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The Impact of Liquidity on Bond Pricing

A study comparing municipal bonds and government bonds in the Swedish market

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Abstract: In this study, we find that liquidity impacts bond pricing in the Swedish market. Specifically, we investigate the impact of liquidity by examining the yield spread between two bonds that generally differ in liquidity: Swedish municipal bonds issued by Kommuninvest and Swedish government bonds. We use the bid-ask spread as a measure of liquidity and find that a larger bid-ask spread of the Kommuninvest bond is associated with a larger yield spread. In addition, we evaluate whether the bonds we study can be used to isolate the impact of liquidity on bond pricing. Liquidity is a multidimensional and complex concept, which makes it difficult to capture in its entirety with liquidity measures. In efforts to avoid the reliance on measures, previous studies of the U.S., German and French markets show that pricing differences due to liquidity can be isolated by comparing the yields of two bonds that are considered equivalent in all regards except liquidity. We build on this method by being the first to evaluate whether municipal bonds which are guaranteed by the local government sector can be used for this purpose. However, in our comparison of Kommuninvest bonds to Swedish government bonds we find that credit quality differences impact the yield spread. Hence, we conclude that the Kommuninvest bonds cannot be used in a comparison with Swedish government bonds to isolate the impact of liquidity.

Keywords: Bond liquidity, Bond pricing, Yield spread, Liquidity premium, Municipal bonds

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Contents

1 Introduction

In 1986, Amihud and Mendelson shed light upon the lack of understanding of how liquidity impacts asset prices by showing that liquidity affects stock returns. They highlighted that: "*In the securities industry, portfolio managers and investment consultants tailor portfolios to fit their clients' investment horizons and liquidity objectives. But despite its evident importance in practice, the role of liquidity in capital markets is hardly reflected in academic research*". Amihud and Mendelson's (1986) findings revealed a significant shortcoming of traditional asset pricing models, such as the Capital Asset Pricing Model and Fama French Three Factor Model, as they do not explicitly take liquidity into consideration. The impact of liquidity on asset prices has since gained recognition in academic research. Its importance in the financial markets is also evident in practice, as for example stock exchanges and central banks take actions to influence liquidity (Goldstein and Kavajecz, 2000; Fawley and Neely, 2013). Nevertheless, it remains a heavily investigated area as researchers strive to gain a deeper understanding of the concept of liquidity and how it impacts asset prices.

Understanding liquidity has proven to be a challenging quest, mainly due to the difficulties associated with defining, measuring and capturing the concept. A simple definition of liquidity is "*the ease of trading a security*" (Amihud, Mendelson and Pedersen, 2005), and the concept is generally perceived to encompass three main dimensions: cost, quantity and time (Holden, Jacobsen and Subrahmanyam, 2014). The multidimensional and complex nature of liquidity implies that it is difficult to capture. Researchers commonly rely on liquidity measures that address one or a few dimensions of liquidity to approximate the extent to which a security is liquid or illiquid. Using such measures, liquidity is found to impact stock prices (e.g. Jones, 2002; Bekaert, Harvey and Lundblad, 2007) and bond yields (e.g. Chen, Lesmond and Wei, 2007; Boudoukh et al. 2016) across several markets.

In this study, we contribute to the literature concerning the impact of liquidity on asset prices by investigating whether liquidity is priced in the Swedish bond market. Our approach entails examining the yield spread between two bonds that generally differ in liquidity: a Swedish municipal bond called Kommuninvest and a Swedish government bond. In particular, Swedish government bonds are generally more liquid than Kommuninvest bonds. Kommuninvest is a Swedish local government funding agency that aims to help Swedish municipalities to raise capital by issuing bonds (Kommuninvest, 2016a). We focus on bond-specific liquidity and use the bid-ask spread, which addresses the cost dimension of liquidity, as a measure for liquidity.

Since previous studies establish that bond-specific liquidity impacts prices and that this applies for several markets, our first research question relates to whether this is true also for the Swedish bond market:

Research question 1*: Is bond-specific liquidity priced in the Swedish bond market?*

The use of measures when investigating liquidity is not ideal as these measures do not fully capture liquidity. In efforts to avoid reliance on liquidity measures, researchers that study government bonds develop approaches that allow an isolation of pricing differences due to liquidity. This type of method entails comparing the yield of two bonds that are identical in all regards except liquidity, thus enabling an examination of the impact of liquidity in its entirety. One of the first researchers to employ this method is Longstaff (2004), who examines U.S. government bonds and bonds issued by the government agency Refcorp. Refcorp bonds are special in the sense that they are guaranteed by the U.S. government. Hence, they have the same credit quality as government bonds and should therefore have comparable yields. The liquidity of the Refcorp bonds is however substantially lower than the liquidity of the government bonds, implying that any potential yield spread between the two reflects pricing impact due to liquidity. Longstaff (2004) finds that the yields of Refcorp bonds exceed the yields of government bonds, and thereby concludes that liquidity affects bond pricing. This approach has inspired a large part of the most recent studies of liquidity and bond prices such as Ejsing, Grothe and Grothe (2015), Schwarz (2016) and Black, Stock and Yadav (2016) who all compare government bonds to government-guaranteed bonds.

Studies using this particular approach are however limited to the U.S., German and French market as government-guaranteed bonds are relatively rare. In this paper, we further build on and contribute to this approach by investigating whether a particular municipal bond can be used in this context. Specifically, we examine if Kommuninvest bonds can be used to isolate pricing difference due to liquidity by comparing them to government bonds. This isolation of liquidity is only possible if the bonds compared in the yield spread carry the same credit risk. The members of Kommuninvest, currently including more than 90% of the local government sector in Sweden, are jointly and severally liable for all debt obligations (Kommuninvest, 2016b). Thanks to this guarantee and the strength of the Swedish local government sector it is possible that Kommuninvest bonds are comparable to Swedish government bonds in terms of credit quality. In sum, our second research question concerns an evaluation of whether Kommuninvest bonds can be used for this purpose and is as follows:

Research question 2*: Can the yield spread between Kommuninvest bonds and Swedish government bonds be used to isolate the impact of liquidity on bond pricing?*

We explore our two research questions in conjunction by investigating whether liquidity and credit quality differences affect the yield spread between Kommuninvest bonds and Swedish government bonds. To facilitate the interpretation of our results we include the German market as a control group. In the German sample we compare government-guaranteed agency bonds issued by Kreditanstalt für Wiederaufbau (KfW) to German government bonds.

We find that bond-specific liquidity impacts pricing in the Swedish bond market and this paper thus contributes to the understanding of this phenomena in the Swedish market. Moreover, our results show that the yield spread between the Kommuninvest bond and Swedish government bond is impacted by credit quality differences between the two bonds. Thus, the yield spread does not exclusively capture liquidity differences and we thereby contribute to the field by establishing that this sort of municipal bond cannot be used for the purpose of isolating the impact of liquidity. Our findings are supported by similar results in our control group, the German market.

2 Literature review

In this section we review previous research relating to our study. First, we discuss the concept of liquidity and thereafter outline studies examining the impact of liquidity on asset prices. We focus particularly on studies examining yield spreads as these are highly relevant to our study. Last in this section we motivate our study.

2.1 Definition and measures of liquidity

In previous literature, there is no established unanimous definition of liquidity or a single measure that captures all of its aspects. Amihud et al. (2005) state that a short definition of liquidity is the ease of trading a security. Holden et al. (2014) present a slightly more elaborate definition as "*the ability to trade a significant quantity of a security at a low cost in a short time*", which highlights the fact that liquidity encompasses several dimensions: quantity, cost and time.

The three dimensions are easiest understood by examining the trading process, which is often described as an interaction between liquidity suppliers and liquidity demanders. Liquidity suppliers (market makers) offer to buy a specific security at a bid price or sell it at an ask (offer) price. A liquidity demander (price taker) on the other hand, agrees to buy the security at an ask price and sell it at the bid price. A trade occurs when these two market participants meet. Liquidity is thereby represented by the cost, quantity and time of the trade for the liquidity demander and the profit, quantity and time of the trade for the liquidity supplier.

Researchers use different measures to capture the different dimensions of liquidity. Starting with the *cost* dimension of liquidity, Holden et al. (2014) state that it is commonly measured using different bid-ask spread measures as well as by examining price impact. The bid-ask spread captures the transaction cost as it represents the price difference between the ask price and the bid price, while the price impact refers to the change in asset price following a trade in the asset.

The *quantity* aspect of liquidity is often captured by different types of depth measures. The offer depth is the quantity of the asset that a liquidity supplier is willing to sell at the ask price. Respectively, the bid depth is the quantity that the liquidity supplier is willing to buy at the bid price. The depth measures gives a better understanding of the quantities available to trade in an asset.

Lastly, the *time* dimension of liquidity is often measured by examining the execution time of orders in the market. Liquidity-demanding orders (i.e. a liquidity demander agrees to execute at a certain bid or ask price) on electronic exchanges are generally executed very quickly (within a second), whereas liquidity-supplying orders must wait for a counterparty to trade with, which can take significantly longer.

2.2 Background to the impact of liquidity on asset prices

In traditional asset pricing models such as the well-known Capital Asset Pricing Model (CAPM) and Fama-French Three-Factor Model[1], liquidity is not explicitly accounted for and hence not considered to affect asset prices (Titman and Martin, 2010). Despite this, practitioners seem to believe liquidity is an important aspect when investing (Amihud and Mendelson, 1986) and stock exchanges as well as central banks take actions in attempts to improve liquidity (Goldstein and Kavajecz, 2000; Fawley and Neely, 2013).

One of the first papers to contest the traditional view and explore whether liquidity does in fact impact asset prices is Amihud and Mendelson (1986), whose work has become a seminal study in the field of liquidity and asset pricing. The study is motivated by the fact that the role of liquidity in capital markets to a great extent has been overlooked, and the authors strive to narrow this gap by examining how liquidity affects asset prices. The underlying argument is that investors value the ability to trade assets with immediacy, in relative large quantities, and without a significant price impact. Thus, they require compensation for holding illiquid securities which do not fill these requirements (Boudoukh et al., 2016).

[1] CAPM was developed independently by several researchers simultaneously (e.g. Sharpe, 1964 and Lintner, 1965). In short, CAPM is used to price a security or a portfolio and includes variables of systematic risk, market risk and the risk free rate. Building on the CAPM, Fama and French (1993) introduced an extended model named the Fama-French Three-Factor model. It explains equity returns using three different risk premiums; the market risk premium from the CAPM model, a size risk premium and a risk premium related to the relative value of the firm compared to its book value. None of these models explicitly account for liquidity as an aspect impacting asset prices.

Amihud and Mendelson (1986) focus on stocks and the cost dimension of liquidity, which they capture with the bid-ask spread. When executing a transaction, an investor faces a trade-off between either buying or selling immediately at the ask or bid price, or waiting until a more favorable price is available. Hence, the current ask price contains a premium for buying immediately and the current bid price contains a concession for selling immediately. The bid-ask spread in turn becomes a natural measure for liquidity cost as it represents the cost for immediate execution. The lower bid-ask spread the more liquid the security is.

Amihud and Mendelson (1986) show that asset return is an increasing function of the bid-ask spread in their study of NYSE stocks during the period 1961-1980, thereby suggesting that traditional asset pricing models that do not take liquidity into account seem to neglect a significant factor. The authors underscore that their results do not point at market inefficiency, but rather reflect rational responses by investors who face trading friction and transaction costs.

2.3 Extension of research field to other markets and instruments

Following Amihud and Mendelson (1986), the impact of liquidity on asset prices has been further confirmed in the context of stocks by several researchers. Jones (2002) finds that bid-ask spreads and turnover measures can be used to predict stock returns, and Amihud (2002) relate stock returns to a liquidity measures aiming to capture the price impact aspect of liquidity.

Researchers have also attempted to extend the traditional asset pricing models, e.g. Acharya and Pedersen (2005) develop a Liquidity-adjusted CAPM to account for liquidity impact. Moreover, they show that market-wide liquidity also affects asset prices. When general liquidity conditions worsen, the ability to trade a security easily becomes especially valuable. In this context, investors are willing to pay more for liquid securities, and require a larger return premium for holding illiquid securities.

Although the majority of studies are focused on the U.S. market, the finding that liquidity affects stock returns is confirmed across several markets such as emerging markets (Bekeart et al., 2007), and the Nordic markets (Butt and Virk, 2015). The research field has also been extended to encompass corporate bonds. Using the bid-ask spread and two alternative liquidity measures, Chen et al. (2007) show that both the level and the changes in the spread between corporate bond yields and government bond yields are affected by liquidity. Friewald, Jankowitsch and Subrahmanyam (2012) show that the effect of liquidity on corporate bond yields is significantly larger during crises, a finding echoed by Acharya, Amihud and Bharath (2013) who establish that liquidity matters more in times of financial stress.

2.4 Examination of yield spreads to isolate the impact of liquidity

Papers that examine how liquidity affects stock returns and corporate bond yields primarily use different liquidity measures to approximate the extent to which a security is liquid or illiquid. As argued by Amihud et al. (2005), the use of these measures is not ideal. First of all, no single measure can capture all aspects of liquidity. Secondly, the use of measures is dependent on data availability and reliability. This is particularly often an issue in bond markets as the majority of trades occur over-the-counter (OTC) and there is consequently no centralized market place that registers all trades (Houweling, Mentink and Vorst, 2005).

In the area of bonds, researchers that examine government bonds have managed to come closer to avoid the reliance on measures and be able to fully capture liquidity. The papers described below utilize a comparison of the yields of two bonds that are equivalent in all regards except liquidity. The papers exploit the fact that any spread between these two bond yields represents the difference in pricing due to liquidity. Given that the liquidity difference is priced, the bond with the higher liquidity will have a lower yield. A lower yield implies a higher price, and the liquidity impact is thus commonly referred to as a liquidity premium.

2.4.1 Yield spread between government notes and government bills

One of the first studies to employ yield spreads in the investigation of liquidity is Amihud and Mendelson (1991), who examine whether liquidity differences in U.S. government bonds are priced. The authors compare Treasury notes and Treasury bills[2]. These bonds have the same credit quality but Treasury bills are generally more liquid than notes due to the fact that they are issued in much larger quantities and because notes often are absorbed into portfolios over time. Thus, matching a bill and a note with the same maturity enables an investigation of how liquidity impacts pricing, without the need to control for other factors. Amihud and Mendelson (1991) establish that there is a significant yield spread between the two bonds and conclude that liquidity impacts the pricing of the bonds. Their results are echoed by Kamara (1994) who also confirms that a measure for immediacy risk, which primarily relates to the time dimension of liquidity, is related to the yield spread[3].

[2] The U.S. Treasury issues three different type of bonds called; bills, notes and bonds. Bills have less than 1 year to maturity and do not pay any interest before it matures. Notes and bonds on the other hand generally pay interest in the form of coupons on a semi-annual basis. Notes are issued at maturities ranging from 2-10 year whereas bonds are investments with terms longer than 10 years (Wright, 2003).

[3] Immediacy is defined as the risk that the transaction is closed at a different price than the currently quoted price in the market.

2.4.2 *Yield spread between on-the-run and off-the-run government bonds*

The impact of liquidity on government bond prices is further confirmed by Warga (1992) who employs an alternative approach to isolating liquidity effects: the comparison between on-the-run and off-the-run government bonds. On-the-run bonds are the most recently issued bonds, all other bonds are defined as off-the-run. On-the-run bonds are typically more liquid than their off-the-run counterparts due to the fact that government bonds generally are absorbed in portfolios over time, and the circulation of a government bond thus decreases with its age. By comparing returns of the two bonds, Warga (1992) establishes that off-the-run bonds are priced to return an average premium of about 0.55 percentage points per annum over on-the-run bonds, due to liquidity differences. Krishnamurthy (2002) confirms the findings of Warga (1992), and further investigates whether this spread enables an arbitrage opportunity. However, he finds that this is not the case when taking the whole financing cost into consideration. Boudoukh et al. (2016) extend Warga's (1992) findings geographically by confirming yield spreads between on-the-run and off-the-run bonds in ten countries[4].

2.4.3 *Yield spread between government bonds and government-guaranteed bonds*

2.4.3.1 *Longstaff (2004)*

The two methods outlined above utilize two government bonds with different liquidity characteristics to isolate liquidity. Longstaff (2004) extends the approach by showing that a non-government bond can be used in the comparison for the same purpose. However, this comparison requires that the non-government bond carries the same credit risk as the government bond. If not, credit quality differences will impact the yield spread and the liquidity effect will thus not be isolated.

Longstaff (2004) examines U.S. Treasury bonds and compares these to Resolution Funding Corporation (Refcorp) bonds during the period 1991-2001. Refcorp is a U.S. government agency created in 1989, and the bonds are special in the sense that they are guaranteed by the Treasury and consequently carry the same credit risk as Treasury bonds. However, as Treasury bonds are more popular than Refcorp bonds, the liquidity of the former is higher than of the latter and any pricing differences are thereby attributed to liquidity.

Longstaff (2004) finds a significant liquidity premium in the prices of Treasury bonds, and confirms that the premium is linked to the phenomenon of "flight-to-liquidity". Flight-to-liquidity

[4] The countries include Belgium, Canada, France, Italy, Germany, Japan, Netherlands, Spain, the United Kingdom and the United States.

implies that market participants show a preference for holding highly liquid securities, similarly to the established "flight-to-quality" phenomenon which entails that assets with low credit risk are preferred. By showing that the yield spread is related to a number of measures concerning Treasury bond popularity, Longstaff (2004) finds evidence that the spread can be linked to the flight-to-liquidity phenomenon.

2.4.3.2 Ejsing, Grothe and Grothe (2015)

Ejsing, Grothe and Grothe (2015) build on Longstaff (2004) by performing a similar examination in the German and French markets. In addition, the authors develop a model that enables an examination of the impact of "safe-haven flows" on government yields. Safe-haven flows are defined as large shifts in demand for assets that have high credit-ratings and are highly liquid. Thus, it can be regarded as a description of both flight-to-liquidity and flight-to-quality.

Ejsing et al. (2015) compare government bonds to government-guaranteed agency bonds in the German and French markets respectively during the period 1999-2014 and find that there is a significant yield spread in both countries, indicating that liquidity is priced in these markets. Moreover, they document that the yield spreads increase during the financial crisis of 2008/2009 and the following sovereign debt crisis, indicating a flight-to-liquidity during this time.

The results of Ejsing et al. (2015) are reinforced by Schwarz (2016) who also shows further applications of the yield spread between German government bonds and German government-guaranteed agency bonds. In particular, she finds that the yield spread can be applied as a measure of market liquidity in the euro-area.

2.4.3.3 Black, Stock and Yadav (2016)

The yield spread between government bonds and government-guaranteed bonds is further examined by Black, Stock and Yadav (2016), who show that the spread to a large extent can be accounted for by liquidity measures that address the three dimensions of liquidity. The study uses bank bonds issued under the protection of the U.S. Government Debt Guarantee Program of 2008, which means these bank bonds were issued with the full backing of the credit of the U.S. government. Hence, any yield difference compared to Treasury bonds can be accredited to difference in liquidity between the instruments. Black et al. (2016) confirm that there is a yield spread between the Treasury bonds and these bank bonds. Moreover, they show that three liquidity measures, specifically the bid-ask spread, depth and resiliency[5], account for virtually the whole yield

[5] Black et al. (2016) use a definition of resiliency adapted for OTC-markets that captures the resiliency of liquidity by measuring the time required for liquidity distortions to get neutralized.

spread. The bid-ask spread and resiliency aspects of liquidity are found to be relatively more important than the depth dimensions as determinants of the yield spread. Furthermore, they conclude that both bond-specific and market-wide liquidity measures are associated with the yield spread.

2.5 Motivation of study

In the studies outlined above, liquidity is confirmed to impact asset prices across several markets and instruments. However, to our knowledge, the research on the Swedish bond market seems to be limited. In this study, we fill this gap by examining whether bond-specific liquidity affects bond pricing in the Swedish market.

An evident trend in recent papers is the use of yield spreads, which allows an examination of the liquidity impact on prices without using liquidity measures. This field is in turn extended to incorporate non-government bonds in terms of government-guaranteed bonds, a research design that allows for deeper investigations of liquidity as the size of the liquidity premium associated with government bonds is identified (Longstaff, 2004). However, the studies that use government-guaranteed bonds in combination with government bonds are limited to the U.S., German and French markets as government-guaranteed bonds are relatively rare. In this study, we extend this field by investigating whether another type of bond, namely bonds guaranteed by the local government sector, can be used for the purpose of isolating liquidity impact.

3 Research design and development of hypotheses

3.1 Research design

The purpose of our study is twofold; first we explore whether liquidity impacts bond prices in the Swedish market and second we investigate if the approach introduced by Longstaff (2004) can be extended to incorporate municipal bonds guaranteed by the local government sector. We select our research design with the objective to investigate these questions in conjunction.

Our approach entails comparing the yields of Swedish government bonds to the yields of municipal bonds issued by Kommuninvest, which are generally less liquid than government bonds. Kommuninvest is a Swedish local government funding agency that aims to help Swedish municipalities to raise capital by issuing bonds. The members of the agency are jointly and severally liable for all debt obligations. Currently, the member base covers 90% of the local government sector in Sweden (Kommuninvest, 2016b)[6].

First, we investigate whether liquidity impacts bond prices by testing whether the yield spread between the two bonds is associated with the bid-ask spread, a measure which captures the cost dimension of liquidity. There is a wide range of liquidity measures aiming to capture bond-specific liquidity used by previous studies, but the bid-ask spread is arguably the most utilized measure for liquidity cost (Chen et al., 2007). Moreover, Black et al. (2016) who perform a similar study to ours in the U.S. market finds that the bid-ask spread is strongly associated with the spread between government bonds and government-guaranteed bonds, which further supports this choice[7].

Secondly, we test whether the yield spread between Kommuninvest bonds and government bonds can be used to isolate liquidity effects. The central issue in this context is whether the two bonds have the same credit quality, as any credit quality differences would impact the yield spread and thereby obstruct the isolation of liquidity impact. Previous studies achieve this by comparing government-guaranteed bonds to government bonds, which arguably should have the same credit quality.

Although Kommuninvest bonds are not explicitly guaranteed by the government, they can be argued to be comparable to government bonds in terms of credit risk. Kommuninvest comment on their credit risk by concluding *"Debt issued to Swedish municipalities and county councils have very low risk and according to applicable capital cover ratios, exposure towards the municipalities should be considered equal to having exposure to the government and have risk weight of 0 percent"* (Höök, Simonsson and Lennartsson, 2006)[8].

The arguments of Kommuninvest includes the joint and several guarantee of all members, which is a solid guarantee as it is a legal impossibility for Swedish municipalities to go into bankruptcy and it has never previously occurred. Additionally, the municipalities are entitled to levy taxes in order to raise additional funds if needed (Kommunekredit, Kommuninvest and Munifin, 2012).

[6] Kommuninvest bonds differ to regular municipal bonds in the sense that Kommuninvest bonds are jointly and severally guaranteed by all Kommuninvest's members, thus diversifying the risk exposure for the investors. Regular municipal bonds on the other hand only imply risk exposure towards the issuing municipality, and are likely to have poorer liquidity in the bonds (Kommunekredit, Kommuninvest and Munifin, 2012).

[7] This decision is also based on the fact that majority of bond trading in both the Swedish and the German market occurs over-the-counter (ASCB, 2016; Ejsing and Sihvonen, 2009) which makes it difficult for us to attain reliable data for other liquidity measures.

[8] The quote is translated from Swedish to English by the authors of this paper. Original quote: "Lån till svenska kommuner och landsting har en mycket låg riskprofil och enligt gällande kapitaltäckningsregler skall en exponering mot den kommunala sektorn likställas med en statsexponering och ha 0 procent i riskvikt".

Furthermore, the credit institutes Moody's and Standard & Poor's reinforce the view of comparability between Kommuninvest bonds and Swedish government bonds in terms of credit quality. They highlight that Kommuninvest's mandate for issuing debt is very limited and concentrated to municipalities and public sector, and that the credit risk is ultimately backed by the public sector's ability to raise taxes. Moreover, Kommuninvest's liquidity position is strong and supported by the ability to enter into repurchase agreements with the Swedish Riksbank. (Skogberg, Sperlein and Harris, 2014; Hellsing and Nyrerod, 2016)

In conclusion, the argument that Kommuninvest bonds are comparable to government bonds relies on the strength of the local government sector in Sweden in combination with the joint and several guarantee. To our knowledge, no previous study has tested whether this type of municipal bond can be used to isolate the impact of liquidity on pricing. In order to enable an evaluation of our results, we include a parallel examination of the German market, using the yield spread between government-guaranteed agency bonds and government bonds. Similarly to Ejsing et al. (2015) and Schwarz (2016), we compare the German government bonds to KfW (Kreditanstalt für Wiederaufbau) bonds. KfW is a German development bank primarily supporting public policies such as lending to small and medium sized companies, infrastructure, housing and environment projects. Bonds issued by the KfW agency are guaranteed by the German government by law (Leubner, 2012). From here on, when referring to both Kommuninvest and KfW bonds we use the term *agency bonds*.

3.2 Development of hypotheses

As we aim to capture the impact of liquidity on bond prices by examining a yield spread, our first hypothesis relates to whether pricing differences between Kommuninvest bonds and Swedish government bonds exist. Following the findings by Longstaff (2004), Schwarz (2016), Ejsing et al. (2015) and Black et al. (2016), we expect that there is a yield spread between the bonds we study. In particular, we expect that the Kommuninvest bond, which is generally less liquid, will have a higher yield than the government bond. The same hypothesis is tested for our control group, the German market, using KfW bonds and German government bonds. Hence, our first hypothesis is as follows:

H1: *The yield of the agency bond exceeds the yield of a comparable government bond*

Following the establishment of the impact of liquidity on asset prices across several markets in previous literature, we expect that the pricing in the Swedish bond market is affected by liquidity as well. We focus on bond-specific liquidity and use the bid-ask spread to capture the cost dimension of liquidity, a widely accepted approach in previous literature. We test the same hypothesis for the German market to evaluate our results. Our second hypothesis is as follows:

H2: *Bond-specific liquidity impacts the yield spread between the agency bonds and government bonds*

The appropriateness of using the Kommuninvest bond to isolate liquidity impact relies on the assumption that no credit quality differences are priced in the yield spread. As the Kommuninvest bond is not explicitly government-guaranteed, it may carry a different credit risk than government bonds. To evaluate whether the Kommuninvest bond can be used to isolate liquidity impact, we test whether the yield spread is affected by potential differences in credit quality. Following the argumentation above, we expect no differences in credit quality. Similarly, the KfW bonds we study in the German market are expected to have the same credit quality as German government bonds as they are explicitly government-guaranteed. Hence, we expect that both of the agency bonds we study have equal credit quality to government bonds and our third hypothesis is as follows:

H3: *There are no differences in credit quality priced in the yield spread between the agency bonds and the government bonds*

4 Data

This chapter describes the data selection process we use to attain a homogenous and comparable sample of Swedish and German bonds from our raw data set. First, the bond selection process is reviewed and thereafter the selection of sample days.

4.1 Selection of bonds

The objective of our sample selection process is to achieve a comparable sample in two regards; the first regard being similarity of bonds included in the individual market samples, and the second one being comparability between the two market samples. The selection process and remaining bonds after each step for all of the four bond types we review (agency bonds and government bonds in both markets) are summarized in Table 1.

We first limit our review of all registered bonds to Swedish bonds that are issued in SEK and German bonds that are issued in EUR[9]. This decision is based on the fact that bonds issued in other currencies involve currency risks. Second, we are only interested in normal fixed coupon bonds and zero-coupon bonds and thus exclude floating rate bonds, index linked bonds, and graduated rate bonds[10], in order to only keep bonds with similar characteristics. We also exclude STRIPS (Separate Trading of Registered Interest and Principal of Securities) which occur in our

[9] We perform our review of bonds in Datastream because our access to Bloomberg unfortunately is very limited.
[10] Graduated rate bonds have a coupon rate that changes once or more during the life of the bond (Terry, 2000).

sample of German bonds[11]. STRIPS often differ in liquidity compared to regular bonds (Sack, 2000), and are therefore excluded based on our objective to achieve comparability between the two market samples. In the second step we also limit the sample to only include bonds that have been active during our sample period Jan 2012 to Jun 2016[12]. We select this sample period as it should both be representative for current conditions, which we are interested in, and large enough to attain reliable results.

In the third and last step we exclude bonds that do not have accessible data in Bloomberg. The data we obtain from Bloomberg includes closing bid and ask price, issue date, maturity date, day-count convention, coupon frequency and coupon rate for each bond in our sample. The respective active periods of selected agency bonds are illustrated in Figure 1, each series represents one bond and depicts its remaining time to maturity. We find that the maximum time to maturity at issue for Kommuninvest bonds is 7 years. Hence, to make the Swedish and German samples comparable, we also exclude any KfW bonds with a time to maturity exceeding 10 years in this third step.

In total, our final sample covers 10 Kommuninvest bonds and 29 KfW bonds. The final number of government bonds totals 59 for Sweden and 123 for Germany.

Table 1
Data sample selection - Number of bonds

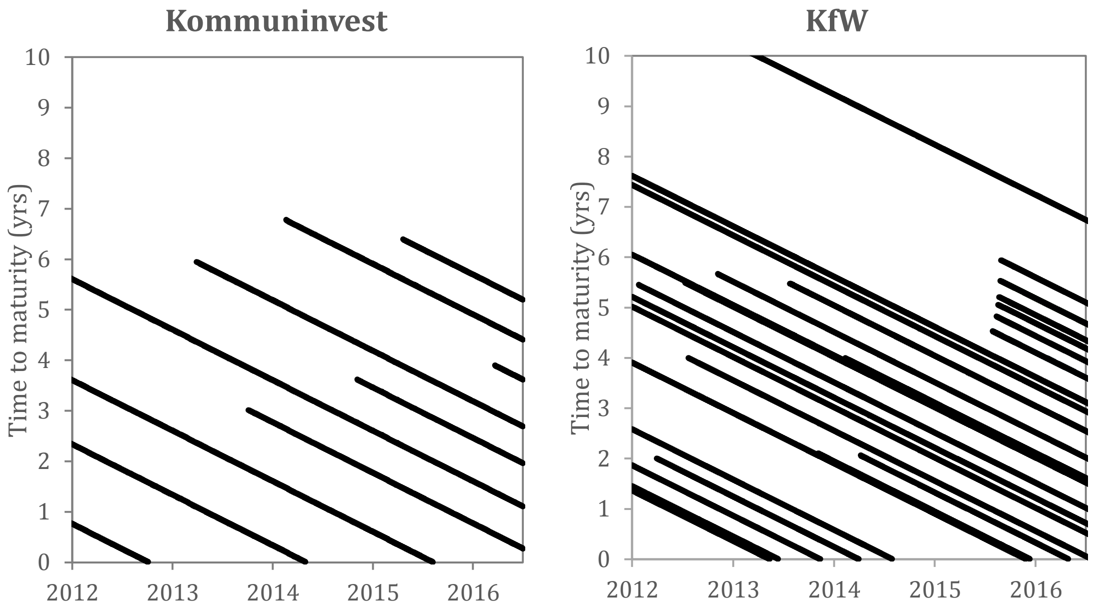
Criteria	Agency	Government	Total
Swedish market			
1. Number of registered bonds issued in SEK	41	343	384
2. Fixed or zero-coupon bonds active during sample period	10	77	87
3. Bonds with accessible data	10	59	69
German market			
1. Number of registered bonds issued in EUR	374	1649	2023
2. Fixed or zero-coupon bonds active during sample period	58	124	182
3. Bonds with accessible data, agency bonds with TTM <10 years	29	123	152

This table summarizes the data selection process applied to achieve comparable and homogenous samples of Swedish and German agency bonds and government bonds. Agency bonds are Kommuninvest and KfW bonds in Sweden and Germany respectively. The starting point is the number of registered bonds issued in SEK and EUR respectively. Each criteria for selection is stated in the criteria column and the number of bonds remaining when each criteria is applied is visible on the right hand side. The sample period is Jan 2012 - Jun 2016. In step 3 in the German sample we also exclude German agency bonds that have a time to maturity (TTM) exceeding 10 years during the sample period. This decision is based on achieving comparability with the Swedish sample.

[11] STRIPS are created when the principal and all coupons of a bond are separated into individual securities. In this sense, both principal STRIPS and coupon STRIPS are zero coupon bonds that pay their respective principal or coupon at maturity (Sack, 2000).

[12] We initially used Jan 2010 – Jun 2016 as our sample period. However, few Kommuninvest bonds were outstanding during the first two years of this period and we therefore changed the starting date of the sample period to Jan 2012.

Figure 1
Time to maturity of agency bonds in sample



This figure displays the remaining time to maturity in years for agency bonds (Kommuninvest and KfW bonds) that are included in the sample. The sample period is Jan 2012-Jun 2016. Each series represents one bond and depicts its remaining time to maturity during the sample period.

4.2 Selection of sample days

We are interested in weekly data and therefore select weekly closing days in our set of daily Bloomberg data. This frequency is selected to maintain a manageable data set that still captures short-time fluctuations in the data. If there is no bond price available on the Friday of a certain week, the Thursday price is used. If there is no price available for the Thursday, we use the Wednesday price and so on until Tuesday. A week is classified as missing if less than two daily prices in the week are available. Moreover, we exclude any price observations that are regarded as faulty data points. Specifically, in our data set we find observations of bond prices around 1 (normalized to a face value of 100) as well as observations that occur before/after the issue/maturity date. These observations are excluded as they are considered to be errors inflicting on the quality of the data. After this selection process, our sample size consists of 236 weekly closing days in both markets.

5 Method

In this section, we describe the method we apply to answer the research questions of our study. We first outline how we calculate the spread between agency bonds and government bonds. Thereafter we describe how we estimate zero-coupon yield curves needed to calculate the yield spread. Lastly, we present the statistical tests used to investigate our hypotheses.

