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A Guarantee – Does the Obligee Agree?
A Risk Premium Decomposition of Sub-Sovereign Bond Spreads*

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Abstract

The purpose of this paper is to investigate if credit markets believe in the existence of a central government guarantee and if this can be observed in the yield spread of the municipal sector. This is done by decomposing the municipal bond yield spread into liquidity and credit risk premiums by variance decomposition in a vector autoregressive setting – an approach which, to our knowledge, has not been previously suggested. Our results show that 62% or 50 basis points of the yield spread is explained by the chosen liquidity and credit variables. The liquidity risk premium makes up 35% or 28 basis points of the yield spