we present the empirical design. In Section 3.3, we provide and discuss the empirical results. Section 3.4 concludes.

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[1] A detailed analysis of the Pfandbrief market is conducted in Chapter 4.

[2] Several studies like Kaserer (1998) and Vogt (1998) only describe the German STRIPS program and discuss potential taxation effects.

3.2 Design of the Study

Subsequently, we recall the most important institutional features of the German STRIPS program as far as they are relevant for our study.[3] In particular, we point out the main differences of the German STRIPS program compared to the United States. We further describe the calculation of observed and synthetic yields. Moreover, we discuss the potential impact of liquidity proxies, taxation, and the unique reconstitution feature on our results. Finally, we present the empirical design of our study.

3.2.1 Institutional Details

In July 1997, the German Federal Ministry of Finance has introduced the facility to strip all newly issued Bunds into their coupon and principal payments. These coupon and principal STRIPS are direct obligations of the German government and the stripping is executed by Clearstream International or the German Finance Agency. The minimum nominal amount for the stripping or the reconstitution of a Bund is EUR 50,000. Theoretically, the complete outstanding amount of a Bund can be stripped.

As in the U.S. Treasury market, German STRIPS are identified by whether they are created from a coupon or a principal payment. Coupon STRIPS that are due on the same day are assigned the same individual security identification number (ISIN), even if they originally come from a different Bund. Contrarily, the principal STRIPS of each Bund are assigned a unique ISIN and they are not interchangeable with other principal or coupon STRIPS. Although every investor is allowed to strip a Bund, only banks are allowed to reconstitute a previously stripped Bund. Due to tax reasons, banks can conduct this transaction only for their own holdings. Thereby, the appropriate proportions of the STRIPS components must be delivered to Clearstream International who executes the reconstitution. It is important to note that the principal STRIPS must have been originally derived from the Bund being reconstituted. This condition is in the interest of a correct disclosure of government debt. For the coupon payments, however, matched-maturity coupon STRIPS stripped from arbitrary Bunds can be used.

[3] A detailed description of the German STRIPS program can be found, e.g., in Deutsche Bundesbank (1997).

Trading in STRIPS primarily takes place over-the-counter between institutional investors and the Federal Government has decided to list German STRIPS only at Frankfurt stock exchange.[4] Moreover, the Bundesbank does not conduct any price management for STRIPS. In contrast to coupon and principal STRIPS, trading in Bunds is much more widespread, already indicating that STRIPS may be perceived as less liquid.

For tax purposes, STRIPS are treated differently for institutional and private investors until 2008.[5] STRIPS held by institutional investors are taxed similar to originally issued discount instruments in the United States according to the constant yield method. For private investors, the taxation of STRIPS substantially differs from the taxation in the United States and depends on whether the investor has originally stripped the corresponding Bund ("first buyer") or whether he has purchased coupon or principal STRIPS that had already been stripped.[6] In the former case, coupon STRIPS are fully taxed as interest income at the date of their sale or redemption. Contrarily, principal STRIPS are not taxed at all and a potential loss may not be deducted from other income as a capital loss. Hence, the taxation of the STRIPS portfolio for the first buyer equals the taxation of the Bund only if all STRIPS are held until maturity. In the case of a sale prior to maturity, a sizable tax drawback compared to holding the Bund or even a capital loss due to taxation may occur.

When a private investor buys coupon or principal STRIPS that have already been stripped, the tax method does not distinguish between the different kind of STRIPS. The taxable income is simply the difference between the sale or redemption proceeds and the purchase price.[7] In contrast to the United States, German STRIPS are taxed at the realization of a gain or a loss, avoiding negative cash flows prior to maturity. This method leads to a tax deferral and, compared to the taxation of Bunds, the investment into the corresponding STRIPS bundle may be advantageous for private investors.[8]

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[4] Since March 2010, German STRIPS have also been listed at Berlin Stock Exchange.

[5] The taxation of interest and capital gains in Germany changed to a flat rate tax on 1 January 2009. Since our sample period ends in 2008, we only describe the previous tax system that is relevant for our study.

[6] See, e.g., Kaserer (1998) and Deutsche Finanzagentur (2006) for a detailed description of the taxation of STRIPS for private investors in Germany.

[7] This method is called "method of difference" or "market yield method". Since STRIPS are not originally issued as zero-bonds, the "issue yield method" cannot be applied.

[8] van Aubel and Riddermann (1998) illustrate this tax effect in detail.

For our empirical study, we determine the observed and synthetic yields similar to the approach in the previous chapter. In contrast to U.S. Treasury notes and bonds, Bunds have annual coupon payments. Therefore, we simply compute the (annual) yield-to-maturity from directly observed STRIPS. These yields are referred to as *observed yields* and denoted by y^C for coupon STRIPS and y^P for principal STRIPS. The *synthetic yields* are denoted by r and calculated applying the standard bootstrapping procedure to Bunds.

3.2.2 Potential Effects on Observed and Synthetic Yields

(1) Liquidity

Coupon STRIPS, principal STRIPS and Bunds clearly differ in terms of their liquidity. German Bunds are usually traded very actively and the major part of all German government securities is traded in 10 year and 30 year Bunds (56%).[9] On the other hand, German STRIPS do not even occur in the trading statistics of the German Finance Agency. Besides the over-the-counter market, they are only traded at Frankfurt stock exchange with little turnover. Therefore, we expect STRIPS to generally trade at a liquidity yield premium compared to Bunds.

To investigate the liquidity differences in more detail, we proxy the liquidity of principal and coupon STRIPS by their outstanding amount. The outstanding amount OA^P of a specific principal STRIPS equals the amount of the underlying Bund held in stripped form. Since stripping and reconstitution occurs frequently, it is important to note that OA^P varies not only in the cross-section of Bunds, but also over time. Due to their fungibility, the outstanding amount of a coupon STRIPS, OA^C, equals the total coupon volume of all Bunds of the same series that mature at or after the specific coupon STRIPS' maturity, and that are held in stripped form. Hence, at a fixed calendar date, OA^C increases with decreasing time to maturity.

In contrast to the United States, only a small fraction of Bunds is held in stripped form. During our sample period, the maximum fraction of a Bund's outstanding volume held in stripped form is only 3.6% for a 10 year Bund. 30 year Bunds, however, are

[9] This figure is based on secondary market data transmitted to the German Finance Agency by the "Bund Issues Auction Group" on their secondary market activities in 2009.

stripped more actively. For example, the two Bunds with maturities in July 2027 and in January 2030 are stripped by approximately 20%. Since the coupon STRIPS obtained by stripping these Bunds are subsumed under one ISIN, their outstanding amounts exceed the outstanding amounts of matched-maturity principal STRIPS corresponding to 10 year Bunds in more than 91% of all monthly observations.

We consider the following determinants of a Bund's liquidity: total issue volume, age, and whether the Bund is trading on-the-run or not. The total issue volume measures the absolute supply of a Bund. The age of a Bund should be negatively related to its liquidity since a major part of the issue volume vanishes in the portfolios of investors and is held until maturity. For coupon STRIPS, this relation is ambiguous as they come from a variety of underlying Bunds. Moreover, ample empirical studies have found that most recently issued bonds trade more liquid and, thus, at lower yields than older ones.[10] We control for this specific effect by including a dummy variable with value one if the Bund trades on-the-run, and zero otherwise.

Furthermore, we capture the liquidation risk for investors by the economic outlook and potential trading needs by the financial market volatility similar to Kempf et al. (2010). As in their paper, we measure the economic outlook by the Ifo business climate index *IFO* and the financial market volatility by the volatility index *VDAX-NEW* of Deutsche Börse Group. A positive shock to *IFO* is considered to be related to a lower need for liquidity. Therefore, we expect any liquidity premia to be negatively related to ΔIFO. In contrast, an increase in *VDAX-NEW* is assumed to be associated with a higher uncertainty in the market that leads to a flight-to-liquidity behavior and, thus, to higher liquidity premia.[11]

(2) Taxation

In the previous section we already have pointed out that STRIPS and Bunds are taxed differently for private and institutional investors. From a pure tax perspective, it is not optimal for a private investor to strip a Bund by oneself, but to buy the corresponding bundle of STRIPS directly on the secondary market. In comparison to buying a Bund,

[10] See, e.g., Krishnamurthy (2002), Goldreich et al. (2005), and Pasquariello and Vega (2009).

[11] For the United States, Ben-Rephael et al. (2010) and Ederington and Golubeva (2009) recently find empirical evidence that flows from equity to bond funds are positively related to changes in *VIX*.

buying the bundle of STRIPS may be advantageous due to a tax deferral. This effect, however, may not be advantageous for all private investors and is not existent for institutional investors. Hence, it is questionable whether the effect can be observed in the market prices.

The potential effect of a Bund's market discount on the yield differences between STRIPS and Bunds is identical for institutional and private investors.[12] Institutional investors have to pay taxes for capital gains due to a market discount in the case of a sale above the purchase price or in the case of the redemption at maturity. Thus, they may profit from a tax deferral. Private investors usually even do not have to pay taxes on this kind on income. Therefore, this tax benefit should be reflected in a relatively high Bund price or, equivalently, in a relatively low yield. Hence, if the tax effect is priced in equilibrium, we expect the (pre-tax) synthetic yield of a Bund to be lower the higher its market discount, leading to a higher yield difference between observed and synthetic yields. In our empirical analysis, we consider this effect by a discount variable that is $100 - P^{Bund}$ if the Bund is trading at a market discount, and zero otherwise.

Similar to the analysis of the U.S. Treasury market in the previous chapter, potential tax differences fortunately do not matter for an important part of our study. Considering secondary market trading, the yields of matched-maturity coupon and principal STRIPS are affected identically by taxation. Hence, the yield differences between these STRIPS can exclusively be traced back to liquidity differences and the specific reconstitution feature. The size of these differences also allows us to control for tax effects in the differences between observed STRIPS yields and synthetic yields obtained from bootstrapping Bunds.

(3) Reconstitution

Even though STRIPS and Bunds have differing liquidity and are taxed asynchronously, an ultimate link exists between these markets. STRIPS cannot only be obtained by stripping a Bund, but also a Bund can be reconstituted by delivering the corresponding coupon and principal STRIPS. Hence, larger valuation differences between Bunds and their corresponding portfolio of coupon and principal STRIPS should directly be exploited by arbitrageurs. As financial institutions are the most active traders in the

[12] See, e.g., Vogt (1998) for a detailed discussion of this effect.

German government bond market, it should not matter that only banks are allowed to reconstitute a previously stripped Bund. In particular, as the principal payment is the largest cash flow component and principal STRIPS are necessary to reconstitute a specific Bund, their observed yields should rather trade in line with synthetic Bund yields.

This unique reconstitution feature of principal STRIPS also shows that coupon and principal STRIPS are not perfect substitutes. Principal STRIPS implicitly contain an "option to reconstitute" a specific Bund and, thus, are necessary to perform a potential arbitrage transaction. Following Daves and Ehrhardt (1993) that this option has a positive value, principal STRIPS should generally trade at lower yields than coupon STRIPS with the same maturity.

3.2.3 Empirical Design

Our sample period covers the time span from January 2004 until September 2008. The start of this period is determined by the ability to compute synthetic yields via bootstrapping Bunds. We divide our sample into two sub-samples. The first sample period covers the time span prior to the financial crisis and ranges from January 2004 until June 2007. The second sample period starts in July 2007 and ends with the collapse of Lehman in September 2008.[13] Comparing these two periods allows insights whether the financial crisis has an impact on the yield differences between German Bunds, coupon STRIPS, and principal STRIPS.

For our analysis, we need prices of Bunds with identical coupon dates and, ideally, with exactly one Bund maturing at every coupon date. Since 1997, German Bunds are at least auctioned semi-annually with annual coupon payments and the redemption payment on 4 January or 4 July.[14] These Bunds have an initial maturity of approximately 10 years, fixed coupons and they do not have embedded options. Being issued on a regular basis, these series are adequate to perform our study. In contrast, we do not include Bundesobligationen (BOBLs) with an initial maturity of 5 years and

[13] Afterwards, price data for STRIPS is often not reported or unreasonable price jumps are observed.

[14] If this day coincides with a weekend or public holiday, the payment is made on the next trading day.

Finanzierungsschätze with an initial maturity of 2 years. These government securities have different maturity dates and are not eligible for stripping. Moreover, we do not include Bunds with a longer initial time to maturity since the exact bootstrapping procedure for these Bunds is not applicable. However, the 10 year Bund series represent the largest segment of German government bonds as they cover approximately 44% of the total outstanding volume and 48% of the average daily trading volume.[15] Actually, approximately 24% of the daily trading volume in *all* European government bonds are in 10 year Bunds.

For the January series, we use January 2004 as the starting date for the bootstrapping. Prior to this month, the exact method is not applicable because no Bund with maturity on 4 January 2004 exists.[16] Similarly, we start on 4 July 2006 with bootstrapping the July series. We consider all Bunds from the two series for which we are able to compute the final synthetic yields during or observation period. This restricts our sample to Bunds with maturities until July 2018. For both series, we are able to exactly determine the synthetic yields for up to ten years.

After these refinements our total sample consists of 14 Bunds of the January series and 14 Bunds of the July series. For each Bund we consider the corresponding principal STRIPS. The first two Bunds of the January series maturing in 2005 and 2006, however, are not eligible for stripping. Therefore, our sample is limited to 26 principal STRIPS. We further consider all 26 coupon STRIPS maturing at a coupon date of a Bund in our sample.[17] From these data we determine one discrete term structures of interest rates for synthetic Bunds, one for coupon STRIPS, and one for principal STRIPS on a daily basis.

We use end-of-day mid prices for calculating the synthetic yields from Bunds as well as the mid prices of coupon and principal STRIPS via Bloomberg.[18] Bloomberg prices are quoted on a three-day settlement basis, and we compute accrued interest on

[15] These numbers are calculated for 2009 using data from the German Finance Agency.

[16] Actually, the following Bunds of this series mature on 3 January 2005 and 5 January 2006. We account for the tiny difference of one day when computing the synthetic yields.

[17] The number of Bunds exceeds the number of coupon STRIPS since in 2008 and 2009 two different Bunds of the July series mature on the same day. For these Bunds, we take the arithmetic mean of their final synthetic yields when proceeding with the bootstrapping.

[18] Thereby, we do not take transaction costs into account. Nevertheless, when interpreting the results, we analyze whether the yield differences exceed the typical bid-ask spreads.

an actual/actual basis. STRIPS are usually traded over-the-counter and their trading at Frankfurt stock exchange is rather thin. Therefore, Bloomberg is a more reliable source since prices are provided by at least five contributors. The prices are generated by truncating the extremes and averaging the remaining quotes.[19] To further verify their reliability, we check a number of prices with data from Frankfurt stock exchange and DZ Bank and do not find substantial differences.

We delete the observations on dates where prices are missing for at least one Bund such that the exact bootstrapping is not applicable. Moreover, we eliminate observations with zero returns and exclude all securities with less than three months to maturity. The trading close to maturity is particularly thin and small price differences will convert to extreme annualized yield differences. After this data preparation, our sample consist of more than 18,800 synthetic yields, about 17,400 yields of principal STRIPS, and about 19,800 yields of coupon STRIPS. Summary information of the data set is presented in Table 3.1.

To study liquidity effects we further collect monthly observations on the total outstanding volume of each Bund and the corresponding amount held in stripped form. This information is collected by Clearstream International and published by Deutsche Bundesbank. The data covers the last 15-month of our sample period from July 2007 to September 2008. Unfortunately, prior data is not available and, thus, we cannot examine the pre-crisis period and the financial crisis separately. Moreover, in contrast to the U.S. Treasury market, Clearstream International does not report the stripping and reconstitution activity of Bunds.

Furthermore, for analyzing the liquidation risk and a potential flight-to-liquidity premium, we obtain monthly observations of the Ifo business climate index (IFO) and the volatility index ($VDAX\text{-}NEW$) of Deutsche Börse Group. This data covers our full sample period from January 2004 to September 2008 and is obtained via the Bloomberg system.

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[19] See, e.g., Van Landschoot (2008).

Table 3.1: Summary Information for German Bunds and STRIPS

This table shows summary information for the German government securities considered in our study. The total outstanding volume and the amount held in stripped form are monthly averages given in EUR million. For Bunds and coupon STRIPS the data is averaged across the different issues. The number of daily observations is the number of observed or synthetic yields of all issues during the whole sample period from January 2004 to September 2008. The overall statistics are based on equal weights of all observations.

10 year Bunds

Series	# Issues	First Maturity	Last Maturity	Total Outstanding	Coupon	# Daily Observations
January	14	01/03/2005	01/04/2018	21,264.8	4.84	12,096
July	14	07/04/2007	07/04/2018	19,894.1	4.46	6,728
Overall	28			20,527.4	4.65	18,824

Principal STRIPS

Series	# Issues	First Maturity	Last Maturity	Amount Stripped	Monthly Observations Amount Stripped	# Daily Observations
January	12	01/04/2007	01/04/2018	197.4	152	10,943
July	14	07/04/2007	07/04/2018	83.5	177	6,464
Overall	26			136.1	329	17,407

Coupon STRIPS

Series	# Issues	First Maturity	Last Maturity	Amount Stripped	Monthly Observations Amount Stripped	# Daily Observations
January	14	01/04/2005	01/04/2018	331.2	152	12,289
July	12	07/04/2007	07/04/2018	248.8	150	7,492
Overall	26			290.3	302	19,781

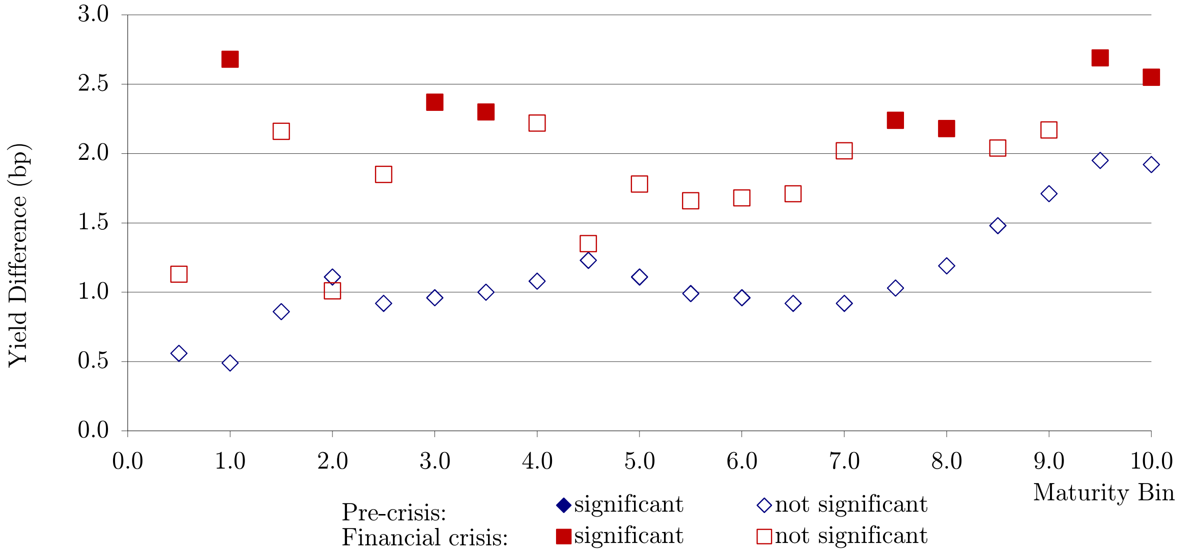

Figure 3.1: Coupon STRIPS Yields – Synthetic Yields ($y^C - r$)

This figure shows the mean difference between coupon STRIPS yields and synthetic yields for each maturity bin. For a given maturity bin, the mean is calculated over time for the period from January 2004 until June 2007 (pre-crisis) and from July 2007 until September 2008 (financial crisis). The filled (empty) rectangles represent mean yield differences that (do not) significantly exceed the typical bid-ask spread.

3.3 Empirical Results

3.3.1 Coupon STRIPS Yields vs. Synthetic Yields

We first investigate the differences between observed yields of coupon STRIPS and synthetic yields, $y^C - r$. We classify them with regard to their remaining time to maturity in half-year maturity bins. Bin T ($T = 0.5, 1.0, \dots$) consists of all yield differences for maturities in the interval $[T - 0.25; T + 0.25)$. The yield differences for a given maturity bin are averaged across Bunds and the descriptive statistics calculated across time.

Figure 3.1 shows the mean yield differences for each maturity bin for the pre-crisis period and the period of the financial crisis. During the pre-crisis period, all mean yield differences are greater than zero and slightly tend to increase with time to maturity. This increase is mainly driven by longer maturities above 8.5 years. However, all mean differences are not significant economically, as they do not significantly exceed the typical bid-ask spread of 2 bp. Hence, in contrast to the results for the U.S. Treasury market, the yield differences cannot be exploited theoretically by buying the synthetic zero-bond and selling the coupon STRIPS. During the pre-crisis period, coupon STRIPS therefore are priced in line with Bunds.

Table 3.2 displays the detailed summary statistics results for the yield differences during the pre-crisis period. Even though they are not significant economically, it is important to note that all mean and median differences between y^C and r are statistically significantly greater than zero. This effect also stems from the fact that the volatility of the yield differences is rather small. Moreover, for 92.4% of all observations the yield difference is greater than zero, indicating that coupon STRIPS persistently trade at a small yield premium compared to Bunds. For maturities below 1.5 years, however, the fraction of positive observations is substantially smaller, although still above 50%. Hence, short term coupon STRIPS seem to be rather liquid compared to longer term ones.

The results considerably change during the period of the financial crisis. Figure 3.1 shows that except for maturity bin 2.0 all mean differences $y^C - r$ are greater than during the pre-crisis period.[20] In contrast to the pre-crisis period, however, one cannot observe a clear maturity structure. The overall mean yield difference rises to 2 bp with economically significant yield differences in seven maturity bins.[21] Hence, coupon STRIPS are priced at a considerable yield premium during the recent financial crisis, suggesting a flight-to-liquidity premium relative to the Bunds market.

The previous analysis does not consider any time variation in the yields differences. In the following, we examine the evolution of selected maturity bins over time. Figure 3.2 presents the mean yield differences for the two, five, and eight year maturity bin. With only a few exceptions, all yield differences vary mostly between 0 bp and 3 bp during the pre-crisis period. During the financial crisis, one clearly observes a shift to generally higher yield differences as already noticed in Figure 3.1. Moreover, we do not observe that the yield differences in one maturity bin are predominantly greater than those in one of the others. In contrast, each of the three maturity bins shows the highest yield differences during some periods and the lowest yield differences

[20] Detailed summary statistics are given in Table B.1 in the appendix of this chapter.

[21] Our calculations assume a typical bid-ask spread of 2 bp for German STRIPS. During the financial crisis, however, the bid-ask spread is expected to considerably increase leading to yield differences being still insignificant economically. Unfortunately, we do not have data on the effective bid-ask spread.

Table 3.2: Coupon STRIPS Yields – Synthetic Yields ($y^C - r$)

This table shows the summary statistics for the differences between coupon STRIPS yields and synthetic yields in basis points. The statistics are based on the mean yield difference at a given date for a given maturity bin and calculated over time. *** (**,*) denotes the significance at the 1% (5%, 10%) level. The significance of the mean is tested using a two-sided t-test with Newey-West HAC standard errors, the significance of the median by a non-parametric Wilcoxon signed-rank test. The significance of the differences between bid and ask yields is tested using one-sided t-tests with Newey-West HAC standard errors. N is the number of daily observations. The overall statistics are based on equal weights of all observations. The sample period ranges from January 2004 to June 2007.

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N	% > 0	$y^C_{bid} - r_{ask}$	$y^C_{ask} - r_{bid}$
0.5	0.6***	1.4	-3.3	0.5***	9.0	566	63.6%	2.6	-1.4
1.0	0.5***	0.8	-5.7	0.6***	2.7	569	80.1%	2.5	-1.5
1.5	0.9***	0.8	-1.6	0.9***	3.0	559	83.7%	2.9	-1.1
2.0	1.1***	1.0	-2.5	1.0***	6.6	571	95.8%	3.1	-0.9
2.5	0.9***	0.5	-1.3	0.9***	3.5	558	96.6%	2.9	-1.1
3.0	1.0***	0.6	-2.7	1.0***	3.6	570	95.8%	3.0	-1.0
3.5	1.0***	0.6	-1.4	0.9***	3.6	577	96.4%	3.0	-1.0
4.0	1.1***	0.8	-2.1	1.0***	4.9	570	93.9%	3.1	-0.9
4.5	1.2***	0.9	-1.0	1.0***	5.3	577	95.5%	3.2	-0.8
5.0	1.1***	0.9	-1.9	1.0***	5.1	571	93.3%	3.1	-0.9
5.5	1.0***	0.6	-1.1	1.0***	4.4	578	94.3%	3.0	-1.0
6.0	1.0***	0.6	-1.5	1.0***	4.8	571	93.5%	3.0	-1.0
6.5	0.9***	0.5	-1.7	0.9***	3.8	577	95.8%	2.9	-1.1
7.0	0.9***	0.6	-1.1	0.9***	5.1	571	95.4%	2.9	-1.1
7.5	1.0***	0.8	-1.9	0.9***	4.6	577	94.8%	3.0	-1.0
8.0	1.2***	0.9	-1.4	1.0***	5.4	571	93.9%	3.2	-0.8
8.5	1.5***	0.9	-1.0	1.3***	4.4	577	95.8%	3.5	-0.5
9.0	1.7***	1.0	-1.3	1.6***	5.1	572	96.2%	3.7	-0.3
9.5	2.0***	1.3	-1.0	1.6***	4.7	577	97.6%	4.0	0.0
10.0	1.9***	1.5	-1.7	1.7***	6.7	425	95.5%	3.9	-0.1
Overall	1.1***	1.0	-5.7	1.0***	9.0	11,284	92.4%	3.1	-0.9

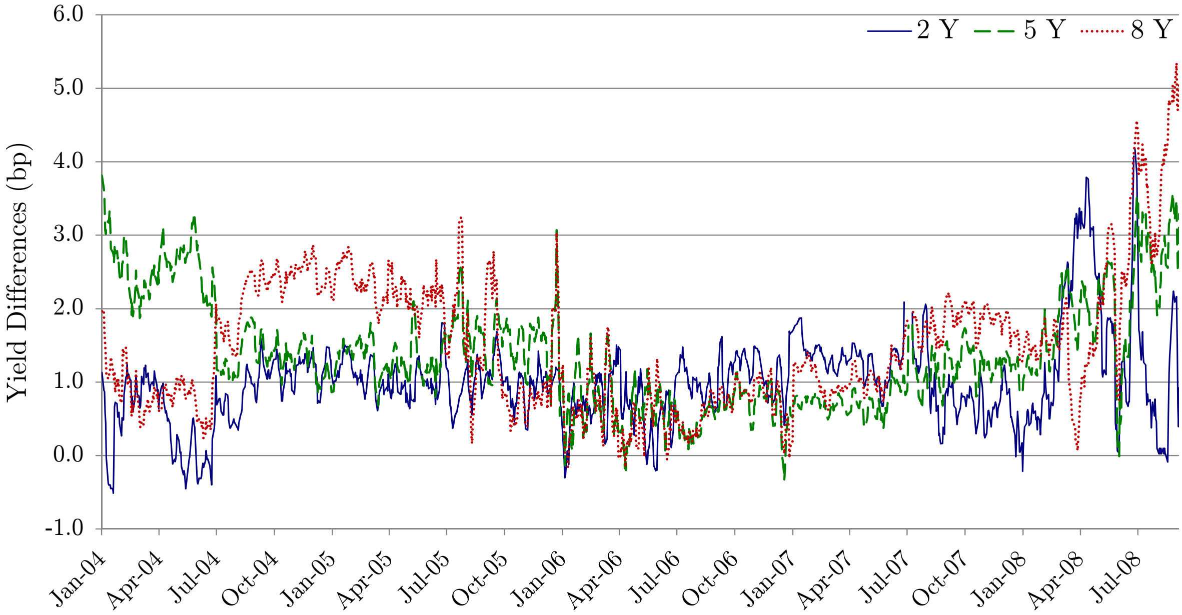

Figure 3.2: Coupon STRIPS Yields – Synthetic Yields ($y^C - r$)

This figure shows the mean differences between coupon STRIPS yields and synthetic yields for the two, five, and eight year maturity bin for the time period from January 2004 until September 2008.

during others.

The results for the German Bunds and STRIPS market strongly differ from the findings of the previous chapter for the U.S. Treasury market. First, we do not find negative mean yield differences between German coupon STRIPS and Bunds as they are observed for short maturities in the U.S. Treasury market. In contrast, the yield difference is significantly positive for all maturity bins. Second, the yield differences do not show a clear maturity structure that may indicate different liquidity premia for short and long maturities. Third, the yield differences in Germany are hardly economically significant. Fourth, the volatility of the yield differences is much smaller in Germany compared to the United States.

So far, we only have shown the existence of yield differences between coupon STRIPS and Bunds. In the following, we try to explain their cross-sectional variation and their time series behavior. Therefore, we relate the yield differences to the proxies for liquidity and taxation as well as to the macroeconomic variables discussed in Section 3.2.2. We use end-of-month observations of $y^C - r$ in our regression analysis as stripping information is available on a monthly basis only. Moreover, due to data availability, we can analyze the impact of the stripping variables for the time period of the financial crisis only. The augmented Dickey-Fuller tests show no sign of a unit root and, therefore, we use level variables. Table 3.3 shows the regression results that differ by the inclusion of the lagged yield difference, the stripping variables, and the macroeconomic variables.

The results for Regressions (1) and (2) show the expected signs, but the coefficients surprisingly are not significant except for the total issue volume of the Bunds. Moreover, the adjusted R^2 is negligible when the lag variable is not included in the regression. These results imply that, at least during the period of the financial crisis, the differences in Bund and STRIPS specific liquidity as well as the asynchronous taxation cannot explain the yield differences. In contrast, the macroeconomic variables have a significant impact. As shown in Regressions (3) and (4), the adjusted R^2 rises substantially. As expected, *VDAX-NEW* has a significantly positive and ΔIFO a significantly negative impact on the yield differences. This result indicates that a market-wide liquidation risk shows up in the liquidity premia between STRIPS and Bunds. Furthermore, we have considered the macroeconomic variables for short, medium, and long maturities separately (not reported). However, the effect is nearly the same for all maturity classes. Therefore, in contrast to Kempf et al. (2010), we conclude that the macroeconomic variables do not affect the term structure of liquidity premia differently at the short end and the long end.

The results remain stable when we exclude the variables on the outstanding amount and examine the whole sample period. Regressions (5) and (6) show that the market discount is still insignificant and all other variables have the expected sign, with the macroeconomic variables being highly significant. Hence, the differences between observed yields from coupon STRIPS and synthetic yields from Bunds are mainly driven by a market-wide liquidation risk rather than by differences in the specific securities or an effect due to the asynchronous taxation.

Comparing these results to the findings for the U.S. Treasury market, we identify three important differences. First, the yield differences between German coupon STRIPS and Bunds are not driven by the security-specific liquidity differences. This result might be due to a substantially lower liquidity for German STRIPS compared to a rather active, and thus more distinguishable Treasury STRIPS market. Second, the yield differences do not show such a high persistence as the yield differences in the U.S. Treasury market. Likewise, the adjusted R^2 is much smaller for the German market. Third, the macroeconomic variables measuring a market-wide liquidation risk have an

Table 3.3: Regression Results of Explanatory Variables for Differences between Coupon STRIPS Yields and Synthetic Yields

This table reports the estimated coefficients and the t-statistics from the regression of the difference between coupon STRIPS yields and synthetic yields with the same time to maturity. The yield differences are calculated in basis points and the total issue volume *TOT* Bunds as well as the outstanding amount OA^C are denoted in EUR billion. *AGE* is given in years, *DISCOUNT* in EUR. *OTR* equals one if the Bund is on-the-run, and zero otherwise. *VDAX-NEW* is Deutsche Börse's volatility index measured in basis points. ΔIFO denotes the first differences of the Ifo business climate index (measured in percentage points). The t-statistic is shown below the coefficient estimates and is computed using Newey-West HAC standard errors. *** (**,*) denotes the significance at the 1% (5%, 10%) level. N is the number of monthly observations. The sample consists of monthly observations from July 2007 to September 2008 (Regression 1-4) and from January 2004 to September 2008 (Regression 5-6).

	7/2007–8/2008		7/2007–8/2008		1/2004–8/2008	
Regression	(1)	(2)	(3)	(4)	(5)	(6)
Constant	**0.87**	**-0.14**	**-1.12**	**-2.91****	**0.71*****	**0.07**
	0.60	-0.12	-0.73	-2.01	2.77	0.29
TOT Bunds	**0.07***	**0.06***	**0.05**	**0.05**		
	1.69	1.68	1.32	1.47		
OA^C	**-1.06**	**-0.74**	**-0.13**	**-0.20**		
	-0.28	-0.27	-0.04	-0.08		
AGE	**0.01**	**0.01**	**-0.01**	**0.02**	**-0.04**	**-0.04**
	0.10	0.20	-0.21	0.28	-0.84	-1.28
OTR	**0.82**	**0.54**	**0.70**	**0.59**	**0.39**	**0.13**
	1.05	1.26	0.93	1.24	1.26	0.61
DISCOUNT	**0.03**	**0.01**	**-0.01**	**0.03**	**0.00**	**-0.01**
	0.35	0.20	-0.10	0.60	0.07	-0.42
VDAX-NEW			**7.52*****	**10.78*****	**4.63*****	**4.78*****
			2.65	3.88	3.49	4.69
ΔIFO			**-0.55*****	**-0.33*****	**-0.29*****	**-0.20*****
			-5.07	-3.11	-3.75	-3.49
Lag Variable		**0.62*****		**0.56*****		**0.45*****
		5.70		5.00		4.87
N	327	325	327	325	883	864
Adjusted R^2	0.007	0.228	0.136	0.302	0.057	0.222

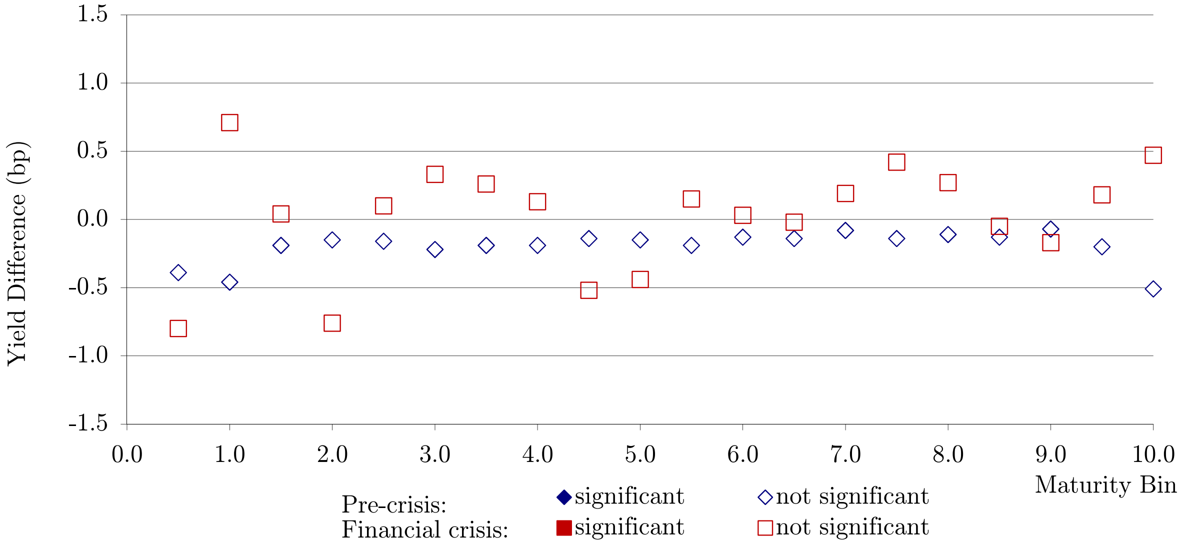

Figure 3.3: Principal STRIPS Yields – Synthetic Yields ($y^P - r$)

This figure shows the mean difference between principal STRIPS yields and synthetic yields for each maturity bin. For a given maturity bin, the mean is calculated over time for the period from January 2004 until June 2007 (pre-crisis) and from July 2007 until September 2008 (financial crisis). The filled (empty) rectangles represent mean yield differences that (do not) significantly exceed the typical bid-ask spread.

important impact. In contrast to the U.S. Treasury market, they affect short and long maturities similarly.

3.3.2 Principal STRIPS Yields vs. Synthetic Yields

In this section, we investigate the differences between the yields of principal STRIPS and the synthetic yields, $y^P - r$. The results are computed and illustrated in the same manner as the results in the previous section and displayed in Figure 3.3. Compared to the yield difference $y^C - r$ depicted in Figure 3.1, we find three important differences. First, it is striking that the mean yield differences $y^P - r$ are negative for all maturity bins during the pre-crisis period. The detailed summary statistics presented in Table 3.4 even show that the mean and median differences are all significantly negative except for maturity bin 9.0. Hence, we do not observe any yield premium as for coupon STRIPS yields relative to synthetic yields. Second, the yield differences do not tend to increase for longer maturities as it is the case for $y^C - r$. Third, the yield differences do not increase during the financial crisis for all maturity bins. However, the yield differences

Table 3.4: Principal STRIPS Yields – Synthetic Yields ($y^P - r$)

This table shows the summary statistics for the differences between principal STRIPS yields and synthetic yields in basis points. The statistics are based on the mean yield difference at a given date for a given maturity bin and calculated over time. *** (**,*) denotes the significance at the 1% (5%, 10%) level. The significance of the mean is tested using a two-sided t-test with Newey-West HAC standard errors, the significance of the median by a non-parametric Wilcoxon signed-rank test. The significance of the differences between bid and ask yields is tested using one-sided t-tests with Newey-West HAC standard errors. N is the number of daily observations. The overall statistics are based on equal weights of all observations. The sample period ranges from January 2004 to June 2007.

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N	% > 0	$y^P_{bid} - r_{ask}$	$y^P_{ask} - r_{bid}$
0.5	-0.39***	0.9	-3.9	-0.34***	3.5	317	37.2%	1.6	-2.4
1.0	-0.46***	0.8	-7.3	-0.31***	1.1	379	25.6%	1.5	-2.5
1.5	-0.19***	0.5	-3.0	-0.15***	1.4	430	35.8%	1.8	-2.2
2.0	-0.15***	0.5	-2.9	-0.10***	4.5	504	40.5%	1.8	-2.2
2.5	-0.16***	0.5	-2.4	-0.14***	1.7	559	40.3%	1.8	-2.2
3.0	-0.22***	0.5	-2.5	-0.17***	2.4	570	33.0%	1.8	-2.2
3.5	-0.19***	0.5	-2.0	-0.11***	1.7	577	40.9%	1.8	-2.2
4.0	-0.19***	0.6	-2.7	-0.09***	2.6	570	41.1%	1.8	-2.2
4.5	-0.14***	0.5	-2.1	-0.06***	2.2	577	46.8%	1.9	-2.1
5.0	-0.15***	0.6	-2.4	-0.05***	3.5	569	44.1%	1.8	-2.2
5.5	-0.19***	0.6	-2.1	-0.05***	1.8	576	45.5%	1.8	-2.2
6.0	-0.13***	0.6	-2.1	-0.01***	3.3	569	48.5%	1.9	-2.1
6.5	-0.14***	0.6	-2.1	-0.04***	1.8	573	45.0%	1.9	-2.1
7.0	-0.08**	0.6	-2.1	0.01**	3.3	567	50.1%	1.9	-2.1
7.5	-0.14***	0.6	-2.1	-0.02***	1.5	570	47.7%	1.9	-2.1
8.0	-0.11***	0.6	-2.0	0.00***	3.3	566	49.5%	1.9	-2.1
8.5	-0.13***	0.5	-2.1	-0.05***	1.2	570	45.3%	1.9	-2.1
9.0	-0.07	0.6	-2.1	0.03	3.1	511	53.0%	1.9	-2.1
9.5	-0.20***	0.6	-3.1	-0.16***	1.3	546	39.7%	1.8	-2.2
10.0	-0.51***	0.8	-3.4	-0.38***	1.1	278	25.9%	1.5	-2.5
Overall	-0.18***	0.6	-7.3	-0.09***	4.5	10,378	42.7%	1.8	-2.2

$y^P - r$ show a higher variation and may take positive and negative values.[22] It is important to note that even during the financial crisis the yield differences remain small in absolute terms and do not exceed 1 bp on average. Moreover, an inspection of the time series provides evidence that the yield differences vary rather randomly around zero. Hence, taking transaction costs into account, principal STRIPS can be regarded as being priced in line with Bunds.

As in the previous section, we formally test the relationship between the yield differences and the proxies for liquidity, taxation, and liquidation risk. The results are presented in Table 3.5. As for the differences between observed coupon STRIPS yields and synthetic yields, Regressions (1) and (2) show the expected signs. The coefficients, however, are not significant except for the outstanding amount. A higher outstanding amount of STRIPS leads to a lower yield differences, meaning that principal STRIPS that are hardly stripped trade at a yield premium compared to their corresponding Bunds. Moreover, the market discount does not have a significant impact on the yield differences, suggesting that an asynchronous taxation of STRIPS and Bunds does not play a role. Regressions (3) to (6) show the impact of the macroeconomic variables. During the financial crisis *VDAX-NEW* has a significantly positive impact, during the whole sample period only the negative impact of ΔIFO is significant. Altogether, these variables account for only a very small part of the variation in the yield differences. Even if including the lagged yield difference, the R^2 remains clearly below 10%.

The results in this section are in line with the findings of the previous chapter for the U.S. Treasury market. However, it is surprising that even though 10 year Bunds are hardly stripped in Germany, principal STRIPS are priced in line with their corresponding synthetic yields. This result clearly suggests that the unique reconstitution feature drives the relationship between the principal STRIPS and the Bunds market. Moreover, taxation does not result in systematic yield differences and liquidity hardly has an impact. In the next section, we compare the observed yields of coupon and principal STRIPS and further investigate the robustness of our results by explicitly controlling for tax effects.

[22]Detailed summary statistics for the financial crisis are given in Table B.2 in the appendix of this chapter.

Table 3.5: Regression Results of Explanatory Variables for Differences between Principal STRIPS Yields and Synthetic Yields

This table reports the estimated coefficients and the t-statistics from the regression of the difference between principal STRIPS yields and synthetic yields with the same time to maturity. The yield differences are calculated in basis points and the total issue volume *TOT* Bunds as well as the outstanding amount OA^P are denoted in EUR billion. *AGE* is given in years, *DISCOUNT* in EUR. *OTR* equals one if the Bund is on-the-run, and zero otherwise. *VDAX-NEW* is Deutsche Börse's volatility index measured in basis points. ΔIFO denotes the first differences of the Ifo business climate index (measured in percentage points). The t-statistic is shown below the coefficient estimates and is computed using Newey-West HAC standard errors. *** (**,*) denotes the significance at the 1% (5%, 10%) level. N is the number of monthly observations. The sample consists of monthly observations from July 2007 to September 2008 (Regression 1-4) and from January 2004 to September 2008 (Regression 5-6).