5.1 Construction of agency-government spread

5.1.1 Calculation of agency-government spread with modelled yield

Our research design builds on the idea of comparing the yields of agency bonds and government bonds. This comparison requires that the agency bonds and government bonds we compare have the same characteristics. The bonds in our sample are however not exactly matched in terms of cash flows and time to maturity. To circumvent this issue we apply a method inspired by Black et al. (2016) that enables us to model the yield to maturity of a government bond as if it would have the same cash flows and time to maturity as a particular agency bond in our sample. Hence, the yield spread we construct and examine is based on an observed agency bond and an exactly matched modelled government bond. We refer to this spread as the agency-government spread (AGS). The AGS is calculated for each agency bond i on each weekly closing day t and is defined as follows:

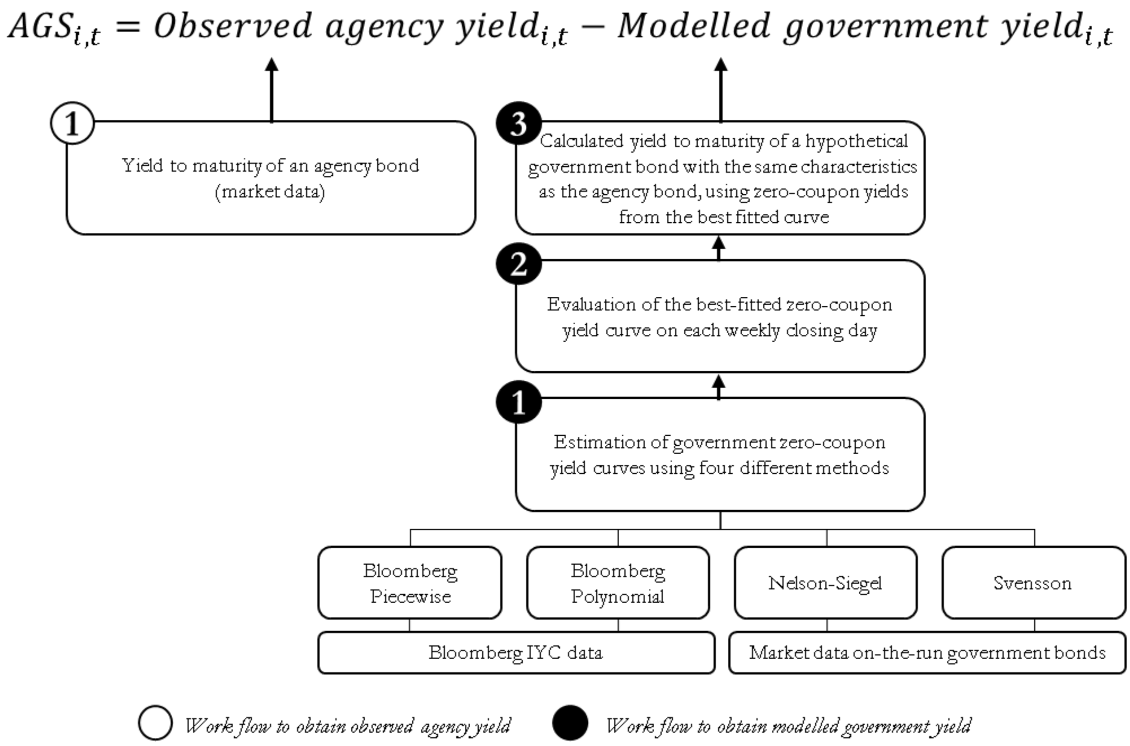
$$AGS_{i,t} = Observed\ agency\ yield_{i,t} - Modelled\ government\ yield_{i,t} \tag{1}$$

Where the $Observed\ agency\ yield_{i,t}$ is the yield to maturity of the agency bond and the $Modelled\ government\ yield_{i,t}$ is the yield to maturity of a hypothetical government bond with the same cash flows and time to maturity as the agency bond.

The observed agency yield is easily obtained as it is based on readily available market data. In contrast, the procedure applied to obtain the modelled government yield involves several steps. Hence, the process of reaching our AGS is rather cumbersome. Figure 2 gives an overall view of the entire process and can be used as guidance for the continued reading of this chapter[13].

[13] Note that in this chapter we describe the different steps of the process in an order suitable for comprehending the process, however the workflow corresponds to the numbers in Figure 2 and is thus not the same.

Figure 2
Illustration of process to obtain agency-government spread



This figure shows the process we apply to obtain the agency-government spread. The left-hand side shows how we obtain the observed agency yield from the market and the right-hand side shows how we calculate the modelled government yield, which is based on a hypothetical government bond with the same cash flows as the agency bond.

5.1.2 Calculation of modelled government yield with government zero-coupon yields

To obtain the modelled government yield in equation (1), we construct a hypothetical government bond that has the same cash flows as an agency bond. The modelled government yield is thereby the yield to maturity that corresponds to the price of this modelled government bond.

We obtain the price of the modelled government bond by discounting the cash flows of the agency bond with estimated government zero-coupon yields. As described by Skinner (2005), a coupon bond can be viewed as a portfolio of zero-coupon bonds generating the same cash flows. Assuming no arbitrage opportunity, the price of a coupon-bearing bond should not differ from the price of a portfolio of zero-coupon bonds with equivalent payments. This implies that we can calculate the price of a coupon bond by discounting each cash flow with the corresponding zero-coupon yield. The τ-year zero-coupon yield is the yield corresponding to a zero-coupon bond with τ years to maturity (Hull, 2011, p.83-84).

Using continuously compounded returns, the bond price P_t at time t is calculated with τ-year zero-coupon yields $y_t(\tau)$ as follows:

$$P_t = \sum_{\tau=1}^{T} \frac{C}{e^{\tau y_t(\tau)}} + \frac{N}{e^{T y_t(T)}} \quad (2)$$

Where C is the annual coupon payment and N is the principal payment at the maturity date T. By using the cash flows (coupons and principal) of a particular agency bond and government zero-coupon yields in equation (2), we can model the price of a hypothetical government bond that is exactly matched to an agency bond in terms of cash flows and time to maturity. Thereafter, we solve for the yield to maturity Y_t, i.e. the internal rate of return, with the following formula:

$$P_t = \sum_{\tau=1}^{T} \frac{C}{e^{\tau Y_t}} + \frac{N}{e^{T Y_t}} \quad (3)$$

Hence, by using the price P_t of a modelled government bond in equation (3), we can solve for the yield to maturity Y_t which represents our modelled government yield[14]. The observed agency yield in equation (1) is also calculated with equation (3), using the market bid price of the agency bond to obtain a yield to maturity[15].

[14] The modelled yield can also be interpreted as the yield to maturity of an agency bond that has been priced as a government bond.

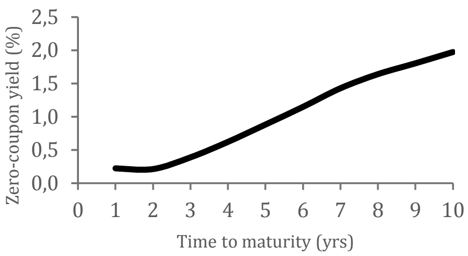
[15] As pointed out by Skinner (2005), the market price P_t is the full (or dirty) price of the bond, as a purchaser of the bond would have to pay for the accrued interest since the last coupon payment. Hence, we use the dirty price of the agency bond to calculate the yield to maturity of the agency bond. The dirty price is equal to the clean price and the accrued interest: *Accrued Interest = Coupon * (Days from last coupon payment/Days in coupon period)*. The number of days are based on the applied day-count convention.

5.2 Estimation of government zero-coupon yield curves

In order to solve for the modelled government yield in equation (3) we require government zero-coupon yields to calculate the price in equation (2). However, government bonds are typically coupon-bearing bonds, with the exception of bills that are short-term zero-coupon bonds. Hence, we cannot directly observe zero-coupon yields for longer maturities.

To extract zero-coupon yields we estimate zero-coupon yield curves. Interest rates typically differ according to the term of the instrument, and the zero-coupon yield curve displays this relationship by relating the yield to the time to maturity. An example of a zero-coupon yield curve is illustrated in Figure 3. According to Stander (2005), yield curves can take four main shapes; upward sloping, flat, downward sloping and humped. Stander (2005) highlights that the standard view is that a yield curve is upward sloping as a consequence of investors demanding a higher yield for longer term investments. However, as a result of market dynamics the curve can take other shapes.

Figure 3
Example of zero-coupon yield curve



This figure displays an example of a zero-coupon yield curve. The example is the German government zero-coupon yield curve 2012-01-02, using IYC curve data from Bloomberg.

Although the use of yield curves is wide-spread in the context of pricing and valuation, there is no common perception of the best approach to estimate the curve. While simple yield curve models can have a limited ability to allow for different shapes of the yield curve, Stander (2005) points out that more complex models often heavily rely on parameters that can be problematic to estimate. As our sample covers four and a half years in total, the shape of the yield curve can have varied significantly during the period. Consequently, we consider two different approaches to yield curve modelling in this paper: models combining *bootstrapping with interpolation* as well as *empirical yield curve models*. The former is regarded as a simpler approach to yield curve modelling and the latter is relatively more complex. In essence, bootstrapping and interpolation implies estimating a yield curve that best fits through a number of observed yields. The bootstrap method is applied to obtain zero-coupon bond yields from observed coupon bond yields, and the interpolation creates a curve from the individual yields. Empirical yield curve models on the other hand, define a functional form for the yield curve. An optimization routine is subsequently employed to estimate the parameters of the function in a manner that minimizes the differences between actual and fitted instrument prices (Stander, 2005).

We apply two variants of each of these two approaches. The outcomes of the four methods we apply are then evaluated to reach a conclusion regarding which model fits best on a particular weekly closing day in our sample. Although rather cumbersome, we argue that the reliability of our study heavily relies on the accuracy of the estimated yield curves. The core studies we draw inspiration from rely on simpler approaches: Longstaff (2004) uses yield curves directly attained from the Bloomberg database and Black et al. (2016) use zero-coupon yields provided by the U.S. Treasury (combined with linear interpolation to attain a continuous curve). Moreover, both Ejsing et al. (2015) and Schwarz (2016) exclusively rely on one yield curve estimation method. By calculating and evaluating four different methods and selecting the model with the highest accuracy, we apply a more thorough approach than previous studies, which we believe benefits the reliability of our study.

5.2.1 Bootstrapping and interpolation

We use two variants of the bootstrapping and interpolation approach, both based on zero-coupon yield curves provided by Bloomberg. The Bloomberg curves used for both Swedish and German government bonds are their respective International Yield Curves (IYC).

To estimate the IYC, Bloomberg uses the bootstrap method to obtain zero-coupon yields. Bootstrapping implies that zero-coupon government bonds and coupon-bearing bonds are used to solve for zero-coupon yields (Hull, 2011, p. 86-88). To illustrate, consider two bonds that mature in one and two years respectively. In the case of annual coupon payments, the one year zero-coupon yield is equal to the yield to maturity of the bond maturing in one year, as only one cash flow remains. This one year zero-coupon yield can be used to discount the first cash flow of the two-year bond, and by solving for the corresponding discount rate of the second cash flow we obtain the two-year zero-coupon yield.

The outcome of a bootstrapping procedure is a set of zero-coupon yields for a certain number of maturity points. Bloomberg provides continuously compounded zero-coupon yields for 15 maturity points ranging between three months and 30 years. However, to obtain a continuous curve an interpolation technique must be applied. Also in this case there is no common view on which technique is best suited for the task (Stander, 2005). Hence, we consider two different interpolation techniques, piecewise-linear (as implemented by Bloomberg) and polynomial, to construct two variants of the Bloomberg IYC.

5.2.1.1 Piecewise-linear interpolation

The piecewise-linear interpolation entails that a separate linear interpolation is made between every point on the curve. This implies that the specific zero-coupon yields obtained in the bootstrapping procedure will perfectly fit the curve, but the yields at maturities for which we do not have bootstrapped data will be linearly interpolated. As pointed out by Stander (2005), there is often a trade-off between smoothness and perfect fit in the estimation of yield curves. This technique generates a perfect fit for the bootstrapped yields, but a shortcoming is that noisy data (outliers) will not be smoothed out.

5.2.1.2 Polynomial interpolation

The polynomial interpolation technique involves estimating a polynomial function that provides the best fit for the bootstrapped zero-coupon yields. We use a five-parameter polynomial model where the function for the τ-year zero-coupon yield $y_t(\tau)$ at time t has the following form:

$$y_t(\tau) = \beta_{0,t} + \beta_{1,t}\tau^1 + \beta_{2,t}\tau^2 + \beta_{3,t}\tau^3 + \beta_{4,t}\tau^4 + \beta_{5,t}\tau^5 \tag{4}$$

The parameters are estimated by minimizing the squared differences between the bootstrapped zero-coupon yields and the estimated zero-coupon yields using equation (4). We perform the polynomial yield curve estimation in MATLAB using the function polyfit. In contrast to the piecewise-linear interpolation, the estimated yields using equation (4) may differ from the bootstrapped yields. However, any potential noise will be smoothed out to a greater extent with the polynomial interpolation. As we include both variants in our estimation procedure, we thereby handle the tension between smoothness and fit.

From here on, we refer to the models outlined above as the *Bloomberg Piecewise* and *Bloomberg Polynomial* models respectively. Stander (2005) highlights that a drawback of these types of models is that they can be over-simplistic and thereby not produce accurate data. This issue is however addressed by the empirical yield curve models that we turn to next.

5.2.2 Empirical yield curve models

We focus on one type of empirical yield curve model, namely the Nelson-Siegel model. We apply two variants of it, the original *Nelson-Siegel* model and the extension by *Svensson*. Both models are extensively used in practice, for example by several European central banks (Bank for International Settlements, 2005).

5.2.2.1 The Nelson-Siegel model

The Nelson-Siegel model was introduced by Nelson and Siegel in 1987. The purpose of the paper is to develop a parsimonious model of yield curves that is flexible enough to take on a range of different shapes; monotonic, humped and S-shaped. The zero-coupon yield curve has the following functional form in the Nelson-Siegel model:

$$y_t(\tau) = \beta_{0,t} + \beta_{1,t}\left(\frac{1 - e^{-\lambda_t\tau}}{\lambda_t\tau}\right) + \beta_{2,t}\left(\frac{1 - e^{-\lambda_t\tau}}{\lambda_t\tau} - e^{-\lambda_t\tau}\right) \quad (5)$$

Where $y_t(\tau)$ is the τ–year continuously compounded zero-coupon yield at time t. β_0, β_1, β_2 and λ are estimated parameters. The interpretations of these parameters provided by Nelson and Siegel (1987) are firstly that β_0 represents a long-term yield level component as it does not decay to zero. In turn, the impact of the β_1 decreases with the time to maturity and hence represents a short term yield level component. β_2 manages the medium-term yield, as the impact starts out at zero and later decays to zero, reaching its maximum impact during the medium term. Lastly, λ represents the rate of decay for the β_1 and β_2 parameters. An alternative interpretation of the β-parameters provided by Diebold and Li (2006) is that they represent the level, slope and curvature of the yield curve.

5.2.2.2 The Svensson model

Another version of the Nelson-Siegel model is the extension introduced by Svensson (1994). He extends the Nelson-Siegel model with two parameters which enables an extra hump on the yield curve, hence making it more flexible. The functional form for the zero-coupon yield curve with the Svensson model is as follows:

$$y_t(\tau) = \beta_{0,t} + \beta_{1,t}\left(\frac{1 - e^{-\lambda_{1,t}\tau}}{\lambda_{1,t}\tau}\right) + \beta_{2,t}\left(\frac{1 - e^{-\lambda_{1,t}\tau}}{\lambda_{1,t}\tau} - e^{-\lambda_{1,t}\tau}\right) + \beta_{3,t}\left(\frac{1 - e^{-\lambda_{2,t}\tau}}{\lambda_{2,t}\tau} - e^{-\lambda_{2,t}\tau}\right) \quad (6)$$

The function is similar to the Nelson-Siegel function displayed in equation (5) with the exception of the additional parameters β_3 and λ_2, which represent the extra hump.

Both the Nelson-Siegel and the Svensson model imply an estimation of parameters which can be problematic as adequate estimates can be difficult to achieve (Stander, 2005). This is especially the case for the Svensson model which includes two additional parameters as compared to the Nelson-Siegel model. Hence, a trade-off between improved fit and reliable estimates is apparent. However, by including both models in our estimation procedure, we handle this tension by selecting the model that fits best on each weekly closing day in our sample.

5.2.2.3 Estimation of the Nelson-Siegel and Svensson models

For each weekly closing day t in our sample, we estimate the parameters of the Nelson-Siegel and Svensson models respectively. We perform our estimations in MATLAB using the fitNelsonSiegel and fitSvensson functions. MATLAB estimates the parameters of the models using data on price, maturity date and coupon rate for each of the selected bonds. A non-linear least squares estimation procedure that aims to minimize the squared differences between observed market prices and estimated model prices is applied. The method used in the optimization process is a trust-region method (MathWorks, 2016). The Nelson-Siegel and Svensson functions in MATLAB allow us to set day-count conventions, coupon frequency and output compounding type as arguments. The day-count conventions for coupon-bearing Swedish and German government bonds are 30/360 and Actual/Actual respectively (for zero-coupon bonds the conventions are Act/360 for both countries)[16]. All coupon-bearing bonds in our sample pay annual coupons. As we use continuous compounding this is selected as our output compounding type.

5.2.2.4 Selection of bonds for yield curve estimation

In order to estimate the yield curve reliably, the bonds used in the estimation must be carefully selected. Stander (2005) points out that the most liquid instruments should be chosen for the estimation as these arguably should have the most representative prices. To fulfil this requirement we only include the government bonds that are on-the-run (most recently issued) on a particular weekly closing day, as on-the-run bonds typically are more liquid than their off-the-run counterparts (Warga, 1992). Nevertheless, as including too few bonds potentially reduces the reliability of the yield curve estimation, we ensure that at least six bonds are included in each estimation. This limit is in line with Stander's (2005) proposition that the number of bonds should at least be equal to the number of parameters estimated. However, for some weeks we do not have observable prices for six on-the-run government bonds. We address this issue by including the bonds that are closest to being on-the-run until the minimum of six bonds is reached.

Additionally, we exclude government bonds that have less than three months or more than 15 years to maturity. By excluding bonds with a short time to maturity, we avoid the impact of potential yield volatility as the bond approaches the maturity date. Similarly, we also apply this lower range exclusion in the case of the agency bonds used to estimate the agency-government spread. Furthermore, as none of the agency bonds in our sample has a time to maturity exceeding 10 years, there is no need to estimate the government zero-coupon yield curves far beyond this point. Moreover, we avoid potential impact of clientele effects, i.e. that investors seek out assets in a certain category (e.g. demand effects driven by pension fund regulation), by excluding very long-term bonds as pointed out by Ejsing et al. (2015).

