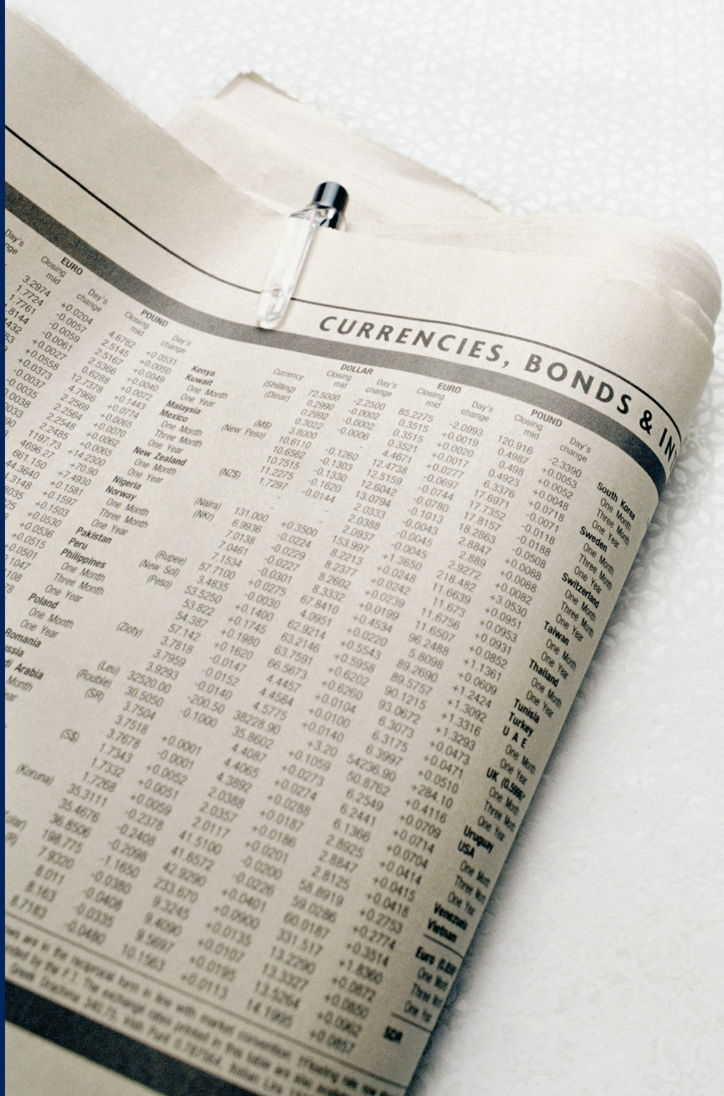
ALBERT MENTINK

Essays on Corporate Bonds



ESSAYS ON CORPORATE BONDS

Essays on Corporate Bonds

Essays over bedrijfsobligaties

Proefschrift

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Aan allen die wij eren en liefhebben

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Woord vooraf
(Preface in Dutch)

Bij AEGON komen vele interessante onderwerpen aan de orde die nadere studie waard zijn. Het schrijven van een proefschrift biedt de mogelijkheid ze diepgaand te bestuderen. Reden waarom ik, met instemming van AEGON, contact heb opgenomen met de Erasmus Universiteit Rotterdam en met name met Ton Vorst. Dit proefschrift heb ik onder zijn gedegen begeleiding en gebruik makend van de faciliteiten van AEGON kunnen voltooien.

Bijzondere dank ben ik dan ook verschuldigd aan mijn promotor Ton Vorst. Hij liet mij de betekenis van een vernieuwende probleemstelling, goede onderbouwing en pakkende samenvatting zien. Door voortdurend polijsten kwamen deze aspecten in de papers terug. Kortom: het is een voorrecht geweest onder zijn inspirerende begeleiding dit werk te verrichten. Daarnaast heb ik geleerd van de plezierige samenwerking met Patrick Houweling. Zijn gedrevenheid, programmeerkennis en precisie waren voorbeeldig. Ook zijn 'laten-wij-dit-nog-even-proberen' zal mij nog lang bijblijven. Deze samenwerking heeft geresulteerd in de hoofdstukken drie en vijf. Hoofdstuk zes is tot stand gekomen mede dankzij de specifieke kennis van Frank de Jong; dat heb ik zeer gewaardeerd. Naar de kleine commissie gaat mijn dank uit voor hun deskundig oordeel. Het aanbod van Marno Verbeek om dit proefschrift op te nemen in de Ph.D. Series Research in Management van het Erasmus Institute of Management heb ik geapprecieerd. Het Tinbergen Institute wil ik mijn waardering uiten voor de geboden studiefaciliteiten; Elli Hoek-van Dijke voor de prettige samenwerking.

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Annemieke Coldeweijer, Rani Piputri, Tim Jansen, Tjeert Keijzer en Roy Kouwenberg hebben de laatste versie van het proefschrift van commentaar voorzien; dit heb ik bijzonder gewaardeerd. Evenzo heb ik de hulp die Herman Geertsema van Concerndocumentatie mij bood bij het zoeken en opvragen van artikelen en boeken op prijs gesteld.

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Albert

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Chapter 1

Introduction

The introduction of the euro on January 1, 1999 created a large, single currency bond market by merging eleven separate bond markets. The euro-denominated corporate bond market has grown substantially ever since and has developed into a mature market. Now, a full maturity spectrum of euro corporate bonds exists. Many different sectors and all possible ratings are present and the secondary market is becoming more liquid as well. Corporate bonds are subject to interest rate, credit, liquidity and tax risk. Traditionally, most research in bond markets has been focused on interest rate risk and sometimes tax risk as well. Over the last few years, credit risk models and their applications have become increasingly important. More recently, modelling and estimating liquidity risk has generated a lot of attention. In this thesis, we will focus on some of these aspects. Below, we will give an introduction to several of the features mentioned above, concentrating especially on the euro corporate bond market. At the same time, this will provide the opportunity to place our chapters into this context. We will also give an overview of these chapters.

1.1 Euro Corporate Bond Market

Broadly, the aggregate investment grade euro-denominated bond market can be decomposed into a government, credit and securitized bond market.[1] Table 1.1 shows the breakdown of this entire market as of May 31, 2004. Further, the credit market can be split into corporate credit and non-corporate credit. From this table we see that the aggregate market consists for the largest part of the government market and for a smaller

[1]We follow the decomposition of the Lehman Brothers Euro-Aggregate Bond Index.

Table 1.1: Euro bond market structure (May 31, 2004)[a]

Aggregate market	5053	
Government market	3426	68%
Credit market	982	19%
Corporate credit market	807	16%
Non-corporate credit market	175	3%
Securitized market	644	13%

[a] in billions of euro

part of the credit and securitized markets. The euro corporate bond market represents 16% of the aggregate bond market.[2]

The aggregate euro bond market grew steadily during the period after the introduction of the euro as displayed in Figure 1.1.[3] Its constituents have also increased, with the exception of the securitized market. The corporate bond market has risen the most compared to the other markets, in absolute terms roughly 75%.

Over the past years, the euro corporate bond market has grown so rapidly for several reasons (Admiraal and De Bondt (2004)):

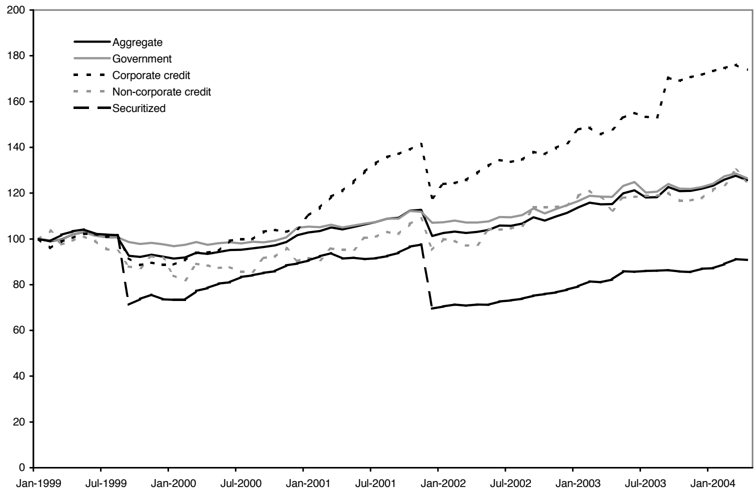
- The introduction of the euro has removed currency risk for European investors and has created a large, single currency market. This bigger market can more easily absorb bonds with a large issued amount.
- The strong economic growth during a long period.
- The growing expertise of credit bonds and derivatives on the side of institutional investors.
- The historically low nominal default-free interest rates have forced many investors to seek higher yields and consequently they have accepted more credit risk.
- The issuance of bonds by telecom companies to finance the UMTS network licenses and acquisitions.

Further, the institutional structure of the euro bond market, issuance pattern of government bonds, composition of investor base and market regulation rules, have also

[2] An analysis of the euro non-corporate credit market is given by Kouwenberg and Mentink (2005).

[3] All markets have been normalized to 100, starting January 1999. The drops in the curves are caused by adjusted index rules, for example: a rise in the minimum amount outstanding that produces a decline in the number of bonds that classify for entry in an index.

Figure 1.1: Euro bond market development (January 1999-May 2004)[a]



[a] Markets are normalized to 100 in January 1999.

developed. Chapter 2 explains these developments with respect to the bond market in the Netherlands.

Next, we give a snapshot of the maturity, rating and sector composition of the euro corporate bond market as of May 31, 2004, as demonstrated in Table 1.2 .[4] All maturities up to ten years are well represented. Low investment grade ratings (A and BBB) dominate and the financial and industrial sectors are most important in this market.[5]

The spectacular growth in the number bonds that are issued by the telecom sector relative to the entire corporate credit bond market can be seen from Figure 1.2. Starting in 2000, the sector's credit worthiness deteriorated fast and equity prices collapsed. These events triggered the introduction of a new type of bond in the euro corporate bond market: the step-up coupon bond: a bond "with embedded step-up covenants, i.e. provisions linking the cash flow of the bond to the rating of the issuer by increasing the coupons as the rating declines" (Lando and Mortensen (2004)). In Chapter 3, we describe and test empirically several models for step-up bonds.

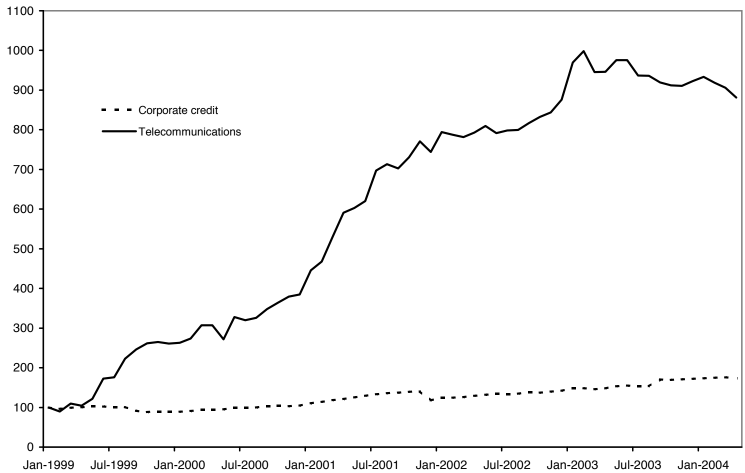
[4]The Lehman Brothers Euro-Aggregate Corporate Bond Index is a sub index of the Lehman Brothers Euro-Aggregate Bond Index employed above.

[5]With regards to the securitized market: all maturities are well represented, around 80% of this market is AAA rated and approximately 70% is backed by public sector or mortgage loans (May 31, 2004).

Table 1.2: Euro corporate bond market maturity, rating and sector distribution (May 31, 2004)

Maturity		Rating		Sector	
1-3	24%	AAA	9%	financial	45%
3-5	26%	AA	17%	industrial	45%
5-7	21%	A	41%	utility	10%
7-10	23%	BBB	33%		
10+	6%				

Figure 1.2: Euro corporate and telecommunications bond market development



Another phenomenon of the credit security market in general and also of the euro credit security market is the impressive growth of the credit derivatives market, most notably: the credit default swap market. "A credit default swap is a form of derivative security that can be viewed as a default insurance on loans or bonds. Credit default swaps pay the buyer of protection a given contingent (on default) amount at the time of a default event" (Duffee and Singleton (2003)). Due to this market growth, euro credit default swaps have often become more liquid than corresponding corporate bonds and they have developed into a standard reference for pricing issuer credit risk. Further, hedging of exotic synthetic CDOs, N-th to default baskets and Dow Jones TRAC-X drive corporate bond prices to a large extent (Duffee and Cunningham Yurday (2004*a*) and Duffee and Cunningham Yurday (2004*b*)).

With the growth of both the (euro) bond market and the credit default swap market, the method of trading these securities by institutional investors and banks has transformed. Instead of over-the-counter trading, single trading platforms where lists of banks quote securities are now employed. These trading platforms make bond markets more transparent. Two examples of such single trading platforms are: Bloomberg L.P. and TradeWeb™Ltd. The introduction of these platforms make new data available for research as these (single) platforms bring together bid and ask quotes from different investment banks with respect to the same bond at the same time. In Chapter 6, we have employed this new database in order to measure commonality in liquidity in euro security markets.

1.2 Corporate Bond Risks

Among others, Elton, Gruber, Agrawal and Mann (2004) have distinguished the following four factors that determine the return and risk of investment grade corporate bonds: interest rate, credit, liquidity and tax risk. We will describe each of these factors below.

1.2.1 Interest Rate Risk

Litterman, Scheinkman and Weiss (1991) defines the source of interest rate risk as the variation of (default-free) interest rates or the term structure of interest rates. Traditionally, the measures duration and convexity quantify the exposure of a bond with respect to interest rate risk. Interest rate risk of a portfolio of bonds can be computed by averaging the duration (plus convexity) of each bond in the portfolio using market weights.

In practice, the interest rate risk of a high investment grade sovereign bond portfolio can be measured using for example the of-the-shelf BARRA Inc. Cosmos portfolio risk model. This model computes the portfolio's interest rate risk with the help of both the usual duration and convexity, but also with the country specific level (shift), steepness (twist) and curvature (butterfly) movements of a (government) yield curve.

1.2.2 Credit Risk

Duffee and Singleton (2003) define credit risk as "the risk of default or of the reduction in market value caused by changes in the credit quality of issuers or counter parties". Credit risk can be measured using ratings from any one of the major, independent rating agencies. Moody's uses the ratings: AAA, AA, A, BBB, BB, B and CCC. Standard & Poor's (S&P) applies a comparable methodology and assigns: Aaa, Aa, A, Baa, Ba, B and Caa. Both rating agencies modify these ratings by adding notches and so produce intermediate ratings. Moody's attaches "+" or ("-"), while S&P appends "1", "2" or "3". For each rating, a historical, average probability of default is calculated based on companies with the same rating that have defaulted. Higher ratings, AAA, AA1, AA2, ... (Aaa, Aa+, Aa, ...) indicate a lower probability of default compared to lower ratings: B2, B3, CCC (B, B-, Caa).

Transition matrices from rating agencies describe the probabilities that a given rating will migrate to another rating over a given period, mostly one year, again based on historical observations. In general, the pattern of these transition matrices indicates that ratings in most cases either do not change or alter more than one notch within one year. However, recently, there have been some exceptions to this pattern such as the defaults of the companies Enron, Tyco International and WorldCom.

Another measure of credit risk is the risk-neutral probability of default. As Duffee and Singleton (2003) explain: "differences between historical and risk-neutral default probabilities reflect the risk premia associated with default. In general, default-risk premia reflect the aversion to both the risk of timing of default and to the severity of loss in the event of default".

Usually, risk-neutral default probabilities are derived from corporate bond and/or credit default swap market prices under the assumption that investors only need to be compensated for their expected pay offs, taken default into account, of the underlying. Reduced form models are usually based on this risk-neutral default probability (or its complement: the risk-neutral survival probability, one minus risk-neutral default probability).

Rating agencies also provide the recovery rates based on historical observations. For example, Moody's measures the recovery rate of a defaulted bond by its price in the secondary market one month after the default date (Hamilton, Cantor, West and Fowlie (2002)). In theoretical models, these recovery rates are often assumed constant. Acharya, Bharath and Srinivasan (2004) show in an extensive analysis of the recovery rates in the United States during the period 1982-1999 that recovery rates are a function of seniority and security (as expected), but also of industry conditions at the time of default.

In order to measure the amount of credit risk of a corporate bond, typically the yield difference (or credit spread) between a corporate bond and a comparable bond (priced using the swap curve) is calculated. In general, a higher spread indicates more credit risk. However, this spread can only be truly meaningful if the corporate and government bond are comparable in every other respect: interest rate, liquidity and tax risk.

1.2.3 Liquidity Risk

Maltz (2003) defines (asset) liquidity as: "an asset is said to be liquid if it is "near" or a good substitute for cash. When used to describe a market, liquidity refers to the ability to maintain a position and unwind in an orderly fashion without excessive transaction costs and without excessive price deterioration."

Ideally, the liquidity risk of corporate bonds is quantified directly, with the help of bid-ask spreads and/or trade flows. We will use bid-ask spreads of euro-denominated corporate bonds in Chapter 6. Often however these data are not reliable or not available (over long time periods) and consequently liquidity risk is approximated, for example De Jong and Driessen (2004) use, among other data, credit spreads to this end. We also quantify liquidity indirectly and use the difference between corporate bond yield and synthetic yield, where the synthetic yield corrects the corporate bond yield for interest rate, credit and tax risk. In Chapter 5, we will employ this indirect approach.

1.2.4 Tax Risk

According to Shiller and Modigliani (1979) the existence of tax risk can be explained by the favorable tax treatment in U.S. tax law of capital gains in bonds in contrast to coupon payments. However, this difference in treatment can change due to new tax laws. In general, this type of risk is quantified with the help of the coupon of a bond versus the (average) coupon of comparable bonds, where a higher coupon should indicate the presence of tax risk.

1.3 Credit Risk Models

1.3.1 Structural Approach

Generally, credit risk models can be classified into two approaches: the structural approach and the reduced form approach. Black and Scholes (1973) and Merton (1974) have pioneered the structural approach. This type of model assumes that the total assets of a company are equal to the sum of the market value of equity and liabilities. A lognormal diffusion process describes the dynamics of these total assets. If the value of the assets is smaller than or equal to the debt book value at maturity, the company goes into default. In this case, the equity holders receive nothing and the bondholders get the residual firm value. Hence, the value of the equity can be seen as a call option on the assets of the firm with strike price equal to the debt. So, the value of the company's equity can be obtained by applying the Black-Scholes call option formula, with the assets as the underlying variable and the debt book value as strike. By put-call parity, we get the alternative interpretation that the bond holder has written a put on the total assets of the firm. Thus, the value of the company's debt can be calculated by subtracting this equity call option value from the total asset value.

The main advantage of this model is that it is conceptually very appealing. However, the disadvantages are that the original model is not easy to implement in practice as market value of assets and asset volatility are difficult to estimate and capital structures are often not that simple. Further, this approach tends to underestimate default probabilities and consequently adjustments have to be made (RiskMetrics Group (2002)). Therefore, in applications of this approach many different modifications of the original model's parameters have been implemented. This type of model is most often employed in risk management: generating corporate bond spreads, predicting rating migrations and forecasting default.

An example of a popular, commercial structural model is Moody's KMV™ model. This model calculates the so-called Expected Default Frequency™ (EDF™): the probability of default during the forthcoming year (Crosbie and Bohn (2003)). Another example is the CreditGrades™ model supported by Deutsche Bank, Goldman Sachs and J.P. Morgan. The primary objective of this model is to calculate a par credit default swap spread (RiskMetrics Group (2002)).

1.3.2 Reduced Form Approach

Now, we turn to the reduced form approach. Instead of endogenously determined default (based on company asset value), this class of models assumes that default occurs exogenously at a historical default rate or at the first jump in a conditional (on no previous default) stochastic process, usually a stochastic Poisson process driven by a hazard rate (or intensity) process. This hazard rate can be interpreted as the conditional, instantaneous probability of default. Assuming no arbitrage opportunities, the theoretical price of corporate bonds can be derived under an equivalent martingale measure (Dai and Singleton (2003)). Litterman and Iben (1991) have pioneered this approach. Many theoretical extensions and refinements of their approach have been made with respect to the modelling of the hazard rate, the recovery rate and the correlation between default-free interest rate and hazard rate; see for example Duffee and Singleton (2003).

The advantage of this type of model is the ease in calibrating the values of its parameters with the help of market prices of liquid corporate bonds (and credit default swap market prices). Yet, modelling of the recovery rate remains difficult in this type of models. This type of model is often used for pricing and hedging of (portfolios of) credit securities, for example: credit default swaps (Houweling and Vorst (2005)). We utilize this approach in the valuation of euro step-up bonds that have been issued by telecom companies, in Chapter 3.

The CreditMetrics^{TM} model (CreditMetrics) (J.P. Morgan (1997)) is a popular, commercial product based on reduced form models. This credit risk portfolio model calculates changes in the value of bonds due to changes in their credit quality. These changes are caused by possible default or rating upgrades or downgrades. Further, the CreditMetrics model produces credit Value-at-Risk measures of portfolios using a Monte Carlo simulation and computes expected loss. In Chapter 5, we have minimized the Conditional Value-at-Risk of a credit bond portfolio employing the CreditMetrics model.

1.4 Overview

In the above, we have referred to the chapters (or papers) in this dissertation in relation to the euro corporate bond market, credit risk models and corporate bond risks. Now, we will summarize these chapters, starting with Chapter 2, the Bond Market in the Netherlands. This chapter describes the institutional structure of the bond market in The Netherlands as part of the larger euro bond market. The introduction of the euro on January 1, 1999 changed the shape of the small market for Dutch bonds. The Dutch government had to find ways to improve the liquidity of their bonds as currency differences between countries disappeared. The euro also influenced Dutch corporate bond issuers, which have become part of the growing euro-denominated credit bond market. In this newly established bond market, a company's home country has become less important than it's rating and sector. The investor base of both Dutch government bonds and corporate bonds has also become more international. So it is clear that both issuers and investors have been affected by the introduction of the euro. One area of common ground for issuers and investors is the EuroNext Amsterdam Stock Exchange, which has now merged with exchanges in Europe, and, most important, the OTC bond markets. There have also been changes to the Dutch financial supervision regime since Dutch supervision has moved from a largely sector-oriented regime, to one that is more cross-sectional based. Finally, ratings agencies also have an impact through their assessment of Dutch government debt and corporate bonds.

Part I describes credit risk of corporate bonds (Chapters 3 and 4). First, in Chapter 3, we value rating-triggered step-up bonds using three different reduced form models: a risk-neutral valuation framework; a similar framework based on historical probabilities; and as plain vanilla bonds. The market seems to value single step-up bonds according to the first model, while it values multiple step-up bonds as plain vanilla bonds. Further, step-up feature market premiums are more volatile than risk-neutral or historical premiums, and the risk-neutral model always approximates market premiums better than the historical method. Finally, most step-up bonds offer a cushion against rating migrations via dampened price movements.

Next, Chapter 4 examines the optimization of a corporate bond portfolio using the CreditMetrics model. Optimal portfolios of credit bonds are less risky, while having at least the same expected return. In this chapter, we investigate whether the "optimal" bond portfolios are really an improvement by analyzing the characteristics of the individual bonds in the optimal portfolio. We find that a portfolio manager should be careful in carrying out the trades as suggested by the portfolio optimization routine because only one or two bonds dominate optimal portfolios. Moreover, the composition of such an optimal portfolio is very sensitive to small changes in the expected forward price of its main constituents. However, portfolio optimization can be used in combination with some common sense restrictions to produce portfolios that both have a lower risk and higher return than a fully diversified portfolio. We also improve on the portfolio by replacing the dominant bond in the optimal portfolio by similar bonds. As a risk measure we use the Conditional Value-at-Risk (CVaR), which at a given percentile equals the expected value of the losses that exceed the Value-at-Risk (VaR) at that percentile. CVaR also provides information about the losses larger than the VaR. Furthermore, the CVaR can be optimized using linear programming.

Part II studies liquidity risk of corporate bonds (Chapter 5 and 6). In Chapter 5, we consider nine different proxies (*issued amount*, *listed*, *euro*, *on-the-run*, *age*, *missing prices*, *yield volatility*, *number of contributors* and *yield dispersion*) to measure corporate bond liquidity and use a four-variable model to control for interest rate risk, credit risk, maturity and rating differences between bonds. The null hypothesis that liquidity risk is not priced in our data set of euro corporate bonds is rejected for eight out of nine liquidity proxies. We find significant liquidity premia, ranging from 13 to 23 basis points. A comparison test between liquidity proxies shows limited differences between the proxies.

In Chapter 6, we concentrate on the commonality in liquidity, return and volatility of the euro-denominated corporate bond, government bond and equity markets. We apply the Chordia, Sarkar and Subrahmanyam (2003) VAR approach using both daily and weekly frequency. Based on our VAR model we run impulse response functions and we find that commonality in liquidity between euro security markets indeed exists. Furthermore, links between liquidity and return and volatility within and between euro security markets can also be strong. Granger causality tests support these results. As we introduce a new corporate bond data set we also compare the average characteristics of frequently quoted and not frequently quoted corporate bonds. We find that the frequently quoted part has a lower average *age*, higher *coupon*, larger *issued amount*, longer *maturity*, lower *rating* and higher *equity market value* than its not frequently quoted counterpart for the total period September 2002 to September 2003.

Finally, in Chapter 7 we review the summaries and conclusions of Chapter 2 and the Parts I and II.

Chapter 2

Dutch Fixed Income Market[1]

2.1 Introduction

The introduction of the euro on January 1, 1999 changed the shape of the small market for Dutch bonds. The guilder bond market disappeared and was absorbed by the large euro-denominated bond market, with the guilder becoming one of the eleven legacy currencies. Before the introduction of the euro, the government yields of the future Euro Member States had already converged; the 10-year government yield spread between Germany and the Netherlands for example was only nine basis points at December 31, 1998 (Bloomberg L.P.) So, for medium-sized government bond issuers, such as the Dutch government, the euro introduction meant that they had to find a way to improve the liquidity of their bonds. The euro also influenced the Dutch corporate bond issuers, which have become part of the growing euro-denominated corporate bond market. In this newly established bond market, a company's home country has become less important than it's rating and sector.

The investor base of both Dutch government bonds and corporate bonds has also become more international. Large institutional investors, both European and non-European, are also now investing in euro corporate bonds that are issued by Dutch companies. So, it is clear that both issuers and investors have been affected by the introduction of the euro. One area of common ground for issuers and investors is the Amsterdam Stock Exchange (AEX), which has now merged with exchanges in Brussels, Lisbon and Paris into Euronext, where Dutch government bonds, corporate bonds, issued by both domestic and foreign companies, and other types of bonds are all listed. Small and

[1]This chapter is based on the chapter "The Netherlands" by Mentink (2004) in the book "European Fixed Income Markets, Money, Bond and Interest Rate Derivatives", published by John Wiley & Sons, Ltd.

irregular bond trades dominate Euronext Amsterdam, suggesting that retail investors are the main participants in this part of the bond market. In contrast, institutional investors mainly trade over-the-counter (OTC) with investment banks. These same institutions are increasingly involved in web trading.

There have also been changes to the Dutch financial supervision regime. As Jonk, Kremers and Schoenmaker (2001) explain, supervision has moved from a largely sector-oriented regime to one that is more cross-sectional based. The driving force behind this reform is the continuing financial market integration, with banks and insurance companies increasingly involved in selling each other's products. The Dutch supervisors want their structure to reflect these market developments although there is still some debate between the different European supervisors over the best way to implement a Europe-wide regime. In addition to this changing national supervision, ratings agencies also have an impact through their assessment of Dutch government debt and corporate bonds.

The content of this chapter consists of the following. First, in Section 2.2, the economic background of the Netherlands is given by analyzing its main economic indicators. Next, the tasks of De Nederlandsche Bank (Dutch Central Bank) and the Ministry of Finance are reviewed. Section 2.3 discusses details of the Dutch government bonds. Both guilder corporate bonds and euro corporate bonds that are issued by Dutch companies are analyzed in Section 2.4. The investors in these Dutch government bonds and euro corporate bonds are discussed in Section 2.5. Euronext Amsterdam and OTC trading bring issuers and investors together as explained in Section 2.7. Dutch government regulators and private rating agencies that are active in the Dutch fixed income market are described in Section 2.7. Finally, Section 2.8 summarizes.

2.2 The Netherlands

2.2.1 Economic Background

During the period 1996-2000, the Dutch economy performed very well as the real gross domestic product (GDP) growth averaged 3.7 percent per year. The breakdown of Dutch GDP is presented in Table 2.1. This shows the national accounts of the Netherlands in the year 2000 both in billions of euro and in percentage of GDP. The table demonstrates that the Netherlands is an open economy, as imports and exports as a percentage of GDP equal 62.4 and 67.2 respectively. Therefore, the downturn in the global economy that started in 2001 also slowed economic growth in the Netherlands. Moreover, rising oil prices, falling stock prices, stabilizing house prices and animal diseases that led to a fall

Table 2.1: Dutch national accounts (2000) (OECD (2002))[a]

Private consumption	199.9	49.8%
Public consumption	91.2	22.7%
Gross fixed investment	90.9	22.7%
Stock building	-0.4	-0.1%
Exports	269.6	67.2%
Imports	250.1	62.4%
GDP	401.1	

[a] in billions of euro

in exports all had a negative effect on economic growth (International Monetary Fund (2002)). In 2003, economic growth did not return and became negative.

Table 2.2 shows the percentage changes in national accounts, prices, wages and employment, personal sector, external trade and public sector accounts of the Netherlands for the years 1997-2001, 2002 (estimation) and 2003 (projection) (International Monetary Fund (2002)). All elements of GDP increased during the period 1997-2000, although imports often grew faster than exports, except in 2000, and gross fixed investments grew faster than both private and public consumption. In addition, employment rose and unemployment fell from 5.5% in 1997 to 2.6% in 2000. Both the growth of real disposable income and the savings ratio were lower in 1999 and 2000 compared to 1997 and 1998. The current account balance showed a surplus during the whole period, despite the fact that imports increased faster than exports. The general government gross debt fell dramatically owing to surpluses starting in 1999 and GDP growth.

On the other hand, this strong economic growth caused the consumer price index and GDP deflator to rise. Both were higher than those in other Euro-zone countries, and hourly labor compensation and unit labor costs also rose in 2001, 2002 and 2003. Consequently, in 2001 and 2002, GDP growth lowered compared to the preceding years with negative growth in 2003. Government consumption growth remained high compared to the other GDP elements; the employment rate lowered, the unemployment rate rose and the general government surplus became smaller and again negative.

The prospects of the revival of economic growth in the short term remain gloomy as industrial and consumer confidence are still at low levels. Important risk factors for the Dutch economy (International Monetary Fund (2002)) are the appreciation of the euro against other main currencies (damaging exports), rising oil prices producing inflation and falling house prices causing lower consumption and distress in the financial sector.

Table 2.2: Percentage changes[a] in the Dutch national accounts[b], prices, wages and employment, personal sector, external trade and public sector accounts for the years 1997, 1998, 1999, 2000, 2001, 2002[c] and 2003[c] (IMF (2003))

National accounts	1997	1998	1999	2000	2001	2002	2003
National accounts							
Private consumption	3.0	4.8	4.7	3.6	1.2	0.9	1.2
Public consumption	3.2	3.6	2.5	1.9	3.1	3.7	1.1
Gross fixed investment	6.6	4.2	7.8	3.5	-0.8	-3.7	-4.0
Exports	8.8	7.4	5.1	10.9	1.7	-1.4	1.1
Imports	9.5	8.5	5.8	10.6	1.9	-2.1	3.1
GDP	3.9	4.3	4.0	3.4	1.2	0.2	-0.2
Prices, wages and employment							
Consumer price index (year average)	1.9	1.8	2.0	2.3	5.1	3.9	2.6
GDP deflator	2.0	1.7	1.5	4.1	5.3	3.2	3.0
Hourly compensation (manufacturing)	3.0	3.2	2.9	3.7	4.2	3.8	3.3
Unit labor costs (manufacturing)	-0.7	1.3	0.9	0.1	5.0	2.8	2.1
Employment	3.4	3.3	3.0	1.6	2.4	1.1	-0.4
Unemployment rate	5.5	4.2	3.2	2.6	2.0	2.3	3.8
Personal sector							
Real disposable income	3.4	4.5	1.0	2.1	4.0	1.5	0.3
Household savings ratio	13.4	12.9	9.7	6.9	9.8	10.8	10.2
(Percentage of real disposable income)							
External trade							
Exports of goods (volume)	9.2	7.4	5.3	10.3	1.7	-0.7	0.8
Imports of goods (volume)	10.5	8.3	6.4	9.8	1.0	-2.6	2.8
Terms of trade	0.5	0.1	-1.5	0.0	1.0	0.2	0.4
Current account balance (percentage of GDP)	6.6	3.3	3.2	1.2	2.1	2.2	3.5
Public sector accounts (percentage of GDP)							
Revenue	47.1	46.4	47.6	47.4	46.5	46.1	45.6
Expenditure	48.2	47.2	46.9	45.3	46.4	47.3	47.8
General government balance	-1.1	-0.8	0.7	2.2	0.1	-1.2	-2.1
General government gross debt	70.0	66.8	63.1	55.8	52.8	52.6	52.5

[a] unless otherwise noted
[b] constant prices
[c] estimation

Nationally, the political situation was uncertain as the newly elected Dutch government resigned after only three months in office, while usually elections are held every four years. New elections were held in January 2003.[2]

[2]For a further explanation of the performance of the Dutch economy in an international perspective, see Ministry of Economic Affairs (2002).

2.2.2 Financial Sector

The Dutch financial sector can be typified by the following five main characteristics (European Central Bank (2002)). Compared to other Euro-zone countries, this sector is large as a percentage of GDP. The sector's intermediary functions, such as bank lending, are important. Much of the dealing in this area occurs between financial institutions. The banking sector is very concentrated, with only four banks controlling 80% of the Dutch lending market and the sector has an international focus with, for example, large operations in the United States. Within the sector there is much cross-sector consolidation such as banks selling insurance products and vice versa.

Institutional investors, both pension funds and the investment portfolios of insurance companies, constitute a considerable segment of the Dutch financial sector. For most employees, it is compulsory, not optional, to participate in a funded pension scheme. Therefore, Dutch pension funds manage huge investment portfolios compared to other countries in the Euro-zone, with ABP, the government employees' pension fund, controlling an investment portfolio of 150 billion euro in 2000 (European Central Bank (2002)).

2.2.3 De Nederlandsche Bank (DNB, Dutch Central Bank)

On January 1, 1999, the independent monetary policy of De Nederlandsche Bank disappeared. Seven months earlier, on June 1, 1998, DNB officially became part of the European System of Central Banks (ESCB), where the Governor of DNB took a seat in the Governing Council. Two of the tasks undertaken by DNB, numbered 1 and 2 below, are also known as the ESCB tasks. Under the 1998 Bank Act, the full list of DNB tasks reads as follows:

1. "Within the framework of the ESCB, the Bank shall contribute to the definition and implementation of monetary policy within the European Union (EU). The Bank's objective is to maintain price stability. Without prejudice to this objective, the Bank shall support the general economic policy in the EU.

2. The Bank shall hold and manage the official foreign reserves and shall conduct foreign-exchange operations.

3. The Bank shall collect statistical data and produce statistics.

4. The Bank shall promote the smooth operation of payment systems and take care of the banknote circulation.

5. The Bank shall supervise banks, investment institutions and exchange offices (see also Section 2.7 below.)

The Bank may, subject to permission by Royal Decree, perform other tasks in the public interest. The ECB may also ask the Bank to perform extra tasks" (Appendix 2.A, DNB.)

Figure 2.1: DNB organizational structure (DNB (2002))

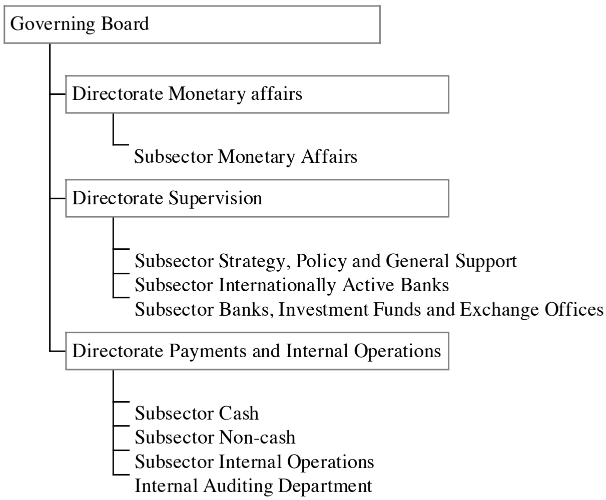


Figure 2.1 shows the organizational structure of DNB: three main directorates - Monetary Affairs, Supervision and Payments and Internal Operations - each directorate subdivided in sections and departments. "The Monetary and Economic Policy department plans the monetary policy to be pursued by DNB. Planning the positions to be taken with regard to monetary and macro-economic matters in the (inter)national fora in which DNB takes part. The Research department carries out pure research, model building and maintenance, historical research and consultative activities. The Export and Import Credit Guarantees department is involved in the reinsurance by the Dutch government of foreign payment risks in respect of exports, imports and investment transactions and any attending foreign exchange risks. The Financial Markets department plans and implements the market-oriented policy conducted by DNB in respect of the money, foreign

exchange and capital markets. Investing DNB's gold and foreign exchange holdings, the general reserve, DNB's pension fund and the balances on staff accounts. The Statistical Information and Reporting department compiles, processes and provides (standard) data for monetary supervision, socio-economic policy and prudential supervision."

"The directorate Supervision consists of eleven sections. The Policy section draws up rules and regulations (including the reporting framework) relating to banking supervision, prepares (inter)national policy consultations. The Strategy section makes long term analyzes of supervisory issues. Internationally active banks section exercises supervision on large banking institutions, which operate internationally. Payment systems and information technology section exercises supervision on payment systems, payment products and providers of payment services. The Banks section exercises supervision on credit institutions subject to supervision. The Investment funds and exchange offices section performs DNB's tasks ensuing from the Act on the supervision of investment institutions and the exchange offices Act and planning the policy to be pursued in these areas" (Appendix 2.A, DNB).

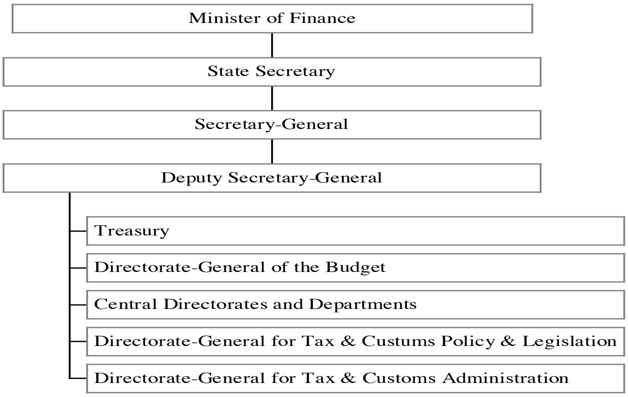
2.2.4 Ministry of Finance (MoF)

The Dutch Minister of Finance is primarily responsible for financial policy, although the Dutch Council of Ministers also has an input. This relationship applies between the different ministries since the Dutch Ministry of Finance shapes financial and economic policies in conjunction with other Government Ministries. Thus, MoF is responsible for fiscal policy, i.e. overall financial policy and the management of government funds. Therefore, MoF is involved in both government income and expenditure and looks at how government spending can best be financed, i.e. via taxes or from issuing government bonds. MoF is also responsible for both drafting and executing tax legislation. Three quarters of government income is raised via taxation. The Tax and customs administration, also part of this Ministry, is responsible for the actual collection of taxes and duties (Appendix 2.A, MoF).

The organization structure of MoF appears in Figure 2.2, which shows the four Directorates-General: Treasury, Budget, Tax & Customs Policy & Legislation and Tax and Customs Administration, together with the Central Directorates and Departments (Appendix 2.A, MoF).