	7/2007–8/2008		7/2007–8/2008		1/2004–8/2008	
Regression	(1)	(2)	(3)	(4)	(5)	(6)
Constant	**-1.07**	**-0.87**	**-2.04***	**-2.50****	**-0.09**	**-0.17**
	-1.36	-1.21	-1.90	-2.42	-0.50	-0.98
TOT Bunds	**0.05**	**0.04**	**0.04**	**0.04**		
	1.48	1.39	1.23	1.17		
OA^P	**-1.42****	**-1.10****	**-1.41****	**-1.08****		
	-2.41	-2.21	-2.40	-2.22		
AGE	**0.08**	**0.05**	**0.07**	**0.06**	**-0.02**	**-0.02**
	1.29	0.95	1.34	1.13	-0.59	-0.59
OTR	**0.56**	**0.26**	**0.55**	**0.51**	**-0.28**	**-0.29**
	1.33	0.51	1.24	1.06	-1.37	-1.50
DISCOUNT	**0.03**	**0.01**	**0.03**	**0.03**	**0.02**	**0.01**
	0.79	0.33	0.81	0.85	1.02	0.28
VDAX-NEW			**4.18****	**6.77*****	**0.57**	**1.13**
			2.00	2.68	0.74	1.38
ΔIFO			**-0.14**	**-0.12**	**-0.10****	**-0.08**
			-1.48	-1.32	-2.04	-1.52
Lag Variable		**0.35*****		**0.38*****		**0.28*****
		2.98		3.03		3.21
N	312	308	312	308	824	800
Adjusted R^2	0.004	0.062	0.019	0.088	0.012	0.057

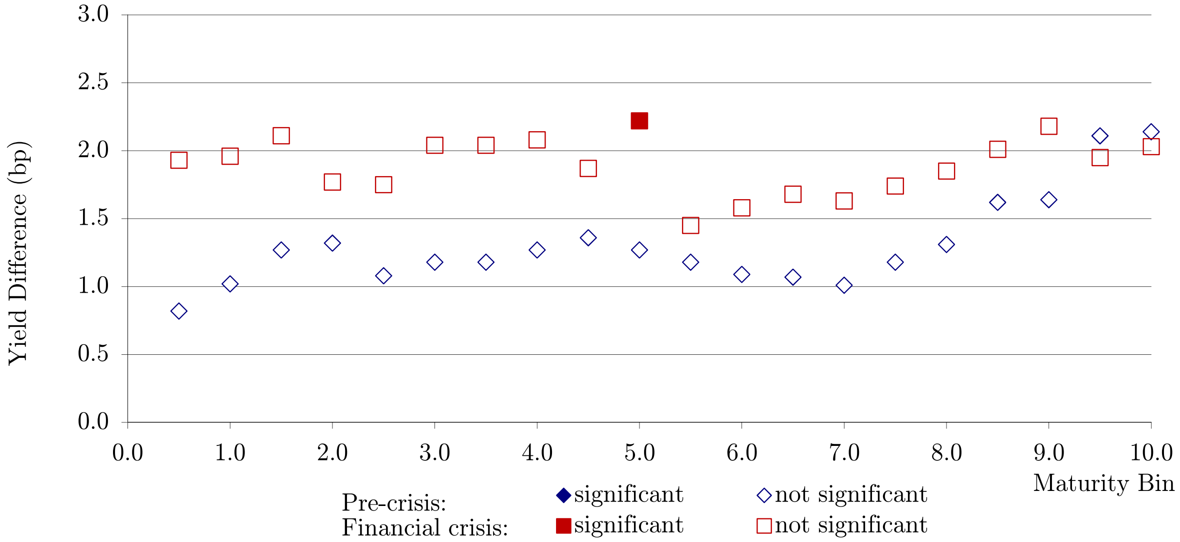

Figure 3.4: Coupon STRIPS Yields – Principal STRIPS Yields $(y^P - y^C)$

This figure shows the mean difference between coupon STRIPS yields and principal STRIPS yields for each maturity bin. For a given maturity bin, the mean is calculated over time for the period from January 2004 until June 2007 (pre-crisis) and from July 2007 until September 2008 (financial crisis). The filled (empty) rectangles represent mean yield differences that (do not) significantly exceed the typical bid-ask spread.

3.3.3 Coupon STRIPS vs. Principal STRIPS

As in the U.S. Treasury market, matched-maturity coupon and principal STRIPS provide exactly the same cash flows at maturity. Moreover, they are taxed symmetrically for each type of investor that buys STRIPS on the secondary market.[23] However, coupon and principal STRIPS differ in terms of their ability to reconstitute a Bund as well as in terms of their liquidity. Since an option to reconstitute is implicitly embedded in principal STRIPS, they should trade at lower yields compared to coupon STRIPS. Liquidity premia, however, may boost or offset this effect, depending on the liquidity differences between the coupon and principal STRIPS of a specific maturity.

Figure 3.4 shows the mean differences between observed yields of coupon and principal STRIPS.[24] We find that coupon STRIPS consistently trade at a yield premium compared to principal STRIPS. This finding confirms the result of Huij et al.

[23]As noted in Section 3.2.1, the taxation of the two instruments differs only for private investors that have originally stripped a Bund. This fact, however, should not have a differential impact on the observed yields.

[24]Detailed summary statistics for the pre-crisis period and for the financial crisis are given in Table B.3 in the appendix of this chapter.

(2010) and further shows that the yield premium is positive for every maturity. In addition, we provide an explanation for the observed yield differences in the following. We observe that this figure is directly related to Figure 3.1: First, the mean yield differences are greater than zero for each maturity bin. Second, the yield differences are not significant economically during the pre-crisis period. Third, the yield differences substantially increase during the period of the financial crisis. However, the observed pattern of the yield differences $y^C - y^P$ differ strongly from the results for the U.S. Treasury market. Nevertheless, one striking finding is in common for both markets: the yield differences $y^C - y^P$ basically show the same pattern as their corresponding yield differences $y^C - r$. Since in both markets principal STRIPS are usually priced according to the corresponding synthetic yields, the liquidity premia between coupon STRIPS and Bunds seem to just pass through.

As in the previous sections, we relate the yield differences to the liquidity proxies and to the macroeconomic variables defined in Section 3.2.2. To account for the differing liquidity in the coupon and principal STRIPS market, we include the difference of the outstanding amount, $OA^C - OA^P$. The age variable measures the age of a principal STRIPS and we expect a similar effect as for the underlying Bund. Further, we control for a potential on-the-run effect that may transmit from a Bund to its corresponding principal STRIPS due to the unique reconstitution feature. Therefore, we include a dummy variable with value one if the underlying Bund trades on-the-run, and zero otherwise. In addition to these variables, we also include $y^C - r$ as a measure for the liquidity premium of coupon STRIPS relative to Bunds. Thereby, we test whether the liquidity premia transmit to the STRIPS market and show up in the yield differences between coupon and principal STRIPS.

Table 3.6 presents the regression results that differ by the inclusion of the lagged yield difference, the macroeconomic variables, and the liquidity premium between coupon STRIPS yields and synthetic yields. As in the previous sections, the liquidity variables are not significant even though their sign is as expected in the majority of cases. The macroeconomic variables, however, show a similar impact as on the differences between coupon STRIPS yields and synthetic yields and the adjusted R^2 substantially increases when these variables are included. Moreover, the results remain

Table 3.6: Regression Results of Explanatory Variables for Yield Differences between Coupon STRIPS and Principal STRIPS

This table reports the estimated coefficients and the t-statistics from the regression of the difference between coupon STRIPS and principal STRIPS yields with the same time to maturity. The yield differences are calculated in basis points and the outstanding amount *OA* is denoted in EUR billion. *AGE* is given in years, *OTR* equals one if the Bund corresponding to the principal STRIPS is on-the-run, and zero otherwise. *VDAX-NEW* is Deutsche Börse's volatility index measured in basis points. ΔIFO denotes the first differences of the Ifo business climate index (measured in percentage points). The t-statistic is shown below the coefficient estimates and is computed using Newey-West HAC standard errors. *** (**,*) denotes the significance at the 1% (5%, 10%) level. N is the number of monthly observations. The sample consists of monthly observations from July 2007 to September 2008 (Regression 1-6) and from January 2004 to September 2008 (Regression 7-8).

	7/2007–8/2008		7/2007–8/2008		7/2007–8/2008		1/2004–8/2008	
Regression	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	**2.14*** **	**0.75*** **	**0.85***	**-0.06**	**1.38*** **	**0.55*** **	**0.40*** **	**0.04**
	8.23	3.56	1.81	-0.17	6.67	3.55	3.14	0.43
$OA^C - OA^P$	**0.22**	**0.12**	**0.21**	**0.12**	**0.69**	**0.43**		
	0.36	0.41	0.44	0.48	1.60	1.65		
AGE	**-0.03**	**-0.01**	**-0.03**	**-0.02**	**-0.03**	**-0.01**	**-0.01**	**0.00**
	-0.74	-0.58	-0.93	-0.75	-0.90	-0.60	-0.69	0.18
OTR	**0.20**	**0.74**	**0.21**	**0.89**	**0.05**	**0.47**	**0.45**	**0.34** **
	0.17	1.08	0.18	1.12	0.06	0.78	1.51	2.00
VDAX-NEW			**4.03** **	**3.38** **			**2.84*** **	**1.55*** **
			2.46	2.42			5.03	3.58
ΔIFO			**-0.39*** **	**-0.22*** **			**-0.10** **	**-0.05**
			-6.97	-3.83			-2.39	-1.52
$y^C - r$					**0.38*** **	**0.28*** **	**0.38*** **	**0.27*** **
					5.15	3.54	6.09	4.51
Lag Variable		**0.73*** **		**0.64*** **		**0.54*** **		**0.51*** **
		9.29		7.59		6.37		8.99
N	314	310	314	310	312	308	824	800
Adjusted R^2	-0.005	0.379	0.168	0.433	0.415	0.581	0.490	0.644

stable when including the lagged yield difference.

Regressions (5) to (8) show the significantly positive impact of the liquidity premium $y^C - r$ on the observed yield differences between coupon and principal STRIPS. Comparing the adjusted R^2 from Regression (2) to Regression (5), it is striking that $y^C - r$ explains a higher part of the variation compared to the lagged yield difference. The results remain stable when we exclude the difference of the outstanding amounts and examine the whole sample period. Hence, the differences between observed yields from coupon and principal STRIPS are mainly driven by a market-wide liquidation risk and the theoretically obtained liquidity premia between coupon STRIPS and Bunds.

This result is in line with the findings of Jordan et al. (2000) and the findings of the previous chapter for the U.S. Treasury market. It shows the strong link between the principal STRIPS and the corresponding Bund due to the unique reconstitution feature. Hence, theoretically obtained liquidity premia between coupon STRIPS and Bunds just pass through and drive the observed yield differences between coupon and principal STRIPS. Direct liquidity differences between these STRIPS are of minor importance.

3.4 Summary and Conclusion

In this chapter we investigate matched-maturity yield differences in the market for German Bunds and STRIPS. We find that observed yields from coupon STRIPS trade at a small liquidity premium compared to synthetic yields from Bunds. This premium is more pronounced during the recent financial crisis and is mainly driven by liquidity related macroeconomic variables. In contrast to the results for the U.S. Treasury market, the liquidity premia are economically negligible and we do not observe a sign change of the yield differences with increasing time to maturity.

Even though principal STRIPS are much less liquid than their corresponding Bunds, we find them trading in line or even at a small yield discount compared to synthetic yields. This result is striking and confirms the finding for the U.S. Treasury market that the unique reconstitution feature leads investors to price principal STRIPS analogously to their corresponding synthetic Bund yields.

The finding also transmits to the yield differences between matched-maturity coupon and principal STRIPS. It is surprising that coupon STRIPS trade at a significant yield premium, even though they have higher outstanding amounts and should be considered as more liquid than principal STRIPS. However, the strong relation between principal STRIPS and their corresponding Bunds leads the liquidity premia between coupon STRIPS and Bunds to just pass through.

Altogether, we have shown both an important distinction and an important similarity between the German government bond market and the U.S. Treasury market. First, due to liquidity differences relative to their corresponding bonds that may vary over the whole maturity spectrum, coupon STRIPS are priced very differently in Germany and the United States. Second, due to the unique reconstitution feature that exists in Germany and the United States, principal STRIPS are anchored to trade in line with their corresponding bonds.

B Appendix to Chapter 3

Table B.1: Coupon STRIPS Yields – Synthetic Yields ($y^C - r$) during the Financial Crisis

This table shows the summary statistics for the differences between coupon STRIPS yields and synthetic yields in basis points. The statistics are based on the mean yield difference at a given date for a given maturity bin and calculated over time. *** (**,*) denotes the significance at the 1% (5%, 10%) level. The significance of the mean is tested using a two-sided t-test with Newey-West HAC standard errors, the significance of the median by a non-parametric Wilcoxon signed-rank test. The significance of the differences between bid and ask yields is tested using one-sided t-tests with Newey-West HAC standard errors. N is the number of daily observations. The overall statistics are based on equal weights of all observations. The sample period ranges from July 2007 to September 2008.

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N	% > 0	$y^C_{bid} - r_{ask}$	$y^C_{ask} - r_{bid}$
0.5	1.1***	3.4	-12.7	0.8***	15.6	308	67.5%	3.1	-0.9
1.0	2.7***	2.9	-3.9	1.5***	15.8	305	92.5%	4.7	0.7***
1.5	2.2***	2.0	-5.0	2.0***	9.4	308	89.9%	4.2	0.2
2.0	1.0***	2.0	-5.1	0.9***	7.3	305	79.7%	3.0	-1.0
2.5	1.9***	1.7	-2.2	1.3***	6.9	308	92.5%	3.9	-0.1
3.0	2.4***	1.9	-0.7	1.6***	8.5	305	97.7%	4.4	0.4**
3.5	2.3***	1.8	-1.4	1.6***	8.7	308	97.1%	4.3	0.3*
4.0	2.2***	1.7	-1.5	1.6***	9.1	305	98.7%	4.2	0.2
4.5	1.4***	0.9	-3.5	1.3***	5.4	309	98.1%	3.4	-0.6
5.0	1.8***	1.1	-2.6	1.6***	7.2	306	98.0%	3.8	-0.2
5.5	1.7***	1.1	-3.5	1.4***	6.5	309	98.4%	3.7	-0.3
6.0	1.7***	1.3	-2.8	1.3***	6.9	306	97.4%	3.7	-0.3
6.5	1.7***	1.2	-2.4	1.4***	6.5	309	97.7%	3.7	-0.3
7.0	2.0***	1.6	-3.9	1.5***	8.1	306	98.4%	4.0	0.0
7.5	2.2***	1.3	-4.5	2.1***	6.6	309	99.4%	4.2	0.2**
8.0	2.2***	1.2	-2.2	1.9***	7.0	306	98.7%	4.2	0.2*
8.5	2.0***	1.3	-2.2	1.6***	6.7	308	98.7%	4.0	0.0
9.0	2.2***	1.2	-1.3	1.8***	6.2	306	98.7%	4.2	0.2
9.5	2.7***	1.9	-1.7	2.1***	7.5	308	98.4%	4.7	0.7***
10.0	2.6***	1.9	-1.0	2.5***	10.3	246	94.3%	4.5	0.5**
Overall	2.0***	1.8	-12.7	1.5***	15.8	6,080	94.6%	4.0	0.0

Table B.2: Principal STRIPS Yields – Synthetic Yields ($y^P - r$) during the Financial Crisis

This table shows the summary statistics for the differences between principal STRIPS yields and synthetic yields in basis points. The statistics are based on the mean yield difference at a given date for a given maturity bin and calculated over time. *** (**,*) denotes the significance at the 1% (5%, 10%) level. The significance of the mean is tested using a two-sided t-test with Newey-West HAC standard errors, the significance of the median by a non-parametric Wilcoxon signed-rank test. The significance of the differences between bid and ask yields is tested using one-sided t-tests with Newey-West HAC standard errors. N is the number of daily observations. The overall statistics are based on equal weights of all observations. The sample period ranges from July 2007 to September 2008.

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N	% > 0	$y^P_{bid} - r_{ask}$	$y^P_{ask} - r_{bid}$
0.5	-0.80**	3.2	-16.5	-0.71***	12.1	308	34.7%	1.2	-2.8
1.0	0.71***	2.3	-4.9	0.09***	14.6	305	52.5%	2.7	-1.3
1.5	0.04	1.6	-11.5	-0.05	6.5	308	48.1%	2.0	-2.0
2.0	-0.76***	2.4	-7.9	-0.29***	5.2	305	36.7%	1.2	-2.8
2.5	0.10	1.4	-4.2	-0.16	5.6	308	39.0%	2.1	-1.9
3.0	0.33**	1.2	-2.9	0.00***	4.9	305	50.2%	2.3	-1.7
3.5	0.26***	1.0	-3.8	0.05***	4.8	308	52.3%	2.3	-1.7
4.0	0.13**	0.9	-3.3	0.02*	4.7	305	51.5%	2.1	-1.9
4.5	-0.52***	1.0	-5.6	-0.26***	2.6	307	33.2%	1.5	-2.5
5.0	-0.44***	1.0	-4.9	-0.29***	5.9	306	32.7%	1.6	-2.4
5.5	0.15*	0.9	-4.4	0.06**	3.9	296	55.1%	2.2	-1.8
6.0	0.03	0.9	-4.2	-0.12	4.3	294	42.2%	2.0	-2.0
6.5	-0.02	1.0	-3.6	-0.18**	4.1	296	36.8%	2.0	-2.0
7.0	0.19*	1.1	-2.9	-0.07	5.5	284	45.8%	2.2	-1.8
7.5	0.42***	0.9	-3.2	0.37***	4.3	296	64.2%	2.4	-1.6
8.0	0.27***	0.9	-3.6	0.17***	4.3	293	59.7%	2.3	-1.7
8.5	-0.05	0.8	-3.9	-0.12**	3.7	295	40.0%	2.0	-2.0
9.0	-0.17***	0.7	-6.1	-0.11***	2.0	261	39.1%	1.8	-2.2
9.5	0.18**	0.8	-3.2	0.11***	2.5	217	55.8%	2.2	-1.8
10.0	0.47**	0.9	-2.9	0.51***	2.1	53	67.9%	2.5	-1.5
Overall	0.00	1.5	-16.5	-0.07**	14.6	5,650	45.8%	2.0	-2.0

Table B.3: Coupon STRIPS Yields - Principal STRIPS Yields ($y^C - y^P$)

This table shows the summary statistics for the yield differences between coupon and principal STRIPS in basis points. The statistics are based on the mean yield difference at a given date for a given maturity bin and calculated over time. *** (**,*) denotes the significance at the 1% (5%, 10%) level. The significance of the mean is tested using a two-sided t-test with Newey-West HAC standard errors, the significance of the median by a non-parametric Wilcoxon signed-rank test. The significance of the differences between bid and ask yields is tested using one-sided t-tests with Newey-West HAC standard errors. N is the number of daily observations. The overall statistics are based on equal weights of all observations. The sample period ranges from January 2004 to June 2007 (Panel A) and from July 2007 to September 2008 (Panel B).

Panel A: Sample Period: 01/05/04 - 06/29/07

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N	% > 0	$y^C_{bid} - y^P_{ask}$	$y^C_{ask} - y^P_{bid}$
0.5	0.8***	0.5	0.0	0.7***	3.5	317	96.2%	2.8	-1.2
1.0	1.0***	0.5	-1.7	1.0***	2.8	379	97.9%	3.0	-1.0
1.5	1.3***	0.5	-0.5	1.3***	2.9	447	99.1%	3.3	-0.7
2.0	1.3***	0.8	-0.8	1.3***	6.6	504	99.4%	3.3	-0.7
2.5	1.1***	0.3	-0.9	1.1***	2.2	576	99.5%	3.1	-0.9
3.0	1.2***	0.3	-0.7	1.2***	3.0	570	98.8%	3.2	-0.8
3.5	1.2***	0.5	-0.4	1.1***	3.6	577	99.1%	3.2	-0.8
4.0	1.3***	0.6	-0.3	1.2***	3.2	570	99.1%	3.3	-0.7
4.5	1.4***	0.9	-0.5	1.0***	3.9	577	98.8%	3.4	-0.6
5.0	1.3***	0.8	-0.3	1.0***	4.0	569	99.6%	3.3	-0.7
5.5	1.2***	0.6	-0.7	1.0***	3.6	576	99.0%	3.2	-0.8
6.0	1.1***	0.5	-0.3	1.0***	3.6	569	99.3%	3.1	-0.9
6.5	1.1***	0.5	-0.6	1.0***	3.8	573	99.3%	3.1	-0.9
7.0	1.0***	0.4	0.0	0.9***	3.3	567	99.8%	3.0	-1.0
7.5	1.2***	0.6	-0.6	1.1***	4.5	570	99.3%	3.2	-0.8
8.0	1.3***	0.7	0.0	1.2***	4.2	566	99.1%	3.3	-0.7
8.5	1.6***	0.9	0.2	1.3***	4.2	570	100.0%	3.6	-0.4
9.0	1.6***	0.9	0.1	1.3***	4.3	511	100.0%	3.6	-0.4
9.5	2.1***	1.4	-0.6	1.3***	6.3	546	98.7%	4.1	0.1
10.0	2.1***	1.7	-1.1	1.6***	7.0	278	96.4%	4.1	0.1
Overall	1.3***	0.8	-1.7	1.1***	7.0	10,412	99.1%	3.3	-0.7

Table B.3 continued.