[16] Day-count conventions determine how the number of days between two dates are calculated. The first number refers to the assumption regarding the number of days in in a month and the second number refers to the number of days assumed for the year. "Actual" means the exact number of days for the period is used (Stander 2005).

5.2.3 *Evaluation of zero-coupon yield curves*

We estimate yield curves for each closing weekday and country in our sample with the four methods outlined above. For each week in our sample we carry out an evaluation procedure that performs two functions, firstly it serves as a basis for selection of the curve with the best fit for a particular week and secondly, it validates the accuracy of the estimated yield curve. The curves are evaluated by comparing the market price and estimated price of each government bond included in the yield curve model. The estimated price is the price obtained when discounting the cash flows with the estimated zero-coupon yields[17]. An average model residual is calculated for each yield curve model j and government bond i on each week t as follows:

$$Average\ model\ residual_{t,j} = \frac{1}{n} * \sum_{i=1}^{n} \left(P_{i,t} - \hat{P}_{i,t,j}\right)^2 \qquad (7)$$

Where n is the number of government bonds included in the estimation, $P_{i,t}$ is the observed market price of an individual government bond and $\hat{P}_{i,t,j}$ is the estimated price of the individual government bond. For each week and country we select a best-fitted model based on the yield curve model that generates the smallest average model residual. Furthermore, we validate the accuracy of the yield curve estimation by evaluating the smallest average model residual attained for each week. If the smallest average model residual is larger than three standard deviations from the mean of the sample, the week is excluded as the estimation of the yield curve is regarded as unreliable.

5.3 Statistical analysis

We proceed by conducting statistical tests to investigate our stipulated hypotheses. Firstly, we conduct a t-test in order to establish whether there is a significant yield difference between agency and government bonds. Secondly, we conduct a regression analysis with the agency-government spread as the dependent variable to investigate which variables impact the AGS.

5.3.1 *T-test*

Our first test entails investigating whether there is a yield spread between the agency bond and the government bond. In line with **H1**, we expect that the agency bond has a higher yield than the government bond as it is less liquid. We perform a paired sample t-test of the observed agency yield and the modelled government yield to test this hypothesis. The paired sample t-test reveals

[17] That is, we use equation (2) to calculate an estimated price of the government bond. However, in this case the cash flows are the actual cash flows of the government bond (as we aim to evaluate how accurate the estimated yield curve is) not the cash flows of the agency bond as in chapter 5.1.2.

if the means of the two respective yields are different, and we specifically expect a positive difference between the observed agency yield and the modelled government yield.

5.3.2 Regression analysis

We use a linear OLS regression model to examine how different variables impact the agency-government yield spread (AGS). The regression model is specified in equation (8). The independent variables firstly include the relative bid-ask spread of an agency bond to capture the impact of bond-specific liquidity. Second, we use a corporate yield spread to test the impact of credit risk. We also include a market bid-ask spread to control for the impact of market-wide liquidity and a variable to control for the impact of quantitative easing programs. Lastly, we include the lagged agency-government spread to eliminate the impact of potential serial correlation. The regression is specified accordingly:

$$AGS_{i,t} = \alpha_{i,t} + \beta_1 AgencyBidAsk_{i,t} + \beta_2 CorpYieldSpread_{i,t} + \beta_3 MarketBidAsk_{i,t} + \beta_4 QE_{i,t} + \beta_5 LaggedSpread_{i,t} + \varepsilon_i \quad (8)$$

The variables are discussed in more detail below.

5.3.2.1 Bond-specific liquidity

In line with **H2,** we expect bond-specific liquidity to impact the agency-government spread. We use the bid-ask spread as a measure for liquidity, which addresses the cost dimension of liquidity by capturing the cost for immediate execution. The lower bid-ask spread the more liquid the security is (Amihud and Mendelson, 1986).

Black et al. (2016) examine the yield spread between government-guaranteed and government bonds in the U.S. market, and find that a larger relative bid-ask spread of the government-guaranteed bond is associated with a larger yield spread. Inspired by this approach, we use the bid-ask spread of the agency bond relative to the bid price in our regression. The measure is calculated as follows:

$$AgencyBidAsk_{i,t} = \frac{Ask\ Price_{i,t} - Bid\ Price_{i,t}}{Bid\ Price_{i,t}} \quad (9)$$

Where i denotes the specific bond and t the weekly closing day. As a larger relative bid-ask spread is associated with lower liquidity, we expect the agency bid-ask spread to be positively related to the AGS.

5.3.2.2 Credit risk

As we hypothesize that the agency bonds we study carry the same credit risk as government bonds (**H3**), we test whether the agency-government spread is impacted by differences in credit quality. This test is mainly relevant for the Kommuninvest bonds as these are not government-guaranteed and we aim to evaluate whether they can be used to isolate liquidity. However, the variable is also relevant in the case of KfW bonds as the market may perceive that there is a higher credit risk associated with the agency bonds. Similarly, both Longstaff (2004) and Black et al. (2016) include a variable controlling for credit risk in order to capture potential market perceptions of credit risk. Inspired by Longstaff (2004), the measure we use in the regression is the corporate yield spread between AAA-rated and AA-rated corporate bonds. Corporate yield spreads mainly capture credit risk (Longstaff, Mithal and Neis, 2005), implying that the AGS is positively associated with corporate yield spread, it indicates that the AGS is indeed influenced by credit risk.

For Sweden, the S&P Sweden AAA and AA Investment Grade Corporate Bond indices are used, which provide historical yield to maturity values for our entire sample period. For Germany, there is no country-specific corporate yield index and the S&P Eurozone AAA and AA Investment Grade Corporate Bond indices are used instead[18]. Considering that there is free movement of capital and the same currency within the Eurozone (European Commission, 2016), it could be considered as one single market and the Eurozone indices are thus applicable to gauge the credit risk in the German market. The corporate yield spread is calculated accordingly:

$$CorpYieldSpread_t = Y_t^{AA} - Y_t^{AAA} \tag{10}$$

Where Y_t is the yield to maturity of the index, t denotes the weekly closing day, AAA is the highest rated corporate bonds and AA the second highest rated. Since we hypothesize that the bonds carry the same credit risk, we expect that the CorpYieldSpread will not affect the AGS.

5.3.2.3 Market-wide liquidity

As Black et al. (2016) find that market-wide liquidity affects the yield spread between government and government-guaranteed bonds, we include a control for this aspect in our regression. Black et al. (2016) show that when market liquidity deteriorates, the yield spread increases as more illiquid bonds are affected to a greater extent. As described by Acharya and Pedersen (2005), illiquid securities are sensitive to market liquidity deterioration as the compensation required by investors

[18] The Eurozone indices are value-weighted and based on corporate bonds from the 19 Eurozone countries (Standard & Poor's Global, 2016).

for holding illiquid securities increases. The market-wide liquidity is defined as the average relative bid-ask spread for on-the-run governments bonds:

$$MarketBidAsk_t = \frac{1}{n} * \sum_{i=1}^{n} \frac{Ask\ Price_{i,t} - Bid\ Price_{i,t}}{Bid\ Price_{i,t}} \tag{11}$$

Where i is a specific on-the-run government bond, t is the weekly closing day and n is the number of on-the-run bonds for the particular t. As a larger bid-ask spread is associated with worse liquidity, we expect the market-wide liquidity measure to impact the AGS positively. Black et al. (2016) argue that constructing a market liquidity measure based on on-the-run government bonds is appropriate as the market for government-guaranteed bonds is more comparable to the government bond market, which carries similar credit risk, than other markets such as the corporate bond market.

Both the AgencyBidAsk and the MarketBidAsk are winsorized at the 1 and 99 percentile levels to limit the impact of outliers. The advantage of this method is that it omits extreme values without dropping observations in the sample.

5.3.2.4 Quantitative easing

During the later years of our sample period, both Sweden and Germany have experienced low interest rate levels. A recent development following the slow economic recovery in combination with the low interest rate environment is the introduction of quantitative easing (QE). QE is an unconventional monetary policy used in situations where conventional monetary policies (such as using the short-term rate to achieve inflation targets) have proven to be insufficient in recovering the economy (Fawley and Neely, 2013).

The Swedish Riksbank launched a QE-program in January 2015 and the European Central Bank (ECB) introduced a similar program for the Eurozone in March 2015. The QE-programs imply that the respective central banks purchase government bonds in order to decrease the outstanding amount of bonds. As the outstanding supply of bonds is reduced, prices increase and yields are pushed downwards. The ambition is to initiate spillover effects to the rest of the economy and affect pricing of other assets as well, through the so called portfolio balance channel. As investors in the market sell their assets to the central bank, the idea is that they will invest in other assets such as agency bonds or corporate bonds and push down yields in these assets as well (Alsterlind et al., 2015; Znidar, 2015).

A number of studies find evidence of QE generating the intended results. Yields of government bonds as well as other bonds are found to decrease as a result of QE-programs (Joyce, Liu and

Tonks, 2014; Carpenter et al., 2015). Moreover, QE-programs with a sole focus on government bonds are found to primarily generate spillover effects to other low-default-risk (Krishnamurthy and Vissing-Jorgensen, 2011).

Based on the recent introductions of quantitative easing in Sweden and Germany, we include a control for these QE-programs in our regression. As QE is expected to affect yields of both the purchased asset and other assets in the market, there is no clear expectation of how the agency-government spread should be affected by the QE-programs. Based on previous studies' findings of lowered interest rates, especially of low-default-risk assets, we expect the yields of both the government and the agency bonds to decline as the QE-programs are introduced. However, if the yields of these assets are impacted equally, the yield spread will remain at previous levels. If the effect on one yield is larger than on the other, the QE-variable will impact the AGS. Moreover, we recognize that the liquidity of the bonds may also be impacted, as Alsterlind et al. (2015) state that a risk of large purchases of government bonds is that the circulation of the bonds decreases. Given that liquidity is priced, it is possible that the decrease of the government yield resulting from QE to some extent will be counterbalanced by the declining liquidity.

The measure we use to capture QE is a ratio that compares the value of government bonds purchased via the respective QE-program to the total transacted value of the government bond[19]. The Swedish transaction volume is attained from the Riksbank and data regarding QE purchases is gathered from Statistics Sweden. German transaction data is retrieved from the German Finance Agency (Bundesrepublik Deutschalnd Finanzagentur GmbH) and the amount of QE purchases is attained from the ECB. We calculate the QE variable on a monthly basis for each respective market using the following formula:

$$QE_m = \frac{Value\ of\ Government\ Bonds\ Purchased\ in\ QE\ Program_m}{Total\ Transaction\ Value\ of\ Government\ Bonds_m} \tag{12}$$

Where m denotes one month during the sample period.

5.3.2.5 *Lagged agency-government spread*

According to Longstaff (2004), the yield spread he investigates is serially correlated and in order to avoid false relations between the spread and other variables with the same time-series properties, he includes a lagged yield spread in the regression model. Dealing with similar data, we have reason to believe our regression might be subject to serial correlation and we therefore also include a

[19] We would like to thank our tutor, Henrik Andersson, for suggesting this approach to measure the impact of QE.

lagged agency-government spread in our regression to control for this aspect. The LaggedAGS variable represents the previously observed agency-government spread $(AGS_{i,t-1})$.

6 Results

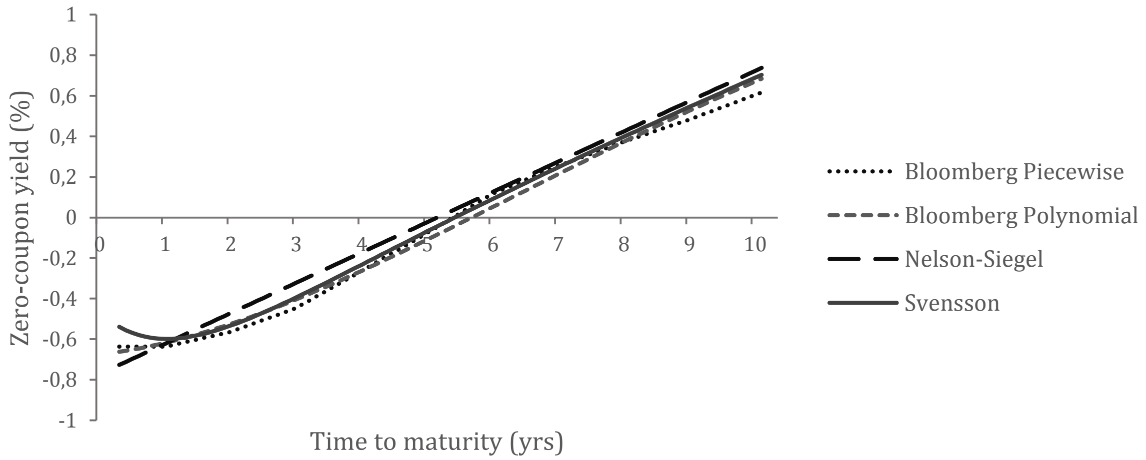
In the following section we first present our estimated government zero-coupon yield curves. Thereafter, we present and discuss our statistical tests. Lastly, we perform robustness tests to further scrutinize our results.

6.1 Estimated zero-coupon yield curves

The government zero-coupon yield curves are estimated with the four methods outlined in chapter 5.2; Bloomberg Piecewise, Bloomberg Polynomial, Nelson-Siegel and Svensson. The estimated yield curves for all four methods are displayed in Appendix 10.1. During some closing weekdays the Nelson-Siegel and Svensson method generate outliers for short maturities. A probable explanation is that these models are sensitive to pricing distortions in the market data used.

An example of the outcome in Sweden for a closing weekday in April 2016 is shown in Figure 4. As the graph illustrates, the yield curves are fairly similar. However, there are some differences in the level of the curve as well as the shape of the curve up to one year to maturity. For this particular day, the Svensson model produces the best fit when we compare government bond market prices to prices calculated with the zero-coupon yields.

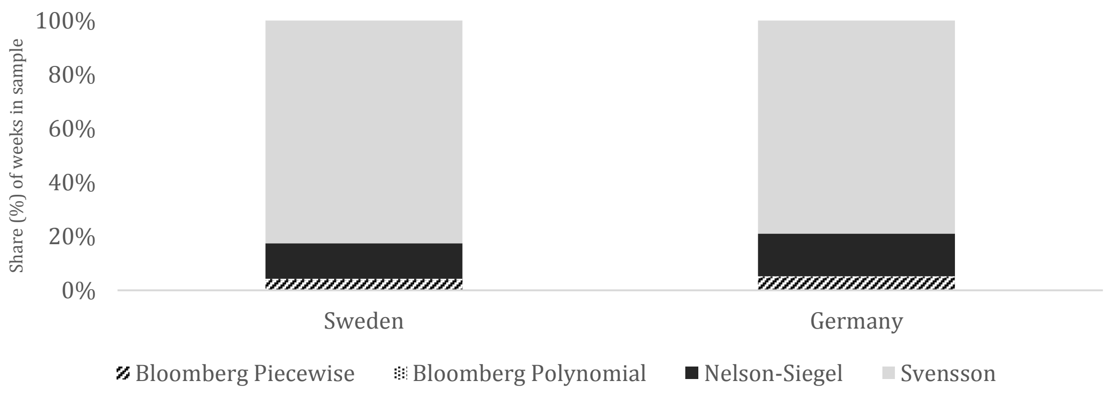
Figure 4
Estimated zero-coupon yield curves for Swedish government bonds 2016-04-08



This figure shows estimated zero-coupon yield curves for Swedish government bonds as of 2016-04-08 using four methods; Bloomberg IYC curves with piecewise linear interpolation, Bloomberg IYC curves with polynomial interpolation, the Nelson-Siegel model and the Svensson model. The data used for the Bloomberg models is the IYC curve. The data used for Nelson-Siegel and Svensson is market data on the most recently issued government bonds.

We evaluate which yield curve model that produces the best fit on each observation day by selecting the model with the smallest average model residual, calculated with equation (7). The results from the evaluation procedure is displayed in Figure 5. Closing weekdays during which there is a large discrepancy between estimated and observable prices are excluded[20], leaving the Swedish sample to cover 234 weekly closing days and the German sample to cover 228 weekly closing days. The majority of the closing weekdays in our sample are best estimated with the Svensson model, followed by the Nelson-Siegel model and the Bloomberg Piecewise method. Since the Svensson model is the most flexible of the methods chosen and the curves are evaluated exclusively on how well market prices fit with estimated prices, we regard this result as reasonable.

Figure 5
Distribution of weeks for yield curve estimations with best fit in Sweden and Germany

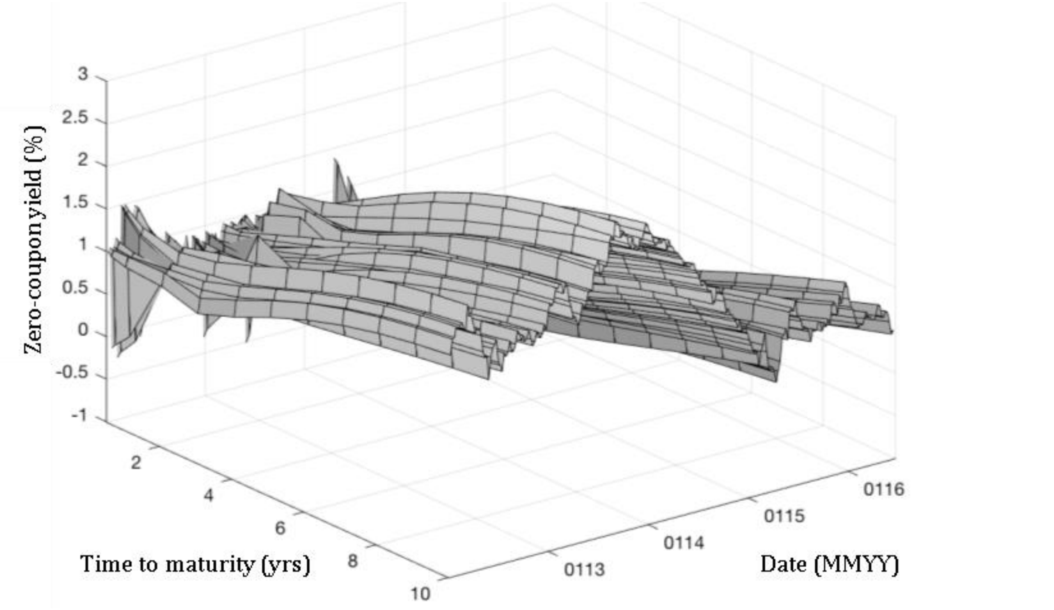


This figure shows the outcome of an evaluation procedure carried out for the estimated yield curves, using four different models. Each observation is a weekly closing day in our sample period (Jan 2012- Jun 2016). The share of each yield curve estimation method represents the share of weekly observations that the particular method is regarded as the best fit. Weeks that are considered to not be reliably estimated are excluded (average model residual exceeding three standard deviations from the mean), leaving the Swedish sample to include 234 weeks and the German sample 228 weeks (as compared to 236 in the initial data set for both markets). Note that very few days are best estimated with Bloomberg Polynomial, therefore it is barely visible in the graph.

The best-fitted zero-coupon yield curve estimation for each observation day is displayed in Figure 6 and 7 for Sweden and Germany respectively. These yield curves are subsequently used to attain the zero-coupon yields from which the modelled yield in the agency-government spread is calculated. As illustrated in the figures, the zero-coupon yields increase with the time to maturity, which is consistent with the standard view of upward-sloping yield curves. Moreover, for both markets it is evident that yields have decreased in the later years of the sample period.

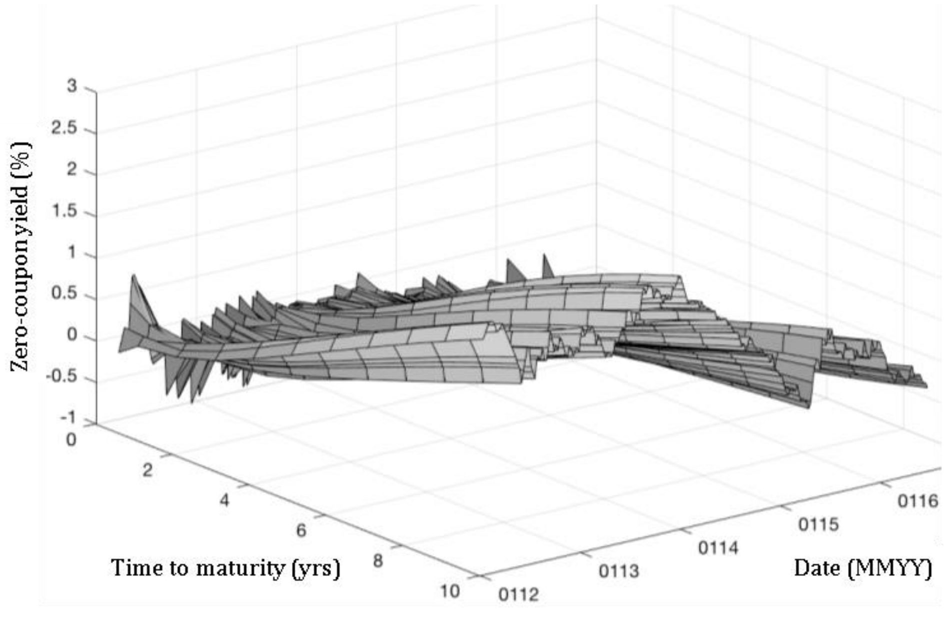
[20] All closing weekdays with an average model residual, calculated with equation (7), exceeding three standard deviations from the mean are excluded.

Figure 6
Best government zero-coupon yield curve estimation for each observation day - Swedish market



This figure displays the best-fitted zero-coupon yield curve estimation for each observation day in the Swedish sample. The yield curve for each day is thus either an estimation from the Bloomberg Piecewise, Bloomberg Polynomial, Nelson-Siegel or Svensson method. The period is Jan 2012-Jun 2016 and covers 234 weekly observations.

Figure 7
Best government zero-coupon yield curve estimation for each observation day - German market



This figure displays the best-fitted zero-coupon yield curve estimation for each observation day in the German sample. The yield curve for each day is thus either an estimation from the Bloomberg Piecewise, Bloomberg Polynomial, Nelson-Siegel or Svensson method. The period is Jan 2012-Jun 2016 and covers 228 weekly observations.

6.2 Paired sample t-test results

We test our first hypothesis (**H1**), that the yield of the agency bond exceeds the yield of a comparable government bond, with a paired sample t-test. We exclude potential outliers by removing observations where the agency-government spreads deviates more than three standard deviations from the mean.

The results for both markets are presented in Table 2. The total samples in terms of bond-days amount to 1041 in Sweden and 3127 in Germany. In both Sweden and Germany, there is a significant positive difference (at 1% level) between the observed agency yield and the modelled government yield. The mean paired yield difference, representing the average agency-government spread, in Sweden and Germany is 0.49 and 0.27 percentage points respectively. We find, in line with our expectations, that the less liquid agency bond has a higher yield than an equivalent government bond. Moreover, we conclude that the additional return from investing in agency bonds over government bonds is quite substantial and should be interesting for investors to investigate further, especially given the current low interest rate environment[21].

Black et al. (2016) document an average spread between government and government-guaranteed bonds in the U.S. market of 0.21 percentage points in 2008-2012. The spread between 5-year German government bonds and KfW bonds found by Ejsing et al. (2015) fluctuates around 0.20 and 0.45 percentage points in 2012-2014. Hence, the German result is in line with previous studies but the Swedish agency-government spread is relatively large[22].

Table 2
Results of paired sample t-test

Country	Obs.	Mean paired difference	Std. Error	Std. Deviation	Sig.
Sweden	1041	0.494	0.008	0.261	0.000
Germany	3127	0.274	0.004	0.198	0.000

This table displays results for the paired sample t-test of the observed agency yield and modelled government yield in each market, where the observed agency yield is the yield to maturity of an agency bond and the modelled government yield is the yield to maturity of an equivalent, hypothetical government bond. The modelled government yield is obtained by calculating the price of a hypothetical government bond with estimated zero-coupon yields and solving for the yield to maturity. The yields used for the t-test are expressed in percentages and the resulting mean paired difference in percentage points.

[21] For reference, the means of the modelled government yields in our sample are -0.21 and -0.31 percent in Sweden and Germany respectively.
[22] Estimations of yield spreads by Kommuninvest (2014; 2016c) for particular Kommuninvest bonds during 2014-2016 vary from slightly above 0 to 0.90 percentage points, indicating that our results for the Swedish market nevertheless are in line with Kommuninvest's estimations.

6.3 Regression analysis results

We conduct regression analyses with the agency-government spread (AGS) as the dependent variable to test whether bond-specific liquidity affects bond pricing (**H2**) and if the credit quality of agency bonds and government bonds is equal (**H3**). The results for the two respective markets are presented separately in this section. Last in this section we discuss and compare the outcomes for the two markets.

6.3.1 Sweden

6.3.1.1 Summary statistics

Summary statistics for the sample used in the regression analysis for the Swedish market are presented in Table 3. As we include the lagged spread as an explanatory variable in our regression, we exclude any observations with no preceding agency-government spread[23]. The remaining sample includes 999 observations. The AGS is on average 0.49 percentage points in our sample and deviates between -0.1 and 1.4. The average relative bid-ask spread of the agency bond, AgencyBidAsk (21.11 bps) is substantially larger than the average MarketBidAsk (11.87 bps), consistent with the view that agency bonds are less liquid than government bonds as the latter variable is the relative bid-ask spread of on on-the-run government bonds. The mean of the CorpYieldSpread is 0.58 percentage points and ranges between 0.01 and 1.28. Moreover, QE is on average 1.87 bps and ranges between 0 and 7.05.

Table 3
Summary statistics of regression variables - Swedish market

Variables	Units	Obs	Mean	Std.dev.	Min	Max
AGS	pct	999	0.49	0.26	-0.10	1.36
AgencyBidAsk	bps	999	21.11	12.61	3.84	70.75
CorpYieldSpread	pct	999	0.58	0.26	0.01	1.28
MarketBidAsk	bps	999	11.87	4.30	4.62	25.98
QE	bps	999	1.87	2.35	0.00	7.05
LaggedAGS	pct	999	0.49	0.26	-0.10	1.36

This table displays summary statistics for the regression variables included in the regression analysis for the Swedish market. The AGS is the yield spread between a Kommuninvest bond and a modelled government bond. The AgencyBidAsk is the relative bid-ask spread of the agency bond. The CorpYieldSpread represents the yield spread between AA and AAA Swedish corporate bond indices. The MarketBidAsk is the average relative bid-ask spread of on-the-run government bonds. QE is the ratio of the Swedish central bank's net purchasing of government bonds and total transaction value of government bonds. The LaggedAGS is the AGS of the previous observation.

[23] We remove the first observation of each bond (as no lagged spread is available) as well as observations succeeding an observation that has been excluded (due to being an outlier).

6.3.1.2 *Regression results*

The result of the regression analysis for the Swedish market is displayed in Table 4. The sample covers 10 Kommuninvest bonds and 231 weeks (weekly closing observations) during the period Jan 2012 – Jun 2016[24]. Model 1 and 2 only include the relative bid-ask spread of the agency bond and corporate yield spread respectively. Model 3 includes all variables except the lagged yield spread. Finally, model 4 represents our main regression model and includes all variables. Similarly to Black et al. (2016), we control for bond fixed effects in all models by including dummy-variables for each bond.

Starting with model 1, the coefficient of the AgencyBidAsk is positive and statistically significant at 1% level, indicating that lower bond-specific liquidity (a higher bid-ask spread), is associated with a larger AGS as expected. In model 2 we find that the coefficient of the CorpYieldSpread is positive and significant at 1% level as well, implying that the AGS is affected by credit risk. This is however not in line with our expectations, as we hypothesize that the credit quality of agency and government bonds is equal.

Continuing with model 3, the MarketBidAsk and QE coefficients are significant at 1% level. The coefficient of MarketBidAsk is positive, implying that the AGS increases when the market liquidity worsens. This finding is consistent with our expectations and with the findings of Black et al. (2016). Moreover, the coefficient of QE is negative which indicates that when the central bank of Sweden purchases government bonds the AGS decreases.

Lastly, we turn to model 4 which is our main regression model. In this model we add a control for serial correlation, the LaggedAGS, which has implications for the interpretation of the other coefficients. If the coefficient (β_5) of the LaggedAGS, which can be rewritten as $AGS_{i,t-1}$, is close to 1 it follows that:

$$\Delta AGS_{i,t} = \alpha_{i,t} + \beta_1 AgencyBidAsk_{i,t} + \beta_2 CorpYieldSpread_{i,t} + \beta_3 MarketBidAsk_{i,t} + \beta_4 QE_{i,t} + \varepsilon_i \tag{13}$$

Hence, a large coefficient of the lagged agency-government spread implies that the coefficients of the other explanatory variables are interpreted as the impact on the *change* in the agency-government spread from one observation to the next. As the coefficient of the LaggedAGS is 0.75 and statistically significant at 1% level in model 4, this interpretation is adequate for our main regression model. Since our aim is to examine whether the AGS is impacted by the independent

[24] Recall that we exclude observations where no lagged spread is available. This exclusion results in the lower number of weeks as compared to the number of weeks for which we have reliable yield curves for (234).

variables, both the impact on the level of the AGS (as in models 1-3) and the change in the AGS (as in model 4) are relevant to us. However, as the LaggedAGS is considered to be an important control variable for serial correlation, we select model 4 as our main regression model.

In our main regression model we find that the signs and statistical significance of the coefficients of all variables are consistent with what we find in model 1-3. Hence, in line with our hypothesis (**H2**) we find that bond-specific liquidity affects the agency-government spread, both in terms of the level of the AGS and change in the AGS. However, our hypothesis (**H3**) that the credit quality of government bonds and agency bonds is equal is contradicted.

The adjusted R-squared of the models range between 0.34 and 0.86. When only including the AgencyBidAsk and bond dummy-variables in model 1, the adjusted R-squared is 0.57. Given the multifaceted nature of liquidity, the bid-ask spread we use to capture liquidity is not expected to explain the entire AGS. However, when comparing the adjusted R-squared values for model 1 and 2 we see that the AgencyBidAsk seems to explain the variation in the AGS to a greater extent than the CorpYieldSpread (adjusted R-squared of 0.34). The relatively high adjusted R-squared in model 4 can be explained by the inclusion of the LaggedAGS.

Table 4
Results of linear regression analysis - Swedish market

	Additional models			*Main model*
Variables	AGS (1)	AGS (2)	AGS (3)	AGS (4)
AgencyBidAsk	0.0133***		0.0111***	0.00325***
	(0.000545)		(0.000523)	(0.000386)
CorpYieldSpread		0.170***	0.189***	0.0460***
		(0.0265)	(0.0210)	(0.0137)
MarketBidAsk			0.0155***	0.00255**
			(0.00153)	(0.00102)
QE			-0.0410***	-0.00739***
			(0.00341)	(0.00231)
LaggedAGS				0.750***
				(0.0193)
Constant	0.207***	0.438***	0.0122	0.00269
	(0.0185)	(0.0213)	(0.0227)	(0.0143)
Fixed effects	Bond	Bond	Bond	Bond
R-squared	0.578	0.349	0.653	0.863
Adj R-squared	0.574	0.343	0.648	0.861
Observations	999	999	999	999
Bonds	10	10	10	10
Weeks	231	231	231	231

*This table displays results for multivariate regression analyses using an unbalanced panel of agency-government spread (AGS) in the Swedish market. The AGS is the yield spread between a Kommuninvest bond and a modelled, comparable, government bond. The AgencyBidAsk is the relative bid-ask spread of the agency bond. The CorpYieldSpread represents the yield spread between AA and AAA Swedish corporate bond indices. The MarketBidAsk is the average relative bid-ask spread of on-the-run government bonds. QE is the ratio of the Swedish central bank's net purchasing of government bonds and total transaction value of government bonds. The LaggedAGS is the AGS of the previous observation. Bond fixed effects are used as controls in all models. Variables are unstandardized coefficient betas. Standard errors in parentheses. P-values are indicated as follows: *** p<0.01, ** p<0.05, * p<0.1*

6.3.2 Germany

6.3.2.1 Summary statistics

The summary statistics for the German sample is presented in Table 5. The number of observations amounts to 3 029 after excluding observations with no preceding yield spread. The mean of the AGS is 0.27 percentage points. Furthermore, the mean of the AgencyBidAsk (19.07 bps) is larger than the MarketBidAsk (1.64 bps), indicating that the government bonds are more liquid than the agency bonds. The mean of the CorpYieldSpread is 0.35 percentage points and ranges between 0.02 and 0.77. QE is on average 1.21 bps, and ranges between 0 and 5.44.

Table 5
Summary statistics of regression variables - German market

Variables	Units	Obs	Mean	Std.dev.	Min	Max
AGS	pct	3 029	0.27	0.19	-1.29	1.50
AgencyBidAsk	bps	3 029	19.07	19.02	1.00	77.50
CorpYieldSpread	pct	3 029	0.35	0.19	0.02	0.77
MarketBidAsk	bps	3 029	1.64	0.66	0.83	6.89
QE	bps	3 029	1.21	1.71	0.00	5.44
LaggedAGS	pct	3 029	0.27	0.19	-1.29	1.50

This table displays summary statistics for the regression variables included in the regression analysis for the German market. The AGS is the yield spread between a KfW bond and a modelled, comparable, government bond. The AgencyBidAsk is the relative bid-ask spread of the agency bond. The CorpYieldSpread represents the yield spread between AA and AAA Eurozone corporate bond indices. The MarketBidAsk is the average relative bid-ask spread of on-the-run government bonds. QE is the ratio of the ECB's net purchasing of German government bonds and total transaction value of government bonds. The LaggedAGS is the AGS of the previous observation.

6.3.2.2 Regression results

The regression results for the German market are presented in Table 6. The sample covers 29 KfW bonds and 219 weeks during the period Jan 2012 – Jun 2016[25].

Similarly to the Swedish results, the coefficient of the LaggedAGS is relatively close to 1 in the main regression model (the coefficient is 0.685, significant at 1% level), which implies that the other variables are interpreted as the impact on the change rather than the level of the agency-government spread.

The coefficients of the AgencyBidAsk and CorpYieldSpread are positive and significant in all models they are included in, implying that these variables impact the level as well as the change of the AGS. Hence, we find that the yield spread is affected by liquidity as expected (**H2**), but our hypothesis that credit risk does not impact the AGS is disproved (**H3**).

Moreover, the MarketBidAsk and QE variable coefficients are insignificant in model 3 and 4. This suggests that market-wide liquidity and quantitative easing do not affect the agency-government spread in the German market, which stands in contrast to the results for the Swedish market.

The adjusted R-squared of the models range between 0.3 and 0.68. The adjusted R-squared for model 1 which only includes the AgencyBidAsk and bond dummy-variables is 0.38, which is higher than for model 2 which only includes the CorpYieldSpread and has an adjusted R-squared of 0.31.

[25] Recall that we exclude observations where no lagged spread is available. This exclusion results in the lower number of weeks as compared to the number of weeks for which we have reliable yield curves for (228).

Table 6
Results of linear regression analysis - German market

	Additional models			*Main model*
Variables	AGS (1)	AGS (2)	AGS (3)	AGS (4)
AgencyBidAsk	0.00457***		0.00398***	0.00128***
	(0.000167)		(0.000186)	(0.000146)
CorpYieldSpread		0.305***	0.157***	0.0454***
		(0.0170)	(0.0193)	(0.0143)
MarketBidAsk			0.00410	0.00364
			(0.00448)	(0.00327)
QE			0.00345	0.00223
			(0.00232)	(0.00169)
LaggedAGS				0.685***
				(0.0133)
Constant	0.0879***	0.0718***	0.0354**	0.00617
	(0.0126)	(0.0141)	(0.0154)	(0.0112)
Fixed effects	Bond	Bond	Bond	Bond
R-squared	0.391	0.313	0.406	0.684
Adj R-squared	0.385	0.307	0.400	0.681
Observations	3029	3029	3029	3029
Bonds	29	29	29	29
Weeks	219	219	219	219

This table displays results for multivariate regression analyses using an unbalanced panel of agency-government spread (AGS) in the German market. The AGS is the yield spread between a KfW bond and a modelled, comparable, government bond. The AgencyBidAsk is the relative bid-ask spread of the agency bond. The CorpYieldSpread represents the yield spread between AA and AAA Eurozone corporate bond indices. The MarketBidAsk is the average relative bid-ask spread of on-the-run government bonds. QE is the ratio of the ECB's net purchasing of German government bonds and total transaction value of government bonds. The LaggedAGS is the AGS of the previous observation. Bond fixed effects are used as controls in all models. Variables are unstandardized coefficient betas. Standard errors in parentheses. P-values are indicated as follows:
**** p<0.01, ** p<0.05, * p<0.1*

6.3.3 Country comparison

6.3.3.1 Main regression model results

In both markets, we find support for the hypothesis (**H2**) that bond-specific liquidity in terms of the relative bid-ask spread affects the agency-government spread. However, the agency-government spread is also affected by the corporate yield spread, which disproves our expectation that the bonds have equal credit quality (**H3**). In the case of the Swedish market, this result is less surprising as the agency bond we study, Kommuninvest, is not guaranteed by the government. The result in the Swedish market implies that the government is perceived to have higher credit quality than the local government sector, which we find reasonable. In contrast, the German agency bond KfW is explicitly guaranteed by the German government. Despite this, our results indicate that the market perceives differences in credit quality between the bonds. Both Black et al. (2016) and Longstaff (2004) recognize that market-perceived differences in credit quality between government-guaranteed bonds and government bonds are possible. For example, the perceived difference in credit quality could be due to investors pricing in the risk of incurring resolution cost, i.e. the cost associated with a default. Even though the KfW bonds are backed by the government and the investor thus should get their funds back in the case of a default, it is probable that the risk of default of a KfW bond is higher than for a German government bond. A default is associated with uncertainty and it is likely that there will be procedural hassles and time delays for the investors to get their principal and interest back, which implies costs for the investor (Sherman, 2016). Thus, we regard the significant impact of the corporate yield spread in the German market as reasonable. However, previous studies establish that there are no perceived credit quality differences between government-guaranteed bonds and government bonds in the U.S. market (Longstaff 2004; Black et al., 2016). Our findings thereby indicate that the German market differs in this regard.

Furthermore, the results for the Swedish and German markets differ in terms of the impact of market-wide liquidity and quantitative easing. Starting with the market-wide liquidity, the Swedish results are in line with our expectations that the agency-government spread is positively impacted by market-wide bid-ask spreads. Conversely, the German results are insignificant in this regard. The expectation of a positive impact of the market bid-ask spread is based on the argument that investors require a larger compensation for holding illiquid securities when the market in general becomes illiquid (Acharya and Pedersen, 2005). A distinct difference between our German and Swedish samples is the agency bond used in each sample. While KfW is perceived as one of the largest bond issuers in the European market (KfW, 2016) and is the fourth largest debt issuer in the euro-area by volume[26] (Schwarz, 2016), Kommuninvest is in comparison a small issuer. Hence, Kommuninvest bonds can be argued to be more illiquid than KfW bonds and thereby more sensitive to market liquidity changes, which would explain the difference in impact of market-wide liquidity on the AGS.

Moving on to the quantitative easing variable, the agency-government spread in the Swedish sample is negatively impacted by QE. There are three main effects that we expect from the introduction of QE. First, we expect the yields of government bonds to decrease as the outstanding supply is reduced due to the purchases by the Riksbank. Second, we expect the yields of agency bonds to decrease as the QE-effects spread through the market. Third, it is possible that the liquidity of government bonds decrease relative to the agency bonds. Given that liquidity is priced, this factor alone would increase the yield of the government bond relative to the agency bond. We

[26] Following the governments of Germany, France and Italy.

investigate these three effects by examining the correlation between the QE-variable and other relevant variables, the results are presented in Appendix 10.2 and 10.3. First, we find that both the yield of the government bond and the yield of the agency bond is negatively related to QE. Second, the liquidity of the government bonds, captured in our MarketBidAsk variable, decreases with the introduction of QE. In contrast, the liquidity of the agency bond (AgencyBidAsk) increases. We thereby find indications that all of the three expected effects have occurred. However, it is the magnitude of these effects that determine how the agency-government spread is impacted and we find it reasonable that the agency-government spread decreases as result of a combination of these effects.

In contrast, the QE measure is not significant in the German sample. Performing a similar investigation as above (see Appendix 10.2 and 10.3) we find indications that all three expected effects occur in the German sample as well. However, in contrast to the Swedish sample, it seems that the magnitude of the effects have been balanced out in the sense that the agency-government spread is not impacted.

6.3.3.2 Relative strength of explanatory variables

We further examine our results by exploring the relative strength of our explanatory variables. First, we review the standardized coefficients of the main regression model in both markets. These results are displayed in Table 7. Apart from the LaggedAGS*,* the AgencyBidAsk has the largest standardized coefficient in both market samples, indicating that the bond-specific liquidity has a relatively large impact on the agency-government spread. In both markets, the relative strength of the CorpYieldSpread is the next highest. In Sweden, the relative strength of QE is larger than the MarketBidAsk.

Table 7
Standardized coefficients for regressions in Sweden and Germany

Variables	AGS (4) - Sweden	AGS (4) - Germany
AgencyBidAsk	0.159***	0.127***
CorpYieldSpread	0.047***	0.044***
MarketBidAsk	0.043**	0.013
QE	-0.067***	0.020
LaggedAGS	0.754***	0.689***

*This table displays standardized coefficients for the main regression models for Sweden and Germany. P-values are indicated as follows: *** $p<0.01$, ** $p<0.05$, * $p<0.1$*

To further build on this analysis we review how much each variable impacts the change in the AGS by using the estimated coefficients and the sample means of each variable. The calculations are summarized in Tables 8 and 9. Apart from the LaggedAGS, the AgencyBidAsk has the largest impact on the change in AGS in both markets. The AgencyBidAsk explains 14% of the change in AGS in Sweden and 9% in Germany. The CorpYieldSpread explains 5% and 6% in Sweden and Germany, respectively. The MarketBidAsk accounts for 6% in Sweden and 2% in Germany. Lastly, QE has an impact of -3% and 1% in Sweden and Germany, respectively[27].

Understanding which variables that impact the yield spread can be important to investors, as it enables a better understanding of what risk exposure that results in the increased returns. The fact that liquidity impacts the yield spread the most indicates that for example investors that are willing to carry liquidity risk can exploit this to earn larger returns. By investing in the agency bond rather than the government bond, they are exposed to larger liquidity risk and get compensated by higher returns, without increasing the credit risk to the same extent.

Table 8
Independent variable impact on AGS using sample means and estimated coefficients - Swedish market

Variables	Sample mean (x)	Estimated coeff. (β)	x*β	Impact as % of mean AGS
AgencyBidAsk	21.11	0.003	0.069	14%
CorpYieldSpread	0.58	0.046	0.027	5%
MarketBidAsk	11.87	0.003	0.030	6%
QE	1.87	-0.007	-0.014	-3%
LaggedAGS	0.49	0.750	0.368	75%
AGS	0.49	-	-	-

*This table shows the estimated unstandardized coefficients (β) for the main regression model and sample means of the included variables for the Swedish market. The "impact as % of mean AGS" is the value of x*β divided by the mean sample AGS. All variables are significant below the 5% level.*

Table 9
Independent variable impact on AGS using sample means and estimated coefficients - German market

Variables	Sample mean (x)	Estimated coeff. (β)	x*β	Impact as % of mean AGS
AgencyBidAsk	19.07	0.001	0.024	9%
CorpYieldSpread	0.35	0.045	0.016	6%
MarketBidAsk	1.64	0.004	0.006	2%
QE	1.21	0.002	0.003	1%
LaggedAGS	0.27	0.685	0.185	69%
AGS	0.27	-	-	-

*This table shows the estimated unstandardized coefficients (β) for the main regression model and sample means of the included variables for the German market. The "impact as % of mean AGS" is the value of x*β divided by the mean sample AGS. The MarketBidAsk and QE variables are statistically insignificant, all other variables are statistically significant.*

[27] However, recall that MarketBidAsk and QE are statistically insignificant in the German market.

6.3.4 *Robustness tests*

6.3.4.1 *Robust standard errors*

There is a risk that our regression results are affected by issues with heteroscedasticity and normality of the error term. Therefore, we test the robustness of our result in this regard by running our regressions with the robust option in the statistical analysis software STATA. This option enables an estimation of the standard errors that deal with such issues. Although the coefficients are not affected, standard errors and p-values can change as issues with heteroscedasticity and normality are taken into account (UCLA: Institute for digital research and education, 2016). The results are presented in Appendix 10.4. Apart from that the statistical significance of the QE-variable in Sweden changes from 1% to 5% in the main regression model, the results are similar to the regression results without the robust option. We thereby draw the conclusion that our results are robust in this regard.

6.3.4.2 *Multicollinearity*

There is a risk that our regression analyses are subject to multicollinearity, i.e. that correlations between the independent variables affect the results. One approach to diagnosing the presence of collinearity is to examine a correlation matrix of the independent variables and review the variance inflation factors (VIFs). A common rule of thumb is that a VIF exceeding 10 is regarded as signaling harmful collinearity (Mason and Perreault, 1991). The VIFs are presented in combination with the correlation matrices in Appendix 10.2. We conclude that multicollinearity is not an issue in our regressions as the variance inflation factors are within the aforementioned cutoff.

6.3.4.3 *Omitted variables*

In their investigation of yield spreads between U.S. Treasury bonds and government-guaranteed bank bonds, Black et al. (2016) find that there is a part of the agency-government spread that cannot be captured by the different liquidity measures they use. When investigating this matter, they find that a general market fear factor, measured by a stock volatility index, is priced in the yield spread. Black et al. (2016) argue that this general market fear factor reflects a preference among investors to primarily invest in assets that allow them to disengage from the market as quickly as possible in times of uncertainty, a phenomena they label as "flight-to-extreme-liquidity". As this general market fear factor is found to impact the agency-government spread of U.S. bonds by Black et al. (2016), we recognize that this factor may also affect the AGS in the markets we study. Our findings may thereby be affected by the omitted variable of general market fear.

To test this we run our main regression model for both markets with a control for general market fear in terms of the stock volatility indices SIXVX and VDAX-New[28]. The results are presented in Table 10. The volatility indices (VIX) in both markets are positive and statistically significant at 1% level, indicating that the spread between agency bonds and government bonds is indeed related to general market fear. While Black et al. (2016) draw the conclusion that the VIX captures a "flight-to-extreme-liquidity" effect, we cannot jump to the same conclusion. Our regression results indicate that the agency-government spreads we study are impacted by credit quality differences (in addition to liquidity differences). Hence, we recognize that this general market fear factor may also capture a corresponding preference among investors to invest in extremely safe assets. This implies that the general market fear factor in our case can be seen to both capture potential "flight-to-extreme-liquidity" and "flight-to-extreme-quality" effects. Nevertheless, the main objective of this test is to examine whether our results hold with an inclusion of the VIX-variable. We find that the signs and statistical significance of all remaining variables are similar to the main regression model result. Hence, we find that our conclusions from the main regression model are robust to the inclusion of a general market fear factor.

[28]SIXVX is based on OMXS30 index options, OMXS30 is an index of the 30 most traded stocks on the Stockholm Stock Exchange (SIX Financial Information, 2014). VDAX-NEW is the German equivalent, based on DAX options. DAX is an index of the 30 largest and most liquid companies on the Frankfurt Stock Exchange (Deutsche Börse, 2016). We obtain the data from Datastream.

Table 10
Results of main regression model with volatility index - Swedish and German markets

	Sweden		Germany	
	VIX model	*Main model*	*VIX model*	*Main model*
Variables	AGS (1)	AGS (2)	AGS (3)	AGS (4)
AgencyBidAsk	0.00316***	0.00325***	0.00139***	0.00128***
	(0.000385)	(0.000386)	(0.000147)	(0.000146)
CorpYieldSpread	0.0349**	0.0460***	0.0455***	0.0454***
	(0.014)	(0.0137)	(0.0142)	(0.0143)
MarketBidAsk	0.00238**	0.00255**	0.00476	0.00364
	(0.00102)	(0.00102)	(0.00327)	(0.00327)
QE	-0.00980***	-0.00739***	-0.00199	0.00223
	(0.00242)	(0.00231)	(0.00192)	(0.00169)
LaggedAGS	0.738***	0.750***	0.676***	0.685***
	(0.0196)	(0.0193)	(0.0134)	(0.0133)
VIX	0.00281***		0.00236***	
	(0.000874)		(0.000514)	
Constant	-0.0224	0.00269	-0.0389***	0.00617
	(0.0162)	(0.0143)	(0.0149)	(0.0112)
Fixed effects	Bond	Bond	Bond	Bond
R-squared	0.864	0.863	0.686	0.684
Adj R-squared	0.862	0.861	0.683	0.681
Observations	999	999	3029	3029
Bonds	10	10	29	29
Weeks	231	231	219	219

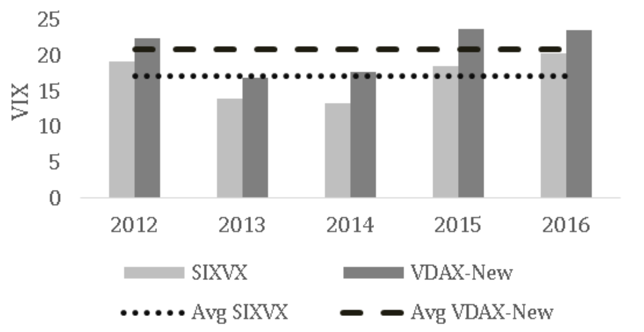
*This table displays results for the main regression model with a volatility index (VIX) included as a control for general market fear. The volatility indices used are SIXVX in Sweden and VDAX-New in Germany. Bond fixed effects are used as controls in all models. Variables are unstandardized coefficient betas. Standard errors in parentheses. P-values are indicated as follows: *** p<0.01, ** p<0.05, * p<0.1*

6.3.4.4 *Sub-periods of sample*

Previous literature on the impact of liquidity on asset prices finds that the effect varies depending on general market conditions. Specifically, the impact of liquidity is found to be stronger during times of financial stress (e.g. Friewald et al., 2012; Acharya et al., 2013). In their analysis of the spread between U.S. government bonds and government-guaranteed bank bonds, Black et al. (2016) split their sample based on whether uncertainty prevails in the market or not to investigate whether their results hold for sub-periods in their sample. In contrast to our sample period, their study covers the financial crisis of 2007-2009 which provides a clear argument for the sample split in their case. However, as our sample period partly covers the sovereign debt crisis and with events such as the introduction of QE-programs (which can be argued signal problems with economic recovery), we recognize that there is a possibility that results do not hold for sub-periods of our sample. Therefore, we argue that it is of interest to examine whether our results are robust in both stable and unstable periods.

As the distinction between stable and unstable times in our sample is less evident than in the case of Black et al. (2016), we use the aforementioned volatility indices to divide our sample into two sub-periods. Since the volatility index can be seen to reflect market uncertainty, we use the yearly average to determine which years in our sample period are characterized by uncertainty. As illustrated in Figure 8, in both Sweden and Germany the respective volatility index (SIXVX and VDAX-New) is on average higher during the years of 2012, 2015 and 2016. Hence, we run separate regressions of our main regression model for the years 2012, 2015-2016 (unstable years) and 2013-2014 (stable years) respectively.

Figure 8
Yearly average of volatility index - Sweden and Germany



This table shows the yearly average of the volatility indices SIXVX (Swedish market) and VDAX-New (German market) for the period 2012-2016, represented by the bars. The average volatility index level during the entire period is represented by the lines.

The results are presented in Tables 11 and 12. Starting with Sweden, the AgencyBidAsk is significant at 1% level for both subsamples, indicating that bond-specific liquidity impacts the AGS irrespective of whether uncertainty prevails in the market or not. This result is in line with Black et al. (2016) who find that the bond-specific bid-ask spread is priced both in times of crisis and not.

However, the results for the CorpYieldSpread and MarketBidAsk variables differ between the two sub-periods in the Swedish market. Firstly, the coefficient of the CorpYieldSpread is insignificant in the stable years but significant and positive during the unstable years. The fact that CorpYieldSpread only impacts the AGS during unstable years is consistent with the view that credit risk matters more during unstable times, both because the risk of default increases and because investors become more sensitive to credit risk (Krishnamurthy, 2016). We further examine this explanation by testing the correlation between the volatility index and the CorpYieldSpread, which we find to be positive (0.48) and strongly significant (at 1% level). Hence, this result supports the view that a high level of uncertainty is associated with a larger impact of credit risk.

The MarketBidAsk is statistically insignificant in the stable years and significant during the unstable years. Acharya et al. (2013) find that the pricing impact of market-wide liquidity shocks is substantially larger during times of financial stress, explained by an increase in the demand for liquidity during such times. Hence, this result is consistent with the view that changes in market-wide liquidity matter more in unstable times.

Moving on to Germany, the AgencyBidAsk is positive and significant in both subsamples, consistent with the results for Sweden. The MarketBidAsk during the unstable years is significant at 5% level, as opposed to the result for both the full sample and the stable years in which the variable is insignificant. Again, this is consistent with previous findings of the importance of market-wide liquidity rising during unstable periods. Lastly, the CorpYieldSpread is positive and significant in both subsamples, in line with the result of the full sample.

To summarize and relate to our previous main findings, we firstly find that bond-specific liquidity impacts the agency-government spread in both stable and unstable periods for both markets. We thereby conclude that this finding is robust in different sub-periods of our sample.

The measure for credit risk is however insignificant during stable periods in Sweden, which stands in contrast to the main regression result as well as the German result in this particular test. While we argue that the Swedish result could be explained by the fact that credit risk matters more during unstable periods, we recognize that the insignificant result in the stable period may be unreliable due to the size of the Swedish sample. The Swedish subsamples are relatively small, especially the sample of the stable years 2013-2014 which only encompasses 423 observations. As small sample sizes are associated with fragile results this can pose a problem for our regression results. This argument is further supported by the fact that the German results are in line with our previously established findings, and that these subsamples are substantially larger than the Swedish subsamples. We are therefore cautious in our interpretation of this result and conclude that while credit risk may be perceived as less important during stable periods, the credit quality of the two bonds is not necessarily perceived as equal. In light of this reasoning, we conclude that our finding that the agency-government spread is impacted by credit quality differences stands.

Table 11
Results of main regression model with sub-period split based on market uncertainty - Swedish market

	Subsamples		*Main model*
Variables	AGS (1)	AGS (2)	AGS (3)
AgencyBidAsk	0.00319***	0.00504***	0.00325***
	(0.000488)	(0.000808)	(0.000386)
CorpYieldSpread	0.0645***	-0.0507	0.0460***
	(0.0207)	(0.0275)	(0.0137)
MarketBidAsk	0.00277**	0.0034	0.00255**
	(0.00119)	(0.00218)	(0.00102)
QE	-0.00729**	n/a	-0.00739***
	(0.00297)	n/a	(0.00231)
LaggedAGS	0.706***	0.621***	0.750***
	(0.0282)	(0.0367)	(0.0193)
Constant	0.0553*	0.0233	0.00269
	(0.0295)	(0.0263)	(0.0143)
Fixed effects	Bond	Bond	Bond
R-squared	0.902	0.747	0.863
Adj R-squared	0.899	0.741	0.861
Observations	567	432	999
Bonds	10	7	10
Weeks	125	106	231
Years	2012, 2015, 2016	2013, 2014	All
Subsample	Unstable years	Stable years	Full

*This table displays results for the main regression model with a split into subsamples based on market uncertainty for the Swedish market. The QE-variable is dropped in the subsample "stable years" as no quantitative easing occurred during these years. Bond fixed effects are used as controls in all models. Variables are unstandardized coefficient betas. Standard errors in parentheses. P-values are indicated as follows: *** p<0.01, ** p<0.05, * p<0.1*

Table 12
Results of main regression model with sub-period split based on market uncertainty - German market

	Subsamples		*Main model*
Variables	AGS (1)	AGS (2)	AGS (3)
AgencyBidAsk	0.00113***	0.00139***	0.00128***
	(0.000330)	(0.000230)	(0.000146)
CorpYieldSpread	0.0953***	0.0564***	0.0454***
	(0.0213)	(0.0217)	(0.0143)
MarketBidAsk	0.00816**	0.000476	0.00364
	(0.00391)	(0.00556)	(0.00327)
QE	-0.000879	n/a	0.00223
	(0.00207)	n/a	(0.00169)
LaggedAGS	0.641***	0.582***	0.685***
	(0.0183)	(0.0231)	(0.0133)
Constant	-0.0177	0.0457**	0.00617
	(0.0157)	(0.0178)	(0.0112)
Fixed effects	Bond	Bond	Bond
R-squared	0.707	0.684	0.684
Adj R-squared	0.701	0.678	0.681
Observations	1683	1346	3 029
Bonds	29	20	29
Weeks	114	105	219
Years	2012, 2015, 2016	2013, 2014	All
Subsample	Unstable years	Stable years	Full

*This table displays results for the main regression model with a split into subsamples based on market uncertainty for the German market. The QE-variable is dropped in the subsample "stable years" as no quantitative easing occurred during these years. Bond fixed effects are used as controls in all models. Variables are unstandardized coefficient betas. Standard errors in parentheses. P-values are indicated as follows: *** p<0.01, ** p<0.05, * p<0.1*

7 Problematization and discussion

In this section, we problematize our results by discussing applied assumptions and further examine the interpretation of the variables used in the regression analysis in detail. Last, we discuss the validity, reliability and generalizability of our study.

7.1 Problematization of regression results

Our regression results show that bond-specific liquidity measured by the relative bid-ask spread impacts the yield spread between agency bonds and government bonds, hence supporting our hypothesis (**H2**) that bond-specific liquidity impacts bond prices. This result holds for both the Swedish and the German market, as well as in all of our robustness tests. However, our result relies on the assumption that the bid-ask spread captures liquidity adequately. Given that liquidity is a multi-dimensional and complex concept, there is a probability that the relative bid-ask spread we use is not an appropriate measure for the task. The bid-ask spread only addresses the cost dimension of liquidity, implying that we leave out the other two dimensions (quantity and time). Nevertheless, in a comparison between three different measures addressing all three dimensions, Black et al. (2016) establish that the bid-ask spread has the highest relative importance for the yield spread they study. Moreover, the bid-ask spread is used as a measure for liquidity cost in a number of studies across different instruments and markets. Examples include Amihud and Mendelson (1986) and Chen et al. (2007) who investigate stocks and corporate bonds respectively. Based on the wide-spread acceptance of the bid-ask spread as a liquidity measure in previous research, we conclude that it is fair to assume that we use an appropriate measure to capture bond-specific liquidity in our study.

Previous studies such as Longstaff (2004), Ejsing et al. (2015), Schwarz (2016) and Black et al. (2016) argue that the spread between government and government-guaranteed bonds fully and exclusively captures pricing differences stemming from liquidity. However, our results indicate that both the agency-government yield spreads we study are affected by credit risk. In Sweden, this result is less surprising as Kommuninvest bonds are guaranteed by the Swedish local government sector and not the Swedish government, and it is reasonable that the credit quality of the local government sector is perceived to be inferior to the credit quality of the government.

In contrast, the German agency bond we use, KfW, is explicitly guaranteed by the German government and it is assumed by both Schwarz (2016) and Ejsing et al. (2015) that no credit quality differences are priced in the yields of these particular bonds. Our results however indicate that the market seems to perceive credit quality differences between KfW bonds and government bonds. We argue that this result is reasonable as previous studies recognize this possibility and that the perceived credit risk can be explained by investors being wary of costs associated with default. Nevertheless, we recognize that the measure we use to investigate credit quality differences has limitations. First, liquidity differences may affect the corporate yield spread we use as our measure. Indeed, previous studies (e.g. Chen et al., 2007) establish that corporate yield spreads (compared to government bonds) are impacted by liquidity. However, we motivate the use of corporate yield spreads to capture credit risk with the fact that it is used in a highly similar context by Longstaff (2004). Moreover, Longstaff, Mithal and Neis (2005) find that credit risk accounts for the majority of corporate yield spreads. A second limitation is that the corporate bond indices we use in the German market sample is based on corporate bonds in the Eurozone and not Germany. Hence, appropriateness of this measure relies on the assumption that the Eurozone corporate yield spreads are equivalent to German corporate yield spreads. However, if this assumption is incorrect we argue that it would rather weaken than strengthen the statistical significance in our regression.

Although not the primary focus of our study, we finally wish to highlight a few limitations relating to our variables capturing market-wide liquidity and quantitative easing. Staring with the market-wide liquidity, we recognize that the appropriateness of the measure we use (the average bid-ask spread of on-the-run government bonds) relies on the assumption that the markets for agency bonds and government bonds are similar, as argued by Black et al. (2016). Since our period covers the introduction of QE-programs, this assumption may not hold for the entire sample period. As highlighted by Alsterlind et al. (2015), the liquidity of government bonds may decline as a result of the purchase program, an effect that is indicated in both of our market samples. However, we argue that this limitation should be at least partly mitigated by the inclusion of a control for QE in our regression.

Moving on to the QE-variable, we firstly recognize that as our variable is based on actual purchases of government bonds, we assume that any potential effects arise in connection to these purchases. Consequently, it does not incorporate potential effects arising e.g. when announcements of future purchases are made. However, the statistically significant impact of QE in the Swedish sample indicates that this assumption has been appropriate for at least the Swedish market.

7.2 Discussion on validity, reliability and generalizability

We argue that the general level of *validity* in our study is high. We follow a well-established research design and use a widely accepted measure to capture the impact of liquidity, reassuring the validity in this regard. However, we recognize that the variable we use to capture credit quality differences might not exclusively capture credit risk. This is because the corporate yield spread we use is likely to be impacted by liquidity, thus implying a relatively lower level of validity in this respect.

Regarding the *reliability* of our study, our main concerns relate to the data we use. Firstly, as the majority of trading with bonds occurs over-the-counter (OTC), differences between databases can exist as transaction data is collected and processed differently. Indeed, we initially planned on using data from Datastream, but found several peculiarities when reviewing the data. Although we consider the Bloomberg data used in this study to be reliable to a greater extent, we recognize that errors and differences compared to other databases can exist.

Secondly, the accuracy of the agency-government spread we study heavily relies on the accuracy of the yield curves we estimate. The accuracy of the yield curves is difficult to evaluate as the true government zero-coupon yield curve cannot be directly observed. We believe this issue is mitigated by our evaluation procedure and the fact that we use four different yield curve modelling methods. In contrast, the previous studies that we draw inspiration from only use one method each to model yield curves. Although the Svensson model seems to produce the best fit for a large part of both our market samples, we find that both the Nelson-Siegel and the Bloomberg Piecewise models are better for some observations. Hence, we show that using a combination of different yield curve models may be the best approach to attain reliable yield curve estimations. Nevertheless, we recognize that the estimated yield curves still are sensitive to the bonds included in the estimation.

Turning to the *generalizability* of our findings, we firstly believe that the generalizability of our result that bond-specific liquidity affects prices in the Swedish bond market should be relatively high. Since the impact of liquidity on bond pricing has been established in previous studies across several markets and types of bonds, we argue that our result can be generalized to both similar markets and other bonds in Sweden.

Another main finding in our study is that the credit quality of the Kommuninvest bond differs compared to government bonds. The Kommuninvest bond is however relatively unique and its credit quality is highly dependent on the strength of the Swedish local government sector. Thus, we argue that this finding cannot be generalized to other markets or bonds. This conclusion is further supported by the fact that we find a similar result for the German market in which we study a government-guaranteed agency bond. As this result stands in contrast to previous studies of government-guaranteed bonds in the U.S. market, we find indications that the credit quality of government-guaranteed bonds differs depending on the characteristics of the market and the bond.

8 Conclusion

In this study, we investigate the impact of liquidity on bond pricing in Sweden and evaluate whether the Kommuninvest bond, a municipal bond guaranteed by the local government sector, can be used to isolate pricing differences due to liquidity. We examine our research questions by comparing the yields of Kommuninvest bonds and Swedish government bonds, specifically by constructing a yield spread which we refer to as the "agency-government spread". This comparison is enabled by modelling zero-coupon yield curves for government bonds. In contrast to previous studies, we do not use readily available zero-coupon yield curves, but calculate and evaluate four different models to ensure a high level of accuracy. We find that although the Svensson model produces the best results for a large part of our sample, the best-fitted model varies for different observation-days which further reinforces our belief that it is beneficial to use several different methods. Our research questions are investigated in conjunction by regressing measures of liquidity and credit risk on the agency-government spread. In addition, we control for the impact of market-wide liquidity and quantitative easing.

The first research question of our study entails whether bond-specific liquidity affects bond pricing in the Swedish market. We conclude that liquidity in terms of the bid-ask spread affects bond pricing, specifically in the sense that lower liquidity of a Kommuninvest bond is related to a higher agency-government spread. Previous studies establish that liquidity impacts pricing across several markets and instruments, and our study contributes to this field by showing that this also applies for the Swedish bond market. Our result holds for various robustness tests and we find that liquidity is priced both in times of uncertainty and in stable conditions. We include the German market as a control group and find similar results, further supporting this conclusion.

The second research question relates to whether the Kommuninvest bonds we study can be used to isolate pricing differences due to liquidity by comparing them to Swedish government bonds. To be able to isolate the liquidity impact, the two bonds compared must have equal credit quality. However, we find that credit risk is priced, implying that the yield spread between Kommuninvest bonds and government bonds cannot be considered to exclusively capture liquidity. Hence, we contribute to the research field by showing that this type of bond cannot be used to isolate the impact of liquidity. Moreover, we find a similar result in the German market. This result is more surprising as the agency bond we use in the German sample, the KfW bond, is a government-guaranteed bond and the credit quality is thereby expected to be equal to government bonds. However, as highlighted by Longstaff (2004) and Black et al. (2016), the market may have a perception that the credit quality of government-guaranteed bonds is inferior to direct government obligations. Nevertheless, previous studies on the U.S. market testing for this possibility find that government-guaranteed bonds and government bonds have equal credit quality. Our results thereby indicate that the German market differs in this regard.

For future research, we firstly believe that further investigations of how quantitative easing affects the liquidity in the bond market is of interest. While present studies in the area focus on whether yields decrease as a result of the reduced outstanding supply, it would be valuable to gain a deeper understanding of how yields are affected indirectly as a result of deterioration in liquidity due to reduced supply. Moreover, our results indicate that the market perceives credit quality differences between KfW bonds and government bonds in the German market, even though the KfW bond is guaranteed by the government. As researchers commonly use government-guaranteed bonds to isolate liquidity impact, it would be of relevance to explore the underlying reasons to the perceived credit quality difference more thoroughly and understand whether this phenomena is found in other markets as well.

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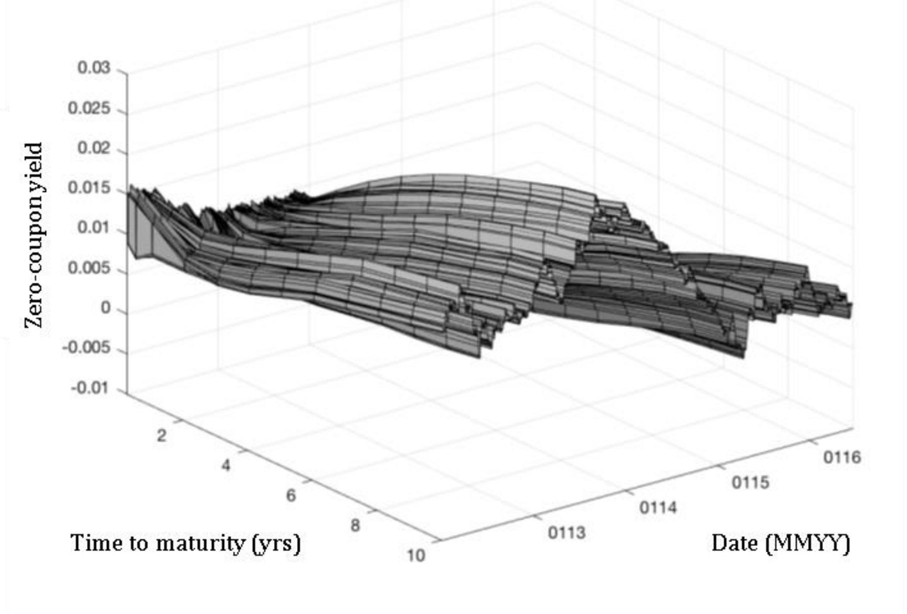
10 Appendix

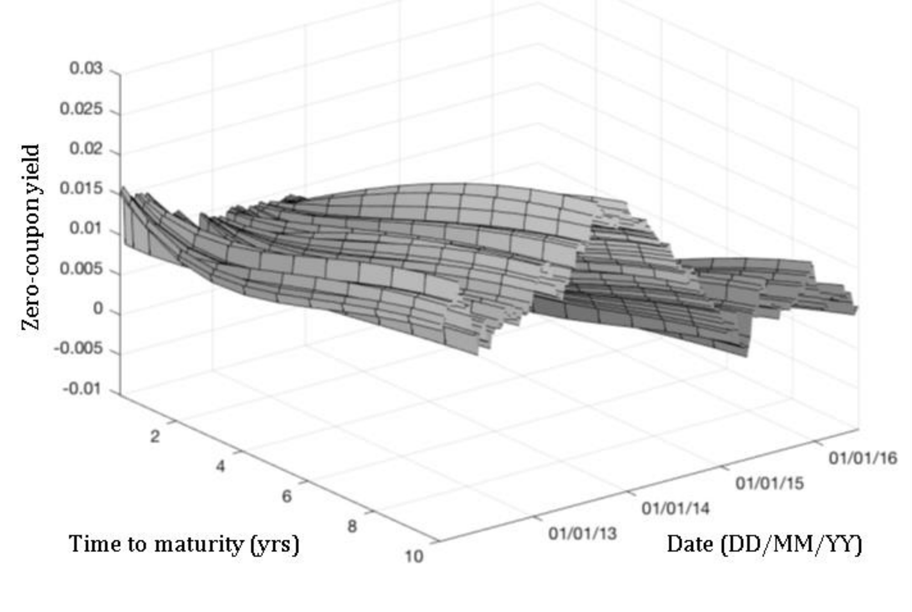
10.1 Estimated government zero-coupon yield curves with all four methods

The following figures illustrate estimated weekly government zero-coupon yield curves for Sweden and Germany during the period Jan 2012 to Jun 2016. For each market we estimate the yield curve with four methods; Bloomberg Piecewise, Bloomberg Polynomial, Nelson-Siegel and Svensson. The surface plots are created in MATLAB.

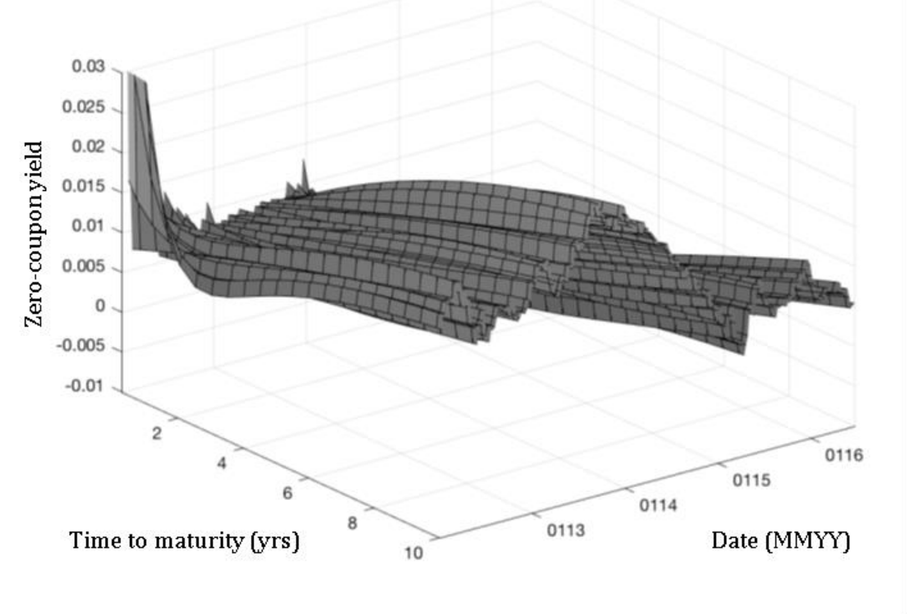
Sweden - Bloomberg Piecewise



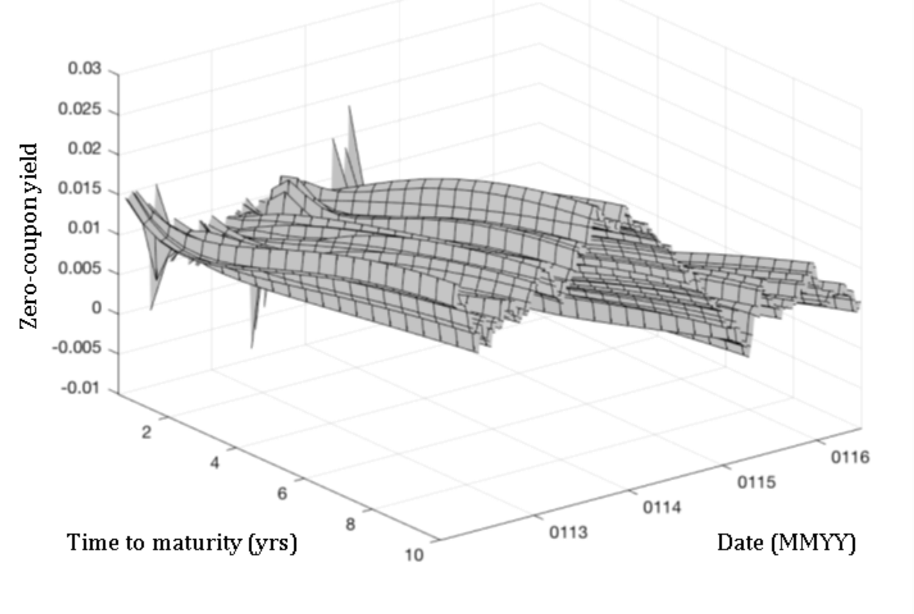
Sweden - Bloomberg Polynomial



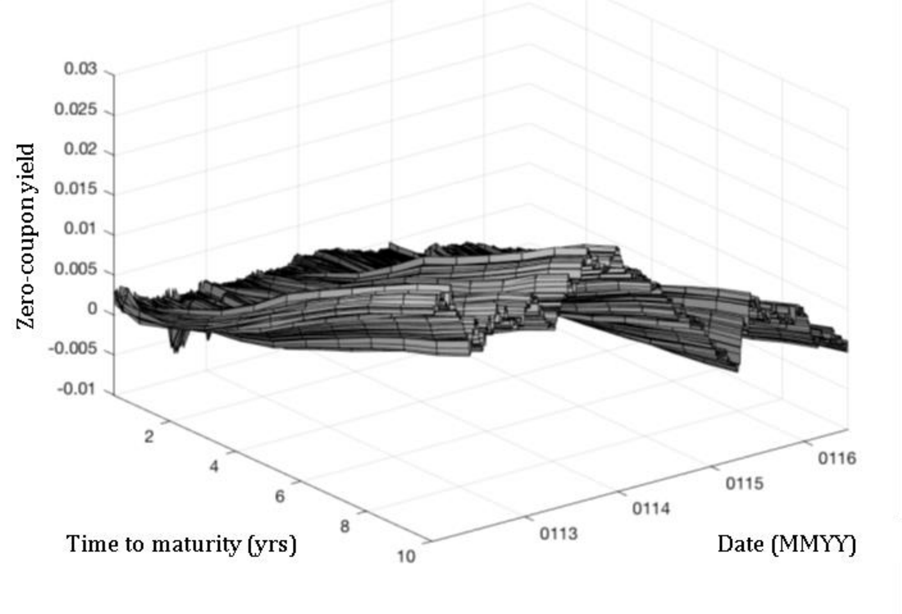
Sweden - Nelson-Siegel



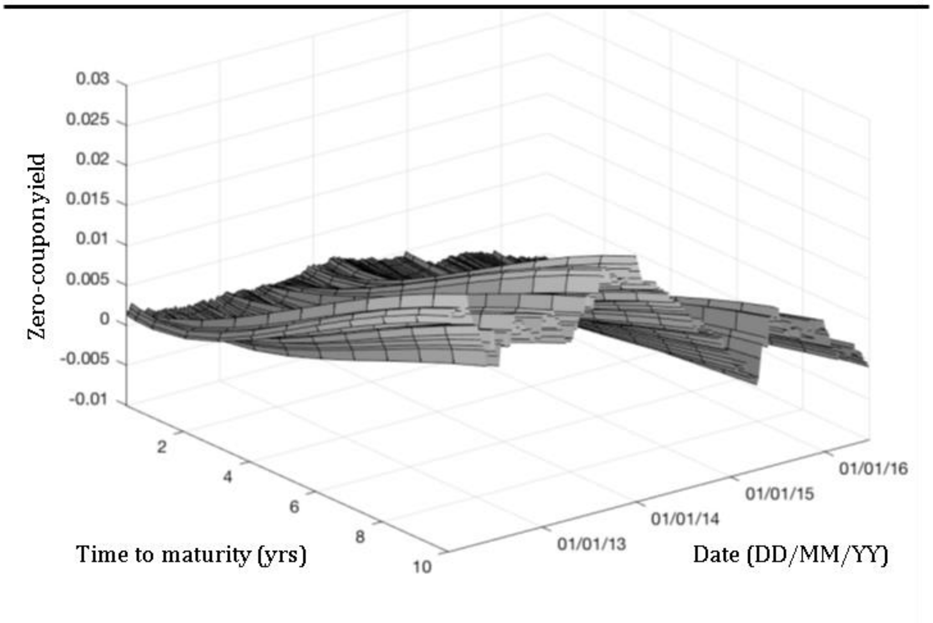
Sweden - Svensson



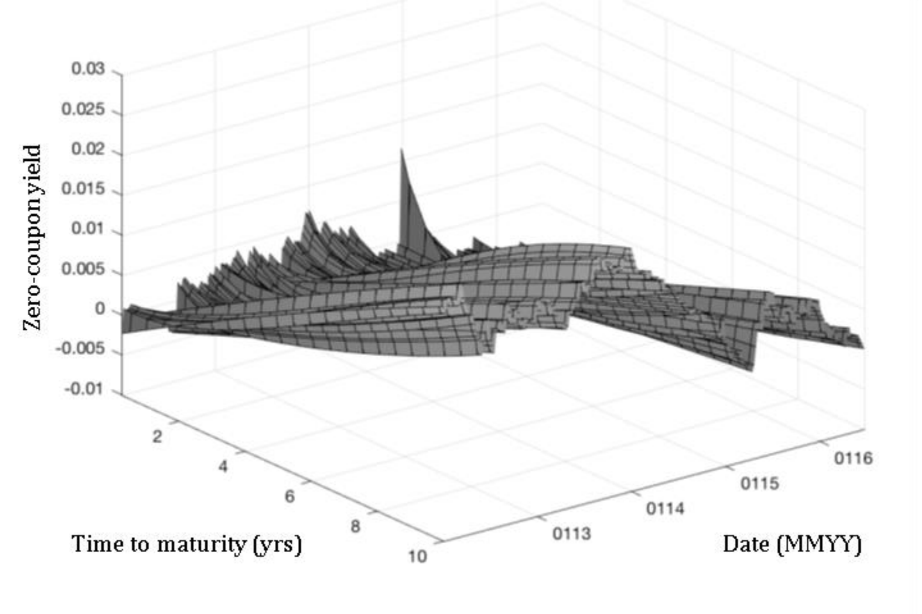
Germany - Bloomberg Piecewise



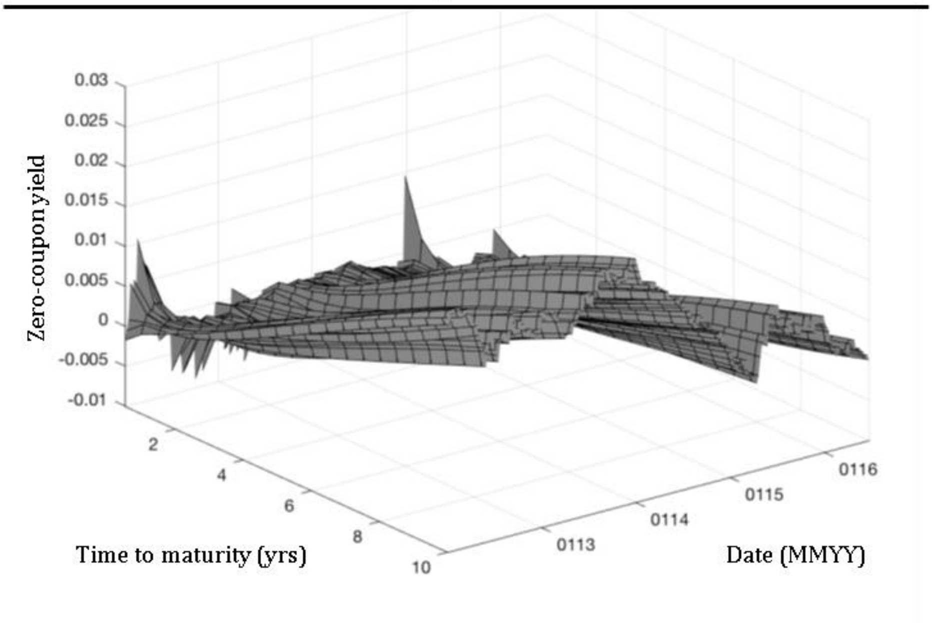
Germany - Bloomberg Polynomial



Germany - Nelson-Siegel



Germany - Svensson



10.2 Correlation matrices for main regression model

Table A1

Correlation matrix and VIFs for independent variables in main regression model - Swedish market

Variables	(1)	(2)	(3)	(4)	(5)	VIF
(1) AgencyBidAsk	1.0000					2.55
(2) CorpYieldSpread	0.0507	1.0000				1.39
(3) MarketBidAsk	0.0303	0.3300***	1.0000			2.07
(4) QE	-0.0549*	0.3979***	0.6014***	1.0000		3.19
(5) LaggedAGS	0.6324***	0.2188***	0.1828***	-0.1300***	1.0000	2.71

*This table shows the correlations and variance inflation factors (VIFs) for all independent variables included in our main regression model. VIFs exceeding 10 are considered to reflect harmful multicollinearity. P-values are indicated as follows: *** p<0.01, ** p<0.05, * p<0.1.*

Table A2

Correlation matrix and VIFs for independent variables in main regression model - German market

Variables	(1)	(2)	(3)	(4)	(5)	VIF
(1) AgencyBidAsk	1.0000					1.97
(2) CorpYieldSpread	0.3177***	1.0000				1.83
(3) MarketBidAsk	-0.0054	-0.0797***	1.0000			1.19
(4) QE	-0.2427***	-0.5827***	0.3505***	1.0000		2.14
(5) LaggedAGS	0.5220***	0.3333***	-0.0391**	-0.2640***	1.0000	1.71

*This table shows the correlations and variance inflation factors (VIFs) for all independent variables included in our main regression model. VIFs exceeding 10 are considered to reflect harmful multicollinearity. P-values are indicated as follows: *** p<0.01, ** p<0.05, * p<0.1.*

10.3 Correlations between yields and QE

Table A3

Correlations between modelled government yield, observed yield and QE - Swedish market

Variables	(1)	(2)	(3)
(1) Modelled government yield	1.0000		
(2) Observed agency yield	0.9807***	1.0000	
(3) QE	-0.4178***	-0.4069***	1.0000

*This table shows the correlations between the modelled yield (based on a hypothetical government bond), the observed yield (based on an agency bond) and the quantitative easing variable for the Swedish market. P-values are indicated as follows: *** p<0,01, ** p<0,05, * p<0,1.*

Table A4

Correlations between modelled government yield, observed yield and QE - German market

Variables	(1)	(2)	(3)
(1) Modelled government yield	1.0000		
(2) Observed agency yield	0.9789***	1.0000	
(3) QE	-0.2789***	-0.3297***	1.0000

*This table shows the correlations between the modelled yield (based on a hypothetical government bond), the observed yield (based on an agency bond) and the quantitative easing variable for the German market. P-values are indicated as follows: *** p<0,01, ** p<0,05, * p<0,1.*

10.4 Robust regressions

Table A5
Results of linear regression analysis with robust standard errors - Swedish market

	Additional models (robust)			*Main model (robust)*
Variables	AGS (1)	AGS (2)	AGS (3)	AGS (4)
AgencyBidAsk	0.0133***		0.0111***	0.00325***
	(0.000457)		(0.000484)	(0.000704)
CorpYieldSpread		0.170***	0.189***	0.0460***
		(0.0303)	(0.0252)	(0.0174)
MarketBidAsk			0.0155***	0.00255**
			(0.00187)	(0.00122)
QE			-0.0410***	-0.00739**
			(0.00432)	(0.00321)
LaggedAGS				0.750***
				(0.0473)
Constant	0.207***	0.438***	0.0122	0.00269
	(0.0265)	(0.0244)	(0.0270)	(0.0220)
Fixed effects	Bond	Bond	Bond	Bond
R-squared	0.578	0.349	0.653	0.863
Adj R-squared	0.574	0.343	0.648	0.861
Observations	999	999	999	999
Bonds	10	10	10	10
Weeks	231	231	231	231

*This table displays results for multivariate regression analyses using an unbalanced panel of agency-government spread (AGS) in the Swedish market. Bond fixed effects are used as controls in all models. Variables are unstandardized coefficient betas. Robust standard errors in parentheses. P-values are indicated as follows: *** p<0.01, ** p<0.05, * p<0.1*

Table A6
Results of linear regression analysis with robust standard errors - German market

	Additional models (robust)			*Main model (robust)*
Variables	AGS (1)	AGS (2)	AGS (3)	AGS (4)
AgencyBidAsk	0.00457***		0.00398***	0.00128***
	(0.000140)		(0.000155)	(0.000238)
CorpYieldSpread		0.305***	0.157***	0.0454***
		(0.0163)	(0.0176)	(0.0117)
MarketBidAsk			0.00410	0.00364
			(0.00536)	(0.00370)
QE			0.00345	0.00223
			(0.00246)	(0.00172)
LaggedAGS				0.685***
				(0.0522)
Constant	0.0879***	0.0718***	0.0354***	0.00617
	(0.00872)	(0.00725)	(0.0125)	(0.00799)
Fixed effects	Bond	Bond	Bond	Bond
R-squared	0.391	0.313	0.406	0.684
Adj R-squared	0.385	0.307	0.400	0.681
Observations	3029	3029	3029	3029
Bonds	29	29	29	29
Weeks	219	219	219	219

*This table displays results for multivariate regression analyses using an unbalanced panel of agency-government spread (AGS) in the German market. Bond fixed effects are used as controls in all models. Variables are unstandardized coefficient betas. Robust standard errors in parentheses. P-values are indicated as follows: *** p<0.01, ** p<0.05, * p<0.1*