"The financial and economic policy fall within the sphere of activity of the Treasury. The Treasury is comprised of six policy Directorates. The responsibilities of the Directorate-General are concerned with the coordination of fiscal policy. The Directorate-

Figure 2.2: MoF organizational structure (MoF (2002))



General is comprised of four Directorates. The Directorate-General for Tax and Customs Policy and Legislation is responsible for drafting national and international tax policy and for the incorporation of these in legislation and international agreements. Once legislation has been published in the Bulletin of Acts, Orders and Decrees it enters the realm of the Directorate-General for the Tax and Customs Administration. This Directorate is responsible for the implementation of tax legislation and non-tax legislation charged to the Administration. The Directorate-General draws up implementing regulations, which are laid down in instructions and resolutions" (Appendix 2.A, MoF).

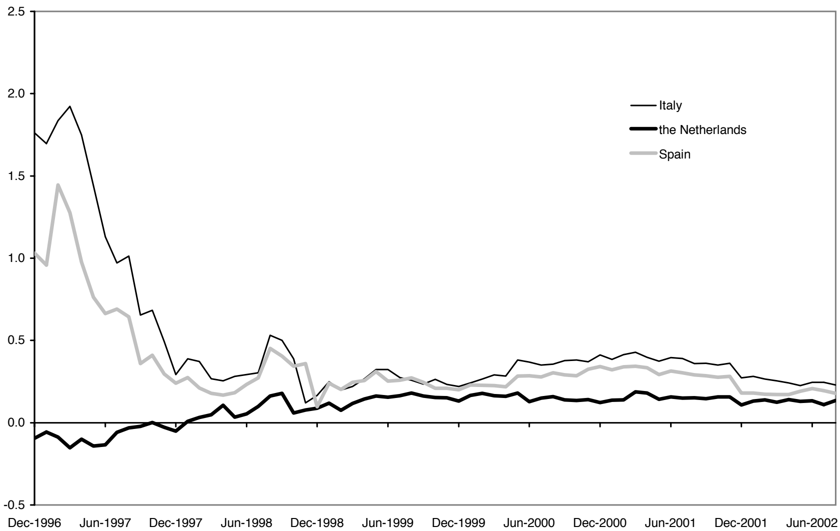
2.3 Government Bonds

2.3.1 Government Bond Market

In the run up to the introduction of the euro, the yield spread between government bonds of the future EMU Member States gradually narrowed. In other words, these government yields converged, because currency risk premiums faded and national monetary polices merged into one (Galati and Tsatsaronis (2001)). Figure 2.3 provides the calculated spreads of three EMU members, Italy, the Netherlands and Spain, for the period December

31, 1996 to August 31, 2002, on a monthly basis.[3] This figure demonstrates the yield convergence as the spread between Italy and Spain versus Germany decreased. Of particular note is the very small yield spread between the Netherlands and Germany.

Figure 2.3: 10-Year yield spread of Italy, the Netherlands and Spain, over the 10-year German yield (December 31, 1996-August 31, 2002) (Bloomberg L.P. (2002))



Although government yields have converged, small spreads still exist. In general, these spreads can be explained by differences in fiscal policy, ratings and liquidity. Typically, the Dutch government yields are only a few basis points higher than those in Germany, for example: the 10-year spread was only 13 basis points as of the end of August 2002. Rating differences are not a factor as their Moody's and Standard & Poor's ratings are the same, i.e. Aaa/AAA. Moreover, the fiscal policy of each country is formally constrained by the "Stability Pact"; which leaves both countries little room to manoeuvre. So, yield differences between these two government curves can best be explained by liquidity differences.

From a Euro-zone perspective, the Dutch government is a medium-sized issuer of debt in terms of total amount of debt outstanding. Table 2.3 presents the percentage

[3]Subtracting the 10-year yield of German government bonds from the 10-year yield of government bonds from Italy, the Netherlands and Spain gives the yield spread against Germany. As the German yield curve is the benchmark curve in the Euro-zone, this yield is used here as the reference yield.

Table 2.3: Percentage distribution of nominal euro-denominated government debt by Euro-zone country (June 30, 2002) (ECB (2003))

Austria	2.9%
Belgium	6.5%
Finland	1.3%
France	19.2%
Germany	22.0%
Greece	3.0%
Ireland	0.6%
Italy	30.0%
Luxembourg	0.0%
the Netherlands	4.9%
Portugal	1.5%
Spain	8.1%

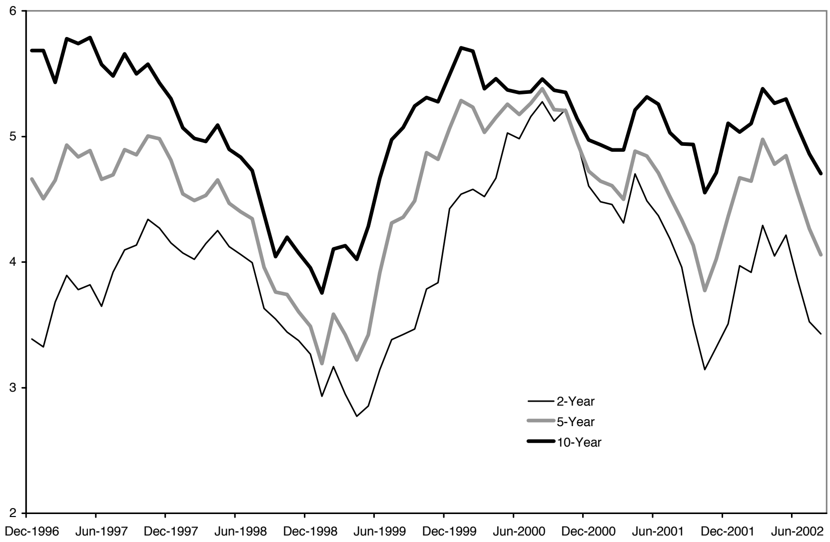
distribution of total nominal euro denominated debt, both short and long term, of each Euro-zone member state at the end of June 2002. As this figure demonstrates, the Dutch government is not a very large debt issuer compared to France, Germany and Italy. As a result, it is important for the Dutch government to make its debt securities as liquid as the debt of these larger countries. Section 2.3.2 below will describe how this goal of increasing liquidity is implemented by the Dutch government. Like the Dutch government, many governments attach high importance to the maintenance of liquid markets for their bonds (Bank of International Settlements (2001)).

Dutch government 2-, 5- and 10-year yields are displayed in Figure 2.4 for the same period December 31, 1996 to August 31, 2002, again on a monthly basis. During this period, the slope of the Dutch government yield curve was always positive. During the months June to October 2000, the yield curve was very flat as the 2-, 5- and 10-year yields were very close to each other. From June 1997 to February 1999, the 10-year yields decreased to around 3.75%, then rose again to a peak of approximately 5.7% in January 2000 before falling once more to 4.7% in August 2002.

2.3.2 Dutch State Treasury Agency (DSTA, Agentschap van het Ministerie van Financiën)

The Dutch State Treasury Agency (DSTA), part of MoF, is the debt manager of the central government of the Netherlands. It conducts the sale of both Dutch Treasury

Figure 2.4: Dutch government 2-, 5- and 10-year bond yields (December 31, 1996-August 31, 2002) (Bloomberg L.P. (2002))



Certificates (DTCs) and Dutch State Loans (DSLs) to fund the central government borrowing requirement and accounts for public debt principal and interest payment (Appendix 2.A, DSTA). The following section outlines DTCs and DSLs, their auction process, primary dealers, market conventions, debt restructuring program and other government bond types.

DTCs and DSLs

DSTA manages the Dutch central government liquid funds. In the event of needing to raise funds, DSTA can issue DTCs, which are discount or zero coupon bills with initial maturity of 3, 6, or 12 months. DSTA started issuing DTCs in January 1997. During 2002, DTCs were issued twice a month, on the first and third Monday. Typically, two maturities are auctioned during each issue.

DSLs are issued with three target maturities of 3-, 10- and 30-years and therefore do not cover the whole range of maturities. These new issues are in bullet form. Typically, issuance of DSLs takes place on a regular basis, on the second Tuesday of the month. Each quarter, the maturity and targeted volume of the issues are announced. The issuance calendar includes all issue and settlement dates and is available on their web site (Appendix 2.A, DSTA). At the end of October 2002, the benchmark DSLs for the three maturity segments were as follows (DSTA):

- 3-year segment: 4.0% July 15, 2005
- 10-year segment: 5.0% July 15, 2012
- 30-year segment: 5.5% January 15, 2028

Auction Process

Since January 17, 2000, DTCs have been auctioned on a uniform price basis, the so-called Dutch auction. Primary dealers (for a full list see below), as well as seven single market specialists can subscribe between 11.00 and 12.00 a.m. Amsterdam time. After this subscription has closed, DSTA will determine the uniform issuance yield. Subscriptions lower than this issuance yield will get a full allocation, subscriptions tendered equal to the issuance yield may get allocated in full or only in part. The issuance yield and total assigned volume will be published by DSTA.

DSTA, with regard to DSLs issuance, works with the following procedure:

"In general, on Friday preceding the issuance of the first tranche of a new bond, the coupon rate, which is relevant for the determination of the yield to maturity, is announced. In addition, the terms and conditions of DSLs apply to the issue, as well as the various ways of settlement. On the day of issue at 10:00 a.m. Amsterdam time, the initial issue price will be announced. It may be revised at any time. Primary dealers and other parties admitted by the DSTA can put buying orders. Individuals are advised to contact a primary dealer, another bank, or a commissioner" (Appendix 2.A, DSTA).

Primary Dealers

The Dutch state has contracted the services of 13 financial institutions to constitute its group of primary dealers for the year 2002. Each primary dealer commits to take, distribute and promote DSLs (Appendix 2.A, DSTA). The list of those primary dealers is: ABN AMRO Bank, BBVA, Credit Suisse First Boston, Deutsche Bank, Fortis Bank, ING Barings/BBL, J.P. Morgan, Merrill Lynch, Morgan Stanley, NIB Capital, Rabobank International, Schroder Salomon Smith Barney and Société Générale.

Market Conventions

The market conventions of both DTCs (DSTA) and DSLs (Bennett, Brusadelli and Simons (2001)) regarding market, accrued interest and settlement characteristics and trading

Table 2.4: DTCs and DSLs market conventions

	DTCs	DSLs
Market characteristics		
Longest maturity issued (years)	1	30
Typical denomination (local)	1	1
Typical outstanding per issue (local, millions)	3.000 - 5.000	10.000 - 20.000
Accrued interest characteristics		
Coupon (date)	discount	annual
Accrual basis	actual	actual
Year basis	360	actual
Holidays	target	target
Settlement characteristics (time frame)		
Domestic investors	t+2	t+3
International investors	t+2	t+3
Trading basis		
Quotation	yield	price (clean)
Tick	decimal	decimal
Bid-ask spread	1–3 bp	0.03–0.20 cents
Commission (%)	0	0
Tax (non-resident, %)	0	0
Typical transaction size (local, millions)	10 - 100	10 - 50
Price/yield method	ISMA discount basis	ISMA

basis are listed in Table 2.4. In this table, TARGET, t, bp and ISMA stand for the payment system consisting of the interlinked real-time gross settlement systems of the EU Member States (Trans-European Automated Real-Time Gross Settlement Express Transfer), trading day, basis points and International Securities Market Association respectively. In terms of trading basis, the figures associated with the bid-ask spread, commission and transaction size apply to the OTC market in Amsterdam and London. As for the typical transaction size, it must be noted that in the OTC market often smaller transactions are also executed. Tax in this table refers to withholding tax on interest payments.

There are three methods for clearing and settlement of DSLs and DTCs (Appendix 2.A, DSTA):

1. "Fully domestic, through Necigef, the Dutch clearing institute. The paying agent is DNB.

2. Directly through Euroclear, or via Necigef with ABN AMRO Bank as cash correspondent and depository.

3. Directly through Cedel, or via Necigef with Rabobank as cash correspondent and Kas Bank as depository for DSLs and ABN AMRO Bank as depository for DTCs."

Debt Restructuring Programme

As indicated above, the Dutch central government wants to improve the liquidity of its bonds by concentrating on large liquid issues.

"In order to accelerate the process of concentration of government debt into a smaller number of large volume benchmark issues and to increase market liquidity, DSTA developed a debt restructuring programme. The concentration process had already started by limiting the issuance of DSLs to mainly two maturity segments, i.e. three- and ten-year and by reducing the number of new issues to two per year. In addition, an exchange offer was set up to enable conversion of smaller size issues. Hence, investors could benefit from the resulting liquidity increase, thereby avoiding the transaction costs of illiquidity. The restructuring programme made it possible to withdraw smaller bonds from the market and to replace them for liquid ones. As a result a total amount of over 30 billion euro has been added to liquid bonds and the Dutch government debt has been concentrated in some 15 large liquid bonds, with an average outstanding size of 10 billion euro" (Appendix 2.A, DSTA).[4]

Other Government Bond Types

Apart from DTCs and DSLs, the Dutch state has also issued other types of bonds, although these only represent a tiny portion of the total Dutch government debt. An example is STRIPS, Separate Trading of Registered Interest and Principal of Securities. This is a zero coupon bond. From February 15, 1993, onwards, MoF allowed trading in STRIPS and DTSA makes a market in them by issuing STRIPS and buying back DSLs or vice versa. This should ensure STRIPS (and DSLs) are priced efficiently. STRIPS are also traded at Euronext Amsterdam. Table 2.5 shows three DSLs that are partly stripped (Toorman (1997)). The liquidity of STRIPS remains low as can be inferred from the small nominal amounts outstanding.

DSTA has also issued perpetual bonds, i.e. bonds without a maturity date. As with STRIPS, the liquidity of perpetuals is low. As Wouters (2001) states, inflation indexed

[4]The results of these operations are also described at the DSTA website.

Table 2.5: Three partly stripped DSLs

DSL maturity	Stripped DSL nominal amount[a]	Stripped DSL[b]
2028	0.40	4.50%
2023	1.75	21.20%
2004	1.06	11.40%

[a] in billions of euro
[b] percentage of total DSL nominal amount

bonds, such as issued recently by the French state, have not been issued by the Dutch state.

Futures

The most liquid standardized bond futures in the Euro-zone are the Bund (10-year), Bobl (5-year) and Schatz (2-year) future, traded at the exchange Eurex. These futures have German government bonds as their underlying asset, not Dutch government bonds. Because the German and Dutch government yields have converged and now move in tandem, interest rate risk of Dutch government bonds can be hedged with Bund, Bobl and/or Schatz futures, because the basis risk is small.

2.4 Corporate Bonds

2.4.1 Guilder Corporate Bond Market

After the introduction of the euro, the small Dutch guilder corporate bond market was absorbed by the large euro-denominated bond market. Investors now usually judge corporate bonds on sector and rating, the issuer's country has become less important. For example J.P. Morgan's Telecom sector report by Levene, Marchakitus and Soderberg (2002) is a clear example of this new approach. One exception to this sector-based approach is the banking and insurance sector in the Euro-zone. Here the country of residence is still important because of the persistent differences in national regulatory environments and the dependency on home markets.

There has been little published research about the Dutch guilder corporate bond market, one exception being Oorschot and Stork (1995). They analyzed the relationship between credit spreads of Dutch corporate bonds and long term interest rates, economic

Table 2.6: Guilder corporate bond market statistics

Rating	Aaa	Aa1	Aa2	Aa3	A1	A2	A3
	58%	11%	15%	13%	1%	1%	1%
Maturity	1-3-year	3-5-year	5-7-year	7-10-year	10+-year		
	86%	12%	1%	1%	0%		
Sector	financial	industrial	utility	supra-national	asset-backed		
	86%	5%	0%	6%	3%		
Country	domestic	non-domestic					
	82%	18%					

growth and bond market volatility. They found that these credit spreads are negatively related to long term interest rates and positively related to both economic growth and bond market volatility. This research was based on pre-euro introduction data.

Analysis of the composition of the investment grade Dutch guilder corporate bond market is available for December 31, 1998, i.e. one day before the introduction of the euro. This bond market is proxied by the Lehman Brothers Euro-Aggregate Bond index Netherlands Guilder.[5] The structure of the umbrella index, the Euro-Aggregate Bond index, consists of investment grade, plain vanilla euro-denominated and legacy bonds with a minimum amount outstanding of 100 million euro (Lehman Brothers, Inc (1998)).[6] As of the end of December 1998, the market capitalization of the guilder corporate bond market was 28.9 billion euro.

Table 2.6 displays the four main characteristics of this bond market, i.e. ratings, maturities, sectors and domestic versus non-domestic bonds respectively. This table shows that bonds with a high rating, with a short (remaining) maturity, from the financial sector and from local issuers dominated the Dutch guilder corporate bond market.

[5]We thank Lehman Brothers, Inc. for providing these data.

[6]This minimum amount has been increased two times, first to 150 million euro and later to 300 million euro.

2.4.2 Dutch Euro Corporate Bond Market

Investment Grade Bond Market

As mentioned above, investors in euro-denominated corporate bonds typically analyze the rating and sector of these bonds; where companies are located, whether in one of the euro-area countries or elsewhere, is of less importance. This also applies for bonds of the Dutch corporate issuers that dominated the guilder bond market as described in Section 2.4.1 above. These guilder bonds are now merged in the euro-denominated corporate bond market. Again, the Lehman Brothers Euro-Aggregate Bond index represents the investment grade euro corporate bond market. This index is often used as a benchmark for investors who invest in this market. A subindex of this index contains the bonds that are issued by Dutch companies only. Analyzing this subindex provides an understanding of the development of this part of the investment grade euro-denominated market since its inception, January 1, 1999 to August 31, 2002.

The development in the composition of two subindices, the Netherlands Credit and Securitized subindex, of the Euro-Aggregate Bond index is displayed in Table 2.7. The percentages of the comparable subindices for the total euro denominated bonds appear in brackets to allow a comparison between Dutch euro issuers and all euro issuers. All percentages in this table are market weighted. Analyzing this table, the following observations can be made: during the sample period, the average maturity of the Dutch issuers index lowers as maturity block 5-7 grows in importance at the expense of maturity block 7-10. Secondly, the average rating decreases, most notably the percentage of Aaa-rated issues goes down and the percentage of A-rated and Baa-rated bonds goes up as a consequence of rating downgrades and issuance. Finally, the industrial sector grows in importance at the expense of the financial sector.

Compared to all euro-denominated bonds, the bonds that are issued by Dutch companies have a lower percentage in the 1-3-year and 3-5-year maturity buckets and a higher percentage in the longer maturity buckets, 7-10-year and 10+-year. There is also a difference in average rating, with Euro-zone bonds having more Aaa-rated, fewer Aa-rated and A-rated bonds, except for the year 1999 and more Baa-rated bonds than their Dutch counterpart, except for the year 2001. Finally, the distribution of sectors - financial, industrial, utility, or other- is different. The presence of (Jumbo) Pfandbriefe in the combined Euro-Aggregate Credit and Securitised index explains the large differences in the financial sector and the other sectors. (Jumbo) Pfandbriefe alone constitute about 48% of the two combined sectors above. The other two sectors show that more Dutch

Table 2.7: Dutch and Euro-zone bonds statistics

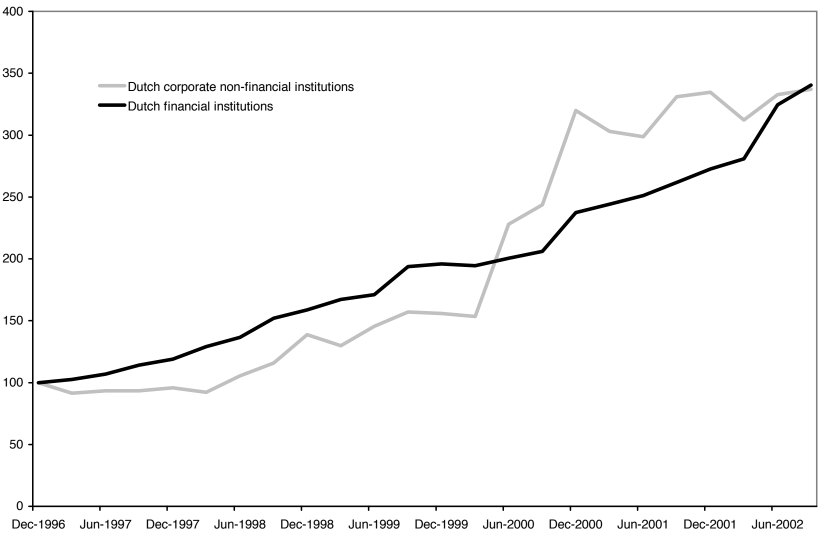
	December 31, 1999	December 31, 2000	December 31, 2001	August 31, 2002
Maturity				
1-3-year	22.2% (28.3%)	21.4% (27.1%)	22.9% (26.1%)	23.4% (28.3%)
3-5-year	25.9% (29.3%)	26.7% (27.8%)	26.9% (28.4%)	25.4% (28.1%)
5-7-year	15.5% (16.6%)	17.4% (16.8%)	22.7% (18.1%)	27.2% (20.8%)
7-10-year	32.7% (22.5%)	30.4% (25.0%)	24.6% (23.9%)	21.1% (19.2%)
10+-year	3.8% (3.3%)	4.1% (3.2%)	2.9% (3.4%)	3.0% (3.7%)
Rating				
Aaa	53.6% (58.2%)	41.9% (56.6%)	33.7% (48.1%)	32.3% (44.2%)
Aa	38.7% (26.9%)	37.1% (24.9%)	33.7% (23.6%)	36.7% (24.5%)
A	7.4% (12.6%)	18.6% (14.4%)	17.9% (16.9%)	19.5% (18.3%)
Baa	0.2% (2.3%)	2.5% (4.2%)	14.7% (11.3%)	11.4% (13.0%)
Sector				
Financial	88.9% (28.5%)	81.9% (24.8%)	69.2% (22.6%)	64.4% (22.9%)
Industrial	9.8% (8.2%)	15.5% (11.9%)	27.4% (20.9%)	23.8% (21.1%)
Utility	0.0% (2.2%)	0.0% (2.4%)	0.0% (3.2%)	7.8% (4.3%)
Other	1.3% (61.1%)	2.6% (60.9%)	3.4% (53.3%)	4.0% (51.7%)

issuers are present in the industrial sector and there are fewer in the utility sector, except for the end of August 2002.

The amount of corporate bonds issued by Dutch companies increased after the euro introduction. Figure 2.5 shows the growth of the amount outstanding in Dutch corporate non-financial issuers and financial institutions (in billions of U.S. dollar) for the period December 1996 to September 2002. Over the period, the amount outstanding has grown in both sectors. The growth of non-financial debt shows a more volatile pattern than debt issued by the financial sector as can be explained by for example: funding mergers and acquisitions and finance third generation mobile phone licences.

In the Netherlands, special financial institutions issue a large amount of bonds. These institutions are "Netherlands-based companies which specialize in group financing and whose shares are directly or indirectly held by nonresidents" (De Nederlandsche Bank (2000)). For that reason, they are not part of the analysis above. So, they fund themselves in a foreign country and invest almost entirely outside the Netherlands. The Netherlands is attractive to these financial institutions mainly for tax reasons. At the end of 1999, the total number of special financial institutions was over 9000. During 1999, their combined issue size was about 70 billion euro, of which 42 billion in euro-denominated issues (De Nederlandsche Bank (2000)).

Figure 2.5: Amount outstanding of Dutch corporate non-financial and financial institutions[a] (December 1996-September 2002) (BIS (2002))



[a] in billions of U.S. dollar

Bank Nederlandse Gemeenten (BNG, Bank for the Dutch Municipalities) and Nederlandse Waterschapsbank (NWB, Bank for the Dutch Water Control Boards)

The Bank Nederlandse Gemeenten is a public sector bank that was founded in 1914 on the initiative of the Association of Dutch Municipalities. BNG is the principal banker for the Dutch public sector and the largest public sector lender in the Netherlands with an overall market share of 35% (Thomson, Cunningham and Theodore (2001)). At present, BNG is ranked the fifth largest bank in the Netherlands in terms of total assets. Moody's, Standard & Poor's and Fitch IBCA have assigned their highest rating to BNG, i.e. Aaa/AAA/AAA. Most of BNG's long term funding comes from bond issuance.

The Dutch central government owns 50% of BNG's shares, while Dutch municipalities, provinces and one water board institution own the other 50%. In spite of these owners, BNG has no formal guarantee from the Dutch state; i.e., the principal behind all lending continues to be the solvency of the borrower. BNG is supervised by DNB. The bank can only lend to: local governments, entities guaranteed - either directly or indirectly - by local governments or central government and entities controlled by local government or central government (Thomson et al. (2001)).

The Nederlandse Waterschapsbank is also a public sector bank. NWB was formed in 1954 in response to the severe floods in the Netherlands during the previous year. Now, it is the seventh largest bank in the Netherlands by assets and holds AAA ratings from both Moody's and Standard & Poor's. NWB issues debentures, MTNs and commercial paper.

The bank's shareholders are: the Central government (17%), water control boards (Waterschappen) (81%) and provinces (2%) (Greenwood and Dutton (2000)). Since 1989, NWB has no longer a state guarantee and is currently supervised by DNB. According to the NWB's articles of association, NWB can only lend to the public sector, including central and local government authorities (including water control boards), entities under state control, and all business transacted under state guarantee (including social housing). Most lending is long term. In addition, NWB also acts as the treasurer of the water control boards.

High Yield Bond Market

The number of Dutch companies that issue subinvestment grade or high yield bonds has been very limited; only 13 euro-denominated high yield bonds are present in the euro-denominated high yield market as represented by Lehman Brothers Pan-European High Yield the Netherlands index in 1999 (22, 25 and 10 in 2000, 2001 and August 30, 2002 respectively). Most of these are linked to the industrial sector, with ratings that cover the whole subinvestment grade spectrum. The maturity bucket 7-10-year dominates this market.

Convertible Bond Market

Dutch companies have also issued convertible bonds, but this type of bond is rare in the Dutch corporate bond market. As Grubben and Van Summeren (1999) show, Dutch convertibles make up only 3.6% of the global convertible bond market as represented by the Merrill Lynch Global Convertible Bond index.

2.5 Investors

2.5.1 Investors in Dutch Government bonds

DTSA provides an overview of the investors in Dutch government bonds as displayed in Table 2.8. This table presents the breakdown of the total Dutch government debt into two categories: public debt and private placements. Investors in public debt are divided in resident investors and non-resident investors. Resident investors in public debt are broken down into investment funds[7], private investors[8], banks, insurance companies and pension funds. This type of debt and type of investor is given in billions of euro and spans the years 1996 to 2000 (as of year-end).

Investment funds, private investors and pension funds invested less in Dutch public debt in the period 1996 to 2000. In contrast, insurance companies and banks invested more and an equal amount respectively in the same period. Investments by non-residents increased and this group held more than 40% of Dutch public debt in the year 2000. During this period, there was a significant fall in private placements outstanding, due to the central government's debt restructuring programme combined with no new issuance of this type of government debt. For a description of the Dutch private placement market see De Haan (1991).

2.5.2 Investors in Euro Corporate bonds

The distribution of type of investors in large euro-denominated corporate bonds, with an issued amount of 300 million euro or more, is shown here using a sample of large, recently issued corporate bonds. On average, each corporate bond transaction in this sample involved 192 investors.[9] Table 2.9 and 2.10 display the distribution by investor type and by geographical distribution of investors respectively. These tables show that banks and investment funds are the dominant type of investors in this sample and investors from the countries in the Euro-zone, most notably Germany and France, put their money in these euro-denominated corporate bonds. However, in general banks do not invest in bonds, but it is possible they have a temporary exposure to bonds they bring as new issues to the market.

[7]Up to 1996, this category included social security funds. Since 1997, social security funds hold their assets in account at the Dutch State.

[8]"It should be noted that the 'private investors' category is not restricted exclusively to natural persons, but also include legal entities (for example, companies, foundations And cooperatives), which do not count financial services among their principal activities" (Appendix 2.A, DSTA).

[9]We thank J.P. Morgan for providing their estimates.

Table 2.8: Breakdown of type of debt instruments and type of investors in Dutch government bonds[a] with the corresponding percentages between brackets (1996-2000) (DSTA (2002))

	1996	1997	1998	1999	2000
Public debt					
Residents:					
Investment funds	5 (3%)	6 (4%)	7 (4%)	5 (3%)	2 (1%)
Private investors	16 (11%)	10 (6%)	13 (8%)	10 (6%)	2 (1%)
Banks	23 (15%)	27 (17%)	29 (18%)	28 (16%)	23 (14%)
Insurance companies	20 (13%)	24 (15%)	25 (15%)	38 (22%)	37 (22%)
Pension funds	50 (33%)	50 (32%)	46 (28%)	35 (20%)	34 (20%)
Non-residents	37 (25%)	39 (25%)	45 (27%)	58 (33%)	71 (42%)
Sum of public debt	151 (100%)	156 (100%)	164 (100%)	174 (100%)	169 (100%)
Private placements	33	22	18	11	5
Total debt	174	178	182	185	174

[a] in billions of euro

Table 2.9: Investors in euro-denominated corporate bonds (J.P. Morgan (2002))

Banks	31%
Insurance companies	13%
Investment funds	50%
Retail customers	6%

2.6 Euronext Amsterdam and OTC Market

2.6.1 Euronext Amsterdam

All DSLs, corporate bonds from Dutch issuers, both investment grade and high yield, and other bond types, such as convertible bonds, are listed at Euronext Amsterdam, where irregular trading in small amounts of Dutch government bonds takes place. Both traded amounts and their frequency suggest that mainly retail investors use this exchange to trade bonds. Most Dutch government bond trading occurs in the OTC market in Amsterdam or London, or via web-based trading platforms, as described below.

Table 2.10: Geographical distribution of investors in euro-denominated corporate bonds (J.P. Morgan (2002))

France	20%
Germany	21%
Iberia	4%
Italy	9%
Scandinavia	5%
United Kingdom	20%
Other	21%

Different types of corporate bonds are also traded at Euronext Amsterdam from time to time. Again, their trading pattern is irregular and only small amounts are bought and sold. Most trading of corporate bonds occurs in the OTC market.

2.6.2 OTC Market

In general, large Dutch institutional investors trade DSLs with investment banks and brokers in the OTC market. Both banks and brokers make markets in these types of bonds. Nowadays, this way of trading is disappearing as more and more sovereign debt trading occurs via web-based trading systems, such as Bloomberg L.P., TradeWeb and MTS SpA.

Dutch government securities are traded via an electronic trading platform that is managed by MTS Amsterdam. The shareholders of MTS Amsterdam are the Dutch state (5%), MTS SpA (30%) and the 13 primary dealers (5% each) designed by DSTA from Section 2.3.2. Three types of eligible financial institutions participate in this market and must satisfy the following requirements (Appendix 2.A, MTS Amsterdam):

- Market makers are primary dealers in the Dutch primary market designated by DSTA that commit themselves to market-making obligations for both DSLs and DTCs.

- Single market specialists are financial institutions in the Dutch primary market of DTCs, designated by DSTA, that commit themselves to market-making obligations for DTCs only.

- Market takers, financial institutions that traded at least 300 million euro in Dutch secondary government bond market in the previous year.

Table 2.11: Traded volumes in DTCs and DSLs at MTS Amsterdam (2001-2002)[a] (MTS Amsterdam (2002))

	2001 (214 days)		2002 (214 days)		
	Volume	Daily average	Volume	Daily average	YTD change in volume
DTCs	30686.0	143.39	43800.0	204.7	42.74%
DSLs	76586.0	357.88	77410.0	361.7	1.08%
Total	107272.0	501.27	121210.0	566.4	12.99%

[a] in billions of euro

The obligations of the market makers above are defined by MTS Amsterdam, which insists that two-way quotes are available for no less than 5 hours each day on all Dutch government bond benchmark issues and an assigned subset of non-benchmark bonds.

MTS Amsterdam reports the traded volumes of DTCs and DSLs in millions of euro in 2001 and 2002, as shown in Table 2.11. During this period, the traded amount in DTCs (DSLs) rose 42.74% (1.08%), but the total volume of DSLs remained higher than DTCs.

However, these web-based trading systems that are used in the euro sovereign bond market are not common practice for the euro corporate bond market yet. This is due to the fact that the secondary market in euro-denominated corporate bonds is not as liquid as expected when it was opened.

Trading hours of DSLs at the various markets, with Amsterdam time equalling GMT + 1 hour, are the following (Bennett et al. (2001)):

- Euronext Amsterdam: 08:00 a.m. to 06:00 p.m.
- MTS Amsterdam: 08:15 a.m. to 05:30 p.m.
- London (GMT): 08:00 a.m. to 05:00 p.m.

2.7 Regulators

The landscape of the Dutch supervision regime of financial companies is changing. Jonk et al. (2001) explain,

"from being predominantly sector-oriented, the Dutch supervisory regime is becoming more cross-sectional in nature. The driving force behind this reform is the continuing financial market integration, for example banks selling insurance products and services and vice versa. The Dutch supervisors want their structure to reflect these market developments. This restructuring from sector to cross-sector supervision has been

Table 2.12: New Dutch financial supervision structure (MoF (2002))

	Systemic Stability	Prudential		Conduct of business		
				Non-securities		Securities
		Sectoral	Cross-sector	Sectoral	Cross-sector	
Banking/Investment	DNB	DNB	DNB/PVK	AFM	AFM	AFM
Securities	DNB	DNB	DNB/PVK	AFM	AFM	AFM
Insurance	DNB	PVK	DNB/PVK	AFM	AFM	AFM

implemented during 2002 and it will be followed by formal legislation" (Tweede Kamer der Staten-Generaal (2002*a*) and Tweede Kamer der Staten-Generaal (2002*b*)).

Table 2.12 presents this new cross-sector oriented supervisory regime (Jonk et al. (2001)). This new regime is built on the following two pillars. First, systemic stability supervision is combined with prudential supervision. Systematic stability supervision falls within the jurisdiction of DNB, as described earlier in Section 2.2. Prudential supervision of the banking, investment funds and security firms sectors is also carried out by DNB. "Prudential supervision addresses the question of whether participants in the financial markets can rely on their contracting parties to meet their financial obligations" (Appendix 2.A, AFM). The insurance supervisor, the Pensions and Insurance Supervisory Authority of the Netherlands (PVK, Pensioen- & Verzekeringskamer) performs the prudential supervision of the insurance sector and pension funds. DNB and PVK join forces through cross-board appointments and combined teams for prudential supervision of financial conglomerates and will merge.

Secondly, the conduct of business supervision is placed under separate supervision of the Netherlands Authority for the Financial Markets (AFM, Autoriteit Financiële Markten), the legal successor of the Securities Board of the Netherlands (STE, Stichting Toezicht Effectenverkeer). "The supervision of market conduct focuses on the question of whether the participants in the financial markets are treated properly and whether they have accurate information" (Appendix 2.A, AFM).

Kremers, Schoenmaker and Wierts (2001) state that there is still disagreement among supervisors throughout Europe of the preferred regime. Policy recommendations regarding the organizational structure of financial supervision range from enhanced cooperation to a centralized structure at a European level.

2.7.1 DNB

As shown in Section 2.2, one of the main tasks of DNB is to supervise the banking system, collective investment schemes and exchange offices. De Nederlandsche Bank (2002) describes that its main two objectives within banking supervision are "to protect the interests of the public who have entrusted their money to banks" and "to protect the stability of the financial system. What this means in practice is that the financial system must be 'sound' enough to absorb the failure of an individual institution without a knock-on effect that brings the whole system down."

Before entering the Dutch market, banks must first get authorization by DNB. After obtaining this authorization, DNB continues to monitor these banks. In order to carry out its tasks, DNB collects detailed information from banks. "DNB has also issued guidelines for assessing the solvency and liquidity of banks" and further are banks required to "keep their administrative affairs in good order and to maintain adequate internal control" and "DNB supervises the structure of cooperative links between banks and other businesses".

As mentioned above, DNB also supervises "companies whose business it is to invest money on behalf of third parties" with the goal of "the smooth operation of financial markets and to protect investors in these markets". Further exchange offices must be registered with DNB in order to counter money laundering via these offices and in this way protecting the integrity of the Dutch financial system. Finally, DNB contributes to the supervision of institutions that provide loans to consumers.

2.7.2 PVK

"The Pensions and Insurance Board supervises the insurance companies and pension funds that operate in the Netherlands with the aim of ensuring that these institutions are and remain financially sound and that they are also able to meet their obligations in the future. A further important task is the testing of the fitness and properness of new and existing executive directors of insurance companies and pension funds" (Appendix 2.A, AFM).

The responsibilities and activities of PVK are carried out in accordance with a number of Acts of Parliament. PVK describes their policy as having a dual character: on the one hand, the PVK applies existing supervision legislation and on the other hand, PVK can exercise its own authority by means of regulations, policy rules and recommendations, each described below (Appendix 2.A, PVK).

"Regulations are the PVK's most compelling powers. Institutions are obliged to comply with the regulations, which are always directly related to statutory or ministerial provisions. If an institution fails to do so, sanctions may be imposed. In issuing a policy rule, the PVK gives its own interpretation of statutory provisions. This is an indication of how the PVK itself will approach the matters in question. In the first instance, these policy rules are binding on the PVK. If, however, an institution deviates from an interpretation, the PVK may impose a sanction or withhold a requested facility or service. The PVK can also make recommendations. These are not obligatory and the PVK cannot enforce compliance with its recommendations by imposing sanctions."

PVK also works alongside other European bodies such as the insurance committee set up by the EU Council, the conference of EU/EEA Insurance Supervisory Authorities and the EU Council working papers to support MoF and pension supervision. This has involved the Conference of Pension Supervisory Authorities, working with British, Irish and German pension supervisory authorities, and work with the EU Council working party in support of the Dutch Ministry of Social Affairs and Employment.

2.7.3 AFM

"The Netherlands Authority for the Financial Markets has been responsible for supervising the operation of the financial markets since 1 March 2002. This means that AFM supervises the conduct of the entire financial market sector: savings, investment, insurance and loans. By supervising the conduct of the financial markets, AFM aims to make a contribution to the efficient operation of these markets. AFM is an autonomous administrative authority (zelfstandig bestuursorgaan) that comes under the political responsibility of the Minister of Finance. The minister appoints the board members of AFM and also approves its budget and any amendments to its statutes."

The three objectives of the supervision by AFM are the following:

1. "To ensure that the financial markets operate in an efficient, fair and orderly manner.
2. To promote transparency between all of the participants in the financial markets and in this connection.
3. To protect the consumer."

AFM supervises:

1. "All Dutch securities exchanges and institutions that offer securities services in or from the Netherlands.
2. All Dutch credit institutions that offer consumer credit (as from 3 March 2002).

3. The provision of Financial Information Leaflets by banks, investment institutions, credit providers, insurance companies and securities institutions (as from 8 March 2002)."

"AFM carries out its supervisory role by checking, enforcing and transferring standards and acts specifically on tip-offs from the market and the findings of its own control organisation. If AFM ascertains that there has been a breach, it may impose penalties. It may issue a reprimand or give a public warning, appoint a secret receiver, withdraw a licence, cancel or refuse a registration, or report an offence to the Public Prosecutions Department. It can also impose penalties and fines" (Appendix 2.A, AFM).

One of the areas that is subject to supervision by AFM is the operation of Euronext Amsterdam. Because this securities exchange is a merger of the Amsterdam, Brussels, Paris and Lisbon stock exchanges, AFM cooperates closely with the Belgian, French and Portuguese securities supervisory authorities in relation to regulations and supervision of Euronext. AFM also participates in the Committee of European Securities Regulators (CESR).

2.7.4 Rating Agencies

In addition to the impact of the Dutch national regulators, foreign rating agencies, such as Moody's Investor Services, Standard & Poor's and Fitch IBCA, also affect the Dutch fixed Income market. These organizations often rate large euro-denominated corporate bonds and/or their Dutch issuers. Most Dutch issuers from the Lehman Brothers index the Netherlands at August 31, 2002 have a high rating as is displayed in Section 2.4. DSLs receive the highest possible rating of Aaa/AAA/AAA from these three rating agencies.

2.8 Summary

The introduction of the euro on January 1, 1999 changed the shape of the small market for Dutch bonds. The Dutch government had to find ways to improve the liquidity of their bonds as national monetary policy and currency differences between countries disappeared. The euro also influenced the Dutch corporate bond issuers, which have become part of the growing euro-denominated corporate bond market. In this newly established bond market, a company's home country has become less important than it's rating and sector. The investor base of both Dutch government bonds and corporate bonds has also become more international. So, it is clear that both issuers and investors have been affected by the introduction of the euro. One area of common ground for issuers and investors is Euronext Amsterdam, which has now merged with other exchanges in Europe, and the OTC bond markets. There have also been changes to the Dutch financial supervision regime since Dutch supervision has moved from a largely sector-oriented regime, to one that is more cross-sectional based. Finally, rating agencies also have an impact through their assessment of Dutch government debt and corporate bonds.

Appendix

2.A Websites

Table 2.13: Websites

2.2 the Netherlands	
Bank for International Settlements	http://www.bis.org
De Nederlandsche Bank	http://www.dnb.nl
European Central Bank	http://www.ecb.int
Eurostat	http://www.eurostat.com
International Monetary Fund	http://www.imf.org
Ministry of Economic Affairs	http://www.ez.nl
Ministry of Finance	http://www.minfin.nl
Organisation of Economic Cooperation and Development	http://www.oecd.org
2.3 Dutch Government Bonds	
Dutch State Treasury Agency	http://www.dutchstate.nl
2.4 Corporate Bonds	
Bank Nederlandse Gemeenten N.V.	http://www.bng.com
Nederlandse Waterschapsbank N.V.	http://www.nwb.nl
2.6 Euronext Amsterdam and OTC Markets	
Bloomberg L.P.	http://www.bloomberg.com
MTS Amsterdam N.V.	http://www.mtsamsterdam.com
Euronext N.V.	http://www.euronext.com
TradeWeb, Ltd.	http://www.tradeweb.com
2.7 Regulators	
Fitch IBCA Inc.	http://www.fitchibca.com
Moody's Investors Service	http://www.moodys.com
Netherlands Authority for the Financial Markets	http://www.autoriteit-fm.nl
Pensions and Insurance Supervisory Authority of the Netherlands	http://www.pvk.nl
Standard & Poor's Rating Group	http://www.standardandpoors.com
Tweede Kamer der Staten-Generaal (House of Representatives of the States General in the Netherlands)	http://www.tweede-kamer.nl

Part I

Credit Risk of Corporate Bonds

Chapter 3

Pricing Step-up Bonds[1]

3.1 Introduction

European telecom companies have issued rating-triggered step-up coupon bonds in order to compensate bond investors for losses in the event of rating downgrades. McAdie, Martin and O'Kane (2000), Fumagalli and Taurén (2001) and Sirinathsingh (2001) have analyzed step-up bonds. These authors largely use historical and subjective rating transition probabilities in their valuation, and show the results of their model for only one day. Our approach is to apply the risk-neutral valuation framework of (Jarrow, Lando and Turnbull, 1997, hereafter JLT) to value step-up bonds, and we demonstrate the model's results over a long time period. For comparison, we also value step-up bonds using historical transition probabilities and as equivalent plain vanilla bonds, i.e., similar bonds except for the step-up feature. We analyze the protection the step-up feature offers to investors in two ways. First, we compare the volatility of a step-up bond to the equivalent plain vanilla bond. Second, we determine whether the step-up bond offers better returns than the equivalent plain vanilla bond in case of rating downgrades and negative outlooks.

Our results indicate that the market seems to use the JLT model to value step-up bonds that make a single step-up after the rating trigger. Step-up bonds that make multiple step-ups seem to be treated as plain vanilla bonds. Also, the JLT model always approximates the step-up feature premium better than the historical method. We further find that the step-up feature reduces bond price volatility for most of the step-up bonds considered. Finally, for all bonds in our sample, the step-up feature does not offer investors positive excess returns in case of a rating downgrade or a trend toward to negative outlook.

[1]This chapter is based on an article by Houweling, Mentink and Vorst (2004), which has been published in the *Journal of Derivatives*. It was also presented at the sixteenth annual conference of the Financial Options Research Center (FORC) in Warwick on September 25, 2003.

Step-up bonds are a relatively new phenomenon in the euro-denominated corporate bond market. The coupon of the step-up bond depends on its issuer's rating or the rating of the issuer's long term debt. If the rating deteriorates and hits a predefined level, the step-up feature is triggered, and the coupon rises with a predefined amount. Depending on the exact specification, the coupon can rise even more if the rating deteriorates further. For most step-up bonds, the reverse also applies; the coupon is reduced if the rating is raised.

Both issuers and investors benefit from the step-up feature; as McAdie et al. (2000) indicate. Issuers have placed more debt at lower yields than would otherwise have occurred. Investors have profited too, because they will be compensated in case of rating downgrades, and because issuers should be more committed to preserve their ratings, as a downgrade will penalize them directly with higher coupons.

We analyze five step-up bonds issued by three companies: Deutsche Telecom, France Telecom and KPN. These are the only three companies in our data set that have issued both step-up bonds and enough euro-denominated plain vanilla bonds that we can reliably estimate issuer-specific interest rate curves. Despite this limited number of step-up bonds, our study is worthwhile because it provides one of the first empirical tests of the JLT model on rating-sensitive instruments and because the behavior of step-up bonds has not been documented in the academic literature.

J.P. Morgan uses historical transition and default probabilities in its valuation; see (Sirinathsingh, 2001). Lehman Brothers estimates the probabilities subjectively according to analysts' opinions; see (McAdie et al., 2000). Schroder Salomon Smith Barney applies both subjective and historical transition probabilities; see (Fumagalli and Taurén, 2001). Société General implements a JLT model form and uses risk-neutral probabilities; see (Turc, 2001).

These studies all show the results of their analysis for only one day. We instead price step-up bonds for a longer period (March 2001-February 2002), and implement three pricing methods.

Despite considerable interest from practitioners, only one article has appeared about the valuation of the euro step-up bonds, as far as we know ((Conroy, 2000)). Conroy values step-up bonds using historical rating transition probabilities. Risk-neutral valuation models that can be used to price rating-triggered instruments have appeared elsewhere in the academic literature. The basis for most of these models is the JLT Markov chain model, which uses a firm's ratings as an indicator of the likelihood of default. Kijima and Komoribayashi (1998) adjust the JLT model to make it numerically more stable by replacing default probabilities with survival probabilities in the calculation of risk premiums. We would expect the JLT model to generate step-up bond valuations that are more in line with corresponding market prices than the historical valuation method, because the JLT model takes the market risk premium into account, while the historical method does not.

Das and Tufano (1996) generalize the JLT model to incorporate stochastic recovery rates. Lando (1998) and Arvanitis, Gregory and Laurent (1999) extend it to make transition and default intensities stochastic and possibly dependent on state variables. Schönbucher (1999), Bielecki and Rutkowski (2000) and Acharya, Das and Sundaram (2002) embed the Markov chain in the Heath, Jarrow and Morton (1992) framework with stochastic forward rates. Acharya et al. (2002) also illustrate their model for a sample step-up bond.

In independent work, Lando and Mortensen (2004) also analyze step-up bonds in the JLT framework. Although their work is similar to ours, they focus on refining the JLT model, while we compare three different valuation methods. Further, we analyze the protection that the step-up feature offers to investors.

The remainder of this chapter is structured as follows. First, we explain the characteristics of step-up bonds in Section 3.2. Next, in Section 3.3, the JLT model is briefly summarized and the risk-neutral valuation of step-up bonds is explained. Further, we describe the valuation methods using historical probabilities and as equivalent plain vanilla bonds. Section 3.4 describes our data set. The results of applying the three valuation methods to the data are given in Section 3.5. We also test whether including step-up features offers the investor sufficient protection using both volatility tests and we conduct an event study on rating and outlook changes. Finally, Section 3.6 summarizes the chapter.

3.2 Step-up Bonds

The coupon of a step-up bond depends on the issuer's rating or the rating of its long term debt. If the rating deteriorates and hits a predefined level, the step-up feature is triggered and the coupon rises with a predefined number of basis points. Depending on the type of step-up coupon, the coupon can rise even more if the rating deteriorates further. For most step-up bonds, the reverse also applies; the coupon is reduced if the rating improves-this is called a step-down feature. The coupon can never go below the original level at issuance, though.

Step-up conditions can differ among bonds. The most important discriminating conditions of the step-up bonds are the following: whether the coupon can step up

Table 3.1: Step-up bond types

Type	Step-up[a]	Step-down[b]	One-off[c]	And/or[d]	Accrual[e]
A	✓	✓		or	next
B	✓	✓	✓	and	next
C	✓		✓	or	immediately

[a] Coupon increases if the rating decreases and hits the rating-trigger.
[b] Coupon decreases if the rating increases again.
[c] Coupon increases only once, even if the rating falls further below the rating-trigger; for bonds that are not one-off, each further decrease in the rating, causes a further increase in the coupon.
[d] Determines whether the coupon is adjusted if Moody's *and* S&P adjust their ratings, or if Moody's *or* S&P adjusts its rating.
[e] Determines the date at which the adjusted coupon starts accruing: *immediately* following a rating action, or on the *next* coupon date after the rating action.

and down or only step up, whether both Moody's and S&P or only one of them must downgrade an issuer before the step-up trigger is hit; the timing of the coupon adjustment; the rating-trigger level; and the number of basis points of the step-up.

Based on McAdie et al. (2000) and Marchakitus, Soderberg and Bramley (2001), Table 3.1 defines three types of step-up bonds.

3.3 Model

We first describe the JLT model and then explain the risk-neutral valuation of step-up bonds.

3.3.1 Rating Transitions

The value of a bond equals the sum of the discounted expected cash flows. Unlike a plain vanilla bond, a step-up bond's coupons are a function of the issuer's rating. We thus have to model the issuer's rating transition process under the equivalent martingale measure. The JLT model provides a suitable framework for this purpose, since it uses a company's rating as an indicator of creditworthiness.

Following the JLT framework, we assume a unique equivalent martingale measure $\tilde{\mathbb{Q}}$ exists that makes all default-free and defaultable bond prices martingales, after normalization by the default-free money market account. Finally, the recovery rate δ

is constant; we follow Jarrow and Turnbull (2000) and Schönbucher (2000) by assuming that δ applies to the principal only, not to the coupons.

The company's rating R_t at day t is modelled as a Markov chain on a finite state space $S = \{1, \ldots, K\}$ under the historical probability measure. Under $\tilde{\mathbb{Q}}$, default-free interest rates and ratings are assumed to be independent. The state space S includes all possible ratings, including the intermediate ratings. State 1 represents the Aaa rating, state 2 Aa1, state 3 Aa2, ..., state $K-1$ Caa, and the last state, K, default. It is assumed that default is an absorbing state.

Under the Markov property, it holds for all $i, j \in S, t \geq s \geq 0$ and $r_u \in S, 0 \leq u < s$ that

$$\begin{aligned} q_{ij}(s,t) &= \mathbb{P}(R_t = j | R_s = i, R_u = r_u, 0 \leq u < s) \\ &= \mathbb{P}(R_t = j | R_s = i), \end{aligned}$$

that is, the probability of going from rating i to rating j in the period from s to t depends only on the rating R_s at time s and not on the history $R_u, 0 \leq u < s$, of reaching that rating. We are aware of the limitations of this assumption, as past rating movements do seem to affect future rating transitions, as shown by Nagpal and Bahar (2000), but this is an assumption common to most theoretical models.

To value step-up bonds, we need the rating transition process under the risk-neutral measure $\tilde{\mathbb{Q}}$. JLT start with the observed historical transition probabilities, such as from a rating transition matrix of Moody's or S&P, and apply risk premiums to transform these into risk-neutral probabilities. We choose to adjust the $(T-t)$-year transition matrix $Q(t,T)$ to get the risk-neutral transition matrix $\tilde{Q}(t,T)$ as follows[2]

$$\tilde{q}_{ij}(t,T) = \begin{cases} \pi(t,T) q_{ij}(t,T) & \text{for } j \neq K \\ 1 - \pi(t,T)(1 - q_{iK}(t,T)) & \text{for } j = K \end{cases} \tag{3.1}$$

for some risk premium $\pi(t,T)$. It follows that the risk premium can be calculated as

$$\pi(t,T) = \frac{1 - \tilde{q}_{R_t,K}(t,T)}{1 - q_{R_t,K}(t,T)}. \tag{3.2}$$

[2]Moody's and S&P usually report (multiples of) one year transition matrices, but the time between the valuation day and coupon and redemption dates almost never exactly equals (multiples of) one year. We adjust the historical transition matrix and make it maturity-dependent using a generator matrix, as described by Israel, Rosenthal and Wei (2001).

The risk premium for time T is the ratio of the risk-neutral survival probability to the historical survival probability, so that we retain the numerical stability of (Kijima and Komoribayashi, 1998, hereafter KK). Note that we use 'cumulative' probabilities $\tilde{q}_{ij}(t, T)$ instead of JLT's and KK's 'forward' probabilities $\tilde{q}_{ij}(t, t+1)$, i.e.

$$\tilde{q}_{ij}(t, t+1) = \pi_i(t, t+1) q_{ij}(t, t+1).$$

The advantage of our risk premium approach is that the calculation is easier, because risk premiums do not require matrix inversion; cf. JLT's Equation (16) and KK's Equation (19). Both approaches, 'forward' and 'cumulative', though generate the same results. Note also that we use only one risk premium for all rating categories. Ideally, we would like to use a separate risk premium for each rating, but each euro-denominated telecom issuer does not cover the full rating spectrum, so we derive one risk premium from the issuer's current rating, and apply that to all ratings.

For each day, we estimate the issuer-specific survival probability curve of each telecom company. Following (Houweling and Vorst, 2005, Section 4), we specify a linear hazard function, assume a recovery rate of 50%, and use the euro zero-coupon swap curve as a proxy for the default-free term structure. The parameters of the hazard function are estimated from the market prices of the issuer's plain vanilla bonds using non-linear least squares. Given the estimated survival probability curve for a company on a particular day, we calculate its risk premium (3.2) and risk-neutral transition matrices (3.1) for all required maturities. These risk-neutral matrices are used to calculate theoretical values for step-up bonds. We also calculate 95% confidence bounds for the survival probability curve, and repeat this series of calculations for the upper and lower bound, hence obtaining upper and lower bounds for the step-up bond values as well.

3.3.2 Step-Up Valuation

To determine the theoretical value of a defaultable step-up and step-down bond, we add another assumption on the set of JLT assumptions: Both Moody's and S&P alter their ratings of an issuer at the same time.[3] In our analysis, we apply the Moody's rating actions.

We use three methods to value step-up bonds of types A and B in Table 3.1, starting with the JLT model. The path-dependent step-up bonds, Type C, are not covered by these methods.

[3]Fumagalli and Taurén (2001) assume that a rating action of one agency is followed by the other agency within six months.

Consider a step-up and step-down bond with n remaining coupon payments and a face value of 1. The bond issuer makes the j^{th} coupon payment at day t_j, $j = 1, 2, \ldots, n$, but only if the firm has not gone into default before t_j. If the rating at t_{j-1} is equal to r, the coupon payment at t_j is equal to $c_r, r = 1, \ldots, K$. The coupon payment at t_1 depends on the rating at t_0, which we define as the previous coupon date, or, if there is no previous coupon, the issue date. The step-up bond's principal amount is paid at maturity t_n, again only if the issuer has not defaulted before t_n. If the issuer does default before the bond matures, the constant recovery rate δ of the notional is paid at the default time. Applying the risk-neutral valuation principle to these coupon, principal and recovery cash flows, yields:

$$\begin{aligned} B^{JLT}(t, \mathbf{t}, \mathbf{c}) = &\sum_{j=1}^{n} p(t, t_j) \tilde{\mathbb{E}}_t \left[\mathbf{1}_{\{\tau > t_j\}} c_{R_{t_{j-1}}} \right] + \\ & p(t, t_n) \tilde{\mathbb{E}}_t \left[\mathbf{1}_{\{\tau > t_n\}} \right] + \tilde{\mathbb{E}}_t \left[p(t, \tau) \mathbf{1}_{\{\tau \leq t_n\}} \delta \right], \end{aligned} \tag{3.3}$$

where $\mathbf{t}$ is an n-vector with the coupon payment dates; $\mathbf{c}$ is a K-vector with the coupon percentages per rating category; $p(t, T)$ denotes the time-t default-free discount factor for time T, $\tilde{\mathbb{E}}_t [X]$ denotes the $\tilde{\mathbb{Q}}$ -expected value of X given the information at day t and $\mathbf{1}_{\{A\}}$ is the indicator function of event A. τ denotes the first date on which a default occurs, and $\tau > t_n$ indicates no default before maturity.

The first line of Equation (3.3) expresses the coupon payments, the second line the principal payment and the potential recovery payment.

For $j > 1$, the first risk-neutral expectation in Equation (3.3) can be evaluated as:[4]

$$\begin{aligned} \tilde{\mathbb{E}}_t \left[\mathbf{1}_{\{\tau > t_j\}} c_{R_{t_{j-1}}} \right] &= \sum_{k=1}^{K} \tilde{\mathbb{P}}_t(\tau > t_j \wedge R_{t_{j-1}} = k) c_k \\ &= \sum_{k=1}^{K} \tilde{\mathbb{P}}_t(\tau > t_j | R_{t_{j-1}} = k) \tilde{\mathbb{P}}_t(R_{t_{j-1}} = k) c_k \\ &= \sum_{k=1}^{K} \tilde{q}_{R_t,k}(t, t_{j-1})(1 - \tilde{q}_{k,K}(t_{j-1}, t_j)) c_k, \end{aligned}$$

where $\wedge$ is the logical "and" operator and $\tilde{\mathbb{P}}_t(A)$ is the risk-neutral probability of event A, given the information at day t; for $j = 1$, the coupon amount is already known (because

[4] Note that the summation may be reduced from K terms to $K - 1$ terms, since the K^{th} term is zero: $\tilde{\mathbb{P}}_t(\tau > t_j \wedge R_{t_{j-1}} = K) = 0$.

R_{t_0} is already known), so

$$\tilde{\mathbb{E}}_t\left[\mathbf{1}_{\{\tau>t_1\}}c_{R_{t_0}}\right] = \tilde{\mathbb{P}}_t(\tau > t_1)c_{R_{t_0}} = (1-\tilde{q}_{R_t,K}(t,t_1))c_{R_{t_0}}.$$

After evaluating the second and third risk-neutral expectations in Equation (3.3), the JLT value of our rating-triggered step-up and step-down bond equals

$$\begin{aligned} B^{JLT}(t,\mathbf{t},\mathbf{c}) = {} & p(t,t_1)(1-\tilde{q}_{R_t,K}(t,t_1))c_{R_{t_0}} + \\ & \sum_{j=2}^{n}\left[p(t,t_j)\sum_{k=1}^{K}\tilde{q}_{R_t,k}(t,t_{j-1})(1-\tilde{q}_{k,K}(t_{j-1},t_j))c_k\right] + \\ & p(t,t_n)(1-\tilde{q}_{R_t,K}(t,t_n)) + \\ & \sum_{j=1}^{n}p(t,t_j)(\tilde{q}_{R_t,K}(t,t_j)-\tilde{q}_{R_t,K}(t,t_{j-1}))\delta, \end{aligned} \tag{3.4}$$

where we follow (Houweling and Vorst, 2005, Section 4) by replacing the integral that results from the recovery payment with a numerical approximation with potential default dates equal to the coupon payment dates. Note that the only difference between Equation (3.4) and the value of a plain vanilla (PV) bond,

$$\begin{aligned} B^{PV}(t,\mathbf{t},c) = {} & \sum_{j=1}^{n}p(t,t_j)(1-\tilde{q}_{R_t,K}(t,t_j))c + \\ & p(t,t_n)(1-\tilde{q}_{R_t,K}(t,t_n)) + \\ & \sum_{j=1}^{n}p(t,t_j)(\tilde{q}_{R_t,K}(t,t_j)-\tilde{q}_{R_t,K}(t,t_{j-1}))\delta, \end{aligned} \tag{3.5}$$

is the part relating to the specific coupon structure of the step-up bond. If we set $c_k = c$ for all k, the expected value of the j^{th} coupon payment reduces to that of a plain vanilla bond

$$\begin{aligned} \sum_{k=1}^{K}\tilde{q}_{R_t,k}(t,t_{j-1})(1-\tilde{q}_{k,K}(t_{j-1},t_j))c &= c\left(\sum_{k=1}^{K}\tilde{q}_{R_t,k}(t,t_{j-1}) - \sum_{k=1}^{K}\tilde{q}_{R_t,k}(t,t_{j-1})\tilde{q}_{k,K}(t_{j-1},t_j)\right) \\ &= c(1-\tilde{\mathbb{P}}_t(R_{t_j}=K)) \\ &= c(1-\tilde{q}_{R_t,K}(t,t_j)). \end{aligned}$$

As a second valuation method, we treat the step-up bond as a bond that is identical except for the step-up feature. We refer to this bond as the *equivalent plain vanilla bond* (EPV). As in the step-up bond, the first coupon of this bond also depends on the rating at t_0, but the remaining coupons are assumed to follow from the current rating; i.e. they are all equal to c_{R_t}. The value of the equivalent plain vanilla bond thus equals

$$\begin{aligned} B^{EPV}(t,\mathbf{t},\mathbf{c}) = {} & p(t,t_1)(1-\tilde{q}_{R_t,K}(t,t_1))c_{R_{t_0}} + \\ & \sum_{j=2}^{n} p(t,t_j)(1-\tilde{q}_{R_t,K}(t,t_j))c_{R_t} + \\ & p(t,t_n)(1-\tilde{q}_{R_t,K}(t,t_n)) + \\ & \sum_{j=1}^{n} p(t,t_j)(\tilde{q}_{R_t,K}(t,t_j)-\tilde{q}_{R_t,K}(t,t_{j-1}))\delta. \end{aligned}$$

The difference from the JLT formula ((3.4)) is the second line, which no longer includes a summation over possible future ratings, but instead assumes the current rating R_t will prevail. The EPV formula also strongly resembles the PV formula (3.5), except that the first coupon may differ from the other coupons.

The third method we consider to value step-up bonds, the *historical valuation method*, is based on the methods that investment banks often apply, e.g. McAdie et al. (2000) and Fumagalli and Taurén (2001). This method uses the telecom company's zero-coupon curve to discount expected coupons, where the expectation is calculated using historical transition probabilities rather than risk-neutral probabilities; again, the first coupon is known. This gives:

$$B^{H}(t,\mathbf{t},\mathbf{c}) = v(t,t_1)c_{R_{t_0}} + \sum_{j=2}^{n}\left[v(t,t_j)\sum_{k=1}^{K} q_{R_t,k}(t,t_{j-1})c_k\right] + v(t,t_n),$$

where $v(t,T)$ denotes the issuer's time-t discount factor for time T.

3.4 Data

Most euro-denominated step-up bonds have been issued by telecom companies. Analyzing these rating-triggered step-up corporate bonds thus automatically means we focus on the telecom sector. Step-up bonds are an important source of financing for telecom companies. As of the end of March 2001, step-up bonds accounted for 42% of the market capitalization of the telecom bond market; see Fumagalli and Taurén (2001). We analyze the euro-denominated step-up coupon telecom bonds as listed by both Lehman Brothers and J.P. Morgan (see (McAdie et al., 2000) (Marchakitus et al., 2001)). For these European telecom

Table 3.2: Total number of euro-(re)denominated, quoted plain vanilla and step-up bonds for all telecom companies

	All bonds	Quoted, plain vanilla bonds	Step-up bonds
British Telecom Group	5	0	3
Deutsche Telecom	29	14	2
France Telecom	37	7	2
KPN	10	5	2
Olivetti SPA/Tecnost	12	0	4
Telecom Italia	7	2	2

companies, we download their main characteristics and the price time series for all their bonds from Bloomberg L.P. on a daily basis for the period from January 4, 1999 through February 13, 2002. We use the Bloomberg Generic (BGN) price. The BGN price is an average of prices quoted by many banks and brokers, and reflects the bid side of London closing. BGN prices are also used to price the Bloomberg/EFFAS government bond indices; see Brown (1994).

We make sure that the bonds used in the curve estimation are plain vanilla. We classify a bond as a plain vanilla bond if the bond has no step-up language and no embedded options, and if it is not floating or convertible. From the downloaded prices, we remove quotes that equal the quote of the preceding day(s) and quote spikes. We seldom have to remove quotes, though. Table 3.2 shows the number of all euro-(re)denominated bonds, plain vanilla bonds and euro-denominated step-up coupon bonds for the telecom companies that have issued step-up bonds. Three issuers, Deutsche Telecom, France Telecom and KPN, have more quoted, plain vanilla bonds compared to the other telecom companies, British Telecom, Olivetti/Tecnost and Telecom Italia. Our analysis focuses on these step-up bonds of the first three issuers only, because we need to estimate issuer-specific survival probability curves, which requires a certain number of plain vanilla bonds. These three companies are large corporate bond issuers as together they represent 6.5% of the Lehman Brothers Euro-Aggregate Corporate Bond Index on May 31, 2002.

Table 3.3 displays the characteristics of the step-up bonds we use in our analysis: the step-up type, as defined in Table 3.1, the number of basis points step-up and the rating-trigger level. We restrict ourselves to step-up bonds with step-up *and* step-down coupons, because among our three telecom issuers just one KPN bond has step-up only language. A step-up *only* bond, type C in Table 3.1, differs from a bond with step-up and step-down

Table 3.3: Characteristics of the step-up bonds

		Type[a]	Step-up[b]	Trigger[c]
Deutsche Telecom	2005	B	50.0	Baa1/BBB+
	2010	B	50.0	Baa1/BBB+
France Telecom	2004	A	25.0	Baa1/BBB+
	2008	A	25.0	Baa1/BBB+
KPN	2006	A	37.5	Baa3/BBB−

[a] type of step-up bond; see Table 3.1
[b] number of basis points the coupon steps up
[c] rating-trigger level (Moody's/S&P)

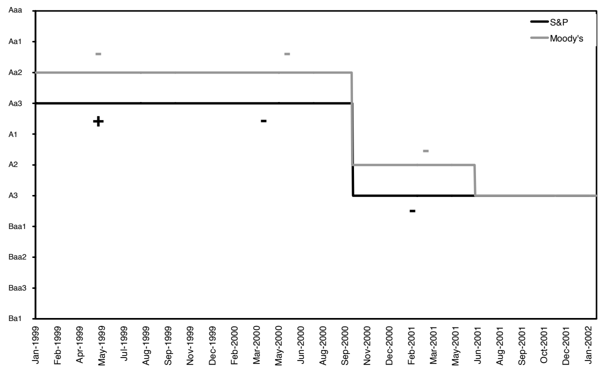
features, types A and B, because the coupon of a step-up only bond is path-dependent. This means that if the rating is below the trigger-level at any time before the coupon date, the coupon payment includes the step-up, even after the issuer is upgraded to or even above the pre step-up rating again; this path-dependence characteristic necessitates an other valuation procedure than Equation (3.4). In short, once triggered, a step-up only bond becomes a plain vanilla bond. This is exactly what happened to the KPN step-up only bond seven months after its issuance. Therefore, from the first coupon date after this rating event, we treat it as a plain vanilla bond and use it in our estimation of the KPN curve.

We download the Moody's and S&P rating and outlook history of Deutsche Telecom, France Telecom and KPN from Bloomberg L.P. as well. From Moody's, we use the issuer's rating and from S&P the rating of long term debt in local currency. Figure 3.1 shows the rating and outlook migrations of Deutsche Telecom, France Telecom and KPN by both Moody's and S&P's for the sample period. A positive (negative) outlook is denoted by a + (−) sign. The plots show that the rating dynamics of both agencies are very similar. At the end of our period, the two agencies assign identical ratings to each telecom company. We believe that these figures justify our additional modelling assumption in Section 3.3.2.

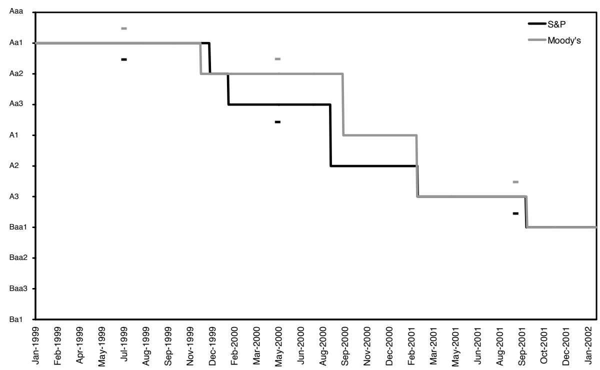
For a historical transition matrix, we use Moody's average one year senior rating transition matrix for corporate bond issuers, estimated from 1983 through 2001; see Cantor, Hamilton and Ou (2002).

Finally, euro swap rates are downloaded from Bloomberg L.P. We apply a standard bootstrapping procedure to extract zero-coupon rates and interpolate linearly between the available maturities to get a curve for all required maturities.

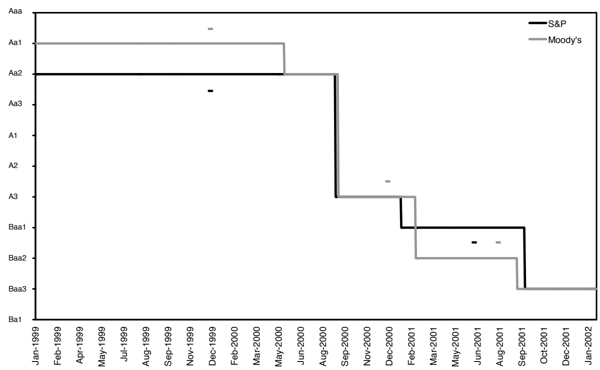
Figure 3.1: Credit ratings history



Deutsche Telecom



France Telecom



KPN

3.5 Results

We present general results and results for each company and elements of the analysis. We examine the protection that step-up procedures offer bond holders.

3.5.1 Step-Up Bond Values and Step-Up Premiums

We define the *pricing error* of a step-up bond as its market price minus its theoretical value. Specifically, PE_{bt}^{i} is the pricing error of bond b at day t, if method i is used to calculate the theoretical value, $i \in \{EPV, JLT, H\}$. EPV is the equivalent plain vanilla bond; JLT is the Jarrow et al. (1997) model and H is the historical model.

APE_{bt}^{i} denotes the *absolute pricing error* for the three methods. The sample means of these six statistics are denoted by MPE_{b}^{i} and MAPE_{b}^{i}. A negative (positive) sign of an MPE statistic indicates that theoretical values are, on average, too high (low). To test whether this over- or underestimation of step-up bond prices is significant for method i, we apply a *one-sample Z-test* (see e.g. Arnold, 1990, Chapter 11)

$$Z_b^i = \sqrt{N_b}\frac{\mathrm{MPE}_b^i}{S_b^i},$$

where S_b^i is the sample standard deviation of the PE_{bt}^{i} series and N_b is the sample size for bond b. Asymptotically, Z_b^i has a standard normal distribution. Similarly, in order to determine if there are significant performance differences among the three methods, we also use a *paired Z-test*; see (Arnold, 1990, Chapter 11). This test tells us whether two time series have the same mean, while allowing for non-zero correlation and unequal variances. The test statistic to compare measures i and j is defined as

$$Z_b^{ij} = \sqrt{N_b}\frac{M_b^{ij}}{S_b^{ij}},$$

where M_b^{ij} and S_b^{ij} are the sample mean and sample standard deviation, respectively, of $D_{bt}^{ij} := \mathrm{APE}_{bt}^{i} - \mathrm{APE}_{bt}^{j}$, $i, j \in \{EPV, JLT, H\}$, $i \neq j$, $t = 1, \ldots, N_b$. Asymptotically, Z_b^{ij} also has a standard normal distribution.

Table 3.4 shows the MPE and MAPE statistics for the telecom step-up bond values generated by the three valuation methods and, for comparison, the MAPE values for the plain vanilla bonds used in the estimation of the issuer-specific survival probability curves.[5]

[5]Note that per definition MPE for the plain vanilla bonds is zero, since the pricing error for a plain vanilla bond is simply its residual from the least squares estimation of the survival probability curve.

Table 3.4: Pricing errors[a]

	Plain vanillas	Step-ups					
		EPV		JLT		Historical	
	MAPE	MPE	MAPE	MPE	MAPE	MPE	MAPE
Deutsche Telecom							
Plain vanilla	0.29						
2005		0.15*	0.24*	-0.09*	0.25*	-0.29*	0.36*
2010		1.05*	1.15*	0.20*	0.82*	-0.34*	0.89*
France Telecom							
Plain vanilla	0.64						
2004		-0.26*	0.33*	-0.41*	0.46*	-0.56*	0.57*
2008		-0.87*	0.94*	-1.99*	1.99*	-2.57*	2.57*
KPN							
Plain vanilla	1.09						
2006		-0.44*	1.13*	-0.95*	1.42*	-2.28*	2.29*

[a] mean absolute pricing errors (MAPE) of the plain vanilla bonds and both mean pricing errors (MPE) and MAPEs of the step-up bonds for the equivalent plain vanilla (EPV), (Jarrow, Lando and Turnbull, 1997, JLT) and historical valuation methods

* Indicates significance of the one-sample Z-test at a 95% confidence level.

The paired Z-tests are presented in Table 3.5 for all combinations of the three valuation methods. In alternative test of the performance of the three methods, we calculate in Table 3.6 the percentage of days that the market price of a step-up bond lies between the 95% confidence bounds of the calculated theoretical values. This tells us how uncertainty in the estimated survival probability curves translates into uncertainty in the calculated theoretical step-up bond values.

We also zoom in on the value of the step-up feature. We define the *market premium* of the step-up feature as the step-up bond's market price minus the value of the equivalent plain vanilla bond. Similarly, we calculate the *JLT premium* (or the *historical premium*) of the step-up feature as the JLT (or the historical) value of the step-up bond minus the value of the equivalent plain vanilla bond. By subtracting the value of the equivalent plain vanilla bond, we 'correct' the market, JLT and historical values for all bond characteristics except for the step-up feature. We thus assume that the step-up feature fully determines the remainder of the performance and no other factors are of importance. We calculate the 95% confidence interval around the premium using the confidence bounds of the equivalent plain vanilla bond. As in the pricing errors introduced for the step-up bond prices, we look at the differences between the market step-up premium and the JLT and historical

Table 3.5: Paired Z-tests[a]

		EPV – JLT	EPV – Historical	JLT – Historical
Deutsche Telecom	2005	0.00	-0.12*	-0.12*
	2010	0.33*	0.26*	-0.07*
France Telecom	2004	-0.13*	-0.24*	-0.11*
	2008	-1.04*	-1.63*	-0.58*
KPN	2006	-0.30*	-1.16*	-0.86*

[a] pairwise differences between mean absolute pricing errors of the equivalent plain vanilla (EPV), (Jarrow, Lando and Turnbull, 1997, JLT) and historical values for the step-up bonds

* Indicates significance of the paired-sample Z-test at a 95% confidence level.

Table 3.6: Confidence interval coverage percentages[a]

		EPV	JLT	Historical
Deutsche Telecom	2005	73%	85%	62%
	2010	33%	68%	50%
France Telecom	2004	90%	85%	72%
	2008	48%	0%	6%
KPN	2006	82%	76%	33%

[a] Percentages of market step-up bond prices that lie between the 95% upper and lower bounds of the equivalent plain vanilla (EPV), (Jarrow, Lando and Turnbull, 1997, JLT), and historical values.

premiums. As all three figures incorporate the value of the equivalent plain vanilla bond as a correction term, the last four columns in Table 3.4 and the last column in Table 3.5 also apply to the step-up premium. Table 3.6 does not pertain to the step-up premium; the coverage percentages for step-up premiums are very similar to those for the step-up bond prices, and are therefore omitted.

Deutsche Telecom

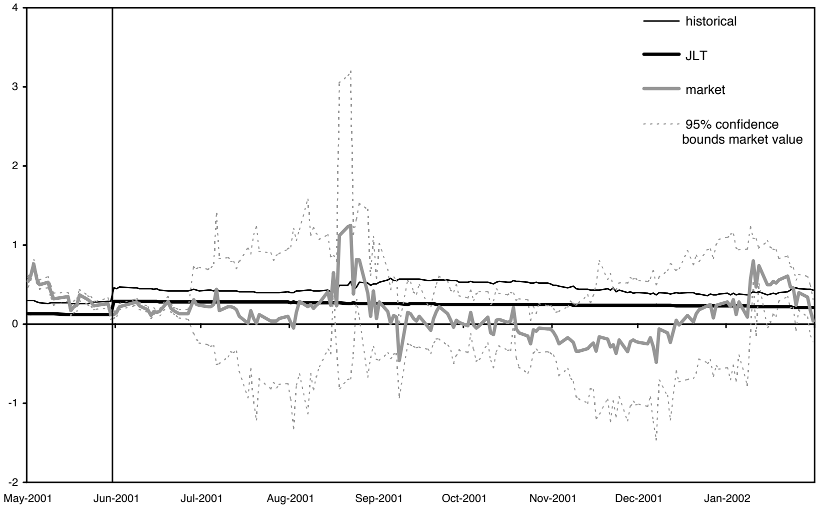
The MPE values in Table 3.4 tell that the EPV method typically undervalues and the JLT and historical methods usually overvalue the 2005-bond. The JLT model has the smallest bias to the market price, since both MPE^{EPV} and MPE^{H} differ more from zero than MPE^{JLT}, even though all three MPEs are statistically different from zero. The percentages in Table 3.6 also show that the JLT model better approximates the step-up market price than the EPV and historical methods. Although the bond values vary across methods, the paired Z-test in Table 3.5 shows that these differences are small, and in case of the difference between the EPV and JLT methods not even statistically significant.

Figure 3.2a shows the market, JLT and historical step-up premiums and the 95% confidence bounds around the market premium for the 2005-Deutsche Telecom bond.[6] Both the JLT and historical premiums are positive and more or less constant, except for a small increase caused by Moody's downgrade of the company on June 13, 2001; the historical premiums are greater than the JLT premiums. In contrast, the market premiums are much more volatile and sometimes even negative.[7] A negative market premium for the step-up feature is counterintuitive: as long as the step-up has not been triggered yet, the coupon cannot be reduced and hence the step-up feature must have a positive value. Even though the negative market premiums may suggest inefficient market pricing, in practice, it is very hard or even impossible to exploit this imperfection, as there are no bonds available that are comparable to the step-up bonds except for the step-up feature. Even if there were such comparable bonds, it would be either impossible or very expensive to take a short position in these bonds. From the confidence bounds of the market premiums, however, if follows that the negative market premiums are not statistically significant. The market premium fluctuates mostly between 0 and 1, except in August 2001, where it is above 1, and in November and December 2001, where it is below 0.

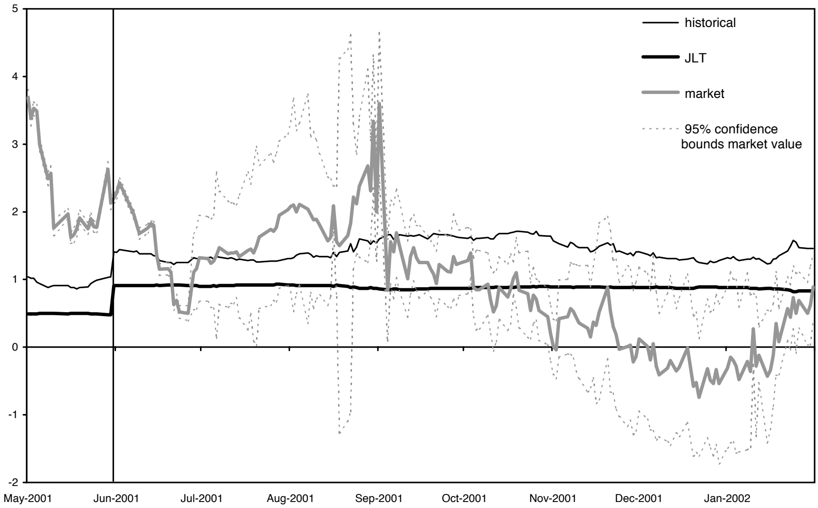
[6] Because there were no plain vanilla Deutsche Telecom bonds before May 14, 2001, Deutsche Telecom figures start well after the step-up bond's issue date of July 6, 2000.

[7] Lehman Brothers (McAdie et al., 2000) also found a negative value in their analysis of euro step-up bonds on July 13, 2000.

Figure 3.2: Deutsche Telecom step-up premiums[a]



(a)



(b)

[a] The market, JLT and historical step-up premium of the (a) 2005- and (b) 2010-Deutsche Telecom step-up bonds. The dotted lines are the 95% confidence bounds of the market premium. The vertical line indicates a rating downgrade by Moody's.

For the 2010-bond, the MPE values in Table 3.4 for the JLT and historical methods are very low, while for the EPV method the MPE value is much higher. Further, all three valuation methods give statistically significant different values at a confidence level of 95%, according to Table 3.5. Table 3.6 also shows that the JLT model generates the highest coverage percentages.

The market step-up premium of the 2010-bond displays an even more volatile pattern than of the premium of the 2005-bond; see Figure 3.2*b*. This makes sense, because with its longer maturity, more coupons are affected by the step-up language. During the first half of the period, until October 2001, the market premium is higher than the JLT and historical premiums, later this pattern is reversed. The market step-up premium becomes negative in December 2001 and January 2002, but again the value is not significant. Both JLT and historical premiums remain roughly constant over the entire period.

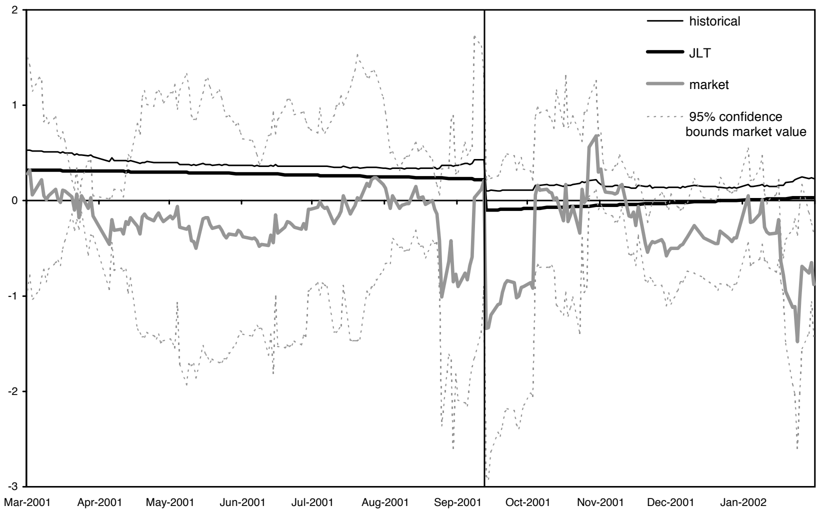
France Telecom

For the 2004-bond, the MPE and MAPE values for the EPV method in Table 3.4 approximate the market prices better than the JLT and historical methods. Apparently, the market values this bond as a plain vanilla bond. In Table 3.6, we observe that the 95% confidence bounds of the EPV values enclose the market prices in 90% of the days, and the JLT and historical methods only 85% and 72%, respectively. Again, Table 3.5 shows that the approximations produced by the three valuation methods differ significantly.

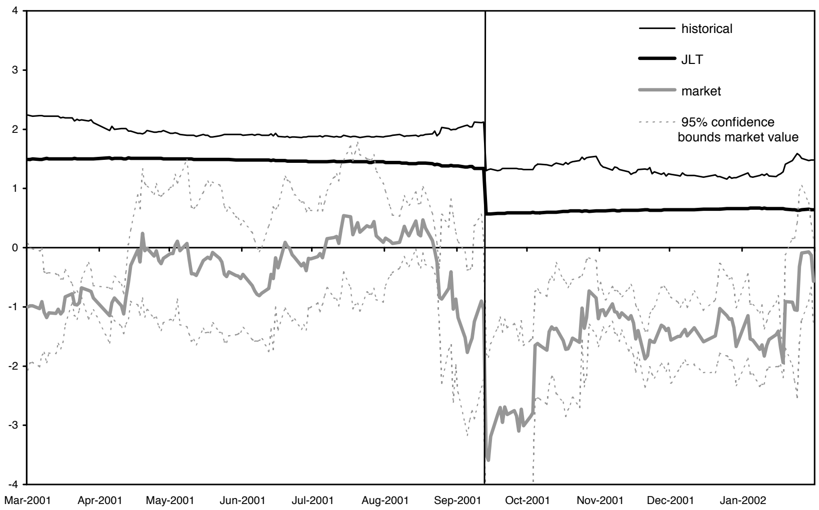
Figure 3.3*a* displays the market step-up premium with its 95% confidence bounds and the JLT and historical premiums. The same pattern as for Deutsche Telecom emerges, with volatile, although insignificant, market premiums and steady JLT and historical premiums. Also, there is a large drop in both theoretical premiums on September 26, 2001 after the downgrade by Moody's from A3 to Baa1. This downgrade triggered the step-up feature (see Table 3.3), so that there are fewer remaining step-ups than the number of step-ups at issuance and the coupon can also step down as the rating improves again. The consequence is a decline in the theoretical step-up premiums, as observed in Figure 3.3*a*.

For the 2008-France Telecom bond, the MPE value is (in absolute value) equal to the MAPE value for both the JLT and historical methods; see Table 3.4. This means that both methods always overestimate the market price. The MPE value for the EPV method is the lowest, but there is still a large bias. The confidence bounds statistics in Table 3.6 reveal that in 48% of the days the market price and EPV value are statistically indistinguishable, while the confidence bounds of the JLT and historical methods almost never include the market price. The paired Z-tests also indicate that the JLT and historical values do not vary much, but that they both differ to a great extent from the EPV values.

Figure 3.3: France Telecom step-up premiums[a]



(a)



(b)

[a] The market, JLT and historical step-up premium of the (a) 2004- and (b) 2008-France Telecom step-up bonds. The dotted lines are the 95% confidence bounds of the market premium. The vertical line indicates a rating downgrade by Moody's.

As Figure 3.3b shows, the market premium of the step-up feature of the 2008-bond is again volatile and even significantly negative during the first few months and also after the downgrade. Both the JLT and historical premiums remain positive during the full period, including after the downgrade, where their values drop as well. As above, we observe that the JLT and historical premiums are typically higher than the market premium and this difference is quite large, because they virtually never lie within the market premium's confidence bounds.

KPN

For the 2006-KPN step-up bond, again the MPE value of the EPV method is closest to zero, although it is significantly below zero; see Table 3.4. The JLT model also typically overvalues the market price, and the historical method even more, as evidenced by their negative MPE values. The same ranking of the three methods emerges from Table 3.6, as in 82% of the cases the market price lies within the EPV confidence bounds, for the JLT and historical methods this is 76% and 33%. Therefore, the market seems to value this bond as a plain vanilla bond.

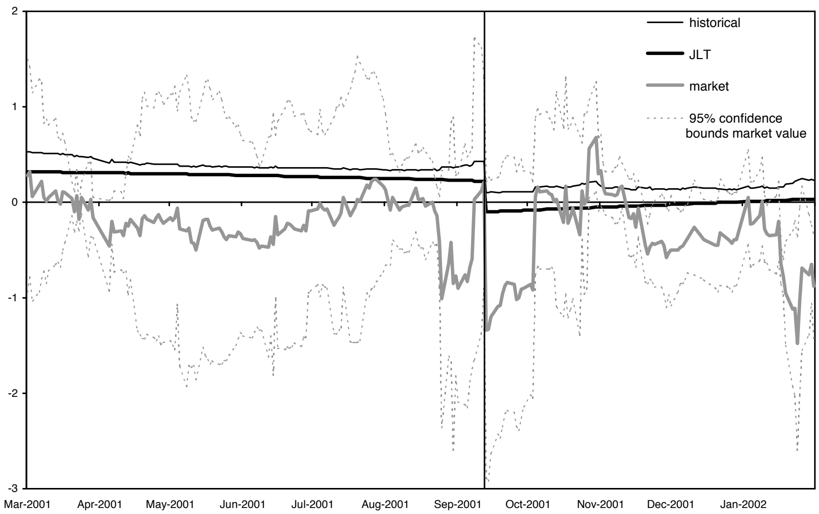
Figure 3.4 plots the market, JLT and historical step-up premiums. As in the two France Telecom bonds, the JLT and historical premiums are less volatile and higher than the market premium, but the premiums of the JLT model often lie within the 95% confidence bounds. The drops in all premiums on September 6, 2001 follow from Moody's rating downgrade from Baa2 to Baa3. The market premium first shows a dramatic fall but then an impressive recovery in the subsequent months to become significantly positive, before it then falls for the second time and becomes negative. Also the JLT premium drops after the downgrade and becomes virtually equal to zero. A similar pattern can be observed for the historical method, since it drops following the downgrade too; unlike the JLT premium, however, it stays positive. Again, the historical premium is always higher than the market premium, something we also noticed for the Deutsche Telecom and France Telecom step-up bonds.

Implications

What is the value of the step-up features at bond issuance? Figure 3.3 shows that the values of both France Telecom bonds do not differ significantly from zero at their issue date, while Figure 3.4 shows that the same applies to the 2006-KPN step-up bond.[8]

[8] For Deutsche Telecom, we cannot value the step-up features at the bond issue date.

Figure 3.4: KPN step-up premiums[a]



[a] The market, JLT and historical step-up premium of the 2006-KPN step-up bonds. The dotted lines are the 95% confidence bounds of the market premium. The vertical line indicates a rating downgrade by Moody's.

In theory, these step-up features should have a positive value. Thus, we conclude these three step-up bonds are undervalued at their issue date. Consequently, the issuer could have issued bonds with a lower (expected) coupon, hereby saving interest payments. This implies that issuing step-up bonds has increased the costs of capital of France Telecom and KPN; see also Lando and Mortensen (2004).

Recovery Rate

The step-up bond values constructed by the EPV, JLT and historical methods all use a recovery rate of 50%. We should note that the 'true' recovery rates for these three Telecom issuers are not known exactly. Of course, this is the case for all corporate issuers that have not experienced default. We thus analyze here how sensitive the mean absolute pricing errors (MAPEs) are to variations in the recovery rate ranging from 30% to 70%.[9]

[9] All other things equal, a higher recovery rate should increase the theoretical value of a step-up bond. Here, however, the recovery rate is first used in the estimation of the survival probabilities, where higher recovery rates result in lower survival probabilities and vice versa. Next, both the recovery rate and the survival probabilities are used in the valuation of the step-up bonds. How the changing recovery rate (and thus the changing survival probabilities) affect the step-up valuation ultimately is therefore not at all straightforward.

Figure 3.5 shows that, for the 2005-Deutsche Telecom bond, the MAPE values produced by the historical and EPV valuation methods always increase, while the MAPEs of the JLT valuation method always declines as the recovery rate increases. For the 2010-Deutsche Telecom bond, both MAPEs and recovery rate always move in the same direction. The same applies for the 2004-France Telecom bond. The MAPEs generated by the historical valuation method rise as the recovery rate increases for both the 2008-France Telecom and the 2006-KPN bond. The opposite pattern can be observed for the MAPEs of the JLT and EPV valuation methods, with the exception of the MAPE of the 2006-KPN bond which rises again at the 70% recovery rate.

We can see that for three of the five step-up bonds - the 2010-Deutsche Telecom and both France Telecom bonds - the order of the valuation methods is always the same, whatever the recovery rate. For the other two bonds, the 2005-Deutsche Telecom bond and the 2006-KPN bond, the historical method always performs most poorly, but the JLT and EPV methods cross at a recovery rate of 50% and 70%, respectively; at lower values, the EPV method is better, while for higher values the JLT method produces smaller errors.

3.5.2 Step-Up Protection

We analyze the protection of a step-up from two perspectives: volatility and excess returns.

Volatility Analysis

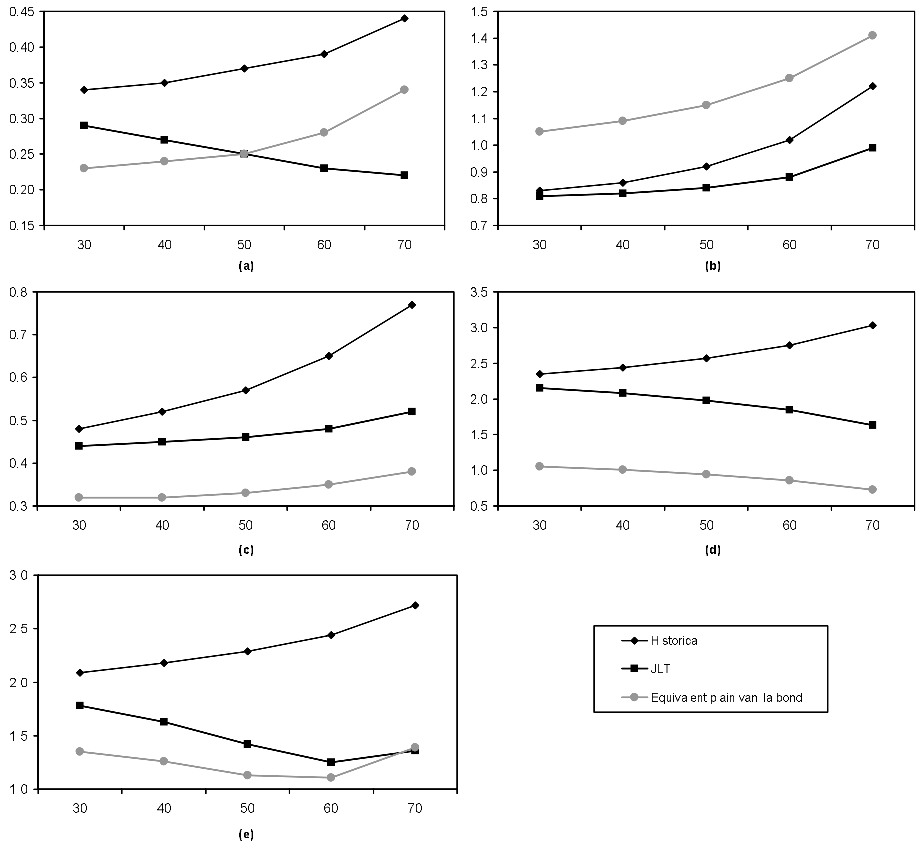
We hypothesize that step-up bond prices are less volatile than an equivalent plain vanilla bond price, because the step-up feature compensates for a lower rating with a higher coupon, and for a higher rating with a lower coupon; see also McAdie et al. (2000).[10] The step-up feature should work as a cushion against rating migrations on bond prices.

We compare the variance of a step-up bond's market prices, $\sigma^2_{step-up}$, with the variance of its equivalent plain vanilla bond's values, σ^2_{EPV}. The null hypothesis

$$H_0 : \frac{\sigma^2_{step-up}}{\sigma^2_{EPV}} = 1,$$

[10] Olivetti/Tecnost's Chief Financial Officer, after linking the coupons of its bonds to its rating, stated: "we think having these sort of volatility protection measures associated with our bonds should result in a lower capital cost" (Bloomberg L.P. Equity News, June 16, 2000, quoted in (Acharya et al., 2002, footnote 9)).

Figure 3.5: Recovery rate sensitivity analysis[a]



[a] The graphs depict the mean absolute pricing errors for various recovery rates, for the equivalent plain vanilla bond, JLT and historical method respectively, for all step-up bonds: **(a)** 2005-Deutsche Telecom, **(b)** 2010-Deutsche Telecom, **(c)** 2004-France Telecom, **(d)** 2008-France Telecom, and **(e)** 2006-KPN.

is tested using the test statistic

$$V = \frac{S^2_{step-up}}{S^2_{EPV}},$$

where $S^2_{step-up}$ and S^2_{EPV} are the sample variances of the step-up bond market prices and equivalent plain vanilla bond values, respectively. V follows an F-distribution with

Table 3.7: Volatility analysis[a]

		Test statistic	p-value
Deutsche Telecom	2005	0.72	0.025
	2010	0.56	0.000
France Telecom	2004	1.04	0.768
	2008	0.75	0.031
KPN	2006	1.00	1.000

[a] F-statistics and p-values for the test that the step-up bonds and their equivalent plain vanilla bonds have equal variances.

$n_{step-up} - 1$ and $n_{EPV} - 1$ degrees of freedom, where n_i equals the number of i-observations, with $i \in \{\text{step-up, EPV}\}$; see e.g. Madsen and Moeschberger (1986).

Table 3.7 shows mixed outcomes. The null hypothesis is easily rejected at the 95% confidence level for both Deutsche Telecom bonds and the 2008-France Telecom bond. So, for these three bonds, the step-up bond price variance is lower than the variance of the equivalent plain vanilla bond.[11] For the 2004-France Telecom and the 2006-KPN bonds, the two variances are statistically indistinguishable.

Event Analysis

As long as the timing or extent of a rating downgrade or negative outlook change is not fully anticipated by the market, plain vanilla bonds should have a negative return on a downgrade or negative information release event date; see, e.g., Hand, Holthausen and Leftwich (1992). Since a step-up bond compensates investors for poorer creditworthiness via a higher coupon, we hypothesize that it has a higher return than its equivalent plain vanilla bond.

To test this hypothesis, we define the *excess step-up return* as the step-up bond market return minus the return of its equivalent plain vanilla bond, so the step-up bond return is fully corrected for all bond characteristics except for the step-up. We first calculate the excess return ER_{it} for bond i for the event day, $t = 0$, and the three succeeding trading days, $t = 1, 2, 3$. Then, we calculate the average ER_t of these excess returns for each day

[11] If the step-up bonds were less liquid than the plain vanilla bonds, then this outcome could be explained by the occurrence of stale prices. In fact, step-up bonds are probably *more* liquid than plain vanilla bonds, because they are younger and have higher notional amounts, see, e.g. Houweling, Mentink and Vorst (2005).

Table 3.8: Event analysis[a]

	Returns				Cumulative returns			
Day	Step-up	EPV	Excess	t-value	Step-up	EPV	Excess	t-value
0	-1.89%	-0.77%	-1.12%	-1.14				
1	0.36%	-0.14%	0.50%	0.65	-1.53%	-0.90%	-0.63%	-0.97
2	-0.11%	-0.61%	0.50%	1.72	-1.64%	-1.51%	-0.13%	-0.20
3	0.16%	0.18%	-0.02%	-0.15	-1.47%	-1.32%	-0.15%	-0.23

[a] Average (cumulative) returns for the step-up bonds and their equivalent plain vanilla (EPV) bonds, as well as the excess returns of the former over the latter and their t-values, after rating downgrades and negative outlook changes, for the event date and the three succeeding days.

for the five step-up bonds. We also consider *cumulative excess returns*, defined as

$$CER_{it} = \sum_{s=0}^{t} ER_{is},$$

and their averages CER_t. We test the significance of the average excess returns and the cumulative average excess returns using simple t-tests as described in Ritter (1991). If both Moody's and S&P's change their ratings of (or outlooks) for the same company at the same time, we treat this as a single event.

Table 3.8 shows the results of this event analysis. On the event date, the return on the EPV bond is indeed negative, as expected. The return on the step-up bond, however, is even more negative, so that the excess step-up return is negative. Although this negative excess return is not significant, it is not consistent with our expectations. During the post event period, the average excess return becomes positive, but stays statistically insignificant. The cumulative excess returns are always negative and insignificant for the entire post event period.

It is counter to our expectations that the step-up feature does not offer investors positive excess returns in the case of a rating downgrade or a negative outlook, but rather statistically identical returns as the EPV bond.

3.6 Summary

In this chapter, we empirically compared several pricing methods for rating-triggered step-up coupon bonds. European telecom companies have issued these bonds in order to compensate bond investors for losses in the event of rating downgrades. The coupon of a step-up bond depends on its issuer rating or the rating of the issuer's long term debt. If this rating deteriorates and hits a predefined level, the step-up coupon is triggered, and the coupon rises with a predefined number of basis points. We applied risk-neutral transition probabilities using the (Jarrow, Lando and Turnbull, 1997, JLT) framework to value these rating-triggered step-up bonds. For comparison purposes, we also valued step-up bonds using historical probabilities and as plain vanilla bonds comparable to step-up bonds except for the step-up feature. Further, we demonstrated our results over a long time period. Next, we tested the volatility of a step-up bond versus the equivalent plain vanilla bond and we performed a rating and outlook change event analysis of excess step-up bond returns.

We found that the market seems to value the Deutsche Telecom step-up bonds, whose coupons make a single step-up after the rating hits the trigger level, according to the JLT model. On the other hand, for the France Telecom and KPN step-up bonds, whose coupons step up every time a rating hits a trigger level, the market seems to resort to valuation as plain vanilla bonds. Market premiums for step-ups are much more volatile than the JLT and historical premiums. These theoretical premiums are stable, except for changes caused by downgrades. Further, as expected, the JLT model approximates the market premiums always better than the historical valuation method.

From the five step-up bonds, the two Deutsche Telecom bonds and the 2008-France Telecom bond have a significantly lower price volatility than their equivalent plain vanilla bonds at a 95% confidence level. So, these three step-up bonds offer protection in terms of a lower price volatility. The volatilities of the 2004-France Telecom and the KPN step-up bond are statistically indistinguishable from their equivalent plain vanilla bonds. Therefore, these step-up bonds do not offer a cushion against rating migrations in the form of dampened price movements. The results from the event analysis, another way of looking at the step-up protection, demonstrates that step-up bonds did not offer superior returns to an investor in case of rating downgrades or negative outlooks.

Chapter 4

Optimizing Credit Bond Portfolios[1]

4.1 Introduction

In recent years both academics and practitioners have put a lot of effort in the development of credit risk models. The CreditMetrics model is the most influential credit portfolio risk model. This model simulates credit bond portfolio distributions and calculates credit bond portfolio risks. Some research has been published (Andersson and Uryasev (1999), Mausser and Rosen (1999*b*) and Andersson, Mausser, Rosen and Uryasev (2001)) in which this model is used to determine optimal portfolios of credit bonds. This research focuses on aggregate portfolio risk measures and shows that the optimization procedure can find portfolios that are less risky, while having at least the same expected return. In this chapter, we will investigate whether the "optimal" bond portfolios are really an improvement by analyzing the characteristics of the bonds in the optimal portfolio.

We find that a portfolio manager should be careful in carrying out the trades as suggested by the optimal portfolio. Optimal portfolios are dominated by only one or two bonds. Even after introducing transaction costs this remains the case. Moreover, the composition of such an optimal portfolio is very sensitive to small changes in the mean forward price of its main constituents. However, the portfolio optimization can be used in combination with some common sense restrictions, such as maximal bond holdings and categorization of bonds using their main characteristics, to produce portfolios that both have a lower risk and higher return than a fully diversified portfolio. We also diversify the optimal portfolio by replacing the dominant bond by similar bonds.

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[1]This chapter is based on an article by Mentink (2005), which has been published in the *ICFAI Journal of Financial Risk Management*. It was also presented at the fourth National Convention of the Associazione Italiana Financial Risk Management (AIFIRM) in Milan on October 9, 2003.

Following Andersson et al. (2001) we use as a risk measure the Conditional Value-at-Risk, which at a given percentile equals the expected value of the losses that exceed the Value-at-Risk at that percentile. Other names for Conditional Value-at-Risk are mean excess loss, mean shortfall, and tail VaR. Conditional Value-at-Risk also provides information about the losses larger than the Value-at-Risk. Moreover, the Conditional Value-at-Risk is sub-additive, convex and can be optimized using linear programming. Value-at-Risk is always lower than or equal to the Conditional Value-at-Risk. Therefore, a low Conditional Value-at-Risk implies a low Value-at-Risk (Andersson et al. (2001)).

In this chapter, we use a CreditMetrics Monte Carlo simulation to generate a bond universe portfolio distribution and optimize its Conditional Value-at-Risk. All bonds in this universe portfolio are U.S. dollar denominated, investment grade or non-investment grade and cover many different countries, maturities, ratings and sectors.

The content of this chapter is the following. Section 4.2 gives a short overview of the credit portfolio optimization literature. In Section 4.3 we define the β-Conditional Value-at-Risk and describe the optimization constraints. The CreditMetrics model is briefly summarized and the J.P. Morgan Active U.S. dollar index and the credit universe portfolio are described in Section 4.4. In Section 4.5 we discuss the results of the β-Conditional Value-at-Risk minimization with and without transaction costs using the simulated CreditMetrics distribution. Sensitivity analyzes with respect to the bond's mean forward price and CreditMetrics simulation are calculated. Finally, Section 4.6 summarizes.

4.2 Literature

The CreditMetrics model by J.P. Morgan/RiskMetrics Group (J.P. Morgan (1997)) is the most influential credit risk portfolio model that has been developed. Related models are: CreditRisk+ of Credit Suisse Financial Products (1997), the McKinsey & Co.-Wilson model (Wilson (1997*a*) and Wilson (1997*b*)) and the KMV model (Kealhofer (1998)). CreditMetrics simulates a credit portfolio distribution and it makes a credit portfolio optimization possible.

A credit portfolio distribution is typically skewed and has a long fat tail. This asymmetric shape is a result from the characteristics of a credit bond. In general, the probability of a loss on a credit bond is low, especially for investment grade credit bonds. However, if a credit bond defaults the resulting loss is large. Moreover, the probability of a profit on a credit bond is higher but only limited and related to its credit spread.

The mean-variance equity portfolio optimization introduced by Markovitz (1952) has also been applied in credit portfolio optimizations. Gollinger and Morgan (1993), Stevenson and Fadil (1996), Kealhofer (1998) and Ramaswamy (2002) all calculate a mean-variance optimization of credit bond portfolios. However, the asymmetric credit portfolio distribution makes a symmetric portfolio risk measure, such as variance, not very useful.

Value-at-Risk (VaR) is an often-used risk measure to account for portfolio distribution asymmetry. It measures the maximum loss at a given confidence level, for example 95%. However, it has both economic and non-economic limitations. By definition, it does not give any information about the portfolio losses larger than the VaR. Furthermore, this risk measure lacks sub-additivity (Artzner, Delbaen, Eber and Heath (1999)). Moreover, as Vorst (2000) demonstrates portfolio return maximization under a VaR restriction generates gambling portfolios. Last, using simulated credit portfolio distributions VaR is a non-smooth, non-convex and multi-extreme function of the portfolio bond amounts (Andersson et al. (2001)). These results make a credit portfolio optimization based on VaR and a simulated distribution difficult to interpret and impossible to implement. To overcome the non-smoothness problem, Arvanitis, Browne, Gregory and Martin (1999) optimize the VaR of their credit portfolio by randomly altering the portfolio amounts of the bonds. This approach generates many portfolios, but does not result in a smooth expected return-VaR efficient frontier.

Expected regret of a credit portfolio gives the expected value of losses that exceed a pre-specified threshold. This measure does take into account the losses that exceed the given threshold. Furthermore, it can be optimized by solving a linear programming model (Mausser and Rosen (1999*a*) and Mausser and Rosen (1999*b*)). But it is not clear what the value of the pre-specified threshold should be. In contrast, Conditional Value-at-Risk (CVaR) does not require a pre-specified threshold and can still be calculated using a linear programming model. Testuri and Uryasev (2000) explain the relationship between expected regret and Conditional Value-at-Risk. Rockafellar and Uryasev (2000), Krokhmal, Palmquist and Uryasev (2001) and Jobst and Zenios (2002) use CVaR to optimize their asset allocation, credit, equity and option portfolios. Further, Alexander and Baptista (2003) analyze the implications for portfolio selection using CVaR and VaR constraints, but they employ a mean-variance model in their analysis.

These papers minimize CVaR and analyze optimal, *aggregate* risk measures. In practice, a portfolio manager is not only interested in the risk of the optimal portfolio, but also in its composition. We focus on the individual credit bonds in the optimal portfolios and analyze their characteristics and sensitivities.

4.3 Conditional Value-at-Risk

We analyze both the β-Value-at-Risk (β-VaR) and the β-*Conditional* Value-at-Risk (β-CVaR) of a credit portfolio using simulated credit portfolio distributions, as described in the next section. A distribution is defined as the portfolio's mean future value minus the simulated distribution (both according to CreditMetrics). So a (very) positive value in this distribution represents a (much) lower value than the mean portfolio value, i.e. a (large) loss. We want to minimize the (1-β%) largest portfolio losses.

The β-VaR of this simulated distribution equals the lowest amount α such that with probability β the portfolio loss will not exceed α. Typical values for β are 90%, 95% and 99%. The β-CVaR is defined as the conditional expected value of those portfolio losses that are larger than α. So β-CVaR equals the expectation of (1-β)% portfolio losses larger than α. β-CVaR and β-VaR are both functions of the credit portfolio composition.

Define the matrix $\mathbf{d} = d_{ji}$ by $d_{ji} = b_i - v_{ji}$ with b_i the probability-weighted mean of the forward prices across all rating categories, including default (mean forward price) of bond i and v_{ji} the forward price in simulation j of bond i, with m the number of simulations and n the number of bonds. Let $\mathbf{x} = (x_1, \ldots, x_n)$, where x_i are the holdings of bond i in the credit portfolio. The β-VaR of the simulated portfolio is denoted by $\alpha(\mathbf{x}, \beta)$ and the β-CVaR of the portfolio by $\theta(\mathbf{x}, \beta)$. Now it easily follows that

$$\theta(\mathbf{x}, \beta) = \alpha(\mathbf{x}, \beta) + \left(\frac{1}{1-\beta}\right)\left(\frac{1}{m}\right)\sum_{j=1}^{m}\left[\sum_{i=1}^{n} d_{ji}x_i - \alpha(\mathbf{x}, \beta)\right]^{+} \tag{4.1}$$

with the $[t]^{+} = \max(0, t)$.

We will minimize this expression under three constraints that are described below. First, the optimal bond portfolio with a minimal β-CVaR has to generate an expected return of at least R. The sum of the product of the expected bond return r_i, its spot price q_i, and amount x_i, is required to be greater than or equal to R times the spot value of the universe portfolio. Initially we assume that we have an amount equal to one of each bond in the universe in our portfolio, $x_i = 1$, $\forall\, i$. So the return constraint reads

$$\sum_{i=1}^{n} q_i r_i x_i \geq R \sum_{i=1}^{n} q_i \tag{4.2}$$

Secondly, the spot value of the optimal bond portfolio has to maintain the spot value of the universe portfolio. Therefore, the value constraint equals

$$\sum_{i=1}^{n} q_i x_i = \sum_{i=1}^{n} q_i \tag{4.3}$$

Third, the optimal amount of each bond has a lower limit l and an upper limit u. Here, both limits have the same value for all bonds. These limits restrict the multiples of the bond's amounts in the optimal portfolio. An optimal bond amount of one means that the amount has not changed compared to its universe amount. The limit constraints look like

$$l \leq x_i \leq u \qquad\qquad i = 1, \ldots, n \tag{4.4}$$

We want to minimize the β-CVaR subject to return, value and holding constraints. This optimization can be solved using linear programming (lp) techniques as shown in Rockafellar and Uryasev (2000) and Andersson et al. (2001). This lp problem is also displayed in Appendix 4.B.

4.4 CreditMetrics and Data

CreditMetrics simulates future bond prices and portfolio values. In fact, CreditMetrics simulates a rating for each individual bond. In our application we use a future horizon of one year. Next, the horizon price for the bond is calculated based on the forward yield curve corresponding to the simulated rating (Benson and Zangari (1997) and J.P. Morgan (1997)). Correlations between rating changes are incorporated via the correlation between equity returns. In this way, for each simulation run a portfolio value can be calculated. By plotting the results of a large number of simulations a distribution of future portfolio values is derived. In the optimization procedure as described in the previous section we not only need the distributions of forward prices of individual bonds, but also for each simulation run the simulated price of each individual bond.

We download the J.P. Morgan Active U.S. dollar index available in CreditMetrics. The members of this index are all straight bullet bonds with a fixed rate coupon and a minimal amount outstanding of 100 million U.S. dollar. All members must be reasonably liquid according to J.P. Morgan criteria before they enter this index. The number of credit bonds equals 680, issued by 232 different issuers. These index data are downloaded from September 20, 2001.

The CreditMetrics characteristics of the issuers are: name, transition matrices (Moody's or S&P), rating (including minor ratings), issuer-specific risk (40% for all issuers), country, country weight, sector and sector weight. J.P. Morgan assigns each issuer to one country and one sector only. (CreditMetrics allows for three different countries and three different industries though.) By selecting just one country and one sector our analyzes of the optimization results are easier to interpret (RiskMetrics Group (1999*b*)). The credit bonds in this index are characterized by name, issuer name, asset type (for example bond or loan), portfolio name, currency (all bonds are denominated in U.S. dollar), recovery rate (47.7% for all bonds), standard deviation of the recovery rate (26.6% for all bonds), issued amount, maturity date, coupon, coupon frequency, seniority and rate type (for example government or swap curve). All characteristics are the same for each bond except for issuer, issuer name, maturity date, coupon and coupon frequency. "CreditMetrics calculates the spot price and the mean forward price for each bond and it produces the expected return and the one year forward price corresponding to each possible rating for each bond."

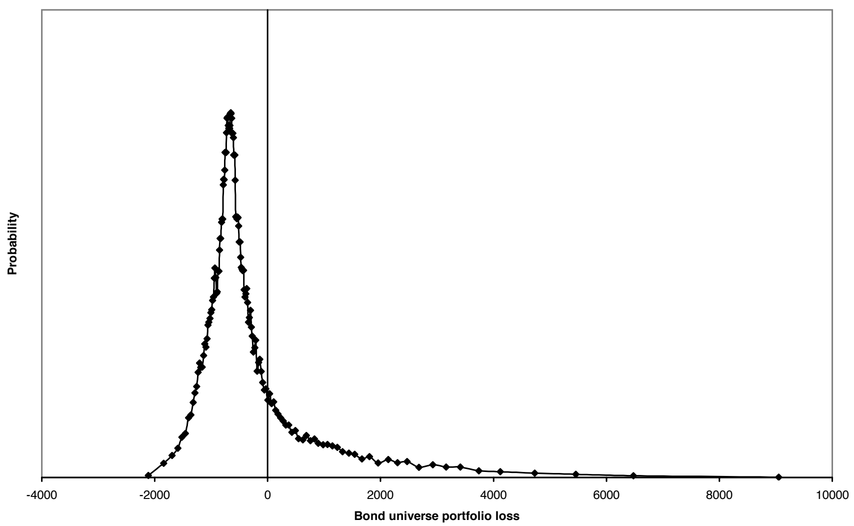
A bond's return is calculated by taking the difference between the one year forward and the spot price and dividing this difference by the spot price. Obviously, this is a forward looking return measure, in contrast to, for example, backward looking equity returns. Using this return measure, it is easy to make it a function of rating opinions of the portfolio manager, for example: if the portfolio manager thinks that the assigned rating is too low, he can raise the expected return to the level that corresponds to his higher rating level (leaving the rating transition probabilities unchanged though).

We construct a credit universe portfolio by imposing restrictions on this J.P. Morgan Active U.S. dollar index. This means that the nominal amount of each bond in our universe is a function of its issued amount. Thus the nominal amounts between bonds can differ. In order to further simplify the interpretation of the results, we randomly select just one bond with each issuer. Additionally, our universe does not contain bonds with a maturity shorter than one year to avoid reinvestment problems. Both restrictions do not limit the universe's variety in countries, maturities, ratings and sectors compared to the original index. Now our bond universe consists of 231 issue(r)s. The spot market value of this bond universe portfolio equals 240840.

We assign to the selected bonds the appropriate credit spread curves. Each bond is mapped to a credit-spread curve according to the issuer's sector and rating. For example: if a bond is issued by a bank with an A1 rating the bond is mapped to the A1 bank spread curve. These credit spread curves are an approximation of the issuer specific credit spread curves. Therefore, we will do sensitivity analyzes of the optimal portfolio composition with respect to changes in the mean forward price and thus the expected returns later in this chapter. These credit spread curves are quoted versus the U.S. dollar government zero curve. Using the sum of this zero coupon curve and the relevant credit spread curve, CreditMetrics calculates the spot and one year (mean) forward prices. The RiskMetrics Group supplies the zero coupon U.S. dollar government interest rate curve, credit spread curves, equity time series and two transition matrices, both Moody's and S&P, as each issuer is mapped to one of these two matrices.

Figure 4.1 shows the bond universe portfolio loss distribution. The simulated distribution is displayed relative to the mean future credit bond universe value. The positive distribution values at the right hand side represent the possible, largest losses in one year: $t = 1$. This distribution is generated with 20000 scenarios (RiskMetrics Group (1999a)). As a consequence of this large number of scenarios the distribution's shape is smooth.

Figure 4.1: Bond universe portfolio loss distribution



As mentioned earlier, the universe portfolio holds one in each bond issue in the universe of bonds considered. If we run the lp optimization from Appendix 4.B with $l = 1$ and $u = 1$, the portfolio composition remains of course equal to the universe portfolio. However, the optimization program gives us the marginal CVAR for each individual bond. A

Table 4.1: Bond universe portfolio statistics

	β-CVaR	β-VaR
β=90%	4532	2556
β=95%	5913	3812
β=99%	9552	7023

positive marginal CVaR means that the β-CVaR will increase for small increases in x_i. Bond characteristics such as the mean forward price, expected return, country, rating and sector determine this marginal CVaR. But, as with β-VaR and β-CVaR, the marginal CVaR also depends on the, arbitrarily chosen, portfolio Monte Carlo simulation, despite the fact that the VaR has converged using 20000 simulations, see Appendix 4.A. Table 4.1 shows the β-VaR and β-CVaR of the universe portfolio for three different confidence levels.

From the universe portfolio, five bonds with the highest and lowest marginal CVaR for confidence level $\beta = 95\%$ are given in Table 4.2 and Table 4.3 respectively. All bonds in Table 4.2 have a very low rating. Since we will minimize the objective function, a high marginal CVaR indicates that we would like to reduce the holdings of these bonds in our portfolio. This low rating means a high probability of default and thus a high β-CVaR contribution of such a bond. Furthermore, a higher (lower) (mean) forward price of a bond also means a higher (lower) marginal CVaR.

We now look at each bond in Table 4.2 in more detail. The Russian (RU) government (SVN) bonds both have a relatively high mean forward price and have the second lowest rating in the universe portfolio. The Argentine (AR) bond has the highest mean forward price of the two lowest rated bonds. There is only one bond in the universe portfolio with a B+ rating. But this bond has a low mean forward price. The Brazilian (BR) bond has the highest mean forward price of the BB-rated bonds. The two other BB-rated bonds have a low mean forward price. The Lucent bond has a high mean forward price.

In contrast, all bonds in Table 4.3 have the highest rating AAA and a very short maturity. Their one year default probability equals zero according to the two used transition matrices. So their marginal CVaR is very low as well.

The five bonds with the highest marginal CVaR in the universe portfolio with confidence levels $\beta = 90\%$ and 99% are comparable to those in the universe portfolio with $\beta = 95\%$. The same applies for the five bonds with the lowest marginal CVaR.

Table 4.2: Five universe portfolio members with the highest marginal CVaR (MC) and their main characteristics: name (N), rating (R), maturity date (M), country (C), sector (S), expected return (ER), with Russian Federation (RU), Argentina (AR), Brazil (BR), United States (US), Sovereign (SVN) and General (GNL)

N	MC	R	M (mm-dd-yyyy)	C	S	ER
Russian Federation	1199.4	B	07-24-2005	RU	SVN	8.88
Russia Minfin Bonds	556.1	B	06-10-2003	RU	SVN	8.75
Argentina	442.3	B−	12-20-2003	AR	SVN	8.94
Brazil	360.3	BB−	04-15-2004	BR	SVN	6.17
Lucent Technologies	173.2	BB+	03-15-2029	US	GNL	5.38

Table 4.3: Five universe portfolio members with the lowest marginal CVaR (MC) and their main characteristics: name (N), rating (R), maturity date (M), country (C), sector (S), expected return (ER), with Supra National (SN), United States (US), Germany (DE), France (FR), Banks (BNK), Financial (FIN) and Railroads (RAI)

N	MC	R	M (mm-dd-yyyy)	C	S	ER
World Bank	0.004	AAA	12-04-2002	SN	BNK	3.61
General Electric	0.007	AAA	10-01-2002	US	FIN	3.72
Baden-Wuerttemberg	0.009	AAA	10-01-2002	DE	BNK	3.60
Asian Development Bank	0.022	AAA	10-21-2002	SN	BNK	3.61
Soc Nationale Chemins Fer Francais	0.027	AAA	01-30-2003	FR	RAI	3.68

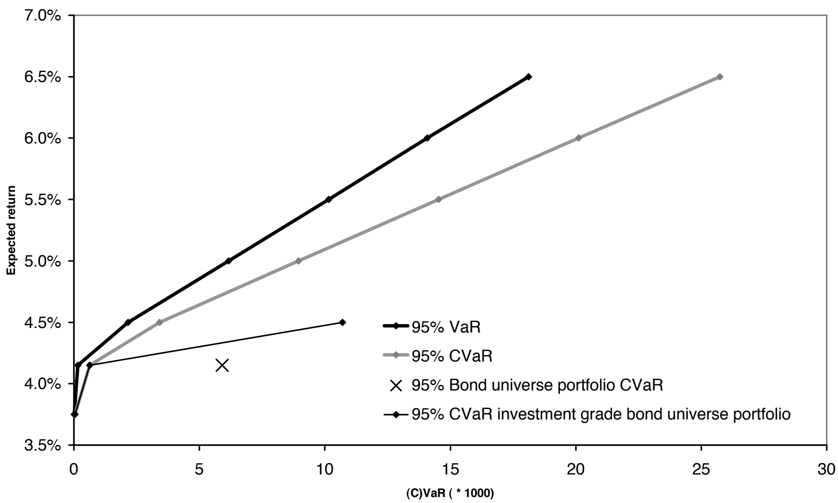
4.5 Results

As stated in Section 4.3, we calculate an optimal portfolio by minimizing the β-CVaR of the universe portfolio. Figure 4.2 displays the expected return 95%-β-(C)VaR efficient frontier, the efficient frontier of the investment grade only universe portfolio and the 95%-CVaR of the universe portfolio.