Panel B: Sample Period: 07/02/07 - 09/12/08

Maturity Bin	Mean	Std. Dev.	Minimum	Median	Maximum	N	% > 0	$y^C_{bid} - y^P_{ask}$	$y^C_{ask} - y^P_{bid}$
0.5	1.9***	2.5	-7.5	1.4***	15.0	308	90.6%	3.9	-0.1
1.0	2.0***	1.6	-9.0	1.7***	12.4	305	99.3%	4.0	0.0
1.5	2.1***	1.7	-2.5	1.6***	17.3	308	97.4%	4.1	0.1
2.0	1.8***	1.1	-0.9	1.4***	7.3	305	99.3%	3.8	-0.2
2.5	1.8***	1.2	-0.9	1.2***	4.3	308	98.7%	3.7	-0.3
3.0	2.0***	1.0	0.0	1.7***	4.3	305	99.7%	4.0	0.0
3.5	2.0***	1.1	-0.2	1.6***	4.7	308	99.4%	4.0	0.0
4.0	2.1***	1.2	0.0	1.6***	6.0	305	99.7%	4.1	0.1
4.5	1.9***	1.0	-1.3	1.4***	4.9	307	99.7%	3.9	-0.1
5.0	2.2***	1.2	-0.5	1.8***	7.0	306	99.7%	4.2	0.2*
5.5	1.5***	0.4	-1.2	1.4***	5.4	296	99.7%	3.4	-0.6
6.0	1.6***	0.7	0.4	1.4***	5.8	294	100.0%	3.6	-0.4
6.5	1.7***	0.6	0.5	1.6***	5.4	296	100.0%	3.7	-0.3
7.0	1.6***	0.7	-1.0	1.5***	5.4	284	99.6%	3.6	-0.4
7.5	1.7***	0.6	-1.4	1.7***	5.0	296	99.7%	3.7	-0.3
8.0	1.9***	0.6	0.3	1.7***	5.1	293	100.0%	3.9	-0.1
8.5	2.0***	0.8	0.8	1.8***	5.5	295	100.0%	4.0	0.0
9.0	2.2***	1.1	0.6	1.9***	6.4	261	100.0%	4.2	0.2
9.5	2.0***	1.6	-1.0	1.6***	7.2	217	91.2%	3.9	-0.1
10.0	2.0***	3.1	-1.5	0.4***	10.3	53	56.6%	4.0	0.0
Overall	1.9***	1.2	-9.0	1.6***	17.3	5,650	98.3%	3.9	-0.1

Chapter 4

Liquidity and Credit Risk Premia in the Pfandbrief Market[1]

4.1 Introduction

It is generally accepted that the recent financial crisis has its origin in the granting of subprime loans and their securitization. As the mortgage pools experienced declines in credit quality and losses, the market prices of mortgage-backed securities (MBS) and other asset-backed securities (ABS) plummeted, leading to write-downs and losses all over the world. Along with a number of moral hazard problems, this caused a general crisis of confidence on the market for securitized mortgage loans. The confidence crisis also considerably affected the market prices of covered bonds, even though they have a different structure and bear different risks.

The increase of yields also spread to the German Pfandbrief market, although Pfandbriefe are usually seen as close substitutes for high-quality government bonds and there has never been a Pfandbrief default. Due to their security mechanisms and the high quality of their collateral, Pfandbriefe have been considered virtually default-free. Therefore, the yield spread with respect to German government securities has often been interpreted as a liquidity premium. During the recent financial crisis, however, one has observed yield differences between segments of the Pfandbrief market or single

[1]This chapter is based on a working paper co-authored with Jan Siewert. Cf. Siewert and Vonhoff (2010).

Pfandbrief issues whose liquidity is nearly the same. Hence, it is becoming evident that the yield spread between Pfandbriefe and German government securities cannot be interpreted as a pure liquidity premium.

The purpose of this study is an in-depth analysis of the yield spreads *within* the Pfandbrief market. We investigate the main risk factors perceived by investors and their relative valuation for the time period from 2000 to 2009. In particular, we examine whether liquidity, the quality of the issuer, the type of collateral, or the quality of the underlying cover pool is the main driver of the yield spreads between individual Pfandbriefe. Moreover, we gain insights into the behavior of Pfandbrief spreads during different periods – the pre-crisis period and the period of the recent financial crisis.

Our contribution to the literature is threefold. First, in contrast to the assumption of Koziol and Sauerbier (2007) or Kempf et al. (2010), we show that liquidity is an important, but not the exclusive factor when explaining Pfandbrief yield spreads. Second, in addition to previous studies such as Birkmeyer and Herbert (2002) and Breger and Stovel (2004), we analyze individual Pfandbrief spreads over time and explicitly account for the issuers' default risk. Third, we are the first to study the impact of the cover pool quality by using the publications according to § 28 Pfandbrief Act.

With its origin in 1769, the German Pfandbrief is one of the oldest asset-backed securities in the world. The cover pools mainly consist of high-quality public sector loans or prime mortgage loans. With an average outstanding volume of EUR 916 billion, the Pfandbrief market is one of the largest fixed income markets in the world.[2] In contrast to MBS and ABS, however, the structure is quite different: (i) the Pfandbrief is a claim on the issuer and the cover loans remain on the issuer's balance sheet instead of being transferred to a special purpose vehicle, (ii) the coupon and redemption payments are agreed on in advance and the investor does not bear any prepayment risks, (iii) the direct access to the cover pool is only necessary if the issuer defaults on its liabilities, (iv) there are very strict legal requirements with regard to the allowed pool assets and their valuation,[3] (v) pool borrowers are liable with all of their assets and not only

[2] Pfandbrief market statistics (2003–2009), Association of German Pfandbrief Banks (vdp).

[3] In comparison to other covered bond markets, the Pfandbrief is considered to have the most restrictive legal requirements.

with the underlying real estate property (no jingle mail). This strong legal protection certainly is one of the reasons that a default on a Pfandbrief has never occurred. As the Pfandbrief has proven to be a successful source of German mortgage and public-sector loan funding and solves some of the moral hazard problems associated with MBS and other ABS, the introduction of a similar covered bond legislation is currently also discussed in the United States.[4]

Our study is particularly related to the literature on German Pfandbriefe and, in general, to the literature on liquidity and credit risk premia in fixed income markets. Despite the ample size of the German Pfandbrief market and its systemic importance for the German banking system, there are only few academic studies analyzing this market in detail. Empirical studies of the Pfandbrief market usually investigate the yield difference between Pfandbriefe and German government bonds (Bunds). Bühler and Hies (1998) and Jobst (2006) investigate the spread dynamics, but do not come up with an economic explanation for the yield differences. Rees (2001) develops a forecasting model for the 10 year Pfandbrief spread using macroeconomic factors. This model, however, does not differentiate between the different types of Pfandbriefe. Koziol and Sauerbier (2007) and Kempf et al. (2010) argue that Pfandbriefe are considered as default-free and that yield differences between Pfandbriefe and Bunds have to be ascribed to liquidity differences. With this presumption, they estimate term structures of illiquidity spreads between Pfandbriefe and Bunds. In contrast to their findings, our results show that liquidity is an important, but not the exclusive factor driving Pfandbrief yield spreads.

Schäfer and Hochstein (1999) and Birkmeyer and Herbert (2002) investigate yield differences in the market for Jumbo Pfandbriefe and relate them to several explanatory variables like the outstanding amount and the Pfandbrief rating. Whereas Schäfer and Hochstein (1999) conclude that the Jumbo Pfandbrief market is rather homogenous, Birkmeyer and Herbert (2002) find higher yields for Pfandbriefe issued by mortgage banks relative to public banks. They expect an increasing importance of the issuer's quality for the relative pricing of Jumbo Pfandbriefe. Breger and Stovel (2004) study the effect of credit risk and liquidity in the market for traditional and Jumbo Pfandbriefe.

[4]See, e.g., Lucas et al. (2008) and Bernanke (2009).

The authors find a significant liquidity premium of 15 bp between traditional and Jumbo Pfandbriefe whereas differences between AAA and AA rated Pfandbriefe do not have a significant effect. Sünderhauf (2006) investigates the impact of the issuer's default risk on the pricing of Pfandbriefe. By applying and calibrating a structural Merton (1974)-type model for a Pfandbrief bank, he comes to the conclusion that mortgage Pfandbriefe should be considered as widely independent from the issuer's quality. We extend this strand of literature by conducting an in-depth analysis of individual Pfandbrief spreads. In addition to the previous studies, we consider the time-variation by investigating different market environments and explicitly account for the issuers' default risk. Moreover, we are the first to study the impact of the cover pool quality by using the publications according to § 28 Pfandbrief Act.

In a study of the European covered bond market, Packer et al. (2007) argue that the pricing of covered bonds is robust to idiosyncratic shocks to issuer credit risk and to the value of cover pools. In contrast to their study, we find that, particularly during times of financial turmoil, the issuer rating as well as the cover pool quality has a considerable impact on the yield spreads. In general, we do not aim to contribute to the literature on yield differences between covered bonds in different regulatory environments. Former studies like Packer et al. (2007) and Volk and Hillenbrand (2006) have shown that covered bond yields significantly depend on the nationality of the issuer. As a uniform covered bond regulation does not exist in Europe, it is nearly impossible to meaningfully compare and to unambiguously extract the different risk components. Therefore, we focus on the German Pfandbrief market with a uniform regulatory environment for all issues.

A large number of studies investigate liquidity and credit risk premia in the corporate bond market. These studies, like Collin-Dufresne et al. (2001), Longstaff et al. (2005), Chen et al. (2007), De Jong and Driessen (2007), and Dick-Nielsen et al. (2009), mostly study unsecured bonds that are not backed by collateral. Studies in the corporate bond market, however, suffer from a considerable heterogeneity of bond characteristics and the issuers strongly differ in terms of risk even within a rating class. Therefore, the authors have to rely on strong assumptions to disentangle liquidity and credit risk. In contrast, due to the high level of standardization and the legal requirements, it is relatively easy to isolate the different risk components within the

Pfandbrief market.

The main results of our study are the following. First, we show that liquidity is not the exclusive driver of yield spreads between Pfandbriefe and German government bonds and issuer-specific effects as well as the quality of the cover pool are also relevant. Second, yield spreads between individual Pfandbriefe are mainly driven by their relative liquidity and whether they are covered by public-sector or mortgage loans. Whereas the type of cover assets appears to be less important during the recent financial crisis, liquidity proves to have the most important effect and accounts for up to 70 bp of the yield spread. Third, our empirical results reveal that Pfandbrief investors demand an additional default risk premium between low rated and high rated issuers of 7 bp during normal market conditions and up to 40 bp during the financial crisis. Fourth, the impact of the cover pool quality appears to be quite small. During the recent financial crisis, however, maturity mismatches between Pfandbriefe and their corresponding cover pool assets, the fraction of German cover assets and the granularity of the cover pool show a significant impact on the yield spreads.

The remainder of this chapter is structured as follows. In Section 4.2, we begin by describing the institutional details of the Pfandbrief market. Section 4.3 describes the methodology of our analysis and presents the data. In Section 4.4, we provide and discuss the empirical results. Section 4.5 concludes.

4.2 Details of the Pfandbrief Market

This section reviews the most important features and the regulatory background of the German Pfandbrief market.[5] The legal basis for a Pfandbrief issuance is the Pfandbrief Act of 2005 that replaced the Public Pfandbrief Act (ÖPG) and the Mortgage Bank Act (HBG) dating back to 1900. Until 2005, Pfandbrief issuers had to be specialized banks, but nowadays every wholesale bank is allowed to apply for a Pfandbrief licence. The Pfandbrief Act, however, sets restrictive formalities such that Pfandbriefe are highly standardized and investors can easily assess their quality. Beyond the general

[5] A more detailed description of the German Pfandbrief and the European covered bond markets can be found, e.g., in Mastroeni (2001), Packer et al. (2007), and Cross (2008). Moreover, Peterson (2008) investigates the main differences between Pfandbriefe and ABS.

banking supervision under the terms of the German Banking Act (KWG), Pfandbrief issuers are permanently supervised by an independent trustee appointed by the German financial supervisory authority (BaFin). This strong regulation is set up to ensure timely payment and remoteness in the case of bankruptcy.

Pfandbriefe are *dual recourse bonds* with (i) a claim on the issuer and (ii) a priority claim on an underlying asset pool in case of a default. The cover pool is kept on the issuer's balance sheet and only separated in case of the issuer's default. The cover pool mainly consists of high-quality public-sector or first-rank residential and commercial mortgage loans.[6] Pfandbriefe backed by loans to public-sector entities are called *public Pfandbriefe* and those backed by mortgage loans are referred to as *mortgage Pfandbriefe*. It is important to note that every issuer has *only one* cover pool for *each* Pfandbrief segment. Hence, every public Pfandbrief of an issuer is backed by the same issuer-specific public cover pool and every mortgage Pfandbrief by the same issuer-specific mortgage cover pool. The Pfandbrief Act sets conservative guidelines for the quality, the size, and the valuation of the cover assets as well as to its supervision to ensure timely payments in case of an issuer's default. Moreover, Pfandbriefe are not subject to prepayment risk, and matured or defaulted loans in the cover pool have to be replaced by the issuer. The issuer also has to assure that the present value of the cover pool assets always exceeds the present value of the outstanding Pfandbriefe by at least 2%. This dynamic feature of the cover pool further ensures a sustainable high collateral value for the Pfandbrief.

Public Pfandbriefe are issued on loans to the federal government, the federal state governments, local authorities, and public-sector institutions in the European Economic Area, Switzerland, the U.S., Canada and Japan. Moreover, loans to German public agencies or public banks that are guaranteed by these bodies are eligible for the public cover pool. It is noteworthy that the withdrawn public sector guarantees for Landesbanks and for debt issued by savings banks in 2005 have led to a shrinking supply of public-sector collateral and, therefore, public Pfandbriefe.[7] *Mortgage Pfandbriefe* are covered by first rank mortgage loans fully collateralized by real estate properties

[6]Moreover, Pfandbriefe on ship and airplane loans exist, but only account for a small fraction of the Pfandbrief market.

[7]See, e.g., ECB (2008), p. 10.

in the European Economic Area, Switzerland, the U.S., Canada and Japan. The underlying properties may be residential, commercial, or both. The loan-to-value ratio of each underlying loan must not exceed 60% and is subject to permanent supervision. Compared to covered bond legislation in other countries or MBS, the maximum loan-to-value ratio required for Pfandbriefe is most conservative. For the purpose of liquidity management, maturity-matching between cover assets and outstanding Pfandbriefe, and currency hedging, it is allowed to further include specified claims against qualified banks as well as derivatives.

Pfandbrief holders have preferential claims on the cover assets in the event of an issuer's insolvency. In this case, the cover pools are separated and managed by an independent trustee ("Sachwalter") in favor of the Pfandbrief holders. The cover pools are not included in the insolvency proceedings until the Pfandbrief creditors are fully redeemed. Alternatively, another Pfandbrief issuer may take over the cover assets and serve the Pfandbrief payments in a timely manner. An early repayment of the Pfandbrief should be avoided. All these arrangements are set to ensure that Pfandbrief holders are additionally protected against insolvency caused outside the issuer's cover operations and that the Pfandbrief payments occur on time.

An important Pfandbrief segment is the market for *Jumbo Pfandbriefe*. This segment is defined by minimum standards agreed on by Pfandbrief banks. It was introduced in 1995 in order to increase the liquidity of large Pfandbrief issues. Jumbo Pfandbriefe are required to be plain-vanilla bearer bonds with fixed coupon payments, a bullet payment at maturity, and without embedded options. The minimal issue size is EUR 1 billion. Moreover, Jumbo Pfandbriefe have to be listed at an exchange, and at least five market makers have to continuously provide a price quote for a trading volume of up to EUR 15 million. In addition, the quoted bid-ask spread is not allowed to exceed a maturity-dependent boundary. These standards significantly enhance the liquidity in this segment, and Jumbo Pfandbriefe are very actively traded.[8] Smaller and less liquid issues in either bearer or registered form are commonly referred to as *traditional Pfandbriefe*.

[8]See, e.g., Winkler (2006).

4.3 Data and Methodology

4.3.1 Bond Prices and Yield Spreads

Our sample period covers the time span from January 2000 until January 2009. To gain insight into the behavior of liquidity and credit risk premia during the recent financial turmoil, we divide our sample period into three sub-sample periods. The first sub-sample period is referred to as *pre-crisis* and covers the time span prior to the subprime crisis. It ranges from January 2000 until June 2007. The second sub-sample period lasts from July 2007 until 14 September 2008 and is considered the *subprime crisis*. The third sub-sample period starts after the collapse of Lehman Brothers on 15 September 2008 and ends in January 2009. We refer to the last period as the *post-Lehman period*.

We consider all public and mortgage Pfandbriefe outstanding in our sample period with fixed coupon and without embedded options. Our total sample consists of 6,398 Pfandbriefe issued by 80 different banks. We exclude all Pfandbriefe that do not have at least one price quote during the sample period or for which the prices exceed reasonable bounds.[9] Since trading close to maturity is particularly thin and small pricing errors translate into relatively large annualized yield errors, we exclude all Pfandbriefe with less than six months to maturity. After this data preparation, we remain with 2,592 Pfandbrief issues and almost 182,000 weekly price observations.

We use weekly mid prices obtained via Bloomberg over the whole observation period. Approximately 60%–70% of the Pfandbrief market volume is traded over the phone and most of the remaining part on electronic trading platforms.[10] Due to marginal trading on stock exchanges, Bloomberg is the most reliable source available since prices are provided by at least five contributors.[11] Bloomberg prices are quoted on a three-day settlement basis, and we compute accrued interest using the respective day count fraction. We select Wednesdays as valuation days as very few holidays happen to coincide with Wednesdays. We use the price of the same week's Tuesday or Thursday

[9] We exclude price quotes below 1% and above 500% that are apparently due to data errors.
[10] See, e.g., Winkler (2006), p. 25.
[11] The prices are indicative and do not represent actual transactions. However, we cross-check our results with data provided by Morgan Stanley and did not find meaningful differences.

if a Wednesday price is not available. In this case, we adjust the calculation of accrued interest.

Table 4.1 presents the summary information of the data set. Panel A shows that traditional Pfandbriefe account for the major part of the number of issues in the German Pfandbrief market. However, we have access to price data of only 35% of these issues in contrast to 90% of the Jumbo issues. Moreover, Jumbo and traditional Pfandbrief issues differ considerably in terms of their outstanding amount which is approximately 10 times higher for Jumbos, and the Jumbos in our sample appear to have a slightly longer time to maturity on average. Due to the higher liquidity in the Jumbo segment, it is not surprising that the number of weekly bond price observations for Jumbos exceeds the number for traditional Pfandbriefe. This discrepancy is even more pronounced during the financial crisis. Moreover, it is important to note that nearly all Jumbo and approximately 90% of all traditional Pfandbrief price observations used in our study are on Wednesdays.

Panel B of Table 4.1 shows the distribution of the Pfandbrief issues with respect to the issuer rating classes. Pfandbrief issues are grouped into the classes according to their issuers' long-term credit rating. We calculate this rating as the average rating from the three major rating agencies Fitch, Moody's and Standard & Poor's. Pfandbrief issuers are mainly rated AA and A and the rating classes are similarly distributed in each of the Pfandbrief segments. As no issuer is rated AAA during the financial crisis periods and the number of issuers rated BB is rather small, we consider only the three different rating segments AAA/AA, A, and BBB/BB for our empirical study.

We compute individual yield spreads for every Pfandbrief on a weekly basis relative to (i) German government bonds (Bunds) and (ii) public Jumbo Pfandbriefe. We choose Bunds as the natural risk-free benchmark and public Jumbo Pfandbriefe as they are considered the safest and most liquid instruments in the Pfandbrief market. This approach facilitates identifying risk premia *within* the Pfandbrief market that are not driven by factors that affect the Pfandbrief market as a whole. For yield spreads relative to Bunds, we use Nelson and Siegel (1987) term structure estimates provided by the Deutsche Bundesbank. For public-sector Jumbo Pfandbriefe, we estimate the Nelson-Siegel parameters on a weekly basis by minimizing the squared

Table 4.1: Summary Information of the Pfandbrief Data Set (Weekly Data)

This table shows the summary information for the Pfandbriefe considered in our study. Panel A breaks down the statistics by the Pfandbrief segment, Panel B by the average long-term issuer credit rating by Fitch, Moody's, and Standard & Poor's. A single issue is unambiguously assigned to a Pfandbrief segment and may be allocated repeatedly for a specific issuer rating due to rating changes. The data on the outstanding amount is averaged across the different issues from the same segment, the data on the time to maturity across the different issues from the same segment and then across time. The number of weekly observations is the number of available bond prices for the respective issues during the three sub-periods and the whole sample period from January 2000 to January 2009. The three sub-periods range from January 2000 to June 2007 (pre-crisis), from July 2007 to September 2008 (subprime crisis) and from September 2008 to January 2009 (post-Lehman).

Panel A: Pfandbrief Segment

Pfandbrief Segment	# Issues	# Issues with Price Availability	Outstanding Amount (EUR million)	Time to Maturity (years)			# Weekly Observations (Bond Prices)				Prices occurring on Wednesdays
				pre-crisis	subprime crisis	post-Lehman	pre-crisis	subprime crisis	post-Lehman	all	
Public Jumbo	464	420	1,467	3.16	2.76	2.89	72,546	7,996	2,098	82,640	99.6%
Mortgage Jumbo	96	84	1,514	4.20	3.29	3.33	13,932	2,862	806	17,600	99.7%
Public Traditional	3,617	1,357	165	2.92	1.81	1.90	40,725	6,992	1,329	49,046	89.2%
Mortgage Trad.	2,221	731	125	2.77	2.25	2.26	29,663	2,527	511	32,701	91.1%
Overall	6,398	2,592	409	2.96	2.21	2.39	156,866	20,377	4,744	181,987	95.3%

Panel B: Issuer Rating

Issuer Rating	# Issues with Price Availability					# Weekly Observations (Bond Prices)			
	Public Jumbo	Mortgage Jumbo	Public Traditional	Mortgage Traditional	all	pre-crisis	subprime crisis	post-Lehman	all
AAA	53	1	567	131	752	11,660	0	0	11,660
AA	261	44	1,158	505	1,968	65,653	7,585	1,822	75,060
A	329	78	541	435	1,383	60,334	11,600	2,711	74,645
BBB	90	20	81	91	282	10,002	299	184	10,485
BB	31	12	36	19	98	839	650	0	1,489
No Rating	90	9	173	81	353	8,378	243	27	8,648

differences between estimated and observed yields.[12] The mean absolute yield error of the estimation is 3.67 bp on average.

To avoid distortions due to maturity, coupon, or taxation effects as in the case of simply comparing yields-to-maturity of duration-matched bonds, we define the yield spread of an individual Pfandbrief as follows: First, we calculate a theoretical bond price as the bond's cash flows discounted with the benchmark yield curve. Second, given the theoretical and the actual bond price, we compute the theoretical and the observed yield-to-maturity. The yield spread is the difference between the actually observed and the theoretical yield.

4.3.2 Explanatory Variables

We relate the obtained yield spreads to the following explanatory variables that capture the different risk factors within the Pfandbrief market. These factors should, at least partially, account for the yield differences between particular issues.

It is an advantage of the Pfandbrief market that different risk components are relatively easy to identify by just comparing the different market segments. First, we compare the yield spread between mortgage and public Jumbo Pfandbriefe by introducing a mortgage Jumbo dummy variable. Usually, at least before the advent of the Greek sovereign debt crisis, Pfandbriefe backed by mortgages are considered to be more risky than Pfandbriefe backed by high-quality public-sector debt. Therefore, we expect mortgage Jumbo Pfandbriefe to trade at a credit risk yield premium compared to public Jumbo Pfandbriefe. Second, we introduce a dummy for a public traditional Pfandbrief. By definition, Jumbo Pfandbriefe are more liquid in terms of outstanding volume, a maximal bid-ask spread, and the vested market-making, among others. Hence, public traditional Pfandbriefe should trade at a liquidity yield premium compared to public Jumbo Pfandbriefe. Third, a dummy for traditional mortgage Pfandbriefe measures the joint effect of liquidity and credit risk. For the sovereign bond market, Favero et al. (2010) find yield differences increasing in both liquidity and credit risk with an interaction term of the opposite sign. Moreover, Bühler and Trapp (2010)

[12] This approach is consistent with the methodology of Deutsche Bundesbank. See, e.g., Schich (1997), p. 18.

find a negative correlation between liquidity and credit risk for high quality AAA rated corporate bonds.[13] As the Pfandbrief market is comparable to the European sovereign bond market and to high quality corporate bonds in terms of liquidity and credit risk, it is reasonable to expect a similar result, i.e. a yield premium that is positive, but smaller than the sum of the pure liquidity and the pure credit risk premium.

It is straightforward to classify the different Pfandbrief issues with respect to their Pfandbrief rating. The Pfandbrief rating mainly measures the quality of the underlying cover pool. For a high Pfandbrief rating, it has to be highly plausible that the Pfandbrief payments can be made by the underlying cover pool even if the issuer defaults. At the outset, Pfandbrief ratings were independent from the general financial strength of the issuer, but nowadays rating agencies also consider the issuer rating to compute a limit for the highest possible Pfandbrief rating.[14] As Pfandbriefe are backed by the cover pool, however, their rating exceeds or is at least equal to the issuer's long term credit rating.

We use data on the issuance rating published by Bloomberg. This data, however, should be used with care as the fraction of several rating classes changes significantly over time. At the beginning of our sample period, 80% of all price observations are from Pfandbriefe that are not rated. This number declines to approximately 45% until the end of 2004, presumably driven by rating requirements from investors. Starting with the advent of the subprime crisis, this fraction steadily declines below 1%. This sharp decline provides evidence that Pfandbriefe without rating are scarcely traded during the recent financial turmoil. Moreover, conversation with Pfandbrief issuers suggest that in recent years it has become hardly possible to place a Pfandbrief without rating due to the investors' requirements. Vice versa, the fraction of AAA-rated Pfandbrief observations increase from 20% to 88% during our sample period and the fraction of AA-rated Pfandbrief observations from 0% to 11%.

Even though Pfandbriefe are backed by high-quality cover pools that may serve the Pfandbrief payments after an issuer's default, the issuer rating may also have an impact on their relative pricing. For our study, we use the long-term issuer credit

[13]For lower rated bonds, however, they find a positive correlation.

[14]Standard & Poor's were the last to consider the issuer's rating when they changed their rating methodology at the end of 2009.

rating from the three major rating agencies Fitch, Moody's and Standard & Poor's and calculate an average rating. The issuer rating serves as a measure for the issuer's default risk, and its impact on the yield spread can be interpreted either as credit risk premium or as liquidity premium, or both. The credit risk view considers that the cover pool may not be sufficient to serve the Pfandbrief payments after the issuer's default. Then, a direct loss on the Pfandbrief may occur. The liquidity view deems the cover pool to be valuable enough to serve the payments but anticipates a collapse in trading the defaulted issuer's Pfandbriefe. Since both risks are serious for investors and should affect the yield spread in the same direction, it is difficult to isolate the particular premia. In general, however, a better long-term issuer credit rating should lead to a lower yield spread.[15]

Pfandbrief issuers also differ by the type of institution. Pfandbriefe issued by Landesbanks until 18 July 2005 are guaranteed by the German federal states through a so-called guarantor liability ("Gewährträgerhaftung") mechanism.[16] Due to this guarantee, we expect Landesbanks' Pfandbriefe that are issued until 18 July 2005 trading at a yield discount relative to comparable Pfandbriefe of other issuers. After its discontinuation, the yield spreads should rise considerably. Moreover, we investigate whether Landesbank Pfandbriefe trade at significant discounts or premia during the recent financial turmoil.

Typical proxies for the liquidity of a fixed income security are trading activity, the bid-ask spread, the proportion of zero-return days, the outstanding amount, and the age. For this study, only the last two proxies are available. A higher outstanding amount signals a higher liquidity and, therefore, should lead to a lower yield spread. Moreover, trading directly after the issuance date is usually more active and diminishes as the security ages. Therefore, the liquidity premium and, thus, the yield spread should be positively related to the Pfandbrief's age. To account for differences in the maturity spectrum of the Pfandbriefe, we standardize the liquidity measure and use the relative age, i.e. the age divided by the initial time to maturity.

[15]Instead of only using the rating categories, the use of the Pfandbrief issuers' CDS spreads would be a meaningful alternative. Unfortunately, CDS spreads are not available for most of the issuers.

[16]Due to a Grandfather clause, Pfandbriefe issued after 19 July 2001 are guaranteed if they do not mature after 31 December 2015.

For our study we also consider fixed effects for the single Pfandbrief issuers. Thereby, we take idiosyncratic effects like the financial disorder of Allgemeine Hypothekenbank Rheinboden (AHBR) in 2001–2005 and the tremendous problems of DEPFA and Hypo Real Estate during the recent financial turmoil into account. We will address these particular effects when presenting our empirical results.

4.3.3 Cover Pool Information According to § 28 Pfandbrief Act

For an in-depth yield spread analysis, we further obtain information on the particular cover pools. Since the Pfandbrief Act came into effect on 19 July 2005, issuers are required to publish details of their cover pool composition to enhance the transparency of the Pfandbrief market. These publications according to § 28 Pfandbrief Act are compulsory for all issuers starting on 31 December 2005 and are released on a quarterly basis as of 31 March, 30 June, 30 September, and 31 December. The reports are usually published on the issuer's website within six weeks after the reporting date.[17]

The transparency report of an issuer basically contains the following information on the public-sector cover pool and all outstanding public Pfandbriefe as well as on the mortgage cover pool and all outstanding mortgage Pfandbriefe:[18]

– Notional Pfandbrief volume outstanding, the corresponding cover pool values, and the amount of overcollateralization

– Present value[19] of outstanding Pfandbriefe, the corresponding cover pool present values, and the amount of overcollateralization

– Maturity profile of outstanding Pfandbriefe and cover loans

– Categorization of mortgage cover pool by cover loan size

– Breakdown of public cover pool by borrower's place of residence

[17] Recently, the Association of German Pfandbrief Banks has started a transparency initiative and publishes the reports of all their members in a uniform format on their website. This data, however, only dates back to the fourth quarter 2009.

[18] Additional cover pool assets and derivatives as well as the cover loans being overdue for at least 90 days are also reported. These values, however, usually account for a negligible fraction of the cover pool and, therefore, are not considered in our study.

[19] In this context, the "present value" is defined according to the Pfandbrief-Barwertverordnung (PfandBarwertV) as the sum of future cash flows discounted by using customary yield curves.

– Breakdown of mortgage cover pool by real property location and property type financed

We collect these data for 40 Pfandbrief issuers from their website or their investor relations department for the time span from December 2005 to December 2008.[20] These dates are determined by the first compulsory report and the last report within our sample period, respectively. Table 4.2 presents the summary information for the cover pool information. The results show that cover pools differ considerably between different issuers. For public Pfandbriefe, for example, the cover pool's notional values range between EUR 60 million and EUR 91,383 million. For mortgage Pfandbriefe, the range lies between EUR 75 million and EUR 54,237 million. On average, approximately 3/4 of the total cover pool consists of public-sector loans. This number slightly declines over time.

Most of the outstanding Pfandbriefe and cover pool loans have a maturity of 1 to 5 years with slight differences between the issuers. For public Pfandbriefe, a large fraction of the pool consists of German cover pool assets. For mortgage Pfandbriefe, the majority is also backed by German cover loans. Whereas a considerable amount of commercial mortgages in the cover pools is from abroad, there is only a small amount of foreign residential mortgages. However, there is a great variety between issuers since issuers without any German cover pool asset as well as issuers without any foreign cover pool asset exist.

Recognizing the differences between the cover pools, we define the following explanatory variables to capture the different types of risk within the cover pools. These variables are calculated for every Pfandbrief issuer on a quarterly basis.

– Overcollateralization: $OC = \frac{\text{Cover pool value} - \text{Outstanding amount Pfandbriefe}}{\text{Outstanding amount Pfandbriefe}}$

– Term transformation: $TRANS =$

  Average maturity of pool assets – Average maturity of outstanding Pfandbriefe

– Percentage of Pfandbriefe due the following year:

  $PB_{DUE} = \frac{\text{Amount of Pfandbriefe due next year}}{\text{Outstanding amount Pfandbriefe}}$

[20] Due to mergers and acquisitions within the last years, the number of Pfandbrief banks in our sample dropped to 46. Six issuers with in total only 27 outstanding Pfandbriefe do not report according to the current Pfandbrief Act.

Table 4.2: Summary Statistics of the Cover Pool Information according to § 28 Pfandbrief Act

This table reports the summary statistics of the cover pool information according to § 28 Pfandbrief Act. Panel A shows the data for public Pfandbriefe, Panel B for mortgage Pfandbriefe. The numbers are calculated from quarterly observations for 40 Pfandbrief issuers given in EUR million. Due to missing outstanding Pfandbriefe in a specific segment and acquisitions of Pfandbrief issuers, we remain with 453 observations for public Pfandbriefe and 398 observations for mortgage Pfandbriefe. The total sample consists of quarterly observations from 13 quarters as of December 2005 to December 2008. The overall statistics is based on the average aggregate number for all issuers published by the Association of German Pfandbrief Banks (vdp) over the 13 quarters of the sample period.

Panel A: Public Pfandbriefe

Variable	Mean	Std. Dev.	Min.	25% Perc.	Median	75% Perc.	Max.	Overall
Notional value cover pool	19,844	21,248	60	3,193	13,077	26,499	91,383	692,004
Notional value outstanding Pfandbriefe	17,928	19,592	23	2,689	11,529	25,262	87,781	625,080
Present value cover pool	20,445	21,971	56	3,216	13,616	26,353	97,382	712,928
Present value outstanding Pfandbriefe	18,216	19,942	23	2,771	11,893	24,983	88,902	635,050
Cover loans with maturity up to 1 year	4,393	5,732	0	426	2,533	5,163	37,377	153,189
Cover loans with maturity > 1 year up to 5 years	7,416	8,376	0	1,061	5,278	9,475	40,150	258,551
Cover loans with maturity > 5 years up to 10 years	5,672	6,792	0	1,235	3,044	6,825	34,105	197,569
Cover loans with maturity > 10 years	2,364	3,293	0	224	1,139	2,782	16,708	81,671
Outstanding Pfandbriefe with maturity up to 1 year	3,413	4,184	0	435	2,232	4,311	24,046	118,811
Outstanding Pfandbriefe with maturity > 1 year up to 5 years	8,919	10,537	0	1,204	6,288	10,528	45,866	311,401
Outstanding Pfandbriefe with maturity > 5 years up to 10 years	3,501	4,180	0	444	2,011	4,878	24,220	121,542
Outstanding Pfandbriefe with maturity > 10 years	2,095	2,775	0	144	1,206	2,849	13,191	72,784
German cover pool assets	16,150	17,884	60	2,885	10,870	20,792	87,158	556,932
Foreign cover pool assets	3,587	6,088	0	274	1,105	4,181	30,875	113,278

Table 4.2 continued.

Panel B: Mortgage Pfandbriefe

Variable	Mean	Std. Dev.	Min.	25% Perc.	Median	75% Perc.	Max.	Overall
Notional value cover pool	7,619	11,518	75	839	4,509	7,362	54,237	234,364
Notional value outstanding Pfandbriefe	6,567	10,261	3	576	3,970	6,435	48,165	202,058
Present value cover pool	7,915	12,028	76	864	4,621	7,585	58,110	243,416
Present value outstanding Pfandbriefe	6,695	10,549	3	570	4,044	6,406	51,496	205,909
Cover loans with maturity up to 1 year	2,028	3,897	0	112	543	1,778	22,806	62,154
Cover loans with maturity > 1 year up to 5 years	2,985	4,984	7	261	1,632	2,713	28,096	91,984
Cover loans with maturity > 5 years up to 10 years	2,207	2,671	34	318	1,382	2,815	12,624	67,993
Cover loans with maturity > 10 years	396	516	0	34	154	632	1,993	12,062
Outstanding Pfandbriefe with maturity up to 1 year	1,183	2,053	0	22	355	1,305	12,670	36,509
Outstanding Pfandbriefe with maturity > 1 year up to 5 years	3,425	5,580	0	273	1,530	3,559	30,469	105,228
Outstanding Pfandbriefe with maturity > 5 years up to 10 years	1,623	2,642	0	71	782	1,742	16,585	50,082
Outstanding Pfandbriefe with maturity > 10 years	335	564	0	0	116	381	2,765	10,414
Cover loan amount up to EUR 300.000	3,116	5,968	0	87	745	3,229	32,584	95,643
Cover loan amount > EUR 300.000 up to EUR 5 mln	1,758	2,944	0	163	758	1,591	14,055	54,009
Cover loan amount > EUR 5 mln	2,315	3,637	0	190	1,156	3,042	23,562	71,271
German cover pool assets (residential)	4,172	7,238	0	240	1,529	3,735	39,147	131,422
German cover pool assets (commercial)	2,148	3,248	0	345	746	2,392	15,345	62,798
Foreign cover pool assets (residential)	44	132	0	0	0	19	908	1,578
Foreign cover pool assets (commercial)	778	1,876	0	0	22	472	11,514	24,186

- Percentage of cover loans due the following year:
  $CL_{DUE} = \frac{\text{Amount of cover loans due next year}}{\text{Total amount cover loans}}$
- Percentage of German cover pool assets: $GERM = \frac{\text{Amount of German cover pool assets}}{\text{Total amount cover pool assets}}$
- Percentage of small cover loans: $SMALL = \frac{\text{Amount of cover loans} \leq \text{EUR 300.000}}{\text{Total amount cover loans}}$
- Percentage of large cover loans: $LARGE = \frac{\text{Amount of cover loans} > \text{EUR 5 million}}{\text{Total amount cover loans}}$
- Percentage of residential cover loans: $RES = \frac{\text{Amount of residential cover loans}}{\text{Total amount cover loans}}$
- Percentage of commercial cover loans: $COM = \frac{\text{Amount of commercial over loans}}{\text{Total amount cover loans}}$

Table 4.3 shows the summary statistics of these variables. Overcollateralization (OC) can be measured on a notional or present value basis. The median OC amounts to 9.8% for public and 17.8% for mortgage Pfandbriefe on a notional basis and is slightly higher in terms of present value. § 4 Pfandbrief Act requires the OC to be a least 2% on a present value basis and, therefore, the minimum is always above this value. The extreme maximum values are for WestLB that had already built a large cover pool when it started to issue the first public-sector Pfandbriefe under the new Pfandbrief Act, and for SachsenLB with many cover loans, but hardly any mortgage Pfandbrief outstanding shortly before taken over by LBBW. Maintaining the OC on a higher level than the minimum level is often required by rating agencies for assigning a specific Pfandbrief rating. In particular, this requirement is made for mortgage Pfandbriefe, leading to a higher OC on average. In general, however, a higher amount of OC shows a relatively higher amount of assets to guarantee for the outstanding Pfandbrief payments for both, public and mortgage Pfandbriefe. Therefore, we expect the yield spread to be negatively related to OC.

The term transformation ($TRANS$) measures the volume-weighted average maturity of cover pool assets versus outstanding Pfandbriefe. If $TRANS$ is zero, the average maturities coincide. A higher $TRANS$ signals a shorter average maturity of the outstanding Pfandbriefe, a smaller one signals a shorter average maturity of the cover pool. On average, $TRANS$ is slightly below 1/2 year, i.e. the average cover pool maturity is 1/2 year longer than the average maturity of the outstanding Pfandbriefe. However, there may be large maturity mismatches since $TRANS$ ranges between -6

Table 4.3: Summary Statistics of Cover Pool Explanatory Variables

This table reports the summary statistics of the cover pool explanatory variables. Panel A shows the data for public Pfandbriefe, Panel B for mortgage Pfandbriefe. The numbers are calculated from quarterly observations for 40 Pfandbrief issuers. Due to issuers with outstanding Pfandbriefe in only one segment and due to acquisitions of Pfandbrief issuers, we remain with 453 observations for public Pfandbriefe and 398 observations for mortgage Pfandbriefe. The total sample consists of quarterly observations from 13 quarters as of December 2005 to December 2008.

Panel A: Public Pfandbriefe

Variable	Mean	Std. Dev.	Minimum	25% Perc.	Median	75% Perc.	Maximum
Overcollateralization (notional)	0.2749	0.6241	0.0112	0.0506	0.0976	0.2112	8.1304
Overcollateralization (present value)	0.3453	1.0572	0.0268	0.0731	0.1128	0.2235	14.2730
Average term transformation (years)	0.4323	1.4232	-5.0120	-0.3611	0.4758	1.1438	6.0225
Percentage of Pfandbriefe due the following year	0.1824	0.1290	0.0000	0.1081	0.1820	0.2438	0.9374
Percentage of cover loans due the following year	0.2039	0.1437	0.0000	0.0975	0.1682	0.3117	0.8317
Percentage German cover pool assets	0.8557	0.1353	0.3058	0.7888	0.8851	0.9633	1.0000

Panel B: Mortgage Pfandbriefe

Variable	Mean	Std. Dev.	Minimum	25% Perc.	Median	75% Perc.	Maximum
Overcollateralization (notional)	1.4932	6.1683	0.0228	0.0895	0.1776	0.6506	61.4230
Overcollateralization (present value)	1.4654	5.7029	0.0406	0.1144	0.2035	0.7024	56.4230
Average term transformation (years)	0.4690	1.7885	-6.1132	-0.7951	0.3536	1.5977	5.6263
Percentage of Pfandbriefe due the following year	0.1590	0.1620	0.0000	0.0485	0.1335	0.2145	1.0000
Percentage of cover loans due the following year	0.2082	0.1413	0.0000	0.1080	0.1645	0.2774	0.7331
Percentage of German cover pool assets	0.8943	0.2008	0.0849	0.8944	0.9797	1.0000	1.0000
Percentage of small cover loans	0.3322	0.3025	0.0000	0.0503	0.2449	0.5979	0.9951
Percentage of large cover loans	0.4051	0.2980	0.0000	0.1125	0.3866	0.6290	1.0000
Percentage of residential cover loans	0.4930	0.2856	0.0000	0.2315	0.5013	0.7558	1.0000
Percentage of commercial cover loans	0.5070	0.2856	0.0000	0.2442	0.4987	0.7685	1.0000

and 6 years. In general, a maturity mismatch may cause several problems. First, the cover pool and the outstanding Pfandbriefe may react differently to interest rate changes. Second, a shorter maturity of the outstanding Pfandbriefe may lead to the need of refinancing for the issuer. In particular, this is important when markets dry up and refinancing is difficult. Third, a shorter maturity of the cover pool may force the issuer to provide additional cover assets. Therefore, a higher $TRANS$ as well as a lower $TRANS$ may signal higher risks for the Pfandbrief holder and we expect a positive relation between the yield spread and $|TRANS|$.

The interpretation of the next two variables, the percentage of Pfandbriefe and cover loans due the following year (PB_{DUE} and CL_{DUE}), is quite similar. A higher PB_{DUE} may signal the need of short-term refinancing, a higher CL_{DUE} the necessity to provide additional cover assets. Hence, we expect both variables to be positively related to the yield spread. Table 4.3 shows meaningful differences between the issuers. On average, PB_{DUE} and CL_{DUE} amount to 15% to 20%, but may also be 0% or almost 100%. These variables, however, have to be used with care since maturity mismatches can also be compensated by the use of derivatives or other bank assets and liabilities.

Pfandbriefe are mainly backed by German cover assets with median values of 89% for public and 98% for mortgage Pfandbriefe. However, the percentage of German cover assets ($GERM$) varies substantially between 8.5% and 100%. This variable can have two opposite effects. On the one hand, $GERM$ signals lower diversification and, therefore, higher residual risk, which should lead to a higher risk premium. On the other hand, German public-sector debt is considered relatively safe compared to other European countries, and the German real estate market has shown less volatile and less overvalued than real estate markets of other countries.[21] Therefore, German cover assets can be regarded as less risky leading to a lower yield spread. The empirical analysis will provide evidence whether one of these effects is prevalent or whether the impact even depends on the considered sample period.

$SMALL$ and $LARGE$ show the percentage of mortgage cover loan amounts below EUR 300,000 and above EUR 5 million, respectively. Their values range between 0%

[21] For the last ten years, the IPD Total Return Property Index for Germany shows a substantially lower annualized volatility of below 1% compared to values above 2% for most other countries (up to 5% for the United States).

and 100%. A higher value of *SMALL* means that the cover pool is more granular and hence, ceteris paribus, less risky. Therefore, we expect the yield spread being negatively related to *SMALL*. Vice versa, we predict a positive relation for *LARGE* as a measure for low diversification.

On average, Pfandbrief issuers finance residential and commercial mortgages in equal shares. However, there are large differences between issuers, ranging from complete residential financing to complete commercial financing. Since commercial financing is usually more risky and shows a higher dependence on the business cycle, a high fraction of commercial mortgages (*COM*) – or, equivalently, a low fraction of residential mortgages (*RES*) – should lead to a risk premium for the corresponding Pfandbriefe. Moreover, it is important to note that the variables *RES* and *COM* are closely related to *SMALL* and *LARGE* as residential mortgages are typically smaller and commercial mortgages often exceed EUR 5 million. Therefore, is is not surprising that the variables are positively correlated, with $\rho(SMALL, RES) = 0.93$ and $\rho(LARGE, COM) = 0.89$. To avoid the problem of multicollinearity, we do not simultaneously include them into a regression.

We compute the quarterly yield spreads for each Pfandbrief as the average of the weekly yield spreads during the six weeks following the record date. This period is the usual time by which nearly all issuers have published their reports. The calculation of the average yield spread during this period is considered as a trade-off between using the yield spread precisely at the record date or using the yield spread after six weeks when the information is actually available to all market participants. As the cover pool composition for a single issuer remains relatively constant over time, this assumption is not likely to distort our results. After the quarterly calculation, we remain with 972 outstanding Pfandbriefe with available price data and 4,678 quarterly yield spreads for the time span from December 2005 to December 2008. Table 4.4 presents the summary information for the quarterly data. The number of available issues drops due to the modification of the time period. The composition of the data set in terms of Pfandbrief segments and rating classes, however, does not change notably.

Table 4.4: Summary Information of the Pfandbrief Data Set (Quarterly Data)

This table shows the summary information for the Pfandbriefe considered in our study. Panel A breaks down the statistics by the Pfandbrief segment, Panel B by the average long-term issuer credit rating by Fitch, Moody's, and Standard & Poor's. A single issue is unambiguously assigned to a Pfandbrief segment and may allocated repeatedly for a specific issuer rating due to rating changes. The data on the outstanding amount is averaged across the different issues from the same segment, the data on the time to maturity across the different issues from the same segment and across time. The number of quarterly observations is the number of bond prices of the respective issues during the three sub-periods and the whole sample period from January 2006 to January 2009. The three sub-periods range from January 2006 to June 2007 (pre-crisis), from July 2007 to September 2008 (subprime crisis) and from September 2008 to January 2009 (post-Lehman).

Panel A: Pfandbrief Segment

Pfandbrief Segment	# Issues with Price Availability	Outstanding Amount (EUR million)	Time to Maturity (years)			# Weekly Observations (Bond Prices)			
			pre-crisis	subprime crisis	post-Lehman	pre-crisis	subprime crisis	post-Lehman	all
Public Jumbo Pfandbrief	194	1,440	3.01	2.72	2.86	822	630	210	1,662
Mortgage Jumbo Pfandbrief	57	1,523	3.93	3.40	3.37	261	207	78	546
Public traditional Pfandbrief	526	165	1.79	1.18	0.88	737	761	239	1,737
Mortgage traditional Pfandbrief	195	125	2.03	1.79	0.98	380	255	98	733
Overall	972	396	2.33	1.79	1.73	2,200	1,853	625	4,678

Panel B: Issuer Rating

Issuer Rating	# Issues with Price Availability					# Weekly Observations (Bond Prices)			
	Public Jumbo	Mortgage Jumbo	Public Traditional	Mortgage Traditional	all	pre-crisis	subprime crisis	post-Lehman	all
AAA	17	0	79	53	149	20	0	0	20
AA	127	8	913	276	1,324	672	759	267	1,698
A	298	67	526	424	1,315	1,288	1,028	339	2,655
BBB	87	15	102	99	303	153	31	15	199
BB	28	7	36	19	90	40	20	0	60
No Rating	9	1	7	14	31	27	15	4	46

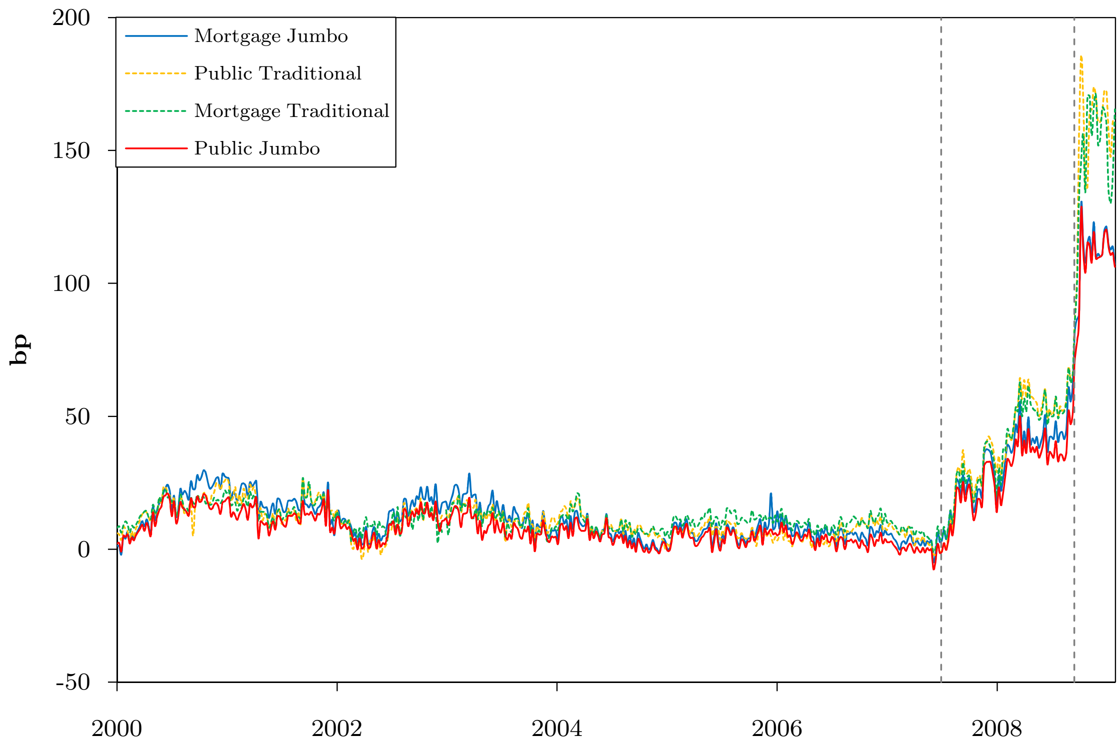

Figure 4.1: Pfandbrief Yield Spreads relative to German Bunds

This figure shows the average yield spreads of the four Pfandbrief segments relative to the term structure of German Bunds in basis points. The average yield spreads are calculated on a weekly basis for the time period from January 2000 until January 2009.

4.4 Empirical Results

4.4.1 Descriptive Statistics

We first investigate the yield spreads of the different Pfandbrief segments relative to Bunds. Figure 4.1 shows the average yield spreads of the four segments on a weekly basis. The vertical lines mark the beginning of the subprime crisis period, and the post-Lehman period, respectively. In the pre-crisis period until June 2007, the average Pfandbrief spread for all segments relative to Bunds is approximately 10 bp with a maximum of up to 30 bp. Surprisingly, also periods with average Pfandbrief spreads below zero exist, showing that Pfandbriefe sometimes even trade at a small yield discount relative to Bunds. This result signals the very high quality of Pfandbriefe perceived by investors.

With the advent of the subprime crisis the picture completely changes. Starting in July 2007, the average yield spreads steadily rise to approximately 50 bp until

Figure 4.2: Pfandbrief Yield Spreads relative to public Jumbo Pfandbriefe
This figure shows the average yield spreads of three Pfandbrief segments relative to the term structure of public Jumbo Pfandbriefe in basis points. The average yield spreads are calculated on a weekly basis for the time period from January 2000 until January 2009.

September 2008. Furthermore, after the collapse of Lehman Brothers, the spreads drastically increase to approximately 120 bp for Jumbo Pfandbriefe and 150 bp for traditional Pfandbriefe. These spreads signal the high risk premia demanded by investors during the recent financial turmoil and suggest that, at least during financial crises, Pfandbriefe cannot be regarded as close substitutes for Bunds in terms of risk. Moreover, this figure clearly supports the partitioning of our sample in a pre-crisis period and separate periods for the subprime and the post-Lehman financial crisis.

Comparing the Pfandbrief spreads with respect to Bunds, however, does not allow to disentangle the different risk premia contained in the Pfandbrief market. Hence, it is still questionable whether the strong increase in yield spreads is mainly driven by liquidity or credit risk. For an in-depth analysis, we therefore compute the yield spreads relative to public Jumbo Pfandbriefe. This approach enables us to better isolate the individual risk premia by comparing Pfandbriefe that only differ in one dimension. Figure 4.2 shows the average yield spreads of the remaining three Pfandbrief segments on a weekly basis and striking yield differences *within* the Pfandbrief market become visible.

Similar to the yield spreads relative to Bunds, this figure also shows a different behavior during the pre-crisis period, the subprime crisis, and the post-Lehman period. In the pre-crisis period, the three average segment yield spreads mostly vary between −5 bp and 10 bp. Whereas mortgage Jumbo Pfandbriefe trade relatively stable at a yield spread of 2 bp on average, traditional Pfandbrief yield spreads are more volatile and trade at a premium of 3–5 bp on average. With the beginning of the subprime crisis, the average yield spreads increase to 10 bp for mortgage Jumbo Pfandbriefe and 20 bp for traditional Pfandbriefe, rising up to 50 bp after the collapse of Lehman Brothers.

For a detailed analysis, Table 4.5 shows the descriptive statistics of the individual yield spreads relative to the average public Jumbo Pfandbrief yield curve for the total sample and the different subperiods. In general, mortgage Jumbo Pfandbriefe trade at a small premium and traditional Pfandbriefe at a larger premium relative to public Jumbo Pfandbriefe. Hence, Pfandbriefe backed by mortgages seem to be considered as more risky than those covered by public-sector loans. Moreover, the lower liquidity of traditional Pfandbriefe is priced with 4–6 bp on average relative to Jumbo Pfandbriefe. During the crisis subperiods the average yield spreads significantly increase up to 38 bp for public traditional Pfandbriefe. Even though a rise in the credit risk premium for mortgage Jumbo Pfandbriefe can be observed, the effect on the liquidity premia for traditional Pfandbriefe is substantially larger.

Within a specific Pfandbrief segment, however, the yield spreads also vary considerably. During the pre-crisis and the subprime crisis period traditional Pfandbrief spreads are much more volatile with an increasing volatility during the latter period. In the post-Lehman period, yield spreads highly fluctuate within all Pfandbrief segments. Even for public Jumbo Pfandbriefe the yield spreads vary between −48 bp and 192 bp. This observation shows that it is not sufficient to partition the Pfandbrief market into the four segments to entirely explain the varying yield spreads. Hence, further risk factors should be considered.

In summary, the results clearly show that the Pfandbrief market cannot be regarded as homogenous and considerable differences between the Pfandbriefe segments

Table 4.5: Descriptive Statistics for Pfandbrief Yield Spreads (Weekly Data)

This table shows the summary statistics for the Pfandbrief yield spreads relative to the term structure of public Jumbo Pfandbriefe in basis points. The statistics are based on the equally weighted yield spread observations in the respective Pfandbrief segment and time period (winsorized at the 0.5th and 99.5th percentiles). N is the number of weekly observations. The sample period ranges from January 2000 to January 2009 (Panel A) and is partitioned into the pre-crisis period (January 2000 to June 2007, Panel B), the period of the subprime crisis (July 2007 to September 2008, Panel C), and the post-Lehman period (September 2008 to January 2009, Panel D).

Panel A: Total Sample

Pfandbrief Segment	Mean	Std. Dev.	Min.	Median	Max.	% > 0	N
Public Jumbo Pfandbrief	0.0	7.2	-48.3	-0.2	191.5	46.3%	82,640
Mortgage Jumbo Pfandbrief	2.6	8.5	-41.3	1.3	120.6	68.6%	17,600
Public Traditional Pfandbrief	5.5	13.9	-61.9	5.4	187.5	77.0%	49,046
Mortgage Traditional Pfandbrief	6.3	11.3	-36.2	6.1	195.9	81.9%	32,701

Panel B: Pre-Crisis Period

Pfandbrief Segment	Mean	Std. Dev.	Min.	Median	Max.	% > 0	N
Public Jumbo Pfandbrief	0.0	3.5	-9.4	-0.2	15.0	46.9%	72,546
Mortgage Jumbo Pfandbrief	2.1	4.5	-7.6	1.2	21.4	68.3%	13,932
Public Traditional Pfandbrief	2.9	9.9	-61.9	4.6	31.9	74.6%	40,725
Mortgage Traditional Pfandbrief	5.4	9.4	-33.1	5.9	63.0	81.7%	29,663

Panel C: Subprime Crisis

Pfandbrief Segment	Mean	Std. Dev.	Min.	Median	Max.	% > 0	N
Public Jumbo Pfandbrief	0.0	4.9	-12.3	-0.4	22.4	45.6%	7,996
Mortgage Jumbo Pfandbrief	4.0	5.8	-7.0	2.7	22.6	77.1%	2,862
Public Traditional Pfandbrief	14.4	13.1	-30.0	14.0	48.1	89.9%	6,992
Mortgage Traditional Pfandbrief	11.6	13.8	-27.7	11.2	52.4	84.7%	2,527

Panel D: Post-Lehman Period

Pfandbrief Segment	Mean	Std. Dev.	Min.	Median	Max.	% > 0	N
Public Jumbo Pfandbrief	-0.1	39.4	-48.3	-11.0	191.5	27.4%	2,098
Mortgage Jumbo Pfandbrief	5.8	32.6	-41.3	-2.7	120.6	43.1%	806
Public Traditional Pfandbrief	38.2	39.4	-42.7	41.8	187.5	82.8%	1,329
Mortgage Traditional Pfandbrief	30.0	36.9	-36.2	26.9	195.9	79.3%	511

as well as between individual Pfandbriefe exist. In the following, we explore the yield spreads within the Pfandbrief market in detail and relate them to liquidity and credit risk proxies.

4.4.2 Analysis of Pfandbrief Spreads

In this section we investigate the Pfandbrief yield spreads on a weekly basis. We aim to assign the different components of the yield spreads to the explanatory variables introduced in Section 4.3.2. Panel A of Table 4.6 displays seven regression results for the pre-crisis period which all comprise segment dummies and differ by the inclusion of Pfandbrief rating dummies (Regression B) and issuer rating dummies (Regression C). Regressions D to G further include the Pfandbrief's relative age and outstanding amount as liquidity proxies as well as two dummies for Landesbank Pfandbriefe issued before and after the abolishment of the guarantor liability on 18 July 2005.

The results show a significant and positive relation between the yield spreads and the dummies for mortgage and traditional Pfandbriefe. Depending on the inclusion of further explanatory variables, the average credit risk premium for mortgage Pfandbriefe relative to public Pfandbriefe amounts to 2 bp and the average liquidity premium for traditional Pfandbriefe relative to Jumbo Pfandbriefe adds up to 4 bp. The joint dummy variable is always higher and approximately equals the sum of the credit risk and the liquidity premium. Altogether, these segment variables already explain some part of the variation in the yield spreads.

As expected, the Pfandbrief rating has a significant influence on the yield spread and a higher rating leads to a lower spread. The differences are around 2 bp between AA and AAA rated Pfandbriefe. Surprisingly, the absence of a Pfandbrief rating does not unambiguously lead to a higher yield spread. This result, however, may be driven by the fact that Pfandbriefe are usually not rated in the beginning of our sample period and, thus, a rating does not signal a higher credit quality per se. Even though the impact of the rating dummies is significant, they hardly explain any variation in the yield spreads when omitting the segment dummies (not reported). In contrast, the issuer rating may explain a meaningful part, increasing the adjusted R^2 up to 10%. The results are also economically significant as a Pfandbrief from a BBB/BB rated issuer

Table 4.6: Regression Results for Pfandbrief Yield Spreads (Weekly Data)

This table reports the estimated coefficients (in bold) and the t-statistics from the regression of the Pfandbrief yield spreads. The yield spreads are calculated in basis points and winsorized at the 0.5th and 99.5th percentile. The outstanding amount is denoted in EUR billion and the age is given relative to initial maturity. The dummy variables are relative to AAA-rated public Jumbo Pfandbriefe issued by AAA/AA-issuers. We report selected issuer fixed effect dummies for Pfandbrief issuers being of particular interest during the respective period. The t-statistic is shown below the coefficient estimates and computed using Newey-West HAC standard errors. *** (**,*) denotes the significance at the 1% (5%, 10%) level. N is the number of weekly observations. The sample consists of weekly observations from January 2000 to June 2007 (Panel A), from July 2007 to September 2008 (Panel B) and from September 2008 to January 2009 (Panel C).

Panel A: Pre-Crisis Period

Regression	A	B	C	D	E	F	G
Constant	**-0.02**	**-0.41*****	**-0.88*****	**-2.94*****	**-3.04*****	**-3.90*****	**-4.02*****
	-1.17	-11.21	-23.54	-37.56	-34.60	-49.90	-46.25
Mortgage Jumbo Pfandbrief	**2.12*****	**1.82*****	**1.76*****	**2.61*****	**2.10*****	**2.43*****	**2.18*****
	37.24	28.50	32.50	40.48	30.91	40.00	33.34
Public Traditional Pfandbrief	**2.95*****	**2.92*****	**3.49*****	**3.89*****	**3.87*****	**4.06*****	**4.06*****
	42.45	41.93	47.42	47.33	47.01	48.94	48.79
Mortgage Traditional Pfandbrief	**5.46*****	**5.33*****	**5.83*****	**6.01*****	**5.91*****	**6.12*****	**6.07*****
	71.10	68.28	71.36	65.75	64.62	64.63	63.99
AA Pfandbrief Rating		**1.82*****			**2.29*****		**1.24*****
		10.44			13.21		7.13
No Pfandbrief Rating		**0.68*****			**0.05**		**0.18*****
		12.64			0.99		3.51
A Issuer Rating			**0.80*****			**0.87*****	**0.86*****
			14.55			14.42	14.17
BBB/BB Issuer Rating			**4.44*****			**4.04*****	**3.91*****
			48.77			42.33	40.69
No Issuer Rating			**1.22*****			**1.61*****	**1.59*****
			8.34			11.05	10.83
Relative Age				**5.94*****	**6.05*****	**5.62*****	**5.62*****
				52.00	53.49	49.91	50.24
Outstanding Amount				**-0.02**	**-0.03**	**-0.06****	**-0.08*****
				-0.86	-0.93	-2.46	-3.06
Landesbank pre July 2005				**-0.72*****	**-0.68*****	**0.13***	**0.14***
				-11.40	-10.68	1.81	1.90
Landesbank post July 2005				**2.62*****	**2.65*****	**3.27*****	**3.30*****
				11.06	11.18	13.19	13.33
N	156,866	156,866	156,866	156,866	156,866	156,866	156,866
Adjusted R^2	0.080	0.083	0.101	0.125	0.127	0.141	0.141

Table 4.6 continued.

Panel B: Subprime Crisis

Regression	A	B	C	D	E	F	G
Constant	**-0.02**	**-0.45*****	**1.33*****	**-4.00*****	**-4.46*****	**-4.33*****	**-4.87*****
	-0.20	-5.05	7.47	-13.24	-14.73	-11.14	-12.39
Mortgage Jumbo Pfandbrief	**4.04*****	**1.99*****	**4.14*****	**5.15*****	**3.15*****	**4.92*****	**3.09*****
	23.60	8.17	26.05	25.51	12.23	26.74	12.74
Public Traditional Pfandbrief	**14.43*****	**14.03*****	**14.03*****	**9.84*****	**9.76*****	**10.27*****	**10.17*****
	63.40	59.92	59.03	32.66	32.74	35.13	35.13
Mortgage Traditional Pfandbrief	**11.59*****	**10.85*****	**11.92*****	**8.67*****	**7.80*****	**8.90*****	**8.04*****
	30.24	29.08	31.55	21.25	19.41	22.16	20.31
AA Pfandbrief Rating		**4.95*****			**4.56*****		**4.23*****
		12.33			12.62		11.90
No Pfandbrief Rating		**2.32*****			**-1.33*****		**-1.55*****
		9.90			-5.29		-6.08
A Issuer Rating			**-2.68*****			**0.00**	**0.00**
			-11.87			-0.01	0.00
BBB/BB Issuer Rating			**5.99*****			**7.64*****	**7.40*****
			15.41			16.63	16.06
No Issuer Rating			**-1.90*****			**2.01*****	**3.24*****
			-3.98			3.60	5.70
Relative Age				**11.42*****	**12.81*****	**10.91*****	**12.51*****
				30.42	29.74	29.22	28.41
Outstanding Amount				**-1.84*****	**-1.87*****	**-1.84*****	**-1.88*****
				-12.86	-13.24	-14.71	-15.09
Landesbank pre July 2005				**1.55*****	**1.36*****	**1.96*****	**1.80*****
				5.32	4.87	5.59	5.26
Landesbank post July 2005				**4.00*****	**4.12*****	**4.25*****	**4.43*****
				15.19	15.70	12.46	12.95
N	20,377	20,377	20,377	20,377	20,377	20,377	20,377
Adjusted R^2	0.302	0.317	0.332	0.371	0.382	0.389	0.400

Table 4.6 continued.

Panel C: Post-Lehman Period

Regression	A	B	C	D	E	F	G
Constant	**-0.13**	**0.02**	**-14.61*** **	**-14.17*** **	**-13.95*** **	**-16.71*** **	**-16.31*** **
	-0.11	0.02	-14.91	-8.07	-7.94	-7.81	-7.73
Mortgage Jumbo Pfandbrief	**5.97*** **	**-5.63*** **	**0.30**	**8.88*** **	**1.10**	**7.47*** **	**1.60**
	3.00	-3.12	0.15	5.44	0.70	4.73	1.06
Public Traditional Pfandbrief	**38.33*** **	**38.02*** **	**45.35*** **	**41.06*** **	**41.36*** **	**42.39*** **	**42.47*** **
	20.67	20.62	26.93	19.14	19.31	19.66	19.80
Mortgage Traditional Pfandbrief	**30.11*** **	**24.15*** **	**29.66*** **	**33.01*** **	**29.54*** **	**33.13*** **	**30.43*** **
	12.57	10.29	12.47	12.93	11.80	12.80	12.03
AA Pfandbrief Rating		**22.62*** **			**14.92*** **		**11.68*** **
		8.55			6.16		4.97
No Pfandbrief Rating		**-16.09*** **			**-16.07*** **		**-13.94*** **
		-5.96			-5.66		-4.70
A Issuer Rating			**20.99*** **			**3.80*** **	**3.31** **
			15.10			2.65	2.35
BBB/BB Issuer Rating			**37.41*** **			**26.28*** **	**22.58*** **
			7.46			5.08	4.33
No Issuer Rating			**3.73**			**-2.49**	**0.87**
			1.00			-0.52	0.27
Relative Age				**24.86*** **	**24.31*** **	**22.38*** **	**22.38*** **
				8.53	8.39	7.72	7.74
Outstanding Amount				**-2.46*** **	**-2.13** **	**-2.87*** **	**-2.54** **
				-2.62	-2.27	-2.83	-2.53
Landesbank pre July 2005				**-16.76*** **	**-16.86*** **	**-13.03*** **	**-13.58*** **
				-10.35	-10.75	-6.92	-7.40
Landesbank post July 2005				**-14.60*** **	**-15.16*** **	**-11.77*** **	**-12.55*** **
				-10.12	-10.46	-6.86	-7.34
DEPFA				**96.58*** **	**95.39*** **	**97.42*** **	**96.37*** **
				19.79	19.42	19.88	19.60
HRE				**51.05*** **	**46.39*** **	**52.15*** **	**48.34*** **
				8.46	7.61	8.53	7.88
N	4,744	4,744	4,744	4,744	4,744	4,744	4,744
Adjusted R^2	0.167	0.188	0.228	0.479	0.488	0.491	0.497

on average trades at a premium of more than 4 bp compared to a AAA/AA rated issuer. This result provides evidence that investors already value the long-term issuer credit quality during the pre-crisis period when Pfandbriefe are typically considered as close substitutes to Bunds.

The results also show a significant and positive relation between the yield differences and the liquidity proxies. Besides the premium for traditional Pfandbriefe, a higher relative age and a lower outstanding amount (both signaling a lower liquidity) lead to a significantly higher yield spread. In particular, a Pfandbrief close to maturity on average trades at an additional yield spread of 6 bp relative to its issuance. Hence, liquidity seems to be an important priced risk factor even during the pre-crisis period.

Our results further show that the average yield spreads for Landesbank Pfandbriefe significantly increase after the discontinuation of the guarantor liability. Investors seem to attribute a risk premium of 3 bp to Pfandbriefe that are not guaranteed by the federal states even though the underlying cover pools did not change considerably. Overall, the full model (Regression G) explains roughly 14% of the yield spread variation within the Pfandbrief market.

The results for the subprime crisis presented in Panel B of Table 4.6 are similar in terms of sign and significance, but much more pronounced. The yield spreads are higher in absolute terms and the adjusted R^2 is up to 40%. It is important to note that the credit risk premium between mortgage and public Pfandbriefe only increases to 3–5 bp whereas the liquidity premium between traditional and Jumbo Pfandbriefe considerably increases up to 14 bp. In contrast to the results in Panel A, the joint effect is smaller than the sum of the credit risk and the liquidity premium, suggesting a negative correlation between liquidity and credit risk. This result complements the findings of Favero et al. (2010) for European sovereign bonds and Bühler and Trapp (2010) for high quality AAA rated corporate bonds that, in contrast to the findings for sub-investment grade bonds, liquidity and credit risk interact negatively in high quality bond markets.

Whereas the yield spread between AA and AAA rated Pfandbriefe is approximately 4 bp, the yield spreads between the issuer rating categories are up to 7 bp. Similar to the pre-crisis period, the issuer rating explains a higher fraction of the variation in the yield spreads. In addition, the Pfandbrief's relative age and its outstanding amount have a significant impact similar to the pre-crisis period, but larger in absolute values. This result, in conjunction with the higher yield spreads for traditional Pfandbriefe, provides evidence of a considerably higher liquidity premium during the subprime crisis.

In contrast to the results during the pre-crisis period, Landesbank Pfandbriefe are penalized with significant yield spreads of up to 4 bp. This result can be rationalized by the fact that nearly all Landesbanks were engaged in unsuccessful investments in the subprime market. Hence, investors also appear to value the risk stemming from non-Pfandbrief businesses. As expected, the yield spread is significantly higher for Pfandbriefe issued after the abolishment of the guarantor liability.

The results substantially change during the period after the collapse of Lehman Brothers. While the explanatory variables explain a large part of the yield spread in the previous regressions, Panel C of Table 4.6 shows that the Pfandbrief segments are able to exclusively explain only 16%. The major part can be proxied by the issuer rating dummies, the liquidity proxies and firm-specific effects leading to an adjusted R^2 of 50% for the full model. However, there are still significant differences between the Pfandbrief segments, most notably between traditional and Jumbo Pfandbriefe. The average yield spread between these segments is up to 45 bp and shows the particular relevance of liquidity in the post-Lehman era. Moreover, yield spreads between low and high rated Pfandbriefe as well as low and high rated issuers increase considerably. The average yield spread of a BBB rated issuer compared to an AA rated issuer exceeds 22 bp and is larger than the impact of the Pfandbrief rating or whether the Pfandbrief is covered by mortgage or public-sector loans. This result strongly indicates that investors consider the issuers' default risk even though Pfandbriefe are backed by high-quality cover assets.

Besides the striking yield difference between traditional and Jumbo Pfandbriefe, the relative age has a strong impact of up to 25 bp between recently issued and almost matured Pfandbriefe. Hence, liquidity seems to be the most important factor considered by Pfandbrief investors. However, the Pfandbrief yield spreads are also driven by various issuer fixed effects during this periods. In contrast to the previous results, Landesbank Pfandbriefe trade at a yield discount of up to 17 bp compared to other Pfandbriefe

– irrespective whether the Pfandbrief is issued before or after the discontinuation of the guarantor liability. This result signals that, against the background of the financial crisis, investors expect the owners or the state to rescue Landesbanks even though a legal guarantee does not apply any more. Apparently, the evident problems of the private banks DEPFA and Hypo Real Estate are priced by investors with yield spreads of approximately 96 bp and 50 bp, respectively. Hence, investors do not completely anticipate the rescue of these issuers in case of default. However, it is important to note that the problems of these issuers did not arise in the cover pool assets, but are due to non-Pfandbrief business. Therefore, our investigation provides further evidence that investors evaluate the default risk of an issuer to a large extent, even though the cover pools remain reliable.

In summary, our results show that the Pfandbrief market exhibits considerable heterogeneity, and the risks perceived by investors strongly vary over time. During the pre-crisis and the subprime crisis period, the four Pfandbrief segments account for a large part of the Pfandbrief yield spreads whereas the issuer rating does not play an important role. After the collapse of Lehman Brothers, however, the issuer rating and issuer-specific factors become more important. Moreover, it is surprising that the specific cover pool quality, proxied by mortgage versus public-sector loans as well as the Pfandbrief rating, seems to be only a subordinate factor beyond liquidity and issuer default risk. Therefore, it seems sensible that rating agencies nowadays consider the issuer quality as an additional factor for their rating methodology. Above all, liquidity appears to be the most important risk factor priced in the secondary Pfandbrief market.

4.4.3 Detailed Analysis Using Cover Pool Data

Up to this point, we only approximate the cover pool quality by the distinction between mortgage and public-sector cover loans and the Pfandbrief rating. In the following, we explicitly consider proxies for the quality of the cover pool using the information according to § 28 Pfandbrief Act presented in Section 4.3.3.

Cover pool information is available on a quarterly basis only. In order to ensure consistency, we initially compare the basic results for weekly and quarterly yield spread data. The summary statistics and the regression results for the quarterly data are shown in the appendix of this chapter. Table C.1 reports the descriptive statistics for the individual Pfandbrief yield spreads relative to public Jumbo Pfandbriefe on a quarterly basis. The results are very similar to those using weekly data and being presented in Table 4.5: Mortgage Jumbo Pfandbriefe trade at a small premium and traditional Pfandbriefe at a larger premium. The premia substantially increase during the financial crisis. Even though the number of observations is much smaller, the regression results do not change considerably when using quarterly data. Table C.2 shows that the sign of the coefficient estimates mostly coincide and the magnitude is quite similar compared to the results displayed in Table 4.6. Hence, the interpretation of the results does not change compared to the results for weekly data presented in Section 4.4.2. This robustness check shows the consistency of the samples with weekly and quarterly data. Therefore, we proceed with quarterly data to analyze the impact of the cover pool variables.

The regression results presented in Tables 4.6 and C.2 have shown that the model including the Pfandbrief segments, the issuer rating, and the liquidity proxies is superior in explaining the individual Pfandbrief yield spreads. Therefore, we use this model as the basic model when measuring the impact of the cover pool variables. In contrast to the previous regressions, however, we refrain from using the Pfandbrief rating dummies since we aim to measure the quality of the cover pool directly by using the cover pool variables defined above. Table 4.7 displays the regression results for the pre-crisis period (Panel A), the subprime crisis (Panel B) and the post-Lehman financial crisis (Panel C). Regression A shows the basic model and Regression B to G include the six cover pool variables defined in Section 4.3.3 separately. Regression H provides the coefficient estimates for the cover pool variables only, and Regression I presents the results for the full model.

During the pre-crisis period, only the impact of the overcollateralization OC is significant when including the cover pool variables separately. As expected, a higher OC leads to a lower yield spread. The impact, however, is economically small given that an OC of 100% may decrease the yield spread by only 0.22 bp. Considering the six cover pool variables alone, the adjusted R^2 amounts to roughly 3% signaling that only a very small part of the Pfandbrief yield spreads can be explained by the cover pool variables. Estimating the full model, however, leads to superior results. Even though

Table 4.7: Regression Results for Pfandbrief Yield Spreads on Cover Pool Variables (Quarterly Data)

This table reports the estimated coefficients (in bold) and the t-statistics from the regression of the Pfandbrief yield spreads. The yield spreads are calculated in basis points and winsorized at the 0.5th and 99.5th percentile on a weekly basis. The outstanding amount is denoted in EUR billion and the age is given relative to initial maturity. The dummy variables are relative to AAA-rated public Jumbo Pfandbriefe issued by AAA/AA-issuers. We report selected issuer fixed effect dummies for Pfandbrief issuers being of particular interest during the respective period. The t-statistic is shown below the coefficient estimates and computed using Newey-West HAC standard errors. *** (**,*) denotes the significance at the 1% (5%, 10%) level. N is the number of quarterly observations. The sample consists of quarterly observations from January 2006 to June 2007 (Panel A), from July 2007 to September 2008 (Panel B) and from September 2008 to January 2009 (Panel C).

Panel A: Pre-Crisis Period

Regression	A	B	C	D	E	F	G	H	I
OC		**-0.22***						**0.10**	**-0.27****
		-1.82						0.93	-2.14
$\lvert TRANS \rvert$ (years)			**0.04**					**0.39**	**0.04**
			0.17					1.42	0.16
PB_{DUE}				**2.88**				**-2.75**	**2.02**
				1.18				-0.93	0.76
CL_{DUE}					**1.42**			**3.37***	**1.00**
					0.91			1.79	0.60
GERM						**1.36**		**8.21*****	**2.51***
						1.21		5.16	1.84
SMALL							**-1.17**	**1.42**	**-2.61***
							-0.95	1.60	-1.75
Constant	**-3.71*****	**-3.79*****	**-3.82*****	**-4.26*****	**-3.99*****	**-4.89*****	**-3.76*****	**-5.72*****	**-6.32*****
	-5.32	-5.39	-5.28	-5.44	-5.24	-4.79	-5.39	-3.74	-5.10
Mortgage Jumbo Pfandbrief	**2.42*****	**2.49*****	**2.47*****	**2.53*****	**2.44*****	**2.33*****	**2.96*****		**3.42*****
	6.03	6.13	6.05	6.24	6.02	5.46	4.36		4.49
Public Traditional Pfandbrief	**2.74*****	**2.73*****	**2.73*****	**2.73*****	**2.75*****	**2.76*****	**2.75*****		**2.82*****
	4.75	4.73	4.72	4.76	4.73	4.83	4.76		4.99
Mortgage Traditional Pfandbrief	**5.16*****	**5.39*****	**5.24*****	**5.26*****	**5.21*****	**5.16*****	**5.79*****		**6.50*****
	7.85	7.79	7.77	7.82	7.74	7.55	6.33		6.71
A Issuer Rating	**0.28**	**0.27**	**0.29**	**0.31**	**0.24**	**0.28**	**0.33**		**0.19**
	0.58	0.53	0.58	0.61	0.49	0.57	0.69		0.38
BBB/BB Issuer Rating	**3.09*****	**3.07*****	**3.07*****	**3.00*****	**2.96*****	**3.07*****	**3.08*****		**2.73*****
	4.71	4.56	4.52	4.47	4.30	4.60	4.62		3.89
No Issuer Rating	**8.54*****	**8.80*****	**8.84*****	**9.06*****	**8.78*****	**8.76*****	**8.58*****		**7.88*****
	5.18	5.00	4.93	4.93	4.97	4.98	4.87		4.32
Relative Age	**7.74*****	**7.83*****	**7.84*****	**7.78*****	**7.80*****	**7.83*****	**7.75*****		**7.75*****
	11.43	11.36	11.38	11.29	11.30	11.36	11.41		11.24
Outstanding Amount	**-1.19*****	**-1.18*****	**-1.19*****	**-1.21*****	**-1.23*****	**-1.16*****	**-1.19*****		**-1.13*****
	-4.59	-4.52	-4.58	-4.64	-4.70	-4.58	-4.57		-4.51
Landesbank pre July 2005	**0.34**	**0.55**	**0.42**	**0.41**	**0.42**	**0.20**	**0.40**		**0.11**
	0.65	0.98	0.76	0.75	0.77	0.34	0.75		0.17
Landesbank post July 2005	**4.24*****	**4.32*****	**4.26*****	**4.27*****	**4.24*****	**4.05*****	**4.28*****		**3.87*****
	5.73	5.68	5.58	5.64	5.58	5.11	5.72		4.80
N	2,200	2,176	2,176	2,176	2,176	2,176	2,183	2,176	2,176
Adjusted R^2	0.237	0.240	0.239	0.240	0.240	0.240	0.237	0.026	0.241

Table 4.7 continued. **Panel B: Subprime Crisis**

Regression	A	B	C	D	E	F	G	H	I
OC		**-0.10**						**0.59**	**-0.10**
		-0.33						1.10	-0.37
$\lvert TRANS \rvert$ (years)			**1.01****					**1.45*****	**0.89****
			2.34					2.76	2.03
PB_{DUE}				**11.57*****				**18.82*****	**11.57****
				2.63				3.09	2.28
CL_{DUE}					**0.93**			**-10.02*****	**-2.50**
					0.42			-3.64	-0.93
GERM						**-1.53**		**9.76*****	**-1.09**
						-0.92		4.13	-0.56
SMALL							**-3.58***	**-3.42****	**-3.96***
							-1.83	-2.10	-1.67
Constant	**-2.09***	**-2.10***	**-3.04****	**-3.91*****	**-2.20***	**-0.83**	**-2.12***	**-2.55**	**-3.59***
	-1.72	-1.73	-2.41	-2.78	-1.74	-0.46	-1.75	-1.13	-1.77
Mortgage Jumbo Pfandbrief	**4.49*****	**4.48*****	**4.37*****	**4.58*****	**4.43*****	**4.60*****	**5.84*****		**6.22*****
	7.32	7.28	7.10	7.28	7.18	7.18	5.89		5.44
Public Traditional Pfandbrief	**10.22*****	**10.22*****	**10.17*****	**10.06*****	**10.21*****	**10.20*****	**10.33*****		**10.13*****
	11.51	11.52	11.53	11.39	11.49	11.40	11.56		11.49
Mortgage Traditional Pfandbrief	**8.44*****	**8.51*****	**8.30*****	**8.47*****	**8.40*****	**8.55*****	**10.14*****		**10.50*****
	7.30	7.13	7.21	7.25	7.24	7.30	6.66		6.14
A Issuer Rating	**-0.88**	**-0.89**	**-0.93**	**-1.08**	**-0.98**	**-0.98**	**-0.96**		**-1.03**
	-1.07	-1.08	-1.14	-1.32	-1.18	-1.18	-1.17		-1.28
BBB/BB Issuer Rating	**3.19***	**3.18***	**3.20***	**2.81***	**3.16***	**3.12***	**3.40****		**3.08***
	1.90	1.90	1.96	1.69	1.88	1.85	2.03		1.88
No Issuer Rating	**2.10**	**2.09**	**1.61**	**1.94**	**1.94**	**2.31**	**1.58**		**1.52**
	1.16	1.16	0.90	0.93	1.04	1.28	0.85		0.72
Relative Age	**10.27*****	**10.28*****	**10.39*****	**10.02*****	**10.24*****	**10.28*****	**10.29*****		**10.23*****
	9.49	9.47	9.59	9.18	9.28	9.47	9.47		9.28
Outstanding Amount	**-2.49*****	**-2.48*****	**-2.47*****	**-2.55*****	**-2.51*****	**-2.52*****	**-2.43*****		**-2.42*****
	-5.70	-5.69	-5.69	-5.86	-5.76	-5.74	-5.52		-5.59
Landesbank pre July 2005	**1.07**	**1.11**	**0.98**	**0.71**	**1.06**	**1.28**	**0.93**		**0.70**
	1.12	1.16	1.05	0.77	1.11	1.30	0.98		0.72
Landesbank post July 2005	**3.27*****	**3.29*****	**3.16*****	**2.94*****	**3.26*****	**3.47*****	**3.13*****		**2.87*****
	3.51	3.51	3.44	3.18	3.50	3.63	3.34		2.98
N	1,853	1,852	1,852	1,852	1,852	1,852	1,852	1,852	1,852
Adjusted R^2	0.422	0.422	0.425	0.426	0.422	0.422	0.423	0.063	0.429