The optimal portfolio with the same expected return as the universe portfolio, i.e. 4.15%, has a 95%-CVaR of 0.629, which is substantially lower than the universe portfolio CVaR of 5913. We also see that the 95%-VaR of this optimal portfolio is much lower, being 0.154 versus 3812 of the universe portfolio. The optimal 95%-CVaR portfolio with

$R = 3.75\%$ has a CVaR that is virtually equal to zero. This optimal portfolio almost fully consists of one AAA-rated General Electric bond, i.e. 94% of the portfolio's spot market value. Andersson et al. (2001) find the same large reductions in their optimal CVaR and they also mention this extreme result in their portfolio optimization. From Figure 4.2 we observe that restricting our optimization to the investment grade universe bonds limits the maximum expected portfolio return to 4.50% and increases the associated 95%-CVaR compared to an unrestricted optimal portfolio with the same return.

Figure 4.2: Expected return 95%-CVaR and 95%-VaR efficient frontiers



Next we analyze the composition of the 95%-CVaR optimal portfolio with $R = 4.50\%$, i.e. one particular portfolio on the efficient frontier. This portfolio has both a higher expected return and a lower 95%-CVaR than the universe portfolio. Table 4.4 shows the name (N), amount (X), rating (R), maturity (M), country (C), sector (S) and expected return (ER) of each bond. This optimal portfolio almost totally consists of the General Motors (GM) bond, i.e. 87% of the portfolios spot market value. It is ranked 87 according to the ascending marginal CVaR of the universe bonds.[2] Thus in terms of CVaR this bond

[2]All bonds in our 95% optimal portfolio are also present in the optimal portfolio with the same required return and confidence levels of 90% and 99%. Moreover, the GM bond gets by far the largest amount in these two optimal portfolios.

Table 4.4: Bonds in the optimal portfolio and their main characteristics: name (N), amount (X), rating (R), maturity (M), country (C), sector (S), expected return (ER), with United States (US), Lebanon (LB), Mexico (MX), Philippines (PH), Malaysia (MY), Colombia (CO), Venezuela (VE), Brazil (BR), Turkey (TR), Financials (FIN), Sovereign (SVN), Banking (BNK), Utilities (UTI) and Food (FOD)

N	X	R	M (mm-dd-yyyy)	C	S	ER
General Motors	163.8	A	01-22-2003	US	FIN	4.24
Lebanon	5.9	B+	12-14-2004	LB	SVN	8.71
Bancomext	4.1	BB+	02-02-2004	MX	FIN	5.86
Philippines	3.6	BB	03-16-2010	PH	BNK	6.22
Philippines	3.4	BB+	04-15-2008	PH	SVN	6.02
Tenaga Nasional	3.3	BBB−	06-15-2004	MY	UTI	4.25
Colombia	3.3	BB	02-15-2007	CO	SVN	6.21
Mexico	3.2	BB+	04-06-2005	MX	SVN	6.01
Venezuela	2.9	B	08-15-2018	VE	SVN	8.84
Escelsa	2.4	BB−	07-15-2007	BR	FIN	6.03
Kellogg Co	2.2	BBB	04-01-2003	US	FOD	4.34
Turkey	1.1	B−	11-05-2004	TR	SVN	8.79
Brazil	0.6	BB−	04-15-2004	BR	SVN	6.17

does not contribute a high risk to the universe portfolio.[3] The GM bond is mapped to the largest country United States (36% of the universe portfolio market value) and the largest sector Financials (20%).

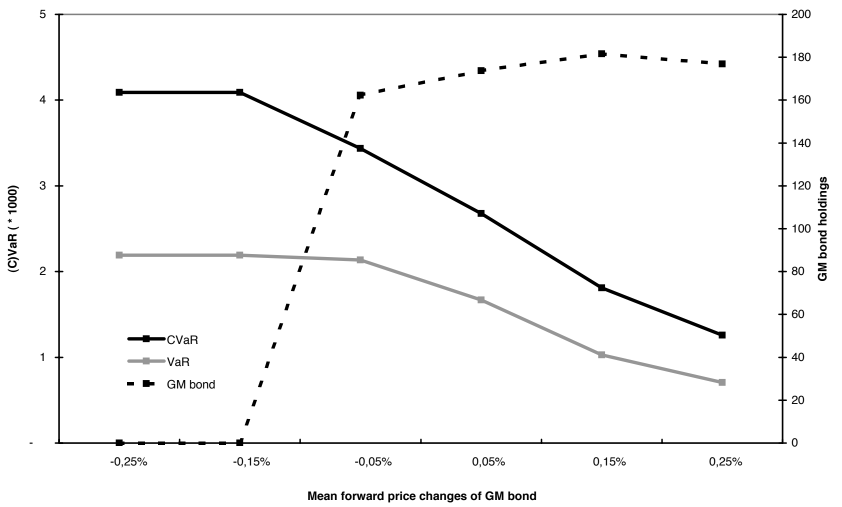
Other portfolios on our 95%-CVaR efficient frontier show the same composition; only one or two bonds dominate the optimal portfolio. In practice a portfolio manager would be very hesitant to put all his money in only one or two bonds. Hence, next follows some more analysis on this ”optimal” portfolio.

In order to study the sensitivity of the optimal portfolio composition to the implicit assumption on the expected return of the GM bond, we alter its mean forward price and thus also its expected return. Figure 4.3 displays the huge impact on both the 95%-(C)VaR and the GM bond holding after the mean forward price changes of -0.25% to 0.25% with steps of 0.10% point. After increasing this mean forward price, the optimal (C)VaR drops sharply, for example: an 0.25% increase in price, lowers the CVaR from

[3]Rerunning the simulation with a higher number of simulations, 25000 in stead of 20000, does not alter the ranking of the bonds significantly.

3409 to 1257. At the same time, the GM holding increases from 163.8 (in Table 4.4) to 177. After lowering the mean forward price with only 0.15% or 0.25%, the GM bond is fully replaced by a comparable Ford Motor Credit bond from Table 4.7 below.

Figure 4.3: Sensitivity analysis of the optimal portfolio



Given the strong concentration in one particular bond in the optimal portfolio and the sensitivity to its return assumption, we have to further diversify our portfolio. To this end we introduce a maximum percentage of each bond in the optimal portfolio. So, we add Equation (4.B.7) to our lp optimization as described in Appendix 4.B. In practice, it is common to impose a maximum amount of a certain issue(r). Table 4.5 shows that 95%-VaR, 95%-CVaR and the number of bonds increase as the maximum percentage decreases. The amount in the GM bond always equals the allowed maximum percentage.

If we consider the portfolio with at most 5% of each bond from the universe portfolio, the 95% CVaR is considerably higher than the 95% CVaR of the "optimal" portfolio: 5004 versus 3409. However, this new optimal portfolio is definitely more diversified. Compared with the universe portfolio it has a lower 95% CVaR, 5004 versus 5913, and a higher expected return: 4.50% versus 4.15%. Hence, the full optimization gives portfolios that would not be very much appreciated by investors since it is too concentrated. However, with restrictions on the amounts of bonds in the portfolio, the optimization procedure creates a portfolio that is definitely better than the universe portfolio.

Table 4.5: Maximum amount percentages, optimal 95%-CVaR, 95%-VaR, GM bond amount and number of bonds

Maximum percentage	95%-CVaR	95%-VaR	GM bond	Number of bonds
5%	5004	3055	9.4	41
10%	4562	2467	18.7	30
20%	4128	2412	37.4	26
No maximum	3409	2159	163.8	13

Another method of diversifying the optimal portfolio can be implemented via categorization all bonds using their main characteristics: country (44 countries), maturity (1-5, 5-10 and 10+), rating (including notches) or sector (21 sectors).[4] The model in Section 4.3 now alters somewhat: the decision variable, x_i, changes into all bonds with the same characteristic, for example: all bonds with a maturity of more than ten year or all bonds with an A1 rating, instead of one single bond. The advantage of this approach is that an optimal amount represents a group of bonds instead of only one bond and thus we avoid extreme results as described above.

Table 4.6 shows that portfolio categorization using country, maturity and sector results in a lower 95%-(C)VaR, whereas using rating generates a higher 95%-(C)VaR than the universe 95%-(C)VaR. In case of the higher expected return of 4.50%, bucketing by country and maturity gives the lowest and highest 95%-(C)VaR respectively. It seems that categorization by means of country and sector is less restrictive than categorization by maturity and rating.

A third approach to derive a better diversified optimal portfolio goes as follows. We have eight bonds in our universe portfolio with comparable characteristics to the GM bond. In Table 4.7 their main characteristics are summarized and ordered according to the ascending marginal CVaR. However, these bonds are not members of the optimal portfolio, partly because their individual marginal CVaR is higher than that of the GM bond in the Monte Carlo simulation. With the purpose of further diversifying our optimal portfolio we divide the invested amount in GM equally across this bond and the eight comparable bonds. Now we again calculate the 95%-CVaR by keeping the holdings of these nine bonds fixed. The optimal 95%-CVaR increases to 4527 and the expected return decreases to 4.43% compared to the "optimal" portfolio. Again, this portfolio has a better risk-return profile than the universe portfolio.

[4]We thank the RiskMetrics Group for this suggestion.

Table 4.6: Optimal portfolio statistics using country, maturity, rating or sector categorization

	R= 4.15%	R= 4.50%
Country		
95% CVaR	3955	6985
95% VaR	2492	4513
N	16	18
Maturity		
95% CVaR	5588	22038
95% VaR	3790	13820
N	231	61
Rating		
95% CVaR	14981	17406
95% VaR	4616	8912
N	9	12
Sector		
95% CVaR	3555	8962
95% VaR	1683	6309
N	95	54

Now we extend our lp optimization problem by incorporating transaction costs as a portfolio manager who trades credit bonds is generally confronted with large bid-ask spreads (Krokhmal et al. (2001)). Here, the transaction costs, c, are a fixed percentage of the sum of the sold and bought bond amounts. This percentage is the same for all bonds in the universe portfolio and equals $c = 0.5\%$.[5] In Appendix 4.B we show this lp extension.

Table 4.8 compares the 95%-CVaR and 95%-VaR of the optimal portfolio without transaction costs (OP) and the optimal portfolio with transaction costs (OPTC). The optimal portfolio without transaction costs equals the "optimal portfolio" from the efficient frontier in Figure 4.2 with $R = 4.50\%$. The percentages between parentheses in Table 4.8 denote the changes in 95%-CVaR and 95%-VaR compared to OP.

The bonds in the optimal portfolio with transaction costs are shown in Table 4.9. Many bonds in the universe portfolio are still sold despite the introduction of transaction costs and they get a holding equal to zero. The optimal amount of the GM bond is lower than its amount in the optimal portfolio without transaction costs but this bond still dominates the new optimal portfolio.

[5] It also possible to make these costs different across bonds.

Table 4.7: Eight bonds that are comparable to the GM bond and their main characteristics: name (N), marginal ranking (MR), rating (R), maturity (M), country (C), sector (S) and expected return (ER), with United States (US) and Financials (FIN).

N	MR	R	M (mm-dd-yyyy)	C	S	ER
American Express Travel	107	A+	01-22-2004	US	FIN	4.18
Ford Motor Credit Co	113	A	01-14-2003	US	FIN	4.24
Cit Group Holdings Inc	120	A+	03-15-2003	US	FIN	4.20
Avco Financial Services Inc	126	A	12-09-2004	US	FIN	4.23
Countrywide Home Loan	130	A	06-15-2004	US	FIN	4.23
Heller Financial Inc	147	A−	05-15-2003	US	FIN	4.27
Team Fleet Finance Corp	189	A	09-15-2005	US	FIN	4.25
Ford Capital BV	207	A	07-16-2004	US	FIN	4.24

Table 4.8: 95%-CVaR and 95%-VaR of the optimal portfolio (OP), the optimal portfolio with transaction costs (OPTC) and the optimal portfolio using a second simulation (OPS), with R= 4.50%

	95%-CVaR	95%-VaR
OP	3409	2159
OPTC	3841	2488
	(12.7%)	(15.2%)
OPS	3912	2098
	(14.7%)	(−2.8%)

As discussed in Section 4.4 the marginal CVaR of bonds in the universe portfolio partly depends on the Monte Carlo simulation. In order to see the effect of this simulation on the 95%-CVaR optimization results, we again optimize the 95%-CVaR but now use a second simulation. In the lp optimization we set the upper and lower limits equal to the amounts of the optimal portfolio. In this way the composition of the optimal portfolio does not change. As Table 4.8 displays both 95%-CVaR and 95%-VaR of the new optimal portfolio (OPS) are not invariant with respect to the simulation.

Table 4.9: Members of the optimal portfolio subject to transaction costs and their characteristics: name (N), amount (X), rating (R), maturity (M), country (C), sector (S) and expected return (ER), with United States (US), Lebanon (LB), Mexico (MX), Philippines (PH), Colombia (CO), Malaysia (MY), Venezuela (VE), Brazil (BR), Turkey (TR), Financials (FIN), Sovereign (SVN), Banking (BNK), Utilities (UTI) and Food (FOD)

N	X	R	M (mm-dd-yyyy)	C	S	ER
General Motors	157.60	A	01-22-2003	US	FIN	4.24
Lebanon	6.80	B+	12-14-2004	LB	SVN	8.71
Bancomext	4.70	BB+	02-02-2004	MX	FIN	5.86
Philippines	4.10	BB	03-16-2010	PH	BNK	6.22
Philippines	3.90	BB+	04-15-2008	PH	SVN	6.02
Colombia	3.80	BB	02-15-2007	CO	SVN	6.21
Mexico	3.70	BB+	04-06-2005	MX	SVN	6.01
Tenaga Nasional	3.50	BBB−	06-15-2004	MY	UTI	4.25
Venezuela	3.40	B	08-15-2018	VE	SVN	8.84
Escelsa	2.60	BB	07-15-2007	BR	FIN	6.03
Kellogg Co	2.40	BBB	04-01-2003	US	FOD	4.34
Turkey	1.20	B−	11-05-2004	TR	SVN	8.79

Thus, as the analyzes above demonstrate, a portfolio manager can use 95%-CVaR optimization after deciding the bonds he wants to trade, determining their transaction costs, adjusting their expected returns, making categories of comparable bonds and imposing maximum constraints.

4.6 Summary

In recent years, some research has been published (Andersson and Uryasev (1999), Mausser and Rosen (1999*b*) and Andersson et al. (2001)) in which the CreditMetrics model has been used to determine optimal portfolios of credit bonds. This model simulates credit bond portfolio distributions and calculates credit bond portfolio risks. This research demonstrates that the optimization procedure can find portfolios that are less risky, while having at least the same expected return as a fully diversified portfolio. In this chapter, we investigated whether the "optimal" bond portfolios are really an improvement by analyzing the characteristics of the optimal portfolio.

We find that a portfolio manager should be careful in carrying out the trades as suggested by the optimal portfolio. Optimal portfolios are dominated by only one or two bonds. Even after introducing transaction costs this remains the case. Moreover, the composition of such an optimal portfolio is very sensitive to small changes in the mean forward price of its main constituents. However, the portfolio optimization can be used in combination with some common sense restrictions, like maximal bond holdings and categorization of bonds using their main characteristics, to produce portfolios that both have a lower risk and higher return than a fully diversified portfolio. We also improve on the portfolio by replacing the dominant bond in the optimal portfolio by similar bonds.

Table 4.10: Bond universe 95%-VaR with its upper (UC) and lower confidence bounds (LC)

	95%-LC	β-VaR	95%-UC
β=90%	248172	248308	248422
β=95%	246747	247045	247898
β=99%	243152	243878	244621

Appendix

4.A Simulation Convergence

The bond universe distribution is generated by a CreditMetrics simulation of 20000 scenarios. Convergence of this simulation is measured by the distance between the β-VaR and the 95% upper and lower percentile confidence bounds (J.P. Morgan (1997), RiskMetrics Group (1999*a*) and RiskMetrics Group (1999*c*)). Table 4.10 shows that these upper and lower confidence bounds lie very close to β-VaR. Thus this simulation generates β-VaR convergence.

β-VaR in Table 4.10 and Table 4.1 are related. Subtracting the β-VaR in Table 4.1 from the mean future value of the bond universe portfolio, 250857, gives the β-VaR in Table 4.10. Small differences between these values do occur due to CreditMetrics rounding.

4.B Linear Programming Model

The β-CVaR of the universe portfolio subject to the return, value and amount constraints can be minimized using the lp model below. Solving this lp problem, we find the optimal amounts, the corresponding VaR and the optimal CVaR (Andersson et al. (2001).

Minimize

$$\theta(\mathbf{x},\beta) = \alpha + \left(\frac{1}{1-\beta}\right)\frac{1}{m}\sum_{j=1}^{m} y_j \tag{4.B.1}$$

subject to

$$
\begin{aligned}
y_j &= \sum_{i=1}^{n}((b_i - v_{ji})x_i) - \alpha && && (4.B.2)\\
y_j &\geq 0 && && (4.B.3)\\
\sum_{i=1}^{n} q_i r_i x_i &\geq R\sum_{i=1}^{n} q_i && && (4.B.4)\\
\sum_{i=1}^{n} q_i x_i &= \sum_{i=1}^{n} q_i && && (4.B.5)\\
l &\leq x_i \leq u && i = 1,\dots,n && (4.B.6)\\
q_i x_i &\leq P\sum_{i=1}^{n} q_i && P = 5\%, 10\%, 20\% && (4.B.7)
\end{aligned}
$$

Incorporating transaction costs into this β-CVaR optimization problem replaces constraint (4.B.6) with the four constraints below. The goal function and the other constraints remain the same. The maximum amount sold of a bond in the universe portfolio, δ_i^s, equals one, because its universe portfolio amount equals one and no short positions are allowed. The maximum amount bought of a bond in the universe portfolio, δ_i^b, equals the upper limit u.

$$
\begin{aligned}
\sum_{i=1}^{n} q_i x_i + c\sum_{i=1}^{n} q_i(\delta_i^s + \delta_i^b) &= \sum_{i=1}^{n} q_i && (4.B.8)\\
1 - \delta_i^s + \delta_i^b &= x_i && (4.B.9)\\
0 \leq \delta_i^s &\leq 1 && (4.B.10)\\
0 \leq \delta_i^b &\leq u && (4.B.11)
\end{aligned}
$$

Part II

Liquidity Risk of Corporate Bonds

Chapter 5

Measuring Corporate Bond Liquidity[1]

5.1 Introduction

The effect of liquidity on bond yields has been frequently studied in the recent finance literature. Since liquidity is a rather subjective concept, a lot of measures have been proposed to approximate the extent to which a bond is liquid or illiquid. For corporate bonds, where most transactions occur on the over-the-counter market, direct liquidity measures (based on transaction data) are often not reliable and difficult to obtain. Therefore, researchers resorted to indirect measures ('proxies') that are based on bond characteristics and/or end-of-day prices. This paper makes a number of contributions to this literature on measuring corporate bond liquidity. First, we pay great attention to control for other sources of risk than liquidity to properly identify the premium that is associated with liquidity risk. As far as we know, this is the first study in this strand of the literature to use the well-known Fama and French (1993) two-factor bond-market model to control for interest rate and credit risk and to augment it with individual bond characteristics, rating and maturity, as recommended by Gebhardt, Hvidkjaer and Swaminathan (2001). Second, we do not make a subjective choice of which liquidity proxies to work with, but implement as much of the proxies proposed in the literature as possible on our data set. We evaluate the relative performance of all proxies, employing a method recently applied by Goldreich, Hanke and Nath (2002) on Treasury bonds. Third, the vast majority of empirical papers on sovereign and corporate bond liquidity studied data from the United States and relatively little is known about the extent to which these results apply to the euro market. Although euro corporate bond data were also studied by other authors, including Annaert and De Ceuster (1999), McGinty (2001) and Díaz

[1]This chapter is based on an article by Houweling, Mentink and Vorst (2005), which has been published in the *Journal of Banking & Finance*.

and Navarro (2002), none of them analyzed the euro corporate bond market using data on individual bonds over a substantial time period.

We use the Brennan and Subrahmanyam (1996) methodology of liquidity-sorted portfolios to test whether liquidity is priced in the euro denominated corporate bond market. We use nine proxies of bond liquidity: *issued amount*, *listed*, *on-the-run*, *euro*, *age*, *missing prices*, *yield volatility*, *number of contributors* and *yield dispersion*; see Section 5.3.4 for a detailed description. For each liquidity proxy, we construct P, mutually exclusive portfolios by sorting all bonds on their value of the liquidity proxy and assigning the first $100/P$ % of the bonds to portfolio 1, the next $100/P$ % to portfolio 2, and so on, until the last $100/P$ % of the bonds are assigned to portfolio P. The P time series of portfolio yields are subsequently used in two regression models. In the first model, each portfolio has a constant liquidity premium. In the second model, the liquidity premium is time-varying and a function of the size of liquidity proxy. In both models, the null hypothesis states that the portfolios' liquidity premiums are jointly equal to zero. We use a detailed data set consisting of daily yields of individual corporate bonds which are denominated in euro or in one of the currencies of the euro-participating countries ('legacy' currencies). The results for the first regression model indicate that the null hypothesis of no liquidity premium is rejected for eight out of nine liquidity proxies. So, we find strong evidence of priced liquidity. For the second model, the null hypothesis of no liquidity effects is even always rejected. To determine the relative effectiveness of the different liquidity proxies, we run a series of regressions with pairwise combinations of the liquidity proxies, as proposed by Goldreich et al. (2002). This allows us to rank the different liquidity proxies we consider. The results of the tests point out that no proxy stands out from the rest.

The remainder of this paper is structured as follows. Section 5.2 gives an overview of the methodologies and results of the empirical liquidity literature. Section 5.3 describes how we control for other sources of risk than liquidity risk and how we estimate the liquidity premium. This section also describes the portfolio construction and our nine liquidity proxies. Next, Section 5.4 describes the data that are used to test the hypotheses of corporate bond liquidity. Section 5.5 presents the results from the model implementation. Finally, Section 5.6 summarizes the paper.

5.2 Literature

Both theoretical and empirical evidence demonstrate that liquidity risk is priced in security markets. The market microstructure models of Amihud and Mendelson (1986), Boudoukh and Whitelaw (1993) and Vayanos (1998) show that transaction costs cause liquidity differences between securities, and that illiquid securities have higher expected rates of return than liquid securities.

For equity markets, empirical evidence on priced liquidity risk is provided by, e.g., Amihud and Mendelson (1986), Brennan and Subrahmanyam (1996), Haugen and Baker (1996), Brennan, Chordia and Subrahmanyam (1998), Chordia, Roll and Subrahmanyam (2001) and Chordia, Subrahmanyam and Anshuman (2001). For bond markets, a substantial part of empirical studies analyzed data from the U.S. Treasury market, where bonds are issued on a regular basis and price data are easily available. Also, controlling for other sources of risk than liquidity risk is relatively easy in this market, because credit risk is not an issue. To control for interest rate risk, authors have used several approaches. The first approach is to create pairs of zero-coupon bonds with exactly the same maturity date; this fully eliminates interest rate risk. Amihud and Mendelson (1991), Kamara (1994) and Strebulaev (2002) used this method to test for liquidity differences between U.S. Treasury notes and bills; Fleming (2002) compared U.S. Treasury bonds with small and large outstanding amounts. The second approach is to form triplets of coupon bonds, which, with suitable bond weights, also eliminate interest rate risk. Elton and Green (1998) used this method to examine yield differences between bonds with high and low trading volume. Another frequently used approach is to analyze the yield difference between the *on-the-run* (most recently issued) bond and *off-the-run* (older) bonds; this will, however, leave a small maturity gap between the bonds. Warga (1992), Goldreich et al. (2002) and Krishnamurthy (2002) used this method on U.S. Treasury data and (Boudoukh and Whitelaw, 1991, 1993) on Japanese data. All papers mentioned above, except Strebulaev (2002), found statistically significant liquidity premiums.

Research on corporate bond liquidity is substantially more difficult, because of the presence of credit risk and the smaller number of bonds per issuer. A strategy of matching bonds by maturity and issuer, similar to the Treasury studies above, will typically generate too few observations. As far as we know, there is only one study that successfully applied this approach: Crabbe and Turner (1995) analyzed pairs of new issues, issued by the same borrower, with identical issue and maturity dates, but with different issue sizes. The most popular approach is to regress yields (and occasionally bid-ask spreads or trading volumes) of individual corporate bonds on a range of proxies for interest rate, credit and liquidity risk. Examples of studies that used this method include Gehr and Martell (1992), Shulman, Bayless and Price (1993), Chakravarty and Sarkar (1999), Alexander, Edwards and Ferri (2000), Hong and Warga (2000), Collin-Dufresne, Goldstein and Martin (2001), Ericsson and Renault (2002), Schultz (2001), Díaz and Navarro (2002), Elton et al. (2004)

and Mullineaux and Roten (2002). Remarkably, all papers studied U.S. data, except Díaz and Navarro (2002) who studied Spanish corporate bonds. Cornell (1992), Fridson and Jónsson (1995) and Annaert and De Ceuster (1999) used similar regression approaches, but on *indices* of U.S. mutual funds, U.S. high yield bonds and euro investment grade bonds, respectively. Finally, McGinty (2001) analyzed one month of euro corporate bond data using scatter plots and tables. All papers mentioned above, except for Gehr and Martell (1992) and Crabbe and Turner (1995), found evidence of significant liquidity premiums for at least one liquidity proxy.

To summarize, almost all empirical papers on bond liquidity found significant liquidity effects for government and corporate bonds. However, none of the studies used the portfolio-based testing methodology often employed in the literature on equity liquidity. Moreover, although there is ample research on the U.S. market, the evidence for euro-denominated bonds is limited to papers that study index data (Annaert and De Ceuster, 1999), a small sample period (McGinty, 2001) or data from one country (Díaz and Navarro, 2002).

5.3 Methodology

This section describes the methodology used to test whether liquidity risk is priced in the euro-denominated corporate bond market. First, we explain how we control for other sources of risk than liquidity risk using Fama and French (1993) and Gebhardt et al. (2001). Next, we describe the implementation of our models and the Goldreich et al. (2002) method to compare different liquidity proxies. Finally, we present our liquidity proxies.

5.3.1 Controlling for Other Sources of Risk

In measuring a security's liquidity premium, it is important to realize that the security's expected return is not only affected by liquidity risk but also by other sources of risk. Theory (like the reduced form credit risk models following Jarrow and Turnbull (1995)) nominates two risk factors: (*i*) interest rate risk and (*ii*) credit risk. We use the Fama and French (1993) bond-market model as a starting point to proxy for interest rate and credit risk. They found two risk factors that explained over 90% of the variation in realized *excess returns* on corporate bond portfolios; the excess return was defined as the portfolio return minus the one-month Treasury rate. The first risk factor was calculated as the long-term Treasury bond return minus the one-month Treasury rate at the end of the previous period. Thus, this *slope factor* should explain variations in excess bond returns by changes in the slope of the Treasury yield curve. The second factor was defined as the return on a market portfolio of long-term corporate bonds minus the long-term Treasury bond return. This *credit factor* was therefore related to the likelihood of credit events in the corporate bond portfolio.

Unlike Fama and French (1993), we do not us a bond's realized return as proxy for its expected return, but, following the bond liquidity literature, we use the bond's yield-to-maturity.[2] The advantage of yields is that they are forward-looking, while realized returns are backward looking. In all regressions, we thus replace the excess realized return by the *excess yield*, which is defined as the yield minus the short-term default-free rate.

A second modification to the Fama-French model concerns the choice of the default-free interest rate curve, which is required to calculate the excess yields and the two risk factors. Instead of using the government curve, we use the swap curve. Our motivation is that since the end of the 1990s, fixed-income investors have moved away from using government securities to extract default-free interest rates and started using interest rate swap rates instead; see also Golub and Tilman (2000) and Kocić, Quintos and Yared (2000). In Section 5.5.1, we test both proxies for default-free rates.

Gebhardt et al. (2001) looked at the validity of the Fama-French bond-market model by analyzing whether individual bond characteristics could rival the two Fama-French factors. Three characteristics were considered: rating, duration and Altman (1968) Z-scores. They concluded that both Fama-French factors and bond characteristics were important in explaining bond yields and recommended a model containing four variables: the Fama-French slope and credit factors, rating and duration. In Section 5.5.2, we show that for our data set these four characteristics are also relevant.[3] Therefore, our null model to control for other sources of risk consists of four variables: two Fama-French factors and two characteristics; the model is described formally in Section 5.3.2. Clearly, all our conclusions about the relation between liquidity and bond yields are based on the assumption that our four-variable pricing model correctly and fully controls for interest rate and credit risk; see also Dimson and Hanke (2002).[4]

To the best of our knowledge, no other paper in the liquidity literature has employed both the Fama-French factors and individual bond characteristics to control for other

[2]Changing the return measure from realized return into yield makes our return measure sensitive to time-to-maturity. Therefore, we incorporate time-to-maturity in our regression models as control variable; see also the discussion of the Gebhardt et al. (2001) paper below.

[3]We have replaced duration by maturity, but this should not affect our results as both variables are highly correlated.

[4]We further assume that taxes do not affect bond yields.

sources of risk. One paper, Ericsson and Renault (2002), used the Fama-French factors, but not the characteristics; several papers made use of the rating and maturity characteristics, including Alexander et al. (2000), Hong and Warga (2000) and Mullineaux and Roten (2002), but not of the Fama-French factors; most papers used a list of ad-hoc proxies.

5.3.2 Models

Unlike prior papers on bond liquidity, we do not estimate our models on individual bonds, but on constructed portfolios, like in the equity literature; see e.g. Amihud and Mendelson (1986), Brennan and Subrahmanyam (1996) and Haugen and Baker (1996). Specifically, we follow Brennan and Subrahmanyam (1996) by creating liquidity-sorted portfolios and testing whether the constructed portfolios have significantly different yields, while controlling for other sources of risk as described above. From the literature, we collect nine liquidity proxies, which are detailed in Section 5.3.4. For each proxy i, we create P mutually exclusive portfolios as follows (the choice for P will be discussed at the end of this section).

Every two weeks, we order all bonds in the sample by their value of liquidity proxy i; only bonds that have already been issued and have not yet matured on that date are used in the ordering. Then, we assign the first $100/P$ % of the bonds to portfolio 1, the next $100/P$ % to portfolio 2, and so on, until the last $100/P$ % of the bonds are assigned to portfolio P. The sort order is chosen such that portfolio 1 contains the bonds that proxy i hypothesizes to be the most liquid and portfolio P the most illiquid. Every day we calculate the yield of each portfolio as the unweighted average of the yields of the bonds that make up the portfolio. A bond's yield is determined as follows: if the bond is not quoted, we disregard it for that day; if it is quoted by one pricing source, we use that yield; if it is quoted by more than one pricing source, we use the average quote. For each proxy i, we have now created P time series of portfolio yields.

As in Brennan and Subrahmanyam (1996), the time series are used in two regression models. In the first model, each portfolio has a constant liquidity premium. Formally, model 1 is as follows[5]

$$\begin{aligned} Y^i_{pt} &= \alpha^i_p + \sum_{j=1}^{2} \beta^i_{jp} F_{jt} + \sum_{j=1}^{2} \gamma^i_j C^i_{jpt} + \varepsilon^i_{pt}, \\ E[\varepsilon^i_{pt}] &= 0 \\ E[\varepsilon^i_{pt}\varepsilon^i_{qs}] &= \sigma^i_{pq}, \text{if} t = s, \text{ and 0 otherwise,} \end{aligned}$$

where superscripts i refer to liquidity proxy i, Y^i_{pt} is the excess yield of the p^{th} proxy-i portfolio on day t, F_{1t} and F_{2t} are the two Fama-French factors and C^i_{1pt} and C^i_{2pt} are the two portfolio characteristics. The coefficients are interpreted as follows: α^i_p is the portfolio-specific liquidity premium, β^i_{jp} is the portfolio-specific factor loading for Fama-French factor j and γ^i_j is the marginal effect of portfolio characteristic j. The model controls the portfolio excess yields for the two Fama-French factors and the two bond characteristics. Thus, it gives the effect of a particular liquidity proxy after correcting for the four features. Note that the Fama-French factors have portfolio-specific coefficients and common variable values, while the characteristics have common coefficients and portfolio-specific variable values.

The disturbance terms are allowed to be heteroscedastically distributed and cross-sectionally correlated, but we do assume that they are uncorrelated across time. To correct for possible autocorrelations in the disturbances, we apply the Newey and West (1987) estimator for the covariance matrix. For proxy i, we estimate all $3P+2$ coefficients $(\alpha^i_1, \ldots, \alpha^i_P,\ \beta^i_{11}, \ldots, \beta^i_{1P}, \beta^i_{21}, \ldots, \beta^i_{2P},\ \gamma^i_1, \gamma^i_2)$ for all P portfolios *simultaneously* with Feasible Generalized Least Squares (FGLS) as a system of seemingly unrelated regressions (SUR); see e.g. (Greene, 2000, Chapter 15).

To test the null hypothesis that proxy i has no liquidity premium, or in other words, that the two Fama-French factors and the two portfolio characteristics fully explain the bond yields, we use a Wald test to determine the joint significance of the intercepts: H_0:

[5]As suggested by an anonymous referee, we have extended model 1 and 2 with quadratic terms of the two portfolio characteristics, rating and maturity. The results showed to be robust with respect to this extension of both models.

$\alpha_1^i = 0 \wedge \ldots \wedge \alpha_P^i = 0$. The test statistic is asymptotically χ^2-distributed with P degrees of freedom.[6]

In the second model, we change the functional form of the liquidity premium: all portfolios share a common intercept and a portfolio-specific liquidity variable is added to the regression equation. Formally, regression model 2 reads

$$Y_{pt}^i = \alpha^i + \sum_{j=1}^{2} \beta_{jp}^i F_{jt} + \sum_{j=1}^{2} \gamma_j^i C_{jpt}^i + \delta^i L_{pt}^i + \varepsilon_{pt}^i,$$

where the definitions of the Fama-French factors, the portfolio characteristics and the assumptions on the disturbances are equal to those in Equation (5.3.2) and L_{pt}^i is the value of the liquidity proxy of the p^{th} proxy-i portfolio on day t in deviation from its daily average; so, if l_{pt}^i denotes the value of the liquidity proxy, and $\bar{l}_t^i$ is its daily average, i.e.

$$\bar{l}_t^i = \frac{1}{P} \sum_{p=1}^{P} l_{pt}^i,$$

then L_{pt}^i is calculated as $L_{pt}^i = l_{pt}^i - \bar{l}_t^i$. We have chosen this normalization of the liquidity proxy to correct for a possible change in the mean during our sample period. For example, the average amount outstanding has risen from 353 million on the first day of our sample to 434 million on the last day.

In Equation (5.3.2), the portfolio-specific intercepts of Equation (5.3.2) have been replaced by a single intercept and an additional regressor has been introduced that contains a proxy for portfolio p's liquidity. This changes the functional form of the liquidity premium: the constant liquidity premium of α_p^i in model 1 has been replaced by a time-varying premium $\alpha^i + \delta^i L_{pt}^i$ that is linear in the value of the liquidity proxy (in deviation from its mean). Here, the null hypothesis of no liquidity effect is tested with a Wald test on the joint significance of α^i and δ^i: H_0: $\alpha^i = 0 \wedge \delta^i = 0$. The test statistic is asymptotically χ^2-distributed with 2 degrees of freedom. The joint hypothesis problem discussed in footnote 6 also applies here.

[6] There is caveat in the interpretation of the test results: if we want to test whether proxy i is a good liquidity proxy, we are actually testing a joint hypothesis: illiquidity leads to yield increases *and* proxy i is a proxy for liquidity; see also Kempf and Uhrig-Homburg (2000) and Jankowitsch, Mösenbacher and Pichler (2002). If we reject this joint hypothesis, then either illiquidity does not lead to yield increases or i is not a good liquidity proxy (or both). Given the strong empirical evidence mentioned in Section 5.2, we feel confident that a rejection of the joint hypothesis can in fact be traced to i being an inadequate liquidity proxy.

We now discuss the choice for the number of portfolios P for both models. For model 1, we create two portfolios for each liquidity proxy. This gives an intuitive interpretation of portfolio 1 as the 'liquid portfolio' and portfolio 2 as the 'illiquid portfolio'. Moreover, the difference $\alpha_2^i - \alpha_1^i$ between the two intercepts can be interpreted as the yield premium investors get for bearing liquidity risk caused by proxy i. In model 2, we have to estimate the slope coefficient δ^i, i.e. the relation between a portfolio's value for liquidity proxy i and its excess yield. Clearly, two portfolios would be insufficient to estimate a slope. However, using 'too much' portfolios diminishes the power of the Wald test; see Lys and Sabino (1992). From their Figure 1, it follows that if the portfolios contain approximately 25% of the bonds, the power of the test of no relation between the liquidity proxy and the excess yield is maximized. Therefore, we use 4 portfolios for model 2.

5.3.3 Comparison

Given the large number of liquidity proxies that has been proposed in the literature, a natural question to ask is whether all proxies are equally suited to proxy bond liquidity or if some proxies work better than others. We follow Goldreich et al. (2002) by running a series of regressions with pairwise combinations of the liquidity proxies. For each combination (i, k) of proxies, we estimate a regression like Equation (5.3.2) for proxy i, augmented with proxy k

$$Y_{pt}^i = \alpha^i + \sum_{j=1}^{2} \beta_{jp}^i F_{jt} + \sum_{j=1}^{2} \gamma_j^i C_{jpt}^i + \delta^i L_{pt}^i + \delta^{ik} L_{pt}^{ik} + \varepsilon_{pt}^{ik},$$

where L_{pt}^{ik} is the value of liquidity proxy k for the p^{th} proxy-i portfolio in deviation of its daily average. Further, the coefficients are defined and disturbances behave as in Equation (5.3.2).

In this regression equation[7], we test for the significance of δ^{ik}. If it is significant, we say that 'k adds explanatory power to i', and otherwise we say that 'k is subsumed by i' (this follows the terminology in Goldreich et al. (2002)). By repeating this procedure for all possible combinations, we can count the number of times a proxy adds power to another proxy, and the number of times a proxy subsumes another proxy. This allows us to rank the different liquidity proxies we consider.

[7]Goldreich et al. (2002) first orthogonalized the values of proxy k relative to proxy i and used the orthogonalized values in Equation (5.3.3) instead of L_{pt}^{ik}. This is not necessary, since, by the Frisch-Waugh theorem (see e.g. Greene, 2000, Section 6.4.3)), the regression already 'automatically' does this for us.

5.3.4 Liquidity Proxies

Empirical papers that examined liquidity in bond or equity markets used both *direct* measures (based on transaction data) and *indirect* measures (based on bond characteristics and/or end-of-day prices). Examples of direct liquidity measures are *quoted bid-ask spreads*, *effective bid-ask spreads*, *quote sizes*, *trade sizes*, *quote frequencies*, *trade frequencies* and *trading volume*. For corporate bonds, where most transactions occur on the over-the-counter market, these direct measures are often not reliable and difficult to obtain. Therefore, we use indirect liquidity proxies instead. By searching the theoretical and empirical liquidity literature, we found nine liquidity proxies that can be implemented on our data set.[8] Table 5.1 shows which papers used which proxies and the effects they found; three proxies, *euro*, *missing prices* and *yield dispersion*, are not mentioned in this table, because they were not used in previous studies. We will now discuss each proxy in more detail, elaborating on their interpretation, their expected effect on bond yields and theoretical and/or empirical evidence.

Issued Amount

The *issued amount* of a bond is often assumed to give an indication of its liquidity. Most investment banks use it as liquidity criterion in building their bond indices; for example, Lehman Brothers uses this criterion for their Euro-Aggregate Corporate Bond index. Its use was first proposed by Fisher (1959), who claimed that large issues should trade more often, so that the proxy *issued amount* is actually a proxy for the direct liquidity measure trading volume. Since Fisher, several alternative hypotheses have been put forward that also predict a positive effect of *issued amount* on liquidity (and thus on bond prices). In market microstructure models, like Smidt (1971) and Garman (1976), transaction costs arise, because dealers hold inventories. Further, dealers' inventory costs are higher if it is more difficult to obtain information about a security and if the expected holding time is longer. Crabbe and Turner (1995) subsequently reasoned that large issues may have lower information costs, since more investors own them or have analyzed its features; similarly, information about small issues may be less broadly disseminated among investors. Therefore, small issues will have a higher yield due to an illiquidity premium. Another frequently heard argument, for instance in Sarig and Warga (1989) and Amihud and Mendelson (1991), is that bonds with smaller issued amounts tend to get locked in

[8]We would like to stress that by selecting liquidity proxies from theoretical research and from empirical research on other data bases, the effects of *data-snooping* on portfolio-based tests, as described by Lo and MacKinlay (1990), are probably limited.

Table 5.1: Overview of liquidity proxies from the empirical bond liquidity literature[a]

Authors[a]	Data[b]	Liquidity proxies: Issued amount	Listed	On-the-run	Age	Yield volatility	Number of contributors
Corporate bonds							
AEF00	US	$-^*$	$+^*$		$+^*$	$-^*$	
CT95	US	$^\diamond$					
EGAM04	US	$^\diamond$			$+^*$		
ER02	US				$+^*$		
GM92	US	$+^\diamond$ $-^\diamond$					$-^\diamond$
HW00	US	$-^*$			$+^*$	$+^*$	
M01	EMU	$^\diamond$			$^\diamond$		
MR02	US	$+^\diamond$ $-^\diamond$					
S01	US				$+$		
SBP93	US	$^\diamond$				$+^*$	
Treasury bonds							
AM91	US						
EG98	US			$+^*$	$+^*$		
F02	US	$^\diamond$		$+^*$			
JMP02	EMU[c]	$-^*$		$+^*$			$-^*$
K02	US	$-^*$					
KU00[d]	Germany	$-^*$					
SW89	US	$-$			$+^*$		
W92	US	$-^\diamond$			$+^*$		
Corporate & treasury bonds							
DN02	Spain	$+^*$ $-^*$			$+^*$		
Corporate, municipal & treasury bonds							
CS99	US				$+^*$		

* legend: $-$ negative; $+$ positive; * significant; $^\diamond$ insignificant

[a] AEF00=Alexander, Edwards and Ferri (2000), AM91=Amihud and Mendelson (1991), CS99=Chakravarty and Sarkar (1999), CT95=Crabbe and Turner (1995), DN02=Díaz and Navarro (2002), EG98=Elton and Green (1998), EGAM04=Elton, Gruber, Agrawal and Mann (2004), ER02=Ericsson and Renault (2002), F02=Fleming (2002), GM92=Gehr and Martell (1992), HW00=Hong and Warga (2000), JMP02=Jankowitsch, Mösenbacher and Pichler (2002), K02=Krishnamurthy (2002), KU00=Kempf and Uhrig-Homburg (2000), M01=McGinty (2001), MR02=Mullineaux and Roten (2002), S01=Schultz (2001), SBP93=Shulman, Bayless and Price (1993), SW89=Sarig and Warga (1989), W92=Warga (1992)

[b] EMU=European Monetary Union, US=United States.

[c] JMP02 considers six countries: Austria, France, Germany, Italy, Spain and the Netherlands.

[d] We use the price discounts in KU00's Table 2 to calculate the impact of maturity on yields.

buy-and-hold portfolios more easily, reducing the tradable amount and thus their liquidity. To summarize the above, we hypothesize a negative effect of *issued amount* on yields.

Table 5.1 shows that many empirical papers considered *issued amount* as liquidity proxy. The papers on Treasury bonds found negative and mostly significant effects, so that larger Treasury issues have lower yields, as expected. Research on corporate bonds is inconclusive, though: both negative and positive coefficients are observed. McGinty (2001) confirmed this by showing that even though most large issues in his corporate bond sample were liquid, some large issues were illiquid and some small issues were liquid.

Listed

Alexander et al. (2000) reasoned that companies whose equity is listed on a stock exchange must disclose more information than privately held companies. According to the market microstructure models mentioned above, the costs of making a market in bonds of listed firms should thus be smaller. Therefore, we hypothesize that the proxy *listed* is associated with higher liquidity and lower yields.

Since Alexander et al. (2000) were the only authors to use the liquidity proxy *listed*, the empirical evidence is limited to their results. Contrary to their expectations, they found that issues of private firms trade more actively and thus are more liquid than issues of listed firms. Their explanation of this result was that for private firms debt is the only investment vehicle, while for public firms both debt and equity are traded; therefore, debt of private firms might trade more and have higher liquidity.

Euro

The next liquidity proxy is whether a corporate bond is denominated in euro or in one of the legacy currencies. The market generally sees legacy bonds (i.e. denominated in one of the currencies of the euro-participating countries) as the less liquid ones, because these bonds are relatively old, not well known to the bond investors and more difficult to trade. The predicted sign of the proxy *euro* is thus higher liquidity and lower yields. This bond characteristic splits the corporate bond sample into two excluding groups: euro bonds and legacy bonds. To our best knowledge, no other papers have implemented this liquidity proxy.

On-the-Run[9]

In general, on-the-run, or most recently issued, bonds are considered to be the most liquid bonds, in contrast to off-the-run or older bonds, as market participants often focus their attention on younger bonds. For each issuer, we define the bonds that are issued most recently as on-the-run bonds and the remaining, older bonds as off-the-run bonds. In case an issuer has issued only one bond, we define this bond as an on-the-run bond.[10] We test the hypothesis that on-the-run bonds have a higher liquidity, and consequently a lower yield, than the off-the run bonds.

This liquidity proxy has been implemented in the empirical literature, as Table 5.1 displays, but only for Treasury bonds. All papers found a positive and statistically significant effect of *on-the-run*. As far as we know, no prior papers implemented this proxy on corporate bonds.

Age

The *age* of a bond is a popular proxy of its liquidity. Sarig and Warga (1989) observed that as a bond gets older, an increasing percentage of its issued amount is absorbed in investors' buy-and-hold portfolios. Thus, the older a bond gets, the less trading takes place, and the less liquid it becomes. Moreover, once a bond becomes illiquid, its stays illiquid until it matures. McGinty (2001) and Schultz (2001) also noted that new issues trade more than old issues. McGinty mentioned lead managers' commitment to making market in the newly issued bond. Schultz pointed out that new issues are typically under priced, so that traders buy bonds after the offering and sell them shortly thereafter. Following these arguments, we hypothesize a positive relation between *age* and yield.

Empirical research strongly confirms the positive effect of *age* on yields; see Table 5.1. This finding holds for corporate and sovereign bonds and for U.S. and European data sets. Moreover, Schultz (2001) found evidence for the argument by Sarig and Warga (1989), since in his sample most bonds were bought and not sold; in other words, the bonds were put in buy-and-hold portfolios.

Market practitioners often use a threshold value to determine if a bond is 'old' or 'young': for some T, they mark all bonds with an age smaller than T as 'young' and an

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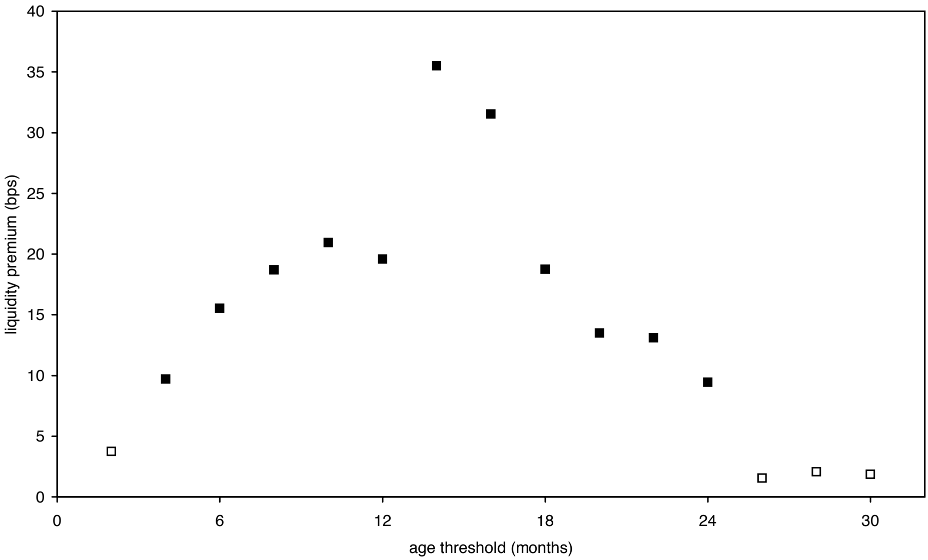
[9] We thank an anonymous referee for this valuable suggestion.

[10] By definition, the distinction between on-the-run and off-the-run bonds is related to *age*. Yet, portfolios that are constructed with the help of each proxy do differ. Using the liquidity proxy *on-the-run*, only bonds possessing this feature, thus both old and young, end up in the liquid portfolio, whereas applying the liquidity proxy *age* the liquid portfolio is only composed of young bonds, both on-the-run and off-the-run.

Figure 5.1: Liquidity premiums for different age thresholds, solid (■) and empty (□) squares denote significance and insignificance, respectively, of the Wald test on the joint significance of the two intercepts (p-value < 0.05).



age larger than T as 'old'. Some academic papers also use such a dichotomous approach for the liquidity proxy *age*. For instance, Alexander et al. (2000) set $T = 2$ years, Ericsson and Renault (2002) used $T = 3$ months, and Elton et al. (2004) employed a threshold value of one year. To determine which threshold values give a useful division of bonds, we estimate model 1 from two portfolios, where portfolio 1 contains all bonds younger than T months and portfolio 2 older than T months, for $T = 2, 4, \ldots, 30$. The difference $\alpha_2 - \alpha_1$ between the portfolio intercepts, i.e. the liquidity premium between old and young bonds, and the significance of the Wald test on H_0: $\alpha_2 - \alpha_1 = 0$ are displayed in Figure 5.1. Thresholds from 4 to 24 months give rise to a significant liquidity premium, while the 2-month threshold and thresholds larger than 24 months do not. The division between young and old bonds seems to be the strongest for a threshold of 14 months, where the premium equals 36 bps. For the remainder of this study, we arbitrarily use a threshold of one year for the proxy *age*, although any other value between four months and two years could also be used.

Missing Prices

The occurrence of 'price runs' and missing values is our first liquidity proxy that uses market information. Sarig and Warga (1989) argued that if the liquidity of a bond is sufficiently low, it may happen that on some business days there is virtually no trading in that bond. In their data set, this was recorded as a 'price run': two consecutive prices for a bond were identical. We extend their notion of illiquidity by considering not only the occurrence of a price run, but also the occurrence of a missing value, since in both cases there is no activity in that bond on that day. We will jointly refer to these events as the proxy *missing prices*. We hypothesize a positive relation between *missing prices* and yield.

Yield Volatility

The proxy *yield volatility* is a measure of yield uncertainty. In the market microstructure models discussed above, dealers' inventory costs are higher if information uncertainty is higher. An important source of uncertainty is related to the predictability of future yield movements. Therefore, we hypothesize that a higher *yield volatility* leads to larger bid-ask spreads, and thus to lower liquidity and higher yields.

The empirical evidence for yield uncertainty as liquidity proxy is mixed; see Table 5.1. Shulman et al. (1993) used *price volatility* as proxy for price uncertainty and found a significantly positive effect on bond spreads. Hong and Warga (2000) proxied uncertainty with squared price return and estimated a positive and significant coefficient in a regression using bid-ask spread as dependent variable; this also implies a positive effect of uncertainty on bond yields. Alexander et al. (2000) approximated uncertainty as the average of absolute price returns; in their regressions, they found a significant, positive effect on trading volume, implying a negative relation between uncertainty and yields.

Number of Contributors

The *number of contributors* is our following proxy of a bond's liquidity, and the first that uses quote composition information. In Ericsson and Renault (2002), a larger number of active traders competing for the same bond leads to a smaller price discount for illiquidity and thus a smaller yield premium. Alternatively, Gehr and Martell (1992) and Jankowitsch et al. (2002) argued that a larger number of market participants makes it easier to trade a bond, because it is easier to find a counter party for a transaction and large orders can be split up into smaller parts without affecting the market price. Either way, we hypothesize a positive relation between the proxy *number of contributors* and liquidity and therefore expect a negative effect of this proxy on bond yields.

Direct empirical evidence on the *number of contributors* liquidity proxy is limited. Jankowitsch et al. (2002) found that bonds with more contributors have lower yields for all but one of the six European countries they analyzed. Indirect evidence is provided by Schultz (2001), who showed that there was a positive relation between the number of trades in a bond and the number of dealers as counter parties. Further, the results of Gehr and Martell (1992) showed a negative, though insignificant effect of the number of dealers on the bid-ask spread.

Yield Dispersion

Our final liquidity proxy, *yield dispersion*, reflects the extent to which market participants agree on the value of a bond. Tychon and Vannetelbosch (2002) derived a model that predicts that if investors have more heterogeneous beliefs, the liquidity premium is larger. The inventory costs argument, mentioned above, applies here as well, since dealers face more uncertainty if prices show a larger diffusion among contributors. Either way, we hypothesize a positive relation between dispersion and bond yields.

We proxy this notion of liquidity with a *yield dispersion* statistic, which has not been used before in the literature, as far as we know. We define the yield dispersion of bond b on day t as the standard deviation of percentage yield differences relative to the mean

$$\text{Dispersion}_{bt} = \sqrt{\frac{1}{n_{bt}-1}\sum_{s=1}^{n_{bt}}\left(\frac{y_{bts}-\bar{y}_{bt}}{\bar{y}_{bt}}\right)^2},$$

where y_{bts} is the yield quoted by pricing source s, $\bar{y}_{bt}$ is the average yield and n_{bt} is the number of contributors. This proxy can only be calculated if we have at least two quotes for a bond on a particular day, i.e. if $n_{bt} > 1$.

Application

Table 5.2 gives details on the calculation of each liquidity proxy. It also shows the expected sign of the proxy. To get the l^i_{pt} variable of Section 5.3.2, we multiply proxies with a negative expected sign by -1. After this transformation, the δ^i coefficient of model 2 is hypothesized to be positive for all proxies; this facilitates checking the results with the hypotheses. Finally, the table shows the order in which bonds are put in the portfolios: the first portfolio always contains the bonds that are hypothesized to be most liquid, the last portfolio contains bonds that we expect to be most illiquid.

Table 5.2: Overview of liquidity proxies, their expected signs and the portfolio order

Liquidity proxy	Details	Sign[a]	Portfolio[b] First	Portfolio[b] Last
Issued amount	total notional in billions of euro	−	largest	smallest
Listed	1 if a firm's equity is publicly traded, 0 otherwise	−	yes	no
Euro	1 if bond is denominated in euro, 0 otherwise	−	euro	legacy
On-the-run	1 if bond is on-the-run, 0 otherwise	−	on-the-run	off-the-run
Age	time between issue date and quote date in years	+	young	old
Missing prices	1 if price is missing or equal to previous price, 0 otherwise	+	least	most
Yield volatility	standard deviation of yields since previous rebalancing	+	lowest	highest
Number of contributors	number of market participants quoting the bond	−	largest	smallest
Yield dispersion	see Equation (5.3.4)	+	smallest	largest

[a] expected signs of the relationship between the proxies and bond yields.
[b] order in which the ranked bonds are assigned to the first (most liquid) portfolio and the last (most illiquid) portfolio.

As described in Section 5.3.2, every two weeks the portfolios for each liquidity proxy are rebalanced according to each bond's value for that proxy. For the proxies *issued amount, listed, euro* (which are fixed characteristics of a bond), for *on-the-run* (which alters due to new issuance) and for *age* (which changes only gradually over time), we use the value of the liquidity proxy on the rebalancing date. For the proxies *missing prices, number of contributors* and *yield dispersion* (which depend on daily market information), we use the average value over the two weeks prior the rebalancing date. For the proxy *yield volatility* (which also depends on daily information), we calculate the standard deviation of the observed yields over the two weeks prior to the rebalancing date. If for a particular bond it is not possible to calculate the value of a liquidity proxy on the rebalancing date, that bond is ignored for that proxy until the next rebalancing date.

5.4 Data

The data are downloaded from three different sources. Lehman Brothers provides the International Securities Identification Numbers (ISINs) of the members of their Euro-Aggregate Corporate Bond index. The required characteristics of these corporate bonds are downloaded from Bloomberg L.P. Reuters 3000 EXtra provides daily bid yields of each bond quoted by different pricing sources. The download period starts on January 1, 1999 and ends on May 31, 2001. The ISINs are obtained for May 31, 2000. The total number of bonds on this date equaled 1190. All bonds that are issued in euro directly after the currency's introduction are included in this analysis. Moreover, the yield time series of each corporate bond has at least twelve months history.

5.4.1 Lehman Brothers

Lehman Brothers provides the ISINs of the corporate bonds in their Euro-Aggregate Corporate Bond index. This index serves as a proxy for the investment-grade euro-denominated, corporate bond market. Lehman Brothers imposes a number of criteria before the corporate bonds can enter its index. All bonds must be denominated in euro or in one of the legacy currencies. Further, all bonds are investment grade, have a fixed-rate coupon, at least one year to maturity and an issued amount of at least 150 million euro. The country of issuance and the country of the issuer are no index criteria. The ratings of all corporate bonds are also provided by Lehman Brothers. All ratings are downloaded for May 31, 2000. Due to data limitations, we have kept these ratings unchanged during the whole sample period. Finally, their Euro-Aggregate Corporate Bond BBB sub index is used to construct the Fama-French credit factor.

5.4.2 Bloomberg L.P.

Bloomberg L.P. provides the required bond characteristics. Using the ISINs that are given by Lehman Brothers these characteristics are downloaded. In case an ISIN code is not recognized by Bloomberg L.P., the bond data are obtained from Lehman Brothers. From the initial 1190 ISINs, three are not available in the Bloomberg L.P. data base. The downloaded corporate bond characteristics are: issued amount, issue date, maturity date, currency, call dates, put dates and sinking fund dates. Euro-denominated par swap data, which are used to calculate the two Fama-French factors and the portfolio excess yields, are also downloaded from Bloomberg L.P.

5.4.3 Reuters

Reuters 3000 EXtra provides the bid yields of the selected corporate bonds. Most corporate bond yields in the Lehman Brothers Euro-Aggregate index are bid yields; only newly issued corporate bonds have ask yields during their first month in the index; see Lehman Brothers, Inc (1998). Therefore, we download bid yields from Reuters. For each corporate bond, all pricing sources (also called contributors) are downloaded. We exclude two Reuters pricing sources, the clearing agency ISMA and two anonymous pricing sources from the list of contributors, since they are averages of other pricing sources. The total number of different pricing sources thus obtained equals 74.

From the original 1190 ISINs in the Lehman Brothers Euro-Aggregate Corporate Bond index, 191 bonds cannot be analyzed, because they either have no Reuters Identification Code (RIC) that matches their ISIN or they do have a RIC but no contributor. For the remaining 999 bonds, all bid yields from all pricing sources are downloaded. This means that a number of time series, equal to the number of pricing sources, shows the yield development of each bond. Most bonds are quoted by more than one pricing source.

5.5 Results

We first present the results of applying the Fama-French bond-market model to the entire sample and show the extension of this model with portfolio characteristics. Next, the regression results for models 1 and 2 are given. Finally, the performance of the liquidity proxies is compared.

5.5.1 Entire Sample

We first test whether the two-factor Fama-French model can be used to describe the average excess yield of all bonds in our sample. This test is relevant, because Fama and French (1993) applied their model to realized returns of U.S. bonds, while we analyze yields of euro-dominated bonds. We estimate the following model

$$Y_t = \alpha + \sum_{j=1}^{2} \beta_j F_{jt} + \varepsilon_t,\ \ \varepsilon_t \sim i.i.d.(0, \sigma^2),$$

where the excess yield Y_t is the average bond yield (calculated over all bonds in the sample) minus the one year euro swap rate, the slope factor F_{1t} is defined as the 10-year swap rate minus the 1-year swap rate of the previous day and the credit factor F_{2t} is calculated as the Lehman Brothers Euro-Aggregate Corporate Bond BBB sub-index minus the 10-year euro swap rate.

The first row of Table 5.3 shows the R^2 and the estimated coefficients along with their t-values. The R^2 value is high and comparable to the values reported by Fama and French (1993). The estimated slope and credit coefficients have the expected positive sign and are highly statistically significant. The intercept is not statistically significant, so that the Fama-French model cannot be rejected for the entire sample.

To test our choice for approximating default-free interest rates with swap rates, regression model (5.5.1) is estimated again, but with swap rates replaced by government rates. So, the excess yields and the slope and credit factors are now calculated with government yields. Our proxy for euro government rates is the Lehman Brothers Euro-Aggregate Treasury index. The second row of Table 5.3 shows the regression results. Both the R^2 and the t-values of the slope and credit factors have decreased compared to the model with swap rates. Moreover, the intercept is now significantly different from zero. Therefore, the Fama-French model should be rejected in case government rates are used as default-free rates. This empirically confirms our choice for using swap rates as proxy for default-free interest rates instead of Treasury rates.

5.5.2 Characteristics

As recommended by Gebhardt et al. (2001), we analyze the added value of incorporating characteristics into the model. We consider two characteristics:

- Rating: rating of the bond's issuer at May 31, 2000: AAA, AA, A or BBB.
- Maturity: the remaining time-to-maturity of a bond, measured in years.

Table 5.3: Fama-French regression model results using the entire sample with either swap rates or government rates as default-free interest rates (t-values between parentheses)

	Intercept	Slope	Credit	R^2
Swap rates	0.0371	0.785	0.173	97.9%
	(1.01)	(36.5)	(6.66)	
Government rates	0.419	0.540	0.273	95.0%
	(12.4)	(31.4)	(5.46)	

To determine whether a characteristic is important for explaining excess bond yields, we follow the same procedure as for our liquidity proxies, as described in Section 5.3.2, except that the null model is now the Fama-French model of the previous section. For each characteristic i, we create portfolios and estimate the following regression model

$$Y_{pt}^{i} = \alpha_{p}^{i} + \sum_{j=1}^{2} \beta_{jp}^{i} F_{jt} + \varepsilon_{pt}^{i},$$

where the assumptions on the disturbances are equal to those in Equation (5.3.2). For the characteristic *rating*, we create four portfolios: portfolio 1 contains the AAA-rated bonds, portfolio 2 the AAs, portfolio 3 the As, and portfolio 4 the BBBs. For the characteristic *maturity*, two portfolios are constructed: portfolio 1 consists of the 50% shortest bonds, and portfolio 2 of the 50% longest bonds.[11]

The regression results are reported in Table 5.4. For *rating*, we find that the intercepts are larger for lower ratings, although the step from AA to A is very small. All Fama-French factor loadings are significant. The Wald test indicates that the four intercepts are highly jointly significant. For *maturity,* the intercepts of the portfolios reveal that short-maturity bonds have smaller yields than long-maturity bonds, with an average difference of 38 bps. The null hypothesis that the two intercepts are jointly equal to zero is easily rejected.

From these results, we conclude that the *rating* and *maturity* characteristics are important determinants of excess yield in the euro corporate bond market. To make the characteristics operational, we have to transform them to a numerical scale:

[11]The portfolios are updated every two weeks, just like in Section 5.3.2.

Table 5.4: Regression results from the Fama-French model estimated from portfolios based on the rating and maturity characteristics (t-values between parentheses). The *Wald* column shows the test on the joint significance of the intercepts (p-value between parentheses).

	Intercept	Slope	Credit	Wald	R^2
Rating					
AAA	-0.220	0.736	0.0838	946	97.2%
	(8.30)	(46.8)	(4.40)	(0.00)	
AA	0.120	0.732	0.0310		
	(5.60)	(55.8)	(2.04)		
A	0.122	0.856	0.295		
	(4.95)	(59.4)	(15.8)		
BBB	0.453	0.824	0.435		
	(8.28)	(24.4)	(10.6)		
Maturity					
Short	-0.135	0.635	0.165	474	98.8%
	(3.09)	(25.0)	(5.36)	(0.00)	
Long	0.247	0.944	0.138		
	(13.6)	(82.0)	(10.6)		

- Rating: the letters are mapped as follows: AAA=1, AA=2, A=3 and BBB=4. Although this linearity assumption is somewhat crude, it is not uncommon in the literature. Moreover, since our bonds are all investment grade, and the non-linearities in S&P's and Moody's rating scales are especially apparent for speculative grade ratings, we believe that the linear scale is a reasonable approximation.
- Maturity: this is already a continuous variable, and thus needs no transformation.

The value of characteristic j for the p^{th} proxy-i portfolio on day t, denoted C^i_{jpt} in Section 5.3.2, is calculated analogously to the liquidity variable L^i_{pt} below Equation (5.3.2). For instance, for the characteristic *maturity*, C^i_{jpt} is the average maturity of all quoted bonds in the p^{th} proxy-i portfolio on day t, in deviation from the average maturity of all quoted bonds on day t.

Table 5.5: Portfolio statistics $P = 2$[a]

	Yield[b]		Maturity[c]		Rating[d]		Liquidity[e]	
	1	2	1	2	1	2	1	2
Issued amount	5.33	5.09	6.47	4.64	2.20	2.10	0.65	0.20
Listed	5.26	5.01	5.68	5.11	2.27	1.66	1.00	0.00
Euro	5.28	5.13	5.94	5.14	2.20	2.08	1.00	0.00
On-the-run	5.44	5.15	6.27	5.38	2.58	2.03	1.00	0.00
Age	5.44	5.16	6.91	5.31	2.42	2.09	0.64	3.80
Missing prices	5.28	5.07	6.09	4.57	2.18	2.10	0.19	0.46
Yield volatility	5.21	5.21	6.11	5.06	2.10	2.20	0.06	0.10
Number of contributors	5.19	5.27	5.58	5.56	2.13	2.19	2.31	0.76
Yield dispersion	5.40	5.14	7.42	4.91	2.18	2.13	0.47	1.50

[a] Summary statistics of the two constructed portfolios using the nine liquidity indicators, where Portfolio 1 (respectively 2) contains the bonds that are hypothesized to be most liquid (respectively most illiquid).
[b] average portfolio yield
[c] average time-to-maturity in years
[d] average credit worthiness, measured on the following scale: AAA=1, AA=2, A=3, BBB=4
[e] average value of the liquidity proxy

5.5.3 Summary Statistics and Correlations

For the first regression model, Equation (5.3.2), we create two portfolios for all nine liquidity proxies. In this section, we show some summary statistics for these 18 portfolios and the correlation between the proxies.

Table 5.5 contains several statistics, averaged over the full sample period of 602 trading days. We observe that the average yields and average liquidity proxies of portfolio 1 (containing the hypothesized liquid bonds) and portfolio 2 (illiquid bonds) are quite different. The yield deviations range from -29 bps (for *on-the-run*) to 8 bps (for *number of contributors*). Except for the latter proxy, we could prematurely conclude that the liquidity premium is negative, since portfolio 1 has a higher average yield than portfolio 2. However, it is not correct to fully attribute the yield differences to differences in liquidity, since the average maturity and the average rating also vary. Therefore, this table illustrates the necessity of correcting for differences in maturity and rating.

To display the correlation between the proxies, we cannot calculate the "normal" correlation (i.e. the Pearson correlation), because 5 out of 9 proxies do not change in value (or only slightly) during the sample period: *amount outstanding*, *listed* and *euro* do not change at all; *on-the-run* alters only at new issuances; *age* changes only gradually. What matters for our proxies, is that their values are used to group the bonds into a set of liquid bonds and a set of illiquid bonds. Therefore, we propose an alternative approach to display the "correlation" between two proxies. For each proxy i, we create two portfolios as described in Section 5.3.2. On each day t, we calculate the average value of proxy i over all bonds in portfolio 1 (and denote it by L^i_{1t}) and similarly for all bonds in portfolio 2 (resulting in L^i_{2t}). Then, for a second proxy j ($\neq i$), we calculate the average value of proxy j over all bonds in portfolio 1 (denoted by L^{ij}_{1t}) and over all bonds in portfolio 2 (L^{ij}_{2t}). If proxies i and j are both capable of splitting the sample in liquid and illiquid bonds, $L^i_{1t} - L^i_{2t}$ and $L^{ij}_{1t} - L^{ij}_{2t}$ should have the same sign. Hence, if we count the number of days that this is the case, and divide by the total number of days in our sample, we get a measure of correlation between proxies i and j. This "correlation" statistic ranges from 0% to 100%. If it equals 100%, the proxies always result in the same ordering of portfolios 1 and 2, which may be interpreted as perfect positive correlation. However, if this statistic is equal to 0%, then the ordering of portfolios 1 and 2 is always reversed, which could be described as perfect negative correlation. Note that the statistic is not necessarily symmetric: the "correlation" between i and j is calculated on portfolios constructed with proxy i, while the "correlation" between j and i uses portfolios constructed with proxy j.

Table 5.6 displays the calculated statistics for all pairs. We observe that the "correlations" are remarkably high: 23 out of 72 proxy pairs are even equal to 100%, while another 29 are between 90% and 100%. In fact, only 3 "correlations" are below 50%: (*listed*, *yield volatility*) equals 10%, (*yield volatility*, *listed*) equals 21%, and (*yield volatility*, *euro*) equals 48%. Since 2 out of 3 involve the proxy *listed*, for which we do not find significant results (see Table 5.7 below), these low "correlations" do not worry us. The vast majority of the "correlations" are substantially above 50%, implying positive relationships between the proxies.

5.5.4 Model 1

Table 5.7 displays the results of estimating model 1 for all liquidity proxies; recall from Section 5.3.2 that the Fama-French factors have portfolio-specific coefficients and the characteristics common coefficients. All Fama-French factor loadings are statistically significant and have the expected positive sign. The same holds for the coefficients of the *rating* and *maturity* characteristics (with one exception: the *rating* coefficient for *issued amount* is insignificant at a 95% confidence level). All R^2-values are around 98%.

Table 5.6: "Correlation statistics" $P = 2$[a]

	Issued amount	Listed	Euro	On-the-run	Age	Missing prices	Yield volatility	Number of contributors	Yield discrepancy
Issued amount		100%	100%	90%	91%	100%	77%	100%	100%
Listed	100%		98%	96%	100%	100%	10%	90%	66%
Euro	100%	98%		93%	92%	97%	50%	97%	98%
On-the-run	100%	97%	94%		100%	98%	62%	100%	82%
Age	100%	92%	100%	100%		100%	91%	100%	97%
Missing prices	100%	91%	95%	91%	96%		78%	100%	88%
Yield volatility	65%	21%	48%	65%	84%	65%		77%	96%
Number of contributors	100%	75%	78%	80%	100%	100%	95%		79%
Yield discrepancy	100%	94%	98%	96%	84%	96%	95%	97%	

[a] "Correlation" statistics between the values of the liquidity proxies of the two constructed portfolios using the nine liquidity indicators.

Except for the liquidity proxy *listed*, all intercept pairs are jointly statistically different from zero at a 95% significance level, as evidenced by the p-values of the Wald statistics. This indicates that the remaining eight proxies are indeed able to separate the bonds in our data set into two mutually exclusive portfolios that have statistically different yields, after controlling for differences in interest rate and credit risk. Next we look at the portfolio intercepts themselves. If our hypotheses on the sign of the liquidity effects are correct, the intercept of portfolio 1 should be smaller than that of portfolio 2 for all liquidity proxies. We see that this holds for eight out of nine cases; for *listed* the order is reversed, but this poses no problem, since the Wald test already indicated that for this proxy there are no significant liquidity effects.

Another way of looking at the intercepts, is to calculate their differences $\alpha_2^i - \alpha_1^i$, which we interpret as the liquidity premium for proxy i. The significance of a premium is tested with a Wald test with null hypothesis H_0: $\alpha_2^i - \alpha_1^i = 0$; the test statistic is asymptotically χ^2-distributed with 1 degree of freedom. The second to last column of Table 5.7 shows that the premiums for proxies *amount outstanding* and *yield dispersion* are the largest with 22.9 bps and 22.5 bps, respectively, while the premiums for the other proxies are between 13.0 and 18.8 bps. All premiums are statistically significant at the 95% confidence level.

5.5.5 Model 2

For model 2, we create four portfolios since it maximizes the power of the test for the presence of liquidity effects; see Section 5.3.2. Unfortunately, this means we cannot conduct the test for proxies *listed*, *age*, *euro* and *on-the-run* since they are all binary variables ('listed' versus 'not listed'; 'young' versus 'old'; 'euro' versus 'legacy'; 'on-the-run' versus 'off-the-run'). The summary statistics for the other five proxies are shown in Table 5.8. Clearly, the differences between the portfolios are now larger than in Table 5.5, since we have assigned the bonds to four size percentiles instead of two.

The regression results are displayed in Table 5.9.[12] The Wald statistic that tests for the joint significance of the intercept and the coefficient of the liquidity proxy is statistically significant for all five proxies. So, also using model 2, we find statistical evidence of the presence of liquidity effects in our data set. The signs of the liquidity coefficients are positive for four out of five proxies, with *number of contributors* as only (statistically insignificant) exception.

[12]The Fama-French factor loadings and the coefficients for the portfolio characteristic are omitted from Table 5.9 for space considerations.

Table 5.7: Results for model 1[a]

	Intercept	Factors: Slope	Factors: Credit	Characteristics: Rating	Characteristics: Maturity	Wald[b]	Premium[c]	R^2
Issued amount								
Large	-0.0846	0.869	0.212					
	(2.807)	(53.1)	(10.7)	0.0850	0.127	73.5	22.9	98.0%
Small	0.145	0.708	0.130	(1.76)	(8.67)	(0.00)	(0.00)	
	(4.28)	(36.3)	(5.42)					
Listed								
Yes	0.0190	0.782	0.164					
	(0.476)	(44.8)	(7.87)	0.132	0.110	2.42	-5.20	98.0%
No	-0.0330	0.749	0.145	(2.16)	(7.61)	(0.30)	(0.12)	
	(0.842)	(43.2)	(6.91)					
Euro								
Euro	-0.0322	0.843	0.196					
	(1.09)	(47.6)	(8.81)	0.369	0.0727	86.0	13.6	98.0%
Legacy	0.104	0.727	0.119	(7.82)	(4.94)	(0.00)	(0.00)	
	(3.55)	(41.1)	(5.66)					
On-the-run								
On	-0.0177	0.858	0.254					
	(0.648)	(52.2)	(11.8)	0.311	0.165	37.5	17.7	98.2%
Off	0.159	0.771	0.145	(6.52)	(14.0)	(0.00)	(0.00)	
	(4.56)	(43.5)	(6.81)					
Age								
<1Y	-0.0326	0.902	0.242					
	(1.18)	(57.0)	(11.7)	0.201	0.120	51.6	18.8	98.1%
>1Y	0.156	0.751	0.190	(6.60)	(12.7)	(0.00)	(0.00)	
	(5.21)	(44.9)	(8.76)					

continued on next page

Table 5.7: *continued*

	Intercept	Factors		Characteristics		Wald[b]	Premium[c]	R^2
		Slope	Credit	Rating	Maturity			
Missing prices								
Few	-0.0329	0.798	0.146					
	(1.06)	(45.3)	(7.03)	0.195	0.163	28.4	13.1	97.6%
Many	0.0984	0.732	0.179	(5.91)	(22.7)	(0.00)	(0.00)	
	(2.88)	(35.3)	(6.84)					
Yield volatility								
Small	-0.0285	0.794	0.156					
	(0.976)	(43.9)	(7.96)	0.235	0.134	11.1	13.0	97.2%
Large	0.101	0.774	0.194	(4.37)	(26.6)	(0.00)	(0.00)	
	(2.58)	(32.8)	(6.91)					
Number of contributors								
Large	0.0182	0.786	0.164					
	(0.600)	(44.3)	(7.40)	0.209	0.139	53.3	13.7	97.6%
Small	0.155	0.748	0.108	(7.09)	(26.2)	(0.00)	(0.00)	
	(4.98)	(40.2)	(4.82)					
Yield dispersion								
Small	-0.0251	0.884	0.160					
	(0.82)	(48.2)	(7.56)	0.322	0.0910	53.1	22.5	98.4%
Large	0.200	0.708	0.122	(8.06)	(15.9)	(0.00)	(0.00)	
	(6.71)	(39.2)	(5.69)					

[a] Regression results for the Fama-French model augmented with portfolio characteristics (see Equation (5.3.2)) estimated from two portfolios based on one of the nine liquidity proxies (t-values between parentheses).

[b] Test on the joint significance of the intercepts (p-value between parentheses).

[c] Difference between the portfolio intercepts in basis points (p-value between parentheses).

Table 5.8: Portfolio statistics $P = 4$[a]

	Yield[b]				Maturity[c]				Rating[d]				Liquidity[e]			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Issued amount	5.38	5.28	5.08	5.10	6.93	5.93	4.93	4.34	2.17	2.23	1.98	2.21	0.88	0.38	0.24	0.16
Missing prices	5.35	5.21	5.07	5.12	6.53	5.63	4.57	4.67	2.21	2.14	2.08	2.22	0.05	0.34	0.45	0.53
Yield volatility	5.25	5.18	5.17	5.26	6.71	5.65	5.25	4.84	2.11	2.08	2.10	2.31	0.06	0.07	0.08	0.12
Number of contributors	5.27	5.10	5.25	5.32	6.24	4.92	5.59	5.41	2.18	2.08	2.15	2.42	3.48	1.13	0.80	0.57
Yield dispersion	5.43	5.37	5.19	5.07	7.94	6.88	5.44	4.30	2.16	2.20	2.14	2.12	0.35	0.60	0.92	2.15

[a] Summary statistics of the four constructed portfolios using five liquidity indicators, where Portfolio 1 (respectively 4) contains the bonds that are hypothesized to be most liquid (respectively most illiquid).

[b] average portfolio yield

[c] average time-to-maturity in years

[d] average credit worthiness, measured on the following scale: AAA=1, AA=2, A=3, BBB=4

[e] average value of the liquidity proxy

Table 5.9: Results for model 2[a]

	Intercept	Liquidity	Wald[b]	R^2
Issued amount	0.0316	0.427	259	97.9%
	(1.32)	(15.9)	(0.00)	
Missing prices	0.0894	0.343	60.8	96.3%
	(3.23)	(7.57)	(0.00)	
Yield volatility	0.0522	1.07	18.4	96.7%
	(2.30)	(3.43)	(0.00)	
Number of contributors	0.102	-0.0037	16.8	96.2%
	(3.99)	(0.618)	(0.00)	
Yield dispersion	0.0855	0.0318	27.5	97.8%
	(4.26)	(3.01)	(0.00)	

[a] Regression results for the Fama-French model augmented with portfolio characteristics and a liquidity variable (see Equation (5.3.2)) estimated from four portfolios based on one of five liquidity proxies (t-values between parentheses). The coefficients and t-values of the Fama-French factors and the characteristics are omitted for space considerations.

[b] test on the joint significance of the intercept and the coefficient of the liquidity variable (p-value between parentheses)

5.5.6 Comparison

Table 5.10 summarizes the results of conducting the pair wise comparisons between the liquidity proxies, as described in Section 5.3.3. For each proxy i, we count the number of times it adds power to a model that already contains proxy j. We also count the number of times a proxy j is subsumed if it is added to the model of proxy i. Looking at the sum of both counts, we see that proxies *yield volatility* and *number of contributors* perform somewhat better than the other four proxies. Since the differences are small, the test does not yield a clear winner.

5.6 Summary

In this paper, we used the Brennan and Subrahmanyam (1996) methodology to test whether bond market liquidity is priced based on liquidity proxies: *issued amount*, *listed*, *age*, *missing prices*, *yield volatility*, *number of contributors*, *yield dispersion*, *euro* and *on-the-run*. For each liquidity proxy, we constructed mutually exclusive portfolios. The time series of portfolio yields were subsequently used in two Fama and French (1993)

Table 5.10: Results of the comparison tests[a]

	Adds power	Subsumes	Total
Issued amount	3	1	4
Missing prices	1	2	3
Yield volatility	2	3	5
Number of contributors	2	3	5
Yield dispersion	1	2	3

[a] Results of the pair wise comparisons of five liquidity proxies (see Equation (5.3.3)), where the table displays the number of times a proxy *adds explanatory power* to another proxy and the number of times a proxy *subsumes another proxy.*

regression models, augmented with portfolio characteristics as recommended by Gebhardt et al. (2001), to control for differences in interest rate risk, credit risk, maturity and rating between the portfolios. We also conducted pair wise comparisons of the liquidity proxies, as proposed by Goldreich et al. (2002).

The results indicated that the null hypothesis of no liquidity premium should be rejected for eight out of nine liquidity proxies. The premium between liquid and illiquid portfolios depended on the liquidity proxy and ranged from 13 to 23 basis points. The highest premiums were found for the proxies *amount outstanding* and *yield dispersion.* The pairwise comparison tests point out that no proxy stands out from the rest.

Chapter 6

Estimating Commonality in Liquidity[1]

6.1 Introduction

Traditionally, market microstructure liquidity has focused on the liquidity characteristics of individual securities. Recently, research attention has broadened to the analysis of *common* determinants of individual security liquidity. Chordia, Roll and Subrahmanyam (2000) study commonality in liquidity for New York Stock Exchange (NYSE) listed stocks, whereas Chordia, Sarkar and Subrahmanyam (2005) analyze common liquidity, return and volatility patterns in the U.S. Treasury and equity markets. We apply the Chordia et al. (2005) approach not only to the government bond and the equity markets, but also to the corporate bond market. Furthermore, we focus on the commonality in liquidity of euro-denominated security markets, whereas all earlier research concentrates on the U.S. dollar security markets.

Our goal is to describe and perform statistical tests of commonality in liquidity between euro security markets as no generally accepted theory is (yet) available. Thus we analyze the extend that liquidity in different security markets has common factors and consequently co-move. If these security markets display such co-movements further research could for example focus on its potential sources.

We examine links between liquidity, return and volatility within and between three security markets: the corporate bond market, the AAA government bond market and the equity market. Total return and volatility of the euro-denominated corporate bond market are proxied by the Lehman Brothers Euro-Aggregate Corporate Bond index, provided by Lehman Brothers, Inc.[2] Liquidity in this market is proxied by the average of the quoted

[1]This chapter is based on the paper "Commonality in Liquidity in Euro Security Markets" by Frank de Jong and Albert Mentink.

[2]We thank Lehman Brothers, Inc. for the data.

bid-ask spreads of those bonds in the Lehman Brothers corporate bond index that are frequently quoted by leading investment banks.

First we test the Granger causality between liquidity, total return and volatility. Following Chordia et al. (2005) we further implement a vector autoregressive model also using these three security characteristics. Then we calculate the impulse response functions based on the estimated vector autoregressive model. Our two liquidity measures are: the average quoted bid-ask spreads of each of the three markets and the average total turnover of the equity market. Both models are implemented for our three security markets, both on a daily and a weekly basis.

We find cross market liquidity between the euro security markets. These links sometimes exhibit time lags. Further, liquidity, total return and volatility links between and within euro security markets are sometimes significant. Granger causality tests confirm these results, although this type of test is very sensitive to the number of time lags.

The remainder of this chapter proceeds as follows. First, Section 6.2 gives a brief review of the literature on commonality in liquidity. Then, in Section 6.3, we describe our extensive data set of liquidity, total return and volatility of the euro-denominated security markets. We then start with a preliminary data analysis in Section 6.4. Next, we perform Granger causality tests and we apply and extend the Chordia et al. (2005) vector autoregressive model and calculate impulse response functions. Subsequently, we analyze the results in Section 6.6. Finally Section 6.7 summarizes this chapter.

6.2 Literature

Research on the commonality of liquidity primarily focuses on the U.S. equity markets. Chordia et al. (2000) implement a market model approach on a sample of 1169 NYSE stocks for the year 1992. They regress liquidity measures (quoted bid-ask spread, effective bid-ask spread and quoted depth) of individual stocks on the aggregate, market measures of liquidity. They find that individual and market liquidity move together. Further, they report company size and industry components of liquidity. This common component remains in place, even after controlling for the average dollar size of the individual transaction, the number of trades in the stock or after accounting for individual volatility, volume and price.

Hasbrouck and Seppi (2001) first analyze the common factors of equity returns and order flows of the 30 Dow Jones stocks for the year 1994. They find that both equity returns and order flows (such as number of trades and dollar volume of trades) exhibit common factors. Secondly, they examine commonality in liquidity measures (such as quoted bid-ask spread, effective bid-ask spread and quoted depth) and they find that common variation in liquidity is small.

Huberman and Halka (2001) model the time-series properties of liquidity (quantified by quoted bid-ask spread, ratio of quoted bid-ask spread and price, depth measured in number of shares and in U.S. dollars) using a sample of 240 NYSE stocks for the year 1996. They find that the variation over time of the four liquidity measures has a common component. Moreover, this temporal variation is positively correlated with return and negatively correlated with volatility.

Brockman and Chung (2002) apply the approach of Chordia et al. (2000) to a data set consisting of 725 companies from the Stock Exchange of Hong Kong (SEHK) for the period May 1996 to December 1999. SEHK is an order driven market, in contrast to the NYSE specialist market in Chordia et al. (2000). They find that there exists also commonality in liquidity in this stock market.

Pascual, Escribano and Tapia (2004) incorporate the interaction of transaction costs and depth measured in U.S. dollars (defined as the bi-dimensionality of liquidity) using a sample of 25 NYSE stocks for the year 1996. They find that the bi-dimensionality factors are superior to bid-ask spreads and market depth in measuring commonality of liquidity.

Recently, Chordia et al. (2005) have estimated a vector autoregressive model for quoted bid-ask spreads, quoted depth, returns, volatility and order flow. They apply this model to a sample of NYSE stocks and the U.S. dollar Treasury bond market for the period June 1991 to December 1998. They find that innovations to the stock and bond market are significantly correlated. This result implies that commonality in both liquidity and volatility exists in these security markets. We adopt this approach and adjust it to meet the requirements of our data set.

Thus, in most empirical literature there is (some) evidence of commonality in liquidity. This chapter extends the Chordia et al. (2005) approach by adding the corporate bond market. Moreover, this analysis uses the euro-denominated security markets, instead of the U.S. dollar security markets.

6.3 Data

6.3.1 Corporate Bond Market

For the corporate bond market we only focus on bonds that are part of the Lehman Brothers Euro-Aggregate Corporate Bond index.[3] We collect the daily and weekly *excess* total return of this index, defined as the return of the indicated index over the corresponding government benchmark for the period September 2002 to September 2003. We choose the excess total return instead of the total return in order to focus on the credit part of the corporate bond return.

Based on the monthly rebalancing frequency of bond indices, the characteristics of all index bonds are also obtained from Lehman Brothers, Inc. over the same period on a monthly basis. One of these characteristics is the Lehman Brothers' index rating (Lehman Brothers, Inc (1998) describes the procedure to obtain a Lehman Brothers' rating using the ratings from the major rating agencies). This allows us to follow the rating dynamics of all bonds.

Bloomberg L.P. provides a single trading platform for corporate bonds where many investment banks publish their bid and ask quotes and associated trading sizes on the same corporate bond at the same time. A bond investor can trade a bond against the quoted price and size by simply clicking on the desired quote. These bid and ask quotes are continuously updated. This competition between dealers on the Bloomberg L.P. platform, the desire of investors to trade with a dealer against the highest bid or the lowest ask quote and the knowledge by all dealers and investors of quotes of other dealers cause dealers to adjust their quotes following the quote adjustments of other dealers (even if no transactions have taken place). The depth of the quotes in this market, defined as the sum of the quoted amount associated with the bid quote and the quoted amount associated with the ask quote, equals around two million euro. In case an investor wants to trade larger amounts, these bid and ask quotes are used as an indication of the price, not as a tradable quote.

We collect from Bloomberg L.P. bid and ask quotes from Credit Suisse, Deutsche Bank, Lehman Brothers, Morgan Stanley and Nomura, for the period September 2002

[3]Bonds have to fulfill the following index criteria before they enter this index: investment grade, denominated in euro (or one of the legacy currencies), fixed coupon, at least one year to maturity, an issued amount of at least 300 million euro, not convertible, no floating rate notes, no perpetual notes, no warrants, no indexed bonds, no structured products, no German Schuldscheine (Lehman Brothers, Inc (1998)).

to September 2003, on a daily and weekly basis.[4] The selection of these five investment banks follows from the fact that we have access to their quotes. They adequately represent the Bloomberg L.P. trading platform as described above. If available, we record the last bid and ask quotes of the day, London closing. We define the (best) bid-ask spread as the best (or lowest) ask quote minus the best (or highest) bid quote.[5]

Negative best bid-ask spreads can occur due to non-synchronous quoting between banks and differences in quoted depth between banks. A negative bid-ask spread could imply an arbitrage opportunity. These negative bid-ask spreads are however close to zero and the quoted depth is limited. Furthermore, this opportunity does not take into account the trading costs involved for the bond investor. In case we encounter a negative bid-ask spread, we first calculate the mean bid quote and the mean ask quote and then we remove the quote (highest bid or lowest ask) that deviates most from its associated mean and next we recalculate the best bid-ask spread. In this way, we remove the quote outliers.

6.3.2 Government Bond Market

Lehman Brothers, Inc. also provides the total return of the AAA Euro-Treasury Bond index. This index approximates the total return and volatility of the euro government bond market. We obtain these data for the same period, September 2002 to September 2003, and with the same frequencies, daily and weekly, as the corporate bond index.

The liquidity in this bond market is measured by the bid and ask quotes of the cheapest-to-deliver bonds associated with the Bund future.[6] We download the daily and weekly closing quotes, generated by the same five investment banks as above, from the Bloomberg L.P. trading platform for the period September 2002 to September 2003. We use the bonds associated with the (ten-year) Bund future as this future is one of the most liquid bond futures of the Euro-zone bond market. So, with respect to both bond markets, market return and volatility is measured using bond indices, whereas liquidity is measured using a (small, frequently quoted) part of the index.

The depth of the Bloomberg L.P. trading platform regarding this government bond is much larger than that of the corporate bond market and ranges approximately between

[4]We thank Bloomberg L.P. for the data. Starting September 2002, we obtain enough quotes to make our analyzes possible. Next to Bloomberg L.P., MarketAxess also offers a credit bonds trading platform for both investment banks and institutional bond investors. Although there is no detailed publicly available information about the market share of each company, these two systems are widely recognized as leading in their field.

[5]In the appendix we analyze the average characteristics of the frequently quoted versus the not frequently quoted corporate bonds.

[6]We thank J.P. Morgan for providing these data.

50 and 100 million euro. Next to Bloomberg L.P., TradeWeb and MTS Group each also offer a trading platform for euro government bonds for investment banks and institutional bond investors.

6.3.3 Equity Market

We apply the Dow Jones Euro Stoxx™ 50 equity index as our proxy of the Euro-zone equity market. This index consists of 50 blue chip companies in the Euro-zone countries. We download from the Stoxx™ web site the index total returns and the index components for the period September 2002 to September 2003, on a daily and weekly basis.[7]

We download from Bloomberg L.P. the best bid quotes, the best ask quotes and the total turnovers of the index components from their primary exchange at their close. The total turnover is defined as the market value of the traded stocks during a day (single counted). This measure approximates the daily total depth of a stock in its primary stock market. Further, we also download the year-end equity market value of these companies in euro in order to be able to calculate market weighted time series.

6.4 Preliminary Data Analysis

6.4.1 Daily Data

Now we take a closer look at our data. Table 6.1 reports the mean, standard deviation and median of two liquidity measures, bid-ask spread *BAS* and total turnover *TTO*, and the total returns of the euro corporate bond market *CBM*, government bond market *GBM* and equity market *EQM*, based on daily observations. The corporate bond bid-ask spreads have a comparable mean and median. The absolute bid-ask spread is defined as the best ask quote minus the best bid quote, whereas the relative bid-ask spread is defined as the absolute best bid-ask spread divided by the best mid-quote. Further, the corporate bond market mean excess total return is positive. The average rating of these corporate bonds ranges between A2 and A3 in the sample period. With respect to all three security markets returns we define the daily volatility *VOL* as the absolute value of the daily return (Gallant, Rossi and Tauchen (1992)).

Table 6.2 displays the correlations between the liquidity measures and the total returns of the three security markets. In general these correlations are low, i.e. lower than 0.20 in absolute value. There are two exceptions to this pattern, first the positive

[7] We thank Stoxx Ltd. for the data.

Table 6.1: Summary statistics, 269 days

	Mean	Standard deviation	Median
Corporate bond market			
Bid-ask spread (absolute and market weighted)[b]	29.03	1.90	28.77
Bid-ask spread (absolute and equally weighted)[b]	29.63	1.55	29.47
Bid-ask spread (relative and market weighted)[a]	27.55	1.83	27.29
Bid-ask spread (relative and equally weighted)[a]	28.16	1.62	27.91
Market total excess return[a]	0.93	5.21	0.92
Government bond market			
Bid-ask spread (absolute)[b]	2.21	0.83	2.00
Bid-ask spread (relative)[a]	2.07	0.78	1.88
Market total return[a]	2.92	24.53	5.43
Equity market			
Bid-ask spread (absolute and market weighted)[b]	6.43	3.17	5.90
Bid-ask spread (absolute and equally weighted)[b]	6.56	3.14	6.00
Bid-ask spread (relative and market weighted)[a]	16.93	6.33	16.07
Bid-ask spread (relative and equally weighted)[a]	18.18	6.04	17.10
Total turnover (market weighted)[c]	21.81	5.86	21.30
Total turnover (equally weighted)[c]	17.32	5.03	17.00
Market total return[a]	0.05	218.80	-10.41

a in basis points
b in euro cents
c in billions of euro

correlation between the corporate bond market total excess return RTN^{CBM} and the equity market total return RTN^{EQM} of 0.30 and secondly the negative correlation between the government bond market total return RTN^{GBM} and the equity market total return RTN^{EQM} of -0.57. The bid-ask spread correlations are close to zero.

The correlations between the equally and market weighted liquidity measures are very high. The same applies to the correlations between the absolute and relative liquidity measures. Consequently, changing absolute to relative and/or market weighted to equally weighted should not really alter our results. In our analyzes we use absolute and market weighted average liquidity measures (further we omit the description average when we use the two liquidity measures).

Table 6.2: Correlation matrix, 269 days

	BAS^{CBM}	RTN^{CBM}	BAS^{GBM}	RTN^{GBM}	BAS^{EQM}	TTO^{EQM}	RTN^{EQM}
BAS^{CBM}	1.00						
RTN^{CBM}	-0.01	1.00					
BAS^{GBM}	-0.02	0.04	1.00				
RTN^{GBM}	-0.13	-0.19	-0.09	1.00			
BAS^{EQM}	0.02	-0.07	-0.06	0.07	1.00		
TTO^{EQM}	0.13	0.03	-0.01	-0.16	0.01	1.00	
RTN^{EQM}	0.14	0.30	0.14	-0.57	-0.09	0.07	1.00

6.4.2 Weekly Data

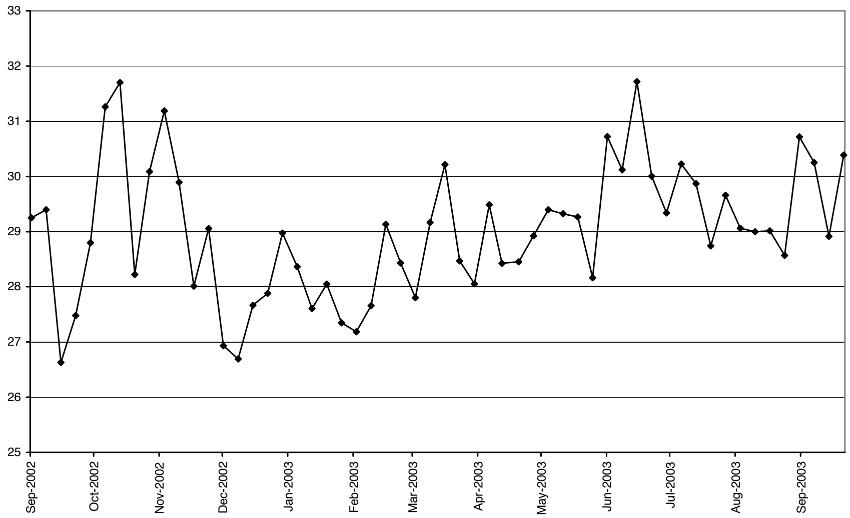
We now focus on the weekly frequency instead of the daily frequency. The weekly total return is calculated for each Friday, the weekly volatility VOL equals the sample standard deviation of (maximal) five trading days ending on a Friday, the bid-ask spread equals the average of the bid-ask spreads of (maximal) five trading days, again ending on a Friday and the total turnover is de sum of the daily total turnover during the whole trading week, ending on a Friday.

The Figures 6.1-6.3 display the bid-ask spreads of the corporate bond, government bond and equity markets, with on the horizontal axis the sample period and on the vertical axis the bid-ak spread in euro cents. The corporate bond bid-ask spread ranges between 26 and 32 euro cents, whereas the government bond bid-ask spread varies between only 1.5 and 3.6 euro cents with a spike at the end of November 2002. The equity bid-ask spread has a maximum 13 of and a minimum of 3 euro cents and a spike at the end of December 2002. So, the government bond market has the lowest bid-ask spread followed by the equity market and the corporate bond market.

Table 6.3 displays the mean, standard deviation and median of the two liquidity measures and the total returns of the three security markets, based on weekly observations.

Table 6.4 reports the correlations between the liquidity measures and the total returns of the three security markets. Typically these correlations are higher, in absolute value, than those in Table 6.2, for example the corporate bond market and the equity market bid-ask spreads are positively correlated, whereas the government bond market and the equity market bid-ask spreads are negatively correlated.

Figure 6.1: Average corporate bond market bid-ask spreads, weekly data



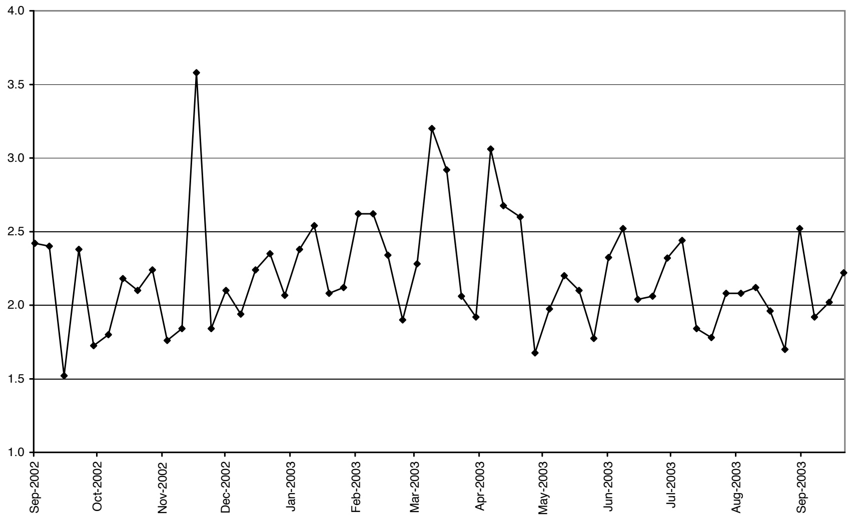
6.4.3 Corporate Bond Market Average Bid-Ask Spreads

In our vector autoregressive model in Section 6.5.2 we analyze the links in liquidity, return and volatility between and within our three security markets. Before we can make this type of analysis we want to adjust the corporate bond bid-ask time series. We adjust these time series because the characteristics of the bonds in the sample changes considerably over the sample period. For example, corporate bond bid-ask spreads typically widen (narrow) as the bond maturity becomes longer (shorter). We want to remove such exogenous factors from the bid-ask spread time series. If we do not correct bid-ask spreads for this relationship, spread widening might be interpreted as diminishing liquidity, whereas the true cause is longer bond maturity.

We adjust the corporate bond bid-ask spread with the help of the average bond characteristics: *age*, *issued amount* and *maturity*. We leave out *coupon* and *rating* from this adjustment because these characteristics are more or less constant during our sample period. The ordinary least squares regression equation reads:

$$BAS_t^{CBM} = \alpha + \beta_1 AGE_t + \beta_2 AMT_t + \beta_3 MAT_t + \varepsilon_t, \tag{6.1}$$

Figure 6.2: Government bond market bid-ask spreads, weekly data

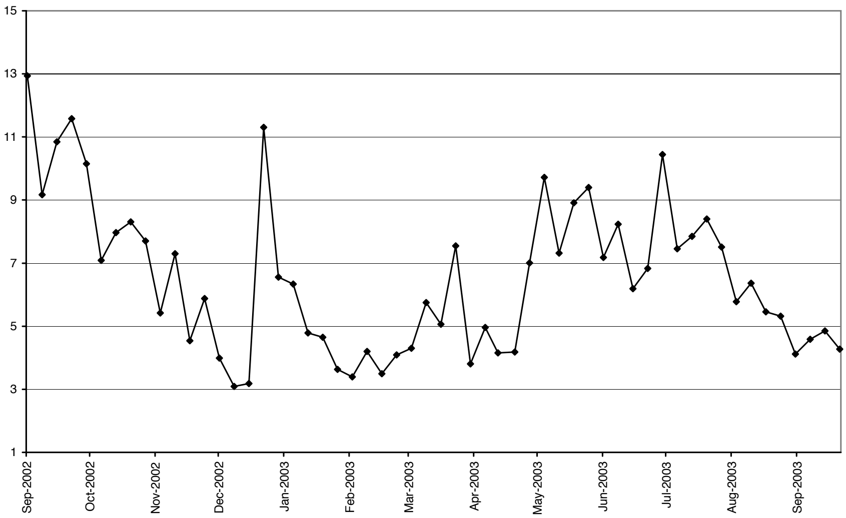


with the corporate bond bid-ask spread BAS_t^{CBM}, the adjustment variables *age* AGE_t (in years), *issued amount* AMT_t (in billions of euro) and *maturity* MAT_t (in years), with the intercept α, the slopes β_i and the regression disturbance ε_t, $i = 1, 2, 3$, $t = 1, 2, \ldots, 269$ or 56. Henceforth we use the residuals as the daily or weekly corporate bond bid-ask spread.

We also test the null hypothesis: $\beta_1 = \beta_2 = \beta_3 = 0$ with the help of a Wald test. This null hypothesis is rejected at all confidence levels using daily data. The β coefficients are statistically different from zero at the 2.5% level using weekly data. Thus, the Wald test indicates that the three adjustment variables are jointly significant.

Table 6.5 displays the results of regression Equation (6.1) for both daily and weekly data. The intercept is always positive and significant at all confidence levels. The *age* coefficient is positive and significant at the 5% confidence level in case of the daily data. This indicates that bid-ask spreads widen as bonds get older. The *issued amount* coefficient does not differ statistically from zero. This may be explained by the fact that all liquid/frequently quoted corporate bonds have a large issued amount. Further, the *maturity* coefficient is positive and significant at the 2.5% level. Finally, the (adjusted) R^2 is always low.

Figure 6.3: Average equity market bid-ask spreads, weekly data



6.5 Models

6.5.1 Granger Causality Tests

An instructive way of looking at the links between and within security markets is the Granger causality test. This test is defined as:

$$M_{1t} \quad = \quad \alpha_0 + \sum_{i=1}^{m} \alpha_i M_{1t-i} + \sum_{j=1}^{m} \beta_j M_{2t-j} + \varepsilon_t \tag{6.2}$$

where M_{1t} and M_{2t} ϵ $\{BAS_t^{CBM}, RTN_t^{CBM}, VOL_t^{CBM}, BAS_t^{GBM}, RTN_t^{GBM}, VOL_t^{GBM}, BAS_t^{EQM}, TTO_t^{EQM}, RTN_t^{EQM}, VOL_t^{EQM}\}$ and $M_{1t} \neq M_{2t}$, with $m = 1, 2, \ldots, 5$, $t = 1, \ldots, n$, $n = 269$ or $n = 56$ and the white noise disturbance ε_t (Enders (1995)).

The null hypothesis states that M_{2t} does not Granger cause M_{1t} in Equation (6.2): $H_0 : \beta_1 = \ldots = \beta_m = 0$. For example, we examine whether the bid-ask spread of corporate bonds ($M_{2t} = BAS_t^{CBM}$) Granger causes the equity returns ($M_{1t} = RTN_t^{EQM}$), and vice versa. Under the null hypothesis, the test statistic follows a F-distribution with m numerator degrees of freedom and $n - (2 * m + 1)$ denominator degrees of freedom.

Table 6.3: Summary statistics, 56 weeks

	Mean	Standard deviation	Median
Corporate bond market			
Bid-ask spread (absolute and market weighted)[b]	29.01	1.21	29.00
Bid-ask spread (absolute and equally weighted)[b]	29.65	1.10	29.60
Bid-ask spread (relative and market weighted)[a]	27.52	1.21	27.49
Bid-ask spread (relative and equally weighted)[a]	28.17	1.24	27.99
Market total excess return[a]	4.58	14.52	5.99
Government bond market			
Bid-ask spread (absolute)[b]	2.20	0.39	2.11
Bid-ask spread (relative)[a]	2.07	0.37	2.00
Market total return[a]	14.22	57.94	22.58
Equity market			
Bid-ask spread (absolute and market weighted)[b]	6.51	2.40	6.26
Bid-ask spread (absolute and equally weighted)[b]	6.65	2.43	6.40
Bid-ask spread (relative and market weighted)[a]	17.08	4.40	16.09
Bid-ask spread (relative and equally weighted)[a]	18.20	4.30	17.49
Total turnover (market weighted)[c]	1.04	0.23	1.0505
Total turnover (equally weighted)[c]	0.83	0.19	0.8253
Market total return[a]	-8.79	380.44	35.23

a in basis points
b in euro cents
c in billions of euro

6.5.2 Vector Autoregressive Model

Now we analyze the links in liquidity, return and volatility between and within our three security markets. Chordia et al. (2005) give examples of these links, such as: liquidity affects returns, but also return affects liquidity (loss aversion results in (lack of) trading depending on return). Liquidity between security markets can exhibit leading, simultaneous and lagging common movements, for example shifting expected returns in one market at the expense of an other market can cause trading and thus liquidity.

We implement a vector autoregressive (further VAR) model that captures both the links between and within markets. Our VAR model consists of $(3 * 3 + 1)$ equations, the quoted bid-ask spread, total return and volatility of each security market and the equity market total turnover. All time series are stationary according to the augmented Dickey-Fuller test at all confidence levels. The VAR model reads:

Table 6.4: Correlation matrix, 56 weeks

	BAS^{CBM}	RTN^{CBM}	BAS^{GBM}	RTN^{GBM}	BAS^{EQM}	TTO^{EQM}	RTN^{EQM}
BAS^{CBM}	1.00						
RTN^{CBM}	0.05	1.00					
BAS^{GBM}	-0.03	0.19	1.00				
RTN^{GBM}	-0.32	0.00	-0.14	1.00			
BAS^{EQM}	0.14	-0.27	-0.22	0.08	1.00		
TTO^{EQM}	0.24	-0.15	0.09	-0.28	-0.15	1.00	
RTN^{EQM}	0.45	0.19	0.26	-0.61	-0.08	-0.01	1.00

Table 6.5: Regression results from Equation (6.1)

		269 days		56 weeks	
Intercept	α	0.1857	(3.46)	0.2194	(3.07)
Age	β_1	0.0295	(1.73)	0.0158	(0.63)
Issued Amount	β_2	0.0074	(0.54)	0.0018	(0.11)
Maturity	β_3	0.0076	(2.53)	0.0070	(2.21)
R^2		0.06		0.14	
Adjusted R^2		0.05		0.09	

$$CBM_t = \phi_1 + \sum_{j=1}^{m} \theta_{1j} CBM_{t-j} + \sum_{j=1}^{m} \pi_{1j} GBM_{t-j} + \sum_{j=1}^{m} \tau_{1j} EQM_{t-j} + \varepsilon_{1t} \quad (6.3)$$

$$GBM_t = \phi_2 + \sum_{j=1}^{m} \theta_{2j} CBM_{t-j} + \sum_{j=1}^{m} \pi_{2j} GBM_{t-j} + \sum_{j=1}^{m} \tau_{2j} EQM_{t-j} + \varepsilon_{2t} \quad (6.4)$$

$$EQM_t = \phi_3 + \sum_{j=1}^{m} \theta_{3j} CBM_{t-j} + \sum_{j=1}^{m} \pi_{3j} GBM_{t-j} + \sum_{j=1}^{m} \tau_{3j} EQM_{t-j} + \varepsilon_{3t}, \quad (6.5)$$

with

$$CBM_t = \begin{bmatrix} BAS_t^{CBM} \\ RTN_t^{CBM} \\ VOL_t^{CBM} \end{bmatrix} \tag{6.6}$$

$$GBM_t = \begin{bmatrix} BAS_t^{GBM} \\ RTN_t^{GBM} \\ VOL_t^{GBM} \end{bmatrix} \tag{6.7}$$

$$EQM_t = \begin{bmatrix} BAS_t^{EQM} \\ TTO_t^{EQM} \\ RTN_t^{EQM} \\ VOL_t^{EQM} \end{bmatrix}, \tag{6.8}$$

where the intercepts are the (3×1) column vectors ϕ_1 and ϕ_2 and the (4×1) column vector ϕ_3, the slopes are (3×1) column vectors $\theta_{ij}, \pi_{ij}, \tau_{ij}$ and the (4×1) column vectors $\theta_{3j}, \pi_{3j}, \tau_{3j}$, with $i = 1, 2$, $j = 1, \ldots, m$. The disturbances are the (3×1) column vectors ε_{1t} and ε_{2t} and the (4×1) column vector ε_{3t}, with $t = 1, 2, \ldots, 269$ (days) or 56 (weeks). Each element in these disturbances vectors is a white noise process and they may be correlated. The VAR model is estimated using ordinary least squares equation by equation. Further, the number of time lags m is derived by first estimating the VAR model for different values of m and then selecting m associated with the lowest value of the Akaike information criterion (Enders (1995) and Verbeek (2000)).

The VAR model and the Granger causality test are related. In order to show this we take the first of the three equations of Equation (6.3), with $\tau_{11j} = 0$ (the first element of τ_{1j}) and $j = 1, \ldots, m$. This gives:

$$BAS_t^{CBM} = \phi_{11} + \sum_{j=1}^{m} \theta_{11j} BAS_{t-j}^{CBM} + \sum_{j=1}^{m} \pi_{11j} BAS_{t-j}^{GBM} + \varepsilon_{11t} \tag{6.9}$$

with ϕ_{11}, θ_{11j} and π_{11j} as the first elements of the column vectors ϕ_1, θ_{1j} and π_{1j}. This equation is comparable to equation (6.2), with $M_{1t} = BAS_t^{CBM}$ and $M_{2t} = BAS_t^{GBM}$.

Impulse Response Functions

We calculate the impulse response (IR) functions based on the estimated parameters of our VAR model above. These IR functions follow the reaction of current and future values of liquidity, return and volatility to a positive one standard deviation shock in one of the disturbances in Equations (6.3)-(6.8). For example: the $\varepsilon_{11,t}$ (the first element of vector ε_{1t}) increases with one standard deviation and consequently BAS_t^{CBM} increases with the same amount as well at t. Furthermore, the values of, for example, other liquidity may also react depending on the VAR model structure. These disturbances are often correlated making the IR function interpretation less straightforward. Usually this is solved by a Cholesky decomposition that generates a diagonal covariance matrix of the disturbances (Enders (1995) and Verbeek (2000)).

6.6 Results

6.6.1 Granger Causality Tests

Table 6.6 only presents the results of the Granger causality tests where the null hypothesis of no Granger causality cannot be rejected at the 10% level of significance. The upper half of the table reports the results associated with the daily data, whereas the lower half contains the results associated with the weekly data. Thus, there are less significant Granger causalities using weekly data than using daily data. The column with the header "1" contains the β_m coefficients of Equation (6.2), with $m = 1$. The "$\star$" sign in the four columns with the headers $2, 3, 4, 5$ indicate that this null hypothesis cannot be rejected at the same level of confidence for longer time lags $m = 2, 3, 4, 5$.

In total we calculate $2 * 90$ Granger causality tests using Equation (6.2). Looking at Table 6.6 only few of these Granger causalities are actually statistically significant. Chordia et al. (2005) also find this result. Using daily data, we find that BAS^{GBM} Granger causes VOL^{EQM} and vice versa. Three links indicate commonality in liquidity: BAS^{GBM} Granger causes BAS^{CBM}, BAS^{EQM} Granger causes BAS^{CBM} and BAS^{EQM} Granger causes BAS^{GBM}. Using weekly data, we also find commonality in liquidity: BAS^{CBM} Granger causes BAS^{EQM} and BAS^{CBM} Granger causes TTO^{EQM}.

Table 6.6: Results from the Granger causality test in Equation (6.2), with the number of time lags m and the indication of the 10% level of significance "$\star$".

			m				
			1	2	3	4	5
Daily data							
BAS^{GBM}		BAS^{CBM}	+	$\star$		$\star$	$\star$
BAS^{GBM}		RTN^{EQM}	+				
BAS^{GBM}		VOL^{EQM}	+				
RTN^{GBM}		RTN^{CBM}	+	$\star$	$\star$	$\star$	
VOL^{GBM}		RTN^{GBM}	−	$\star$	$\star$	$\star$	
VOL^{GBM}		RTN^{EQM}	+	$\star$			$\star$
BAS^{EQM}		BAS^{CBM}	+				
BAS^{EQM}		BAS^{GBM}	−				
BAS^{EQM}		RTN^{EQM}	+				
RTN^{EQM}	Granger causes	BAS^{CBM}	+	$\star$			
RTN^{EQM}		TTO^{EQM}	−				
VOL^{EQM}		BAS^{GBM}	−				
VOL^{EQM}		RTN^{CBM}	+	$\star$	$\star$	$\star$	$\star$
VOL^{EQM}		VOL^{GBM}	−				
BAS^{CBM}		VOL^{CBM}	+	$\star$			
BAS^{CBM}		VOL^{EQM}	+	$\star$	$\star$	$\star$	$\star$
RTN^{CBM}		BAS^{EQM}	−				
RTN^{CBM}		TTO^{EQM}	−	$\star$			
VOL^{CBM}		RTN^{CBM}	−	$\star$			
Weekly data							
VOL^{GBM}		BAS^{EQM}	+	$\star$	$\star$		
VOL^{GBM}		VOL^{EQM}	+				
BAS^{CBM}		BAS^{EQM}	+	$\star$	$\star$	$\star$	$\star$
BAS^{CBM}	Granger causes	TTO^{EQM}	−				
RTN^{CBM}		BAS^{GBM}	+				
RTN^{CBM}		RTN^{EQM}	+	$\star$	$\star$		
VOL^{CBM}		VOL^{EQM}	+	$\star$	$\star$	$\star$	$\star$

6.6.2 Vector Autoregressive Model

Impulse Response Functions, Daily Data

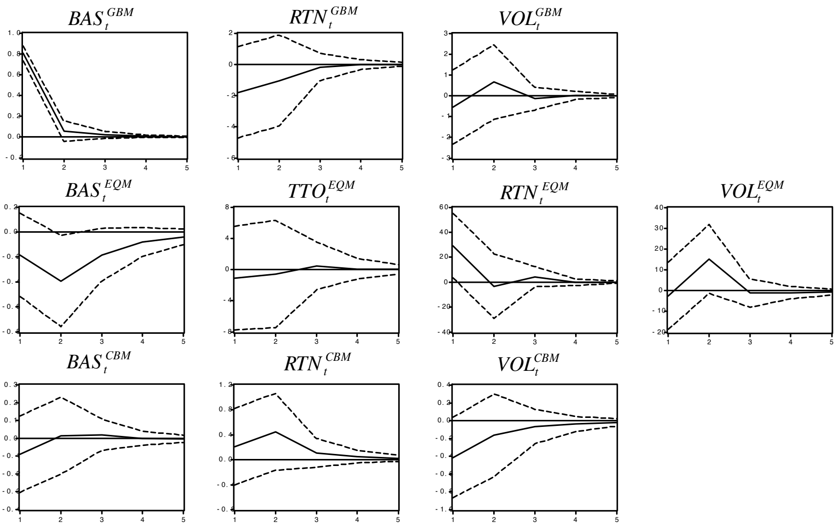
We calculate three series of IR functions with respect to shocks in the bid-ask spreads. Each figure displays the IR functions and their 95% confidence bands, with on the horizontal axis the number of days, starting with the impulse day, and on the vertical axis the change in the liquidity measures, total returns or volatilities of each security market. The units of the liquidity measures on the vertical axis correspond to those that are used for the absolute and market weighted liquidity measures in Table 6.1 and volatility is measured in the same units as return, with one exception: TTO is measured in millions. The number of time lags in this model equals one, $m = 1$.

Figure 6.4 reports the reaction of liquidity, return and volatility to the shock in the government bond bid-ask spread BAS_t^{GBM} at day $t = 1$. The top left graph shows the positive one standard deviation shock of BAS_t^{GBM} of approximately 1 euro cent. The effects of the shock on its future values vanish after only one day. Both the equity market bid-ask spread BAS_t^{EQM} and the corporate bond market bid-ask spread BAS_t^{CBM} show a small negative reaction of -0.4 euro cent at $t = 2$ and -0.1 euro cent at day $t = 1$. The total turnover of the equity market does not show any reaction. Thus, there is some commonality in liquidity between euro security markets, sometimes with a time lag of one day. Chordia et al. (2005) also find some commonality in liquidity for U.S. dollar security markets.

The government bond return RTN_t^{GBM} is negative at day $t = 1$: -2 basis points (further bps), whereas the equity market return RTN_t^{EQM} and the corporate bond market return RTN_t^{CBM} give a positive response of around 30 bps at $t = 1$ and 0.4 bps at $t = 2$. Finally, the government bond market volatility VOL_t^{GBM} and the equity market volatility VOL_t^{EQM} show a small increase at day $t = 2$. In contrast, the corporate bond volatility VOL_t^{CBM} decreases at the impulse day. Looking at all IR functions this shock and its reactions all vanish completely after five days.

The Figures 6.5 and 6.6 can be interpreted in the same way as we interpret Figure 6.4. Figure 6.5 reports the effects of the one standard deviation shock of around 3 euro cents to BAS_t^{EQM}. BAS_t^{GBM} and BAS_t^{CBM} display a negative reaction at day $t = 2$ and day $t = 1$ respectively. TTO_t^{EQM} remains unchanged. So, again there is some evidence of commonality in liquidity. Total return and volatility react immediately and/or with a lag of one day. Figure 6.6 displays the effects of the one standard deviation shock of around 2 euro cents to BAS_t^{CBM}. The bid-ask spreads of the other two security markets also

Figure 6.4: IR functions to a one standard deviation shock in BAS_t^{GBM}, daily data



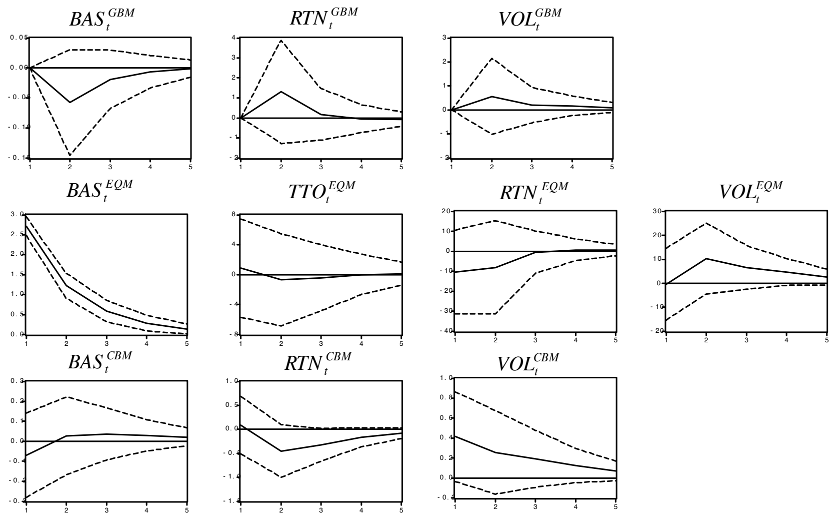
increase with a time lag of one day and commonality in liquidity seems again to exist. Return and volatility also respond, again often with one time lag.

Impulse Response Functions, Weekly Data

We now repeat the IR functions analyzes of shocks to the bid-ask spreads using weekly data instead of daily data. The Figures 6.7-6.9 display these IR functions with on the horizontal axis the number of weeks, starting with the impulse week, and once more on the vertical axis the change in the liquidity measures, returns or volatilities of each security market. The units of the liquidity measures correspond to the absolute and market weighted liquidity measures in Table 6.3, with the exception of TTO that is measured in millions of euro. Again, the number of time lags equals one.

These figures also demonstrate (some) commonality in liquidity as a bid-ask spread shock impacts the other two bid-ask spreads. These reactions sometimes have a time lag. Further, total turnover, return and volatility also respond to these bid-ask spread shocks at the impulse week or one week later most of the time. All these IR functions show convergence after approximately ten weeks. In general, these IR functions do not exhibit exactly the same patterns as the IR functions based on daily data.

Figure 6.5: IR functions to a one standard deviation shock in BAS_t^{EQM}, daily data



Sensitivity Analysis

In all IR function analyzes we follow the ordering according to the most developed security market to the less developed security market: government bond market (BAS_t^{GBM} RTN_t^{GBM} VOL_t^{GBM}), equity market (BAS_t^{EQM} TTO_t^{EQM} RTN_t^{EQM} VOL_t^{EQM}) and corporate bond market (BAS_t^{CBM} RTN_t^{CBM} VOL_t^{CBM}). Changing this ordering could alter the results in Subsection 6.6.2.

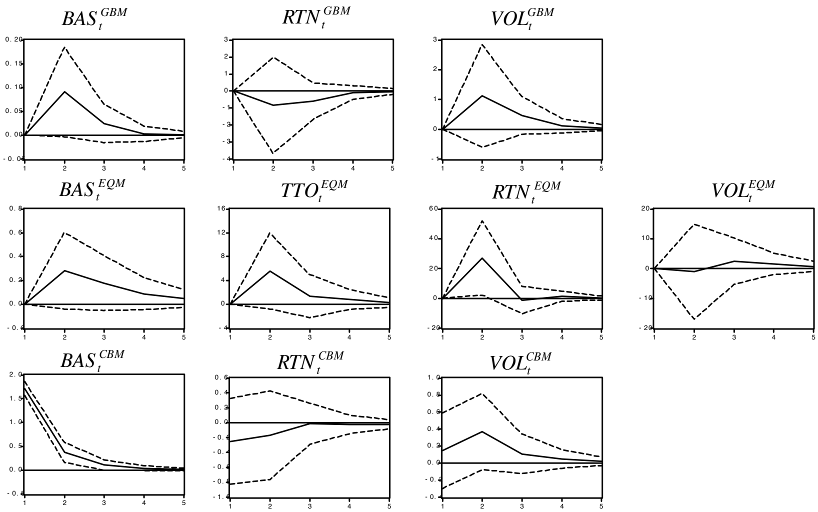
The upper half of Table 6.7 reports the correlations between the disturbances in Equations (6.3)-(6.8). Using daily data, these correlations are very low, i.e. they are lower than 0.20 in absolute value, with only four exceptions. Therefore, the IR functions should not be very sensitive to alterations in the ordering of liquidity, return and volatility in the three security markets. Using weekly data, as displayed at the bottom half of Table 6.7, shows however that the correlations between the VAR model disturbances are high. So, altering the ordering could alter our results.

Table 6.7:
The correlations between the disturbances of the VAR model in Equations (6.3)-(6.8)

Daily data	BAS^{GBM}	RTN^{GBM}	VOL^{GBM}	BAS^{EQM}	TTO^{EQM}	RTN^{EQM}	VOL^{EQM}	BAS^{CBM}	RTN^{CBM}	VOL^{GBM}
BAS^{GBM}	1.00									
RTN^{GBM}	-0.08	1.00								
VOL^{GBM}	-0.04	-0.11	1.00							
BAS^{EQM}	-0.07	0.05	0.09	1.00						
TTO^{EQM}	-0.02	-0.16	-0.02	0.01	1.00					
RTN^{EQM}	0.14	-0.58	0.02	-0.09	0.05	1.00				
VOL^{EQM}	-0.02	-0.07	0.36	0.03	0.13	0.09	1.00			
BAS^{CBM}	-0.05	-0.11	0.07	-0.04	0.11	0.12	0.01	1.00		
RTN^{CBM}	0.04	-0.21	0.00	0.00	0.08	0.33	0.01	0.00	1.00	
VOL^{GBM}	-0.11	-0.05	0.04	0.12	0.03	-0.03	0.12	0.04	-0.08	1.00

Weekly data	BAS^{GBM}	RTN^{GBM}	VOL^{GBM}	BAS^{EQM}	TTO^{EQM}	RTN^{EQM}	VOL^{EQM}	BAS^{CBM}	RTN^{CBM}	VOL^{GBM}
BAS^{GBM}	1.00									
RTN^{GBM}	-0.28	1.00								
VOL^{GBM}	0.11	-0.47	1.00							
BAS^{EQM}	-0.18	0.15	-0.04	1.00						
TTO^{EQM}	0.20	-0.21	0.09	-0.37	1.00					
RTN^{EQM}	0.43	-0.61	0.35	-0.19	-0.01	1.00				
VOL^{EQM}	0.22	-0.03	0.27	0.17	0.00	0.15	1.00			
BAS^{CBM}	0.12	-0.27	0.34	-0.12	0.29	0.39	0.25	1.00		
RTN^{CBM}	0.18	-0.20	0.04	-0.16	-0.07	0.44	-0.20	0.12	1.00	
VOL^{GBM}	-0.05	-0.09	0.12	0.00	0.19	0.15	0.25	0.32	-0.37	1.00

Figure 6.6: IR functions to a one standard deviation shock in BAS_t^{CBM}, daily data



6.7 Summary

Recently, market microstructure research has broadened to the analysis of commonality in liquidity in U.S. dollar equity and Treasury markets. We extend this line of research to the corporate bond, government bond and equity markets. Moreover, we analyze the euro-denominated security markets instead of the U.S. dollar security markets. We apply the Chordia et al. (2005) VAR approach and run impulse response functions and we also implement Granger causality tests. These statistical tests are implemented using both daily and weekly data for the period September 2002 to September 2003.

We find that commonality in liquidity between the three euro security markets indeed exists, sometimes with a time lag of one day or week. Furthermore, links between liquidity and total returns and volatility within and between euro security markets can also be significant. Granger causality tests support these results, although this type of test is very sensitive to the number of time lags. Both the VAR model and impulse response functions and the Granger causality tests results depend however on the data frequency.

Figure 6.7: IR functions to a one standard deviation shock in BAS_t^{GBM}, weekly data

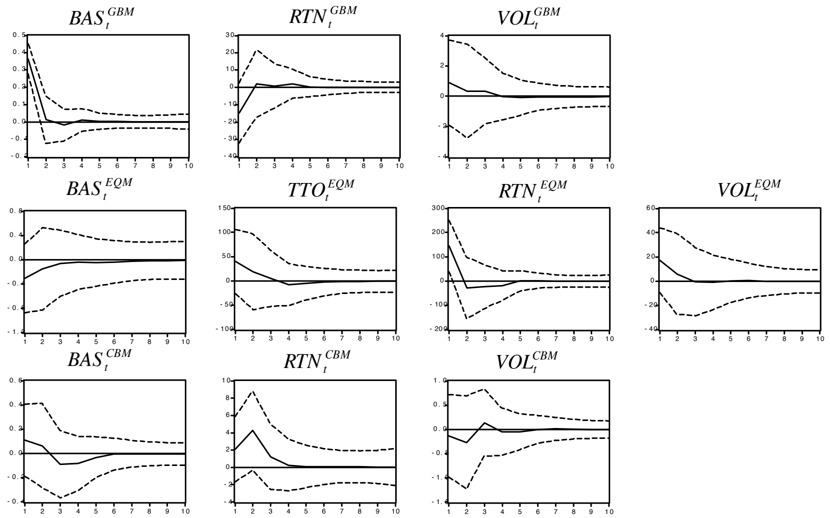


Figure 6.8: IR functions to a one standard deviation shock in BAS_t^{EQM}, weekly data

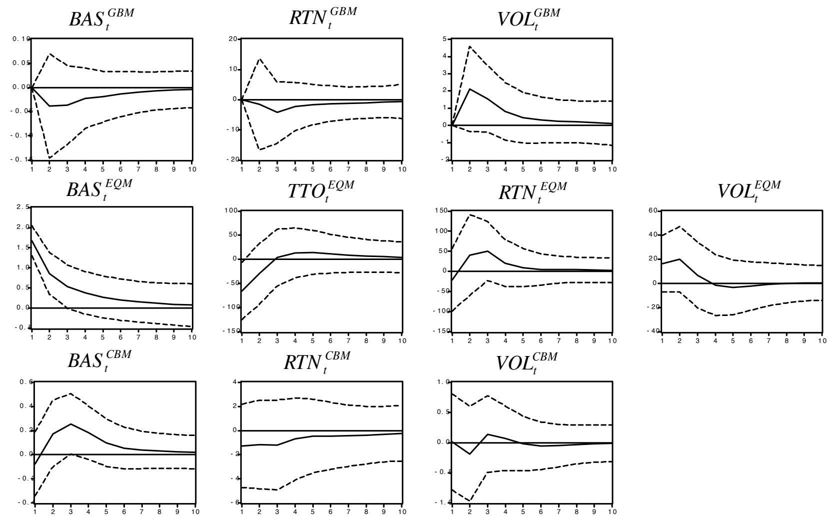
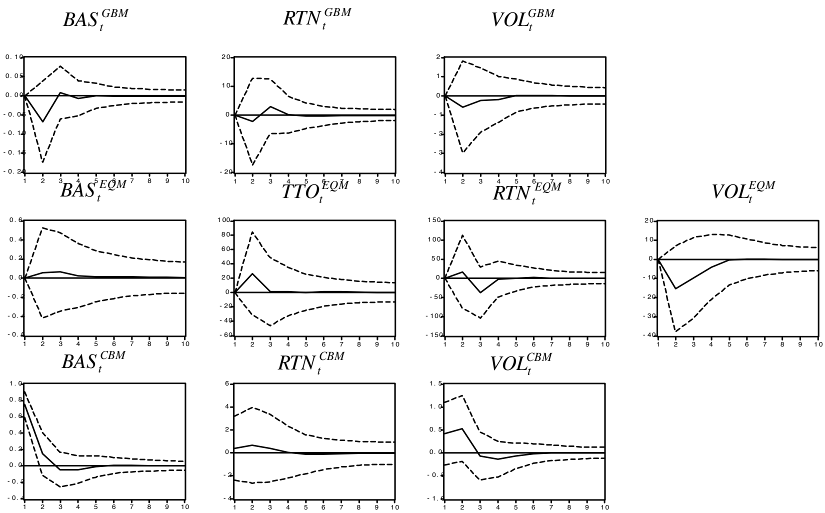


Figure 6.9: IR functions to a one standard deviation shock in BAS_t^{CBM}, weekly data



Appendix

6.A Quoted versus Not Quoted Corporate Bonds

Here we analyze the average characteristics of the frequently quoted versus the not frequently quoted corporate bonds as this chapter introduces a new corporate bond data set.

We define a frequently quoted bond as a bond that is quoted at least 15 times by a bank and by at least three (out of five) banks in total in a given month. So, a bond must be quoted at least $3 * 15$ times by three banks during a month before it is marked as a frequently quoted bond for that month. Following the monthly index rebalancing we select the one-month period. We find that only a very small percentage of the euro corporate bonds is actually frequently quoted on Bloomberg L.P. according to our definition.[8] The monthly average total number of bonds in the Lehman Brothers Corporate Bond index equals 1273, whereas the monthly average number of frequently quoted bonds equals only 113. Thus only about 9% of the index bonds is quoted frequently. The same situation applies to the U.S. dollar corporate bond market as observed by Gehr and Martell (1992).

We compare the characteristics of the frequently quoted bonds versus the characteristics of not frequently quoted bonds. To make this comparison possible, we first split the entire euro corporate bond market into a frequently quoted (FQ) and a not frequently quoted (NFQ) part (the remaining part of the market). Then, we compare the average of frequently quoted bonds characteristics $\overline{x}^i_{FQ\ t}$, with the corresponding average of not frequently quoted bonds characteristics $\overline{x}^i_{NFQ\ t}$, with $t \in$ {September 2002, October 2002, ..., August 2003, September 2003} and $i \in$ {*age*[9] (in years), *coupon* (in euro), *issued amount* (in billions of euro), *maturity* (in years), *rating*[10] and *equity market value* (in billions of euro)}. We test the null hypothesis (Madsen and Moeschberger (1986)):

[8]The number of frequently quoted bonds does not depend on this minimum amount of 15 quotes. Typically, a bond is quoted by a bank at all trading days during a month or not at all. The number of quoting banks however does have a large impact on the number of quoted bonds. Increasing the minimum number of three banks to four banks reduces the number of liquid bonds significantly.

[9]Age is defined as the time elapsed since issuance.

[10]Following Lehman Brothers, Inc (1998) we convert the index ratings as follows: AAA=1, AA1=2, ..., BAA2, BAA3=10. Thus a higher number implies a lower rating.

$$H_{0t}^i : \overline{x}_{FQ\,t}^i = \overline{x}_{NFQ\,t}^i, \tag{6.A.1}$$

using the test statistic:

$$C_t^i = \sqrt{\frac{\left(\sum_{j\epsilon\{FQ,\,NFQ\}} n_{jt}^i (\overline{x}_{jt}^i - \overline{x}_t^i)^2\right)}{\left(\sum_{j\epsilon\{FQ,\,NFQ\}} \sum_{k=1}^{n_{jt}^i} (x_{jtk}^i - \overline{x}_{jt}^i)^2\right) / N_t^i - 2}}, \tag{6.A.2}$$

with the entire market of both frequently quoted and not frequently quoted bonds associated with characteristic i in month t N_t^i, the number of frequently quoted bonds associated with characteristic i in month t $n_{FQ\,t}^i$, the number of not frequently quoted bonds associated with characteristic i in month t $n_{NFQ\,t}^i$, the market average of characteristic i in month t $\overline{x}_t^i$ and characteristic i of a bond k (frequently quoted or not frequently quoted) in month t x_{jtk}^i. Under H_{0t}^i, this test statistic follows a F-distribution with 1 numerator degree of freedom and $N_t^i - 2$ denominator degrees of freedom.

Table 6.8 reports the monthly and total period average value of *age*, *coupon*, *issued amount*, *maturity*, *rating* and *number* of *all* frequently quoted and not frequently quoted bonds and the average value of the *equity market value* and the *number* of *listed* frequently quoted and listed not frequently quoted bonds for the period September 2002 to September 2003. The equity market value is only available for bonds issued by listed companies. Consequently, we differentiate between the number of all bonds and the number of bonds issued by listed companies.

This table shows that the average *age* of frequently quoted bonds is always lower than its not frequently quoted counterpart, at all confidence levels. In most months, this difference equals approximately two years. So, the frequently quoted bonds are younger than their not frequently quoted counterpart. This follows from the fact that most corporate bonds quickly end up in institutional buy-and-hold portfolios after their issuance and therefore disappear from the corporate bond market (see also Chapter 5).

The monthly and the total period average *coupon* of the frequently quoted bonds are significantly higher than the monthly and total period average *coupon* of not frequently quoted bonds at the 5% confidence level and at all levels respectively. The average higher coupon coincides with the longer average maturity and the average lower rating of frequently quoted versus not frequently quoted bonds.

The average *issued amount* of frequently quoted bonds is larger than that of not frequently quoted bonds all the time, at all confidence levels. This difference is roughly one billion euro. Issued amount is often used as an indirect liquidity characteristic (in contrast to the direct liquidity measure bid-ask spread), where higher issued amounts indicate higher liquidity. This is in line with the results in this table (see also Chapter 5).

The average *maturity* of frequently quoted bonds is always longer than the average *maturity* of not frequently quoted bonds and statistically significant at the 10% level for the period March 2003 to September 2003. The average *rating* of frequently quoted bonds is significantly lower than that of not frequently quoted bonds for all months at all significance levels. The *number* of frequently quoted bonds remains very low compared to the number of not frequently quoted bonds, although the number increases in time. The average *equity market value* of the issuers of the frequently quoted bonds is larger than that of the issuers of not frequently quoted bonds. This difference is statistically significant for the months March 2003 to September 2003 and for the total period at the 5% level of significance and at all significance levels respectively.

Thus the characteristics of the frequently quoted part of the euro denominated corporate bond market do not correspond to those of the corporate bond index. In general, the frequently quoted part has a lower average *age*, higher *coupon*, larger *issued amount*, longer *maturity*, lower *rating* and higher *equity market value* than its not frequently quoted counterpart.

Table 6.8: The average values of the characteristics of frequently quoted (FQ) versus the not frequently quoted (NFQ) corporate bonds for the period September 2002 to September 2003, with the p-values associated with Equation (6.A.2).

	Sept. 2002	Oct. 2002	Nov. 2002	Dec. 2002	Jan. 2003	Feb. 2003	Mar. 2003
Age							
FQ	1.20	1.43	1.38	1.48	1.51	1.58	1.45
NFQ	3.43	3.49	3.53	3.55	3.60	3.62	3.58
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coupon							
FQ	6.06	5.90	5.89	5.93	5.83	5.84	5.70
NFQ	5.53	5.52	5.51	5.50	5.50	5.51	5.48
	0.01	0.02	0.03	0.02	0.03	0.02	0.16
Issued amount[a]							
FQ	1.72	1.53	1.57	1.58	1.51	1.52	1.42
NFQ	0.50	0.49	0.50	0.51	0.50	0.50	0.51
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maturity							
FQ	5.90	5.98	5.86	5.71	5.55	6.09	6.56
NFQ	5.47	5.45	5.45	5.45	5.47	5.47	5.54
	0.55	0.38	0.53	0.68	0.88	0.26	0.09
Rating							
FQ	6.51	6.36	6.48	6.49	6.64	6.53	6.13
NFQ	4.98	4.98	4.99	4.99	4.97	5.09	5.12
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Number							
FQ	47	69	61	61	85	91	82
NFQ	1250	1238	1237	1223	1185	1187	1194
Equity market value[a]							
FQ	32.37	26.85	28.17	26.41	28.43	30.94	29.05
NFQ	23.03	23.59	23.69	21.35	21.84	21.59	20.24
	0.06	0.45	0.33	0.22	0.07	0.01	0.02
Listed number							
FQ	30	44	38	46	61	58	52
NFQ	574	563	566	672	653	657	660

continued on next page

	Apr. 2003	May 2003	Jun. 2003	Jul. 2003	Aug. 2003	Sept. 2003	Full sample period
Age							
FQ	1.62	1.61	1.75	1.79	1.66	1.80	1.63
NFQ	3.64	3.67	3.71	3.79	3.75	3.86	3.63
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coupon							
FQ	5.76	5.75	5.67	5.53	5.53	5.47	5.68
NFQ	5.46	5.44	5.44	5.41	5.39	5.40	5.47
	0.02	0.02	0.05	0.23	0.18	0.45	0.00
Issued amount[a]							
FQ	1.40	1.34	1.29	1.23	1.15	1.16	1.34
NFQ	0.49	0.51	0.50	0.46	0.49	0.47	0.50
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Maturity							
FQ	6.41	6.75	6.46	6.38	6.75	6.41	6.33
NFQ	5.51	5.45	5.44	5.24	5.27	5.24	5.42
	0.08	0.01	0.03	0.00	0.00	0.00	0.00
Rating							
FQ	6.51	6.76	6.63	6.14	6.53	6.19	6.42
NFQ	5.06	5.04	5.04	5.09	5.08	5.11	5.04
	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Number							
FQ	109	114	137	199	190	222	1467
NFQ	1154	1143	1117	1062	1064	1030	15084
Equity market value[a]							
FQ	28.38	29.29	36.03	31.84	31.10	31.33	30.63
NFQ	20.14	20.22	22.77	22.99	22.83	22.91	22.02
	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Listed number							
FQ	69	80	100	129	135	143	985
NFQ	631	623	603	579	572	561	9714

a in billions of euro

Chapter 7

Summary

In this thesis, we started in Chapter 2 with a description of the Dutch government and corporate bond markets. Subsequently, we implemented and analyzed some empirical models of corporate bonds, particularly euro corporate bonds, where Part I (Chapters 3 and 4) concentrated on credit risk and Part II (Chapters 5 and 6) focused on liquidity risk of corporate bonds.

Chapter 2 discussed the changes of the small market for Dutch bonds after the introduction of the euro on January 1, 1999. After this event, the Dutch government had to find ways to improve the liquidity of sovereign debt as national monetary policy and currency differences between euro-zone countries disappeared. The euro also influenced Dutch corporate bond issuers, who have become part of a growing euro-denominated corporate bond market. In this newly established bond market, a company's home country has become less important than it's rating and sector. The investor base of both Dutch government bonds and corporate bonds has become more internationally oriented as well. So, it is clear that both issuers and investors have been affected by the introduction of the euro. One common ground for issuers and investors are the OTC bond markets. Also, there have been changes to the Dutch financial supervision regime, since Dutch supervision has moved from a largely sector-oriented regime, to one that is more cross-sectional based. Finally, rating agencies also have an impact through their assessment of Dutch government debt and corporate bonds.

Chapter 3 empirically compared several pricing methods for rating-triggered step-up coupon bonds. European telecom companies have issued these bonds in order to compensate bond investors for losses in the event of rating downgrades. If this rating deteriorates and hits a predefined level, the step-up coupon is triggered and the coupon increases with a predefined number of basis points. Risk-neutral transition probabilities were applied using the Jarrow et al. (1997) (JLT) framework to value these rating-triggered

step-up bonds. For comparison purposes, Chapter 3 also valued step-up bonds using historical probabilities and plain vanilla bonds comparable to step-up bonds save for the step-up feature. We found that the market seems to value telecom step-up bonds, bearing coupons that make a single step-up after the rating hits the trigger level, according to the JLT model. Furthermore, the market appears to value step-up bonds, bearing coupons that step up every time a rating hits a trigger level, as plain vanilla bonds. Market premiums of the step-up feature are much more volatile than the JLT and historical premiums. As expected, the JLT model in all cases approximates the market premiums better than the historical valuation method. Finally, most step-up bonds offer protection in the form of lower price volatility. However, step-up bonds do not offer superior returns to an investor in case of rating downgrades or negative outlooks.

Chapter 4 demonstrated that minimizing credit portfolio Conditional Value-at-Risk using the CreditMetrics model generates portfolios that are less risky than a fully diversified portfolio. At the same time, the expected return remains at least the same. CreditMetrics simulates credit bond portfolio distributions and calculates credit bond portfolio risks. We found that a portfolio manager should be careful in carrying out the trades as suggested by the "optimal" portfolio. Only one or two bonds dominate optimal portfolios. Even when transaction costs are introduced this remains the case. Moreover, the composition of such an optimal portfolio is very sensitive to small changes in the expected forward price of its main constituents. However, portfolio optimization can be used in combination with some common sense restrictions, such as maximum bond holdings and categorization of bonds using their main characteristics, to produce portfolios that have both a lower risk and higher return than a fully diversified portfolio. We also improved the portfolio by replacing the dominant bond in the optimal portfolio by similar bonds.

Chapter 5 tested whether bond market liquidity is priced using liquidity proxies: *issued amount*, *listed*, *age*, *missing prices*, *yield volatility*, *number of contributors*, *yield dispersion*, *euro* and *on-the-run*. For each liquidity proxy, we constructed mutually exclusive portfolios. The time series of portfolio yields were subsequently used in two Fama and French (1993) regression models, augmented with additional portfolio characteristics to control for differences in interest rate risk, credit risk, maturity and rating between the portfolios. We also conducted pair wise comparisons of the liquidity proxies. We found that the null hypothesis of no liquidity premium should be rejected for eight out of nine liquidity proxies. The premium between liquid and illiquid portfolios depends on the liquidity proxy and ranges from 13 to 23 basis points. The highest premiums are found for the proxies *amount outstanding* and *yield dispersion*. The pair wise comparison tests point out that no proxy stands out from the rest.

Chapter 6 analyzed the commonality in liquidity, return and volatility of the euro-denominated corporate bond, government bond and equity markets. We first applied the Chordia et al. (2003) VAR approach using both daily and weekly frequency. Based on our VAR model we ran impulse response functions and we found that commonality in liquidity between euro security markets indeed exists. Furthermore, links between liquidity and returns and volatility within and between euro security markets can also be strong. We further found that Granger causality tests support these results. As we introduced a new corporate bond data set we next compared the average characteristics of frequently quoted and not frequently quoted corporate bonds. We found that the frequently quoted part has a lower average *age*, higher *coupon*, larger *issued amount*, longer *maturity*, lower *rating* and higher issuer *equity market value* than its not frequently quoted counterpart for the total period: September 2002 to September 2003.

Nederlandse samenvatting (Summary in Dutch)

Inleiding

De afgelopen jaren is de belangstelling van zowel wetenschap als praktijk voor bedrijfsobligaties toegenomen. Hieraan liggen uiteenlopende redenen ten grondslag. Een belangrijke reden was de invoering van de girale euro op 1 januari 1999. Die voegde elf afzonderlijke obligatiemarkten samen en creëerde daarmee één grote obligatiemarkt met één gemeenschappelijk munt. De in euro luidende markt voor bedrijfsobligaties is sindsdien sterk gegroeid en heeft zich ontwikkeld tot een volwassen markt. Een andere reden voor de toegenomen belangstelling voor bedrijfsobligaties waren de grote boekhoudschandalen van bedrijven als Enron en WorldCom. Zij leidden tot hun ondergang. Dit proefschrift gaat dan ook in op een aantal aspecten van bedrijfsobligaties.

De bovengenoemde belangstelling resulteerde in een reeks nieuwe, vooral theoretische, modellen met betrekking tot het kredietrisico van bedrijfsobligaties. Meer recent is er ook aandacht gekomen voor modellering van het liquiditeitsrisico van bedrijfsobligaties. Een belangrijke reden hiervoor is dat rente en kredietwaardigheid - de gebruikelijke factoren om bedrijfsobligaties te modelleren - de prijzen van dit type obligaties niet volledig konden verklaren.

Dit proefschrift geeft eerst de ontwikkelingen van de Nederlandse obligatiemarkt na de introductie van de euro weer. Dan volgt empirisch onderzoek naar kredietrisico van bedrijfsobligaties (Deel I), respectievelijk liquiditeitsrisico van die obligaties (Deel II). Voorafgaand aan de samenvattingen van de hoofdstukken worden veelgebruikte termen gedefinieerd.

Definities

Een (standaard)obligatie is een "verhandelbaar bewijs van deelneming in een geldlening, met een vaste nominale waarde waarover een, meestal vaste, rente wordt betaald. Na verloop van de looptijd wordt de geldlening afgelost"(bron: Autoriteit Financiële Markten, URL: http://www.afm.nl/). Een bedrijfsobligatie is een obligatie die is uitgegeven door een bedrijf.

Het kredietrisico van een obligatie is de kans dat beleggers verlies lijden op hun obligaties "door het niet nakomen van verplichtingen [van het uitgevend bedrijf (of emittent)] ten aanzien van rente en aflossing, bijvoorbeeld als gevolg van faillissement"(bron: bijlage bij het jaarverslag 1998 van De Nederlandsche Bank). Dit kredietrisico wordt vaak uitgedrukt aan de hand van een rating. De rating van een emittent geeft de huidige inschatting door een ratingbureau van de financiële capaciteit (of kredietwaardigheid) om te voldoen aan zijn financiële verplichtingen (bron: Standard & Poor's, URL: http://www.standardandpoors.com/, vertaald uit het Engels door Albert Mentink (verder AM)). Twee belangrijke ratingbureaus zijn Moody's Investors Service en Standard & Poor's. Als compensatie voor het kredietrisico ontvangt een belegger in bedrijfsobligaties een hoger verwacht rendement dan op vergelijkbare obligaties zonder dit risico, bijvoorbeeld Nederlandse Staatsobligaties. Het verschil in verwacht rendement tussen beide typen van obligaties wordt (yield) spread genoemd. In het algemeen geldt: hoe groter de (yield) spread hoe groter het kredietrisico.

Een obligatieportefeuille is een verzameling van twee of meer obligaties. Van een (obligatie)portefeuille kunnen de risicomaatstaven Value-at-Risk en Conditional Value-at-Risk worden berekend. Value-at-Risk is gedefinieerd als "het, op basis van een statistisch model berekende, mogelijk verlies op de [obligatieportefeuille] ten gevolg van verandering in de marktprijzen van (één of meer van) [de obligaties in de portefeuille]. Dit mogelijke verlies is zodanig berekend dat werkelijke verliezen daar met een kans van bijvoorbeeld 99% onder blijven. Hierbij wordt aangenomen dat de samenstelling van de [obligatieportefeuille] gedurende bijvoorbeeld [één jaar] onveranderd blijft"(bron: bijlage bij het jaarverslag 1998 van De Nederlandsche Bank). Conditional Value-at-Risk is, bij een gegeven kans, gelijk aan de verwachte waarde van de portefeuilleverliezen groter dan de Value-at-Risk over een bepaalde horizon, bijvoorbeeld één jaar (bron: Rockafellar, R. en S. Uryasev (2000), 'Optimization of Conditional Value-at-Risk', The Journal of Risk 2(3), 21-41, vertaald uit het Engels door AM).

Een obligatie is liquide als deze een (bijna) volledig substituut is voor kasgeld. Een obligatiemarkt is liquide als obligaties snel, in grote hoeveelheden, tegen lage transactiekosten en zonder grote marktprijseffecten kunnen worden verhandeld (bron: Maltz, A. (2003), 'Liquidity risk: Current research and practice', RiskMetrics Journal 4(1), 35-72, vertaald uit het Engels door AM). Gaat dit niet op dan is een obligatie illiquide. Een directe maatstaf voor de liquiditeit van een obligatie is de hoogte van transactiekosten: de bied-laat spread. Deze spread is gedefinieerd als het verschil tussen de bied- en laatprijs. De biedprijs is "de prijs die 'de markt' wil betalen voor de aankoop van een bepaalde obligatie"; de laatprijs is "de prijs die 'de markt' wil ontvangen voor de verkoop van een bepaalde obligatie"(bron: EuroNext, URL: http://www.euronext.com/). In de regel is de bied-laat spread positief. Een grote (kleine) bied-laat spread duidt op een lage (hoge) liquiditeit. Beleggers zijn gebaat bij grote liquiditeit, omdat zij dan tegen lage transactiekosten kunnen handelen.

De Nederlandse obligatiemarkt

In dit hoofdstuk stellen wij de vraag aan de orde welke invloed de invoering van de girale euro op 1 januari 1999 heeft gehad op de Nederlandse obligatiemarkt. Op de nieuwe, grotere in euro luidende obligatiemarkt vielen valutaverschillen weg. Mede hierdoor moest de Nederlandse Staat manieren zoeken om zich positief te onderscheiden van andere deelnemende landen. Zij vergrootte daarom de liquiditeit van haar obligaties met als doel voor beleggers aantrekkelijk te blijven. Voor de Nederlandse uitgevers van bedrijfsobligaties gold vanaf dat moment dat land van herkomst minder belangrijk was dan rating en sector. Zowel de Nederlandse Staats- als bedrijfsobligaties moesten dus door de komst van de euro internationaal meer concurrerend worden. Tevens werd het aandeel van buitenlandse beleggers in beide typen obligaties groter.

Om de toegenomen internationalisering van financiële markten het hoofd te kunnen bieden, fuseerde de Amsterdamse beurs op 22 september 2000 met een aantal andere Europese beurzen tot Euronext. Daarnaast bleven vraag en aanbod van obligaties bij elkaar komen op de veel grotere Over-the-Counter (OTC) obligatiemarkt. Een markt waar obligaties tussen koper en verkoper worden verhandeld zonder tussenkomst van een beurs.

Het toezicht op de Nederlandse obligatiemarkt veranderde eveneens; de sectorbenadering maakte plaats voor een cross sectie (sector overschrijdende) benadering. Tenslotte hebben de internationale ratingbureaus met hun beoordelingen meer dan voorheen greep op de Nederlandse obligatiemarkt gekregen.

Wij concluderen dat de invoering van de euro de markt van Nederlandse obligaties voor vele betrokken partijen ingrijpend heeft veranderd.

Kredietrisico

De waardering van step-up obligaties

In dit hoofdstuk toetsen wij empirisch welke waarderingsmethode het beste de marktprijs van step-up obligaties benadert. Vooral Europese telecommunicatiebedrijven hebben step-up obligaties uitgegeven ter financiering van de UMTS licenties. Het doel van step-up obligaties is beleggers te compenseren voor prijsdalingen als gevolg van verslechtering van de kredietwaardigheid van een telecommunicatiebedrijf. Bij dit obligatietype neemt de hoogte van de coupon toe met een van tevoren vastgesteld aantal basispunten (één basispunt is gelijk aan 1/100 procent) bij een verlaging van de rating tot een van tevoren vastgesteld niveau. Bij een enkelvoudige step-up obligatie kan de coupon slechts éénmaal worden verhoogd; bij een meervoudige step-up obligatie kan de coupon meermalen worden verhoogd.

Wij onderzoeken de theoretische waarde van step-up obligaties aan de hand van het Jarrow-Lando-Turnbull (verder JLT) model uit 1997. Ook wordt dit soort obligaties gewaardeerd met behulp van een historisch model. Dit model maakt gebruik van kansen gebaseerd op ratingveranderingen in het verleden. Bovendien worden theoretische waarden van de step-up obligaties berekend alsof het standaardobligaties zijn. Daarnaast vergelijken wij de prijsfluctuaties van de step-up obligaties met die van vergelijkbare standaardobligaties. Tenslotte analyseren wij het effect van een (kans op een) ratingverlaging op het rendement van enerzijds step-up obligaties en anderzijds vergelijkbare standaardobligaties.

Wij concluderen dat het JLT-model voor de obligaties met een enkelvoudige step-up een waardering oplevert die de marktprijzen het beste benadert. De obligaties met meervoudige step-ups daarentegen worden door de markt als een standaardobligatie geprijsd. Verder blijkt dat de marktprijzen van de step-up eigenschap meer fluctueren dan op grond van de waarderingen volgens het JLT-model of het historische model te verwachten is. De step-up eigenschap is gelijk aan de step-up marktprijs minus de waardering van de vergelijkbare standaardobligatie. Het JLT-model benadert de marktprijs van de step-up eigenschap altijd beter dan het historische model. Ook blijkt dat de prijzen van de meeste step-up obligaties minder fluctueren dan die van vergelijkbare standaardobligaties. Met andere woorden: de meeste step-up obligaties bieden bescherming door middel van lagere prijsfluctuaties. Tenslotte genereren step-up obligaties geen hoger rendement bij (een kans op) ratingverlaging ten opzichte van vergelijkbare standaardobligaties.

De optimalisatie van portefeuilles met bedrijfsobligaties

In dit hoofdstuk onderzoeken wij de vraag of optimale bedrijfsobligatieportefeuilles in de praktijk een verbetering vormen ten opzichte van de startportefeuille. Optimale portefeuilles zijn portefeuilles met een lager (of tenminste hetzelfde) risico dan de startportefeuille en met tenminste hetzelfde (of hoger) rendement.

Wij onderzoeken de kenmerken van dergelijke optimale portefeuilles. Het CreditMetrics model simuleert hiertoe eerst een verdeling van een bedrijfsobligatieportefeuille en berekent vervolgens portefeuillerisico's, zoals Value-at-Risk. Daarna worden optimale bedrijfsobligatieportefeuilles berekend met behulp van de gesimuleerde verdeling en optimalisatietechnieken.

Wij concluderen dat een portefeuillemanager de transacties in de startportefeuille om tot een optimale portefeuille te komen niet zonder meer dient op te volgen. Optimale portefeuilles bestaan namelijk uit slechts één of twee dominante obligaties. Daarbij komt dat deze portefeuilles zeer gevoelig zijn voor wijzigingen in de verwachte prijs van deze dominante obligaties, hoe klein deze ook zijn. De optimalisatie wordt praktisch meer bruikbaar na toevoeging van enkele voor de hand liggende randvoorwaarden. Hierbij kan worden gedacht aan een maximum gewicht van individuele obligaties en categorisering van obligaties aan de hand van obligatiekarakteristieken, bijvoorbeeld rating. Wij hebben tenslotte optimale portefeuilles verder gediversifieerd door de dominante obligaties deels te vervangen door andere met vergelijkbare karakteristieken.

Liquiditeitsrisico

De meting van liquiditeit van bedrijfsobligaties

In dit hoofdstuk gaan wij in op de meting van de liquiditeit van bedrijfsobligaties. Het is van belang te weten in hoeverre liquiditeit het verwachte rendement van bedrijfsobligaties beïnvloedt. In het algemeen geldt dat portefeuilles bestaande uit illiquide obligaties een hoger verwacht rendement genereren dan portefeuilles van vergelijkbare liquide obligaties. De vergoeding voor illiquiditeit is hier gedefinieerd als de yield spread tussen beide portefeuilles.

Wij onderzoeken illiquiditeit door gebruik te maken van negen indirecte liquiditeitscriteria. Om tot een juiste vergelijking te komen tussen liquide en illiquide portefeuilles hebben wij eerst de portefeuillerendementen gecorrigeerd voor andere obligatiekarakteristieken die, evenals liquiditeit, ook het verwachte rendement van bedrijfsobligatieportefeuilles bepalen. Voorbeelden hiervan zijn: resterende looptijd en rating. Om te bepalen welk criterium het beste liquiditeit meet, hebben wij daarna vijf van de negen liquiditeitscriteria paarsgewijs vergeleken en de uitkomsten ervan naast elkaar gezet.

Wij concluderen dat de yield spread tussen liquide en illiquide portefeuilles uiteen kan lopen van 13 tot 23 basispunten. Daarbij blijkt dat met behulp van acht van de negen liquiditeitscriteria dit verwachte rendementsverschil kan worden geïdentificeerd. De criteria totale hoofdsom en spreiding tussen de (door banken) afgegeven verwachte rendementen laten het grootste liquiditeitsverschil tussen beide obligatieportefeuilles zien. Uit de paarsgewijze vergelijking blijkt dat geen van de vijf criteria krachtiger is dan de ander.

De schatting van liquiditeit in effectenmarkten

In dit hoofdstuk schatten wij hoe liquiditeit van in euro luidende bedrijfsobligatie-, staatsobligatie- en aandelenmarkten op elkaar reageren. Hiertoe kwantificeren wij liquiditeit in elk van deze markten met behulp van de gemiddelde bied-laat spread. Verder maken wij een vergelijking tussen de gemiddelde obligatiekarakteristieken van de bedrijfsobligatiemarkt die enerzijds bestaat uit liquide obligaties en anderzijds bestaat uit illiquide obligaties.

Wij maken eerst gebruik van het model van Chordia, Sarkar en Subrahmanyam (2003) en de Granger causaliteitstesten om te bepalen in hoeverre de gemiddelde bied-laat spreads op elkaar reageren. Vervolgens toetsen wij of de gemiddelden van de obligatiekarakteristieken van het liquide en illiquide deel van de bedrijfsobligatiemarkt aan elkaar gelijk zijn.

Wij concluderen dat de gemiddelde bied-laat spreads in de drie onderzochte in euro luidende financiële markten op elkaar reageren, zij het soms met vertraging. Verder vinden wij dat het liquide deel van de bedrijfsobligatiemarkt gemiddeld een kortere looptijd sinds uitgifte, hogere coupon, grotere totale hoofdsom, langere resterende looptijd, lagere rating en hogere aandelenmarktwaarde van de emittent heeft dan het illiquide deel.

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