Table 4.7 continued. **Panel C: Post-Lehman Period**

Regression	A	B	C	D	E	F	G	H	I
OC		**-3.00**						**-2.92**	**-2.69**
		-0.38						-0.30	-0.34
$\|TRANS\|$ (years)			**6.49****					**12.40*****	**10.36*****
			2.43					3.53	3.92
PB_{DUE}				**-16.74**				**-39.99***	**-46.86*****
				-1.02				-1.76	-2.63
CL_{DUE}					**22.90***			**35.82****	**22.12***
					1.83			2.23	1.69
$GERM$						**-47.61*****		**-78.23*****	**-32.83*****
						-4.98		-5.54	-3.46
$SMALL$							**-30.03*****	**-6.93**	**-20.18***
							-2.94	-0.73	-1.74
Constant	**-18.93*****	**-18.70*****	**-25.91*****	**-15.85*****	**-21.09*****	**19.61****	**-18.72*****	**74.76*****	**3.41**
	-3.98	-3.91	-5.08	-2.87	-4.42	2.10	-4.03	5.31	0.33
Mortgage Jumbo Pfandbrief	**8.51****	**8.86****	**4.56**	**7.66***	**7.61***	**10.58*****	**19.64*****		**8.21**
	2.03	2.04	1.03	1.79	1.94	2.80	3.02		1.33
Public Traditional Pfandbrief	**48.23*****	**48.22*****	**48.13*****	**48.04*****	**47.71*****	**49.54*****	**49.30*****		**48.62*****
	11.75	11.77	11.74	11.76	11.54	12.29	12.24		12.12
Mortgage Traditional Pfandbrief	**36.50*****	**37.53*****	**31.68*****	**36.26*****	**35.53*****	**41.76*****	**50.99*****		**41.46*****
	7.47	6.53	5.86	7.46	7.24	8.43	7.01		5.30
A Issuer Rating	**0.54**	**0.32**	**3.99**	**0.67**	**-2.30**	**-1.95**	**0.85**		**1.94**
	0.15	0.09	1.14	0.19	-0.58	-0.57	0.24		0.55
BBB/BB Issuer Rating	**41.76*****	**41.52*****	**43.10*****	**43.47*****	**38.13*****	**40.96*****	**39.68*****		**43.03*****
	2.90	2.88	2.90	3.12	2.74	3.11	2.87		3.57
No Issuer Rating	**-18.26**	**-18.27**	**-18.89**	**-19.91**	**-20.69**	**-11.22**	**-21.24**		**-23.39**
	-1.22	-1.21	-1.20	-1.42	-1.26	-0.79	-1.32		-1.37
Relative Age	**27.30*****	**27.17*****	**29.60*****	**27.79*****	**26.05*****	**24.00*****	**25.65*****		**27.62*****
	4.61	4.57	4.95	4.69	4.41	4.15	4.39		4.81
Outstanding Amount	**-1.35**	**-1.28**	**-1.28**	**-1.34**	**-1.87**	**-0.62**	**-0.72**		**-0.76**
	-0.73	-0.70	-0.68	-0.73	-1.01	-0.35	-0.40		-0.42
Landesbank pre July 2005	**-19.91*****	**-19.40*****	**-22.06*****	**-18.89*****	**-20.18*****	**-13.96*****	**-20.30*****		**-16.43*****
	-4.52	-4.27	-4.99	-4.26	-4.47	-3.20	-4.66		-3.63
Landesbank post July 2005	**-16.06*****	**-15.61*****	**-17.37*****	**-15.47*****	**-16.43*****	**-10.63*****	**-16.84*****		**-13.22*****
	-3.98	-3.67	-4.33	-3.82	-3.92	-2.66	-4.15		-3.05
DEPFA	**104.04*****	**104.15*****	**102.02*****	**103.59*****	**100.30*****	**83.16*****	**103.20*****		**81.09*****
	20.74	20.77	19.99	20.48	18.49	13.01	20.78		12.34
HRE	**41.87*****	**41.83*****	**35.72*****	**42.29*****	**37.78*****	**42.41*****	**37.39*****		**26.62***
	3.38	3.38	2.66	3.40	2.96	3.40	3.16		1.86
N	625	625	625	625	625	625	625	625	625
Adjusted R^2	0.551	0.550	0.557	0.551	0.554	0.574	0.559	0.164	0.587

the cover pool variables only account for a small rise of the adjusted R^2, three of them have a significant impact. First, the OC is significant negative as in Regression B. Second, a higher fraction of German cover assets leads to a higher yield spread. Thus, Pfandbrief investors seem to price the lower regional diversification within the cover pools. Third, Pfandbriefe with a more granular portfolio trade at a significant yield discount, signaling the higher value of Pfandbriefe with a diversified underlying cover pool.[22]

It is important to note that the sign and significance of the basic model variables do not change when including the cover pool variables. Comparing these results to Panel A of Table C.2, we provide evidence that, during the pre-crisis period, the Pfandbrief yield spreads are mainly driven by the differences between the four Pfandbrief segments and their relative liquidity. The additional impact of the issuer rating and the quality of the cover pool is of minor importance.

The results only slightly change during the period of the subprime crisis. Whereas the four Pfandbrief segments and the liquidity proxies already explain 42% of the variation in the yield spreads, the full model only marginally improves the adjusted R^2 by 1%. During the subprime crisis, however, the variable measuring the term transformation, $|TRANS|$, has a significant impact on the yield spreads. A maturity-mismatch of the cover assets and the outstanding Pfandbriefe by one year accounts for 1 bp of the yield spread. Moreover, a higher fraction of Pfandbriefe due within the following year, PB_{DUE}, is significantly related to a higher yield spread. These results indicate that, during the period of the subprime crisis, investors are concerned about the term transformation of the Pfandbrief issuer. Moreover, as during the pre-crisis period, Pfandbriefe with a more granular portfolio trade at a significant yield discount. However, the Pfandbrief segment variables and the liquidity variables remain the primary drivers of the yield spread.

The picture completely changes when investigating the post-Lehman period. Panel C of Table C.2 has already shown that the issuer's long term credit rating is an important driver of the yield spread beyond the Pfandbrief segment and the

[22] Instead of $SMALL$, we separately include $LARGE$, RES, and COM into the regression analysis. The results, however, do not change remarkably, and the interpretation remains identical.

liquidity variables. In addition, Panel C of Table 4.7 provides evidence that Pfandbrief investors also evaluate the cover pool quality in detail. When considering the six cover pool variables separately, four of them are significantly related to the yield spread. As during the subprime period, the term transformation, $|TRANS|$, is positively related to the yield spread with an impact of 6 bp for each year of maturity-mismatch. A higher amount of cover loans due within the following year, CL_{DUE}, is also positively related to the yield spread at a 10% significance level. This is consistent with investors being concerned about the capability of the issuer to provide additional cover assets of at least the same quality.

In contrast to the results for the pre-crisis period, the fraction of German cover pool assets, *GERM*, has a significant negative impact. This result suggests that investors prefer the high quality and lower volatility of German cover assets to international diversification of the cover pool during times of financial turmoils. Moreover, a more granular cover pool as measured with *SMALL* and, equivalently, a higher fraction of residential mortgages have a significantly negative impact on the yield spread. Thus, Pfandbrief investors prefer cover pools that are less volatile and less dependent on the contemporaneous economic conditions.

Considering the full model, Regression I shows that the cover pool variables additionally account for almost 4% of the adjusted R^2 compared to the basic model (Regression A). It is surprising that the cover pool variables even explain a larger part of the Pfandbrief yield spread than the consideration of the Pfandbrief rating as in Regression G in Panel C of Table C.2. Moreover, it is noteworthy that the overcollateralization *OC* does not have a significant impact during the period of the subprime crisis and the post-Lehman period. Moreover, the impact is economically very small in the pre-crisis period. Hence, investors do not seem to take into account the amount of *OC* when pricing a Pfandbrief. On the one hand, this result may show that the legal requirement of a minimal *OC* is sufficient and any additional *OC* does not have any impact. On the other hand, *OC* can be regarded as less relevant since the number frequently may change by the issuance of new Pfandbriefe. Overall, our results show that the general composition of the cover pool is more important than simply the amount of overcollateralization.

Altogether, the results for the post-Lehman financial crisis provide evidence that liquidity is the most important risk factor for pricing Pfandbriefe. Whereas it is less relevant whether the Pfandbrief is backed by public-sector or mortgage loans, the composition of the cover pool gains more importance. The issuer rating as well as firm-specific effects remain relevant.

4.5 Summary and Conclusion

In this chapter we extensively study credit risk and liquidity premia within the Pfandbrief market. In contrast to previous studies, we show that liquidity is not the exclusive driver of yield spreads between Pfandbriefe and German government bonds and issuer-specific effects as well as the cover pool quality is also relevant. Therefore, our results show that the presumption of a homogenous Pfandbrief market cannot be sustained any longer.

Pfandbriefe differ with respect to their type of collateral, the quality of the issuer, the quality of the cover pool, and their liquidity. In general, yield spreads between individual Pfandbriefe are mainly driven by their relative liquidity and whether they are covered by public-sector or mortgage loans. Even though the recent financial crisis has its origin in the mortgage market, the type of cover assets appears to be less important during this period. Liquidity, however, proves to have the most important effect.

Strict legal requirements ensure the high quality of the Pfandbrief cover pool and aim to guarantee the Pfandbrief holder timely payments of the Pfandbrief obligations. However, the general quality of the Pfandbrief issuer still has an important impact, in particular during the financial crisis. This result shows that Pfandbrief investors are concerned about an issuer's default and the potential subsequent illiquidity or devaluation of a Pfandbrief. Hence, it is not surprising that nowadays all major rating agencies consider the issuer rating as an important factor for their Pfandbrief rating methodology.

In general, the impact of the cover pool quality is quite small. Hence, our results provide evidence that the strict regulation of German Pfandbriefe ensures the overall high quality of the cover pool. During the recent financial crisis, however, some variables like the term transformation between Pfandbriefe and their cover pool or the fraction of German cover assets show a significant impact on the yield spreads. Therefore, the mandatory publications according to § 28 Pfandbrief Act seem to be less important during normal market times, but provide additional value in times of financial turmoil. During these periods, Pfandbrief issuers with a sustainable cover pool may profit from relatively lower refinancing cost.

Altogether, the Pfandbrief market has shown to develop from a relatively homogenous market until the end of the nineties to a heterogenous market with issuer-specific and liquidity related risk premia. The understanding of the different risk premia within the Pfandbrief market is important for investors, issuers, and regulators. Investors are mainly interested in accurately knowing about the risks inherent in the Pfandbrief market during different market environments. Issuers need to know the perceived risk factors priced by investors to design an optimal Pfandbrief issuance. As the Pfandbrief market is systemic for the German banking system, regulators are concerned about the issuers' long-term ability to meet their Pfandbrief obligations. Moreover, regulators from other countries should be informed about the important risk factors when setting up a legal framework for covered bonds.

C Appendix to Chapter 4

Table C.1: Descriptive Statistics for Yield Spreads (Quarterly Data)

This table shows the summary statistics for the Pfandbrief yield spreads relative to the term structure of public Jumbo Pfandbriefe in basis points. The statistics are based on the equally weighted yield spread observations in the respective Pfandbrief segment and time period (winsorized at the 0.5th and 99.5th percentiles on a weekly basis). N is the number of quarterly observations. The sample period ranges from January 2006 to January 2009 (Panel A) and is partitioned into the pre-crisis period (January 2006 to June 2007, Panel B), the period of the subprime crisis (July 2007 to September 2008, Panel C), and the post-Lehman period (September 2008 to January 2009, Panel D).

Panel A: Total Sample

Pfandbrief Segment	Mean	Std. Dev.	Min.	Median	Max.	% > 0	N
Public Jumbo Pfandbrief	-0.3	14.1	-43.3	-0.9	157.2	37.9%	1,662
Mortgage Jumbo Pfandbrief	2.3	13.1	-26.8	0.9	100.1	60.1%	546
Public Traditional Pfandbrief	13.9	21.1	-36.8	9.9	166.7	81.2%	1,737
Mortgage Traditional Pfandbrief	11.6	18.1	-29.9	9.0	128.1	79.1%	733

Panel B: Pre-Crisis Period

Pfandbrief Segment	Mean	Std. Dev.	Min.	Median	Max.	% > 0	N
Public Jumbo Pfandbrief	-0.5	3.5	-8.1	-0.8	12.0	36.5%	822
Mortgage Jumbo Pfandbrief	0.8	3.4	-6.5	0.4	18.2	57.5%	261
Public Traditional Pfandbrief	3.5	9.5	-29.2	4.5	24.1	69.2%	737
Mortgage Traditional Pfandbrief	6.0	8.9	-19.8	6.6	29.5	74.5%	380

Panel C: Subprime Crisis

Pfandbrief Segment	Mean	Std. Dev.	Min.	Median	Max.	% > 0	N
Public Jumbo Pfandbrief	-0.3	4.2	-10.5	-0.5	19.9	43.8%	630
Mortgage Jumbo Pfandbrief	2.8	4.5	-6.1	2.1	19.3	73.4%	207
Public Traditional Pfandbrief	15.3	12.1	-23.4	15.8	43.9	91.6%	761
Mortgage Traditional Pfandbrief	12.0	13.3	-23.9	12.1	47.7	85.5%	255

Panel D: Post-Lehman Period

Pfandbrief Segment	Mean	Std. Dev.	Min.	Median	Max.	% > 0	N
Public Jumbo Pfandbrief	0.5	38.5	-43.3	-13.0	157.2	25.7%	210
Mortgage Jumbo Pfandbrief	6.3	33.1	-26.8	-5.3	100.1	33.3%	78
Public Traditional Pfandbrief	41.3	37.7	-36.8	47.1	166.7	84.9%	239
Mortgage Traditional Pfandbrief	32.1	34.1	-29.9	34.8	128.1	80.6%	98

Table C.2: Regression Results for Pfandbrief Yield Spreads (Quarterly Data)

This table reports the estimated coefficients (in bold) and the t-statistics from the regression of the Pfandbrief yield spreads. The yield spreads are calculated in basis points and winsorized at the 0.5th and 99.5th percentile on a weekly basis. The outstanding amount is denoted in EUR billion and the age is given relative to initial maturity. The dummy variables are relative to AAA-rated public Jumbo Pfandbriefe issued by AAA/AA-issuers. We report selected issuer fixed effect dummies for Pfandbrief issuers being of particular interest during the respective period. The t-statistic is shown below the coefficient estimates and computed using Newey-West HAC standard errors. *** (**,*) denotes the significance at the 1% (5%, 10%) level. N is the number of quarterly observations. The sample consists of quarterly observations from January 2006 to June 2007 (Panel A), from July 2007 to September 2008 (Panel B) and from September 2008 to January 2009 (Panel C).

Panel A: Pre-Crisis Period

Regression	A	B	C	D	E	F	G
Constant	**-0.52*****	**-1.15*****	**-0.09**	**-2.53*****	**-2.62*****	**-3.71*****	**-3.76*****
	-3.22	-5.20	-0.26	-4.16	-4.32	-5.32	-5.44
Mortgage Jumbo Pfandbrief	**1.31*****	**0.73****	**1.62*****	**2.34*****	**1.46*****	**2.42*****	**1.64*****
	4.27	2.22	5.09	5.73	3.53	6.03	3.89
Public Traditional Pfandbrief	**4.03*****	**3.84*****	**4.06*****	**2.04*****	**2.12*****	**2.74*****	**2.77*****
	8.76	8.38	8.88	3.47	3.67	4.75	4.88
Mortgage Traditional Pfandbrief	**6.52*****	**6.24*****	**6.64*****	**4.90*****	**4.83*****	**5.16*****	**5.03*****
	11.07	10.57	11.64	7.21	7.10	7.85	7.64
AA Pfandbrief Rating		**2.29*****			**2.47*****		**2.18*****
		3.49			3.68		3.25
No Pfandbrief Rating		**1.56*****			**-0.81***		**-0.83***
		4.03			-1.80		-1.84
A Issuer Rating			**-1.40*****			**0.28**	**0.33**
			-3.27			0.58	0.68
BBB/BB Issuer Rating			**2.74*****			**3.09*****	**2.80*****
			4.11			4.71	4.27
No Issuer Rating			**6.23*****			**8.54*****	**8.92*****
			3.98			5.18	5.20
Relative Age				**7.83*****	**8.78*****	**7.74*****	**8.73*****
				11.45	10.01	11.43	9.87
Outstanding Amount				**-1.50*****	**-1.55*****	**-1.19*****	**-1.27*****
				-5.77	-5.96	-4.59	-4.82
Landesbank pre July 2005				**-0.12**	**-0.23**	**0.34**	**0.23**
				-0.27	-0.52	0.65	0.45
Landesbank post July 2005				**3.86*****	**3.88*****	**4.24*****	**4.28*****
				6.07	6.06	5.73	5.74
N	2,200	2,200	2,200	2,200	2,200	2,200	2,200
Adjusted R^2	0.108	0.119	0.143	0.214	0.220	0.237	0.243

Table C.2 continued.

Panel B: Subprime Crisis

Regression	A	B	C	D	E	F	G
Constant	**-0.26**	**-0.70*****	**1.78*****	**-2.33****	**-2.80*****	**-2.09***	**-2.64****
	-1.21	-2.74	3.42	-2.57	-3.10	-1.72	-2.17
Mortgage Jumbo Pfandbrief	**3.05*****	**0.91**	**3.67*****	**4.39*****	**2.29*****	**4.49*****	**2.38*****
	6.71	1.37	7.28	7.17	3.09	7.32	3.17
Public Traditional Pfandbrief	**15.58*****	**15.23*****	**14.63*****	**9.93*****	**9.87*****	**10.22*****	**10.16*****
	27.92	26.63	23.76	11.27	11.31	11.51	11.57
Mortgage Traditional Pfandbrief	**12.28*****	**11.40*****	**12.36*****	**8.12*****	**7.11*****	**8.44*****	**7.41*****
	11.74	11.20	12.17	7.03	6.22	7.30	6.48
AA Pfandbrief Rating		**5.48*****			**4.85*****		**4.90*****
		4.67			4.61		4.67
No Pfandbrief Rating		**2.18*****			**-1.47****		**-1.50****
		3.53			-2.26		-2.27
A Issuer Rating			**-3.22*****			**-0.88**	**-0.83**
			-5.04			-1.07	-1.02
BBB/BB Issuer Rating			**2.24**			**3.19***	**3.12***
			1.54			1.90	1.90
No Issuer Rating			**-0.76**			**2.10**	**3.31***
			-0.59			1.16	1.83
Relative Age				**10.35*****	**11.86*****	**10.27*****	**11.83*****
				9.58	9.50	9.49	9.35
Outstanding Amount				**-2.70*****	**-2.73*****	**-2.49*****	**-2.51*****
				-6.22	-6.41	-5.70	-5.86
Landesbank pre July 2005				**1.51****	**1.31***	**1.07**	**0.91**
				1.98	1.80	1.12	0.98
Landesbank post July 2005				**3.71*****	**3.81*****	**3.27*****	**3.42*****
				5.34	5.50	3.51	3.65
N	1,853	1,853	1,853	1,853	1,853	1,853	1,853
Adjusted R^2	0.352	0.366	0.369	0.419	0.430	0.422	0.433

Table C.2 continued.

Panel C: Post-Lehman Period

Regression	A	B	C	D	E	F	G
Constant	**0.47**	**0.69**	**-13.94*****	**-16.48*****	**-16.05*****	**-18.93*****	**-18.72*****
	0.14	0.21	-5.10	-4.07	-3.95	-3.98	-4.02
Mortgage Jumbo Pfandbrief	**5.86**	**-7.74**	**-0.04**	**9.76****	**0.15**	**8.51****	**0.53**
	1.03	-1.52	-0.01	2.12	0.04	2.03	0.14
Public Traditional Pfandbrief	**40.81*****	**40.51*****	**48.42*****	**45.49*****	**45.87*****	**48.23*****	**48.46*****
	9.40	9.47	12.74	10.57	10.76	11.75	11.95
Mortgage Traditional Pfandbrief	**31.66*****	**24.65*****	**29.86*****	**34.82*****	**30.54*****	**36.50*****	**32.80*****
	6.27	4.94	6.09	6.99	6.17	7.47	6.79
AA Pfandbrief Rating		**28.22*****			**19.20*****		**16.35*****
		4.14			3.52		3.29
No Pfandbrief Rating		**-22.61*****			**-21.92*****		**-19.40****
		-2.74			-2.77		-2.41
A Issuer Rating			**20.71*****			**0.54**	**0.64**
			6.32			0.15	0.19
BBB/BB Issuer Rating			**55.98*****			**41.76*****	**38.14*****
			3.92			2.90	2.72
No Issuer Rating			**-7.76**			**-18.26**	**-8.00**
			-0.68			-1.22	-0.77
Relative Age				**29.26*****	**28.80*****	**27.30*****	**27.14*****
				4.80	4.85	4.61	4.66
Outstanding Amount				**-2.27**	**-1.84**	**-1.35**	**-0.99**
				-1.19	-0.97	-0.73	-0.54
Landesbank pre July 2005				**-21.41*****	**-21.53*****	**-19.91*****	**-19.94*****
				-5.85	-6.20	-4.52	-4.76
Landesbank post July 2005				**-17.31*****	**-18.39*****	**-16.06*****	**-16.90*****
				-5.52	-5.76	-3.98	-4.22
DEPFA				**103.15*****	**100.48*****	**104.04*****	**101.72*****
				20.05	19.12	20.74	20.05
HRE				**40.25*****	**32.90****	**41.87*****	**35.50*****
				3.28	2.58	3.38	2.79
N	625	625	625	625	625	625	625
Adjusted R^2	0.199	0.234	0.272	0.528	0.546	0.551	0.563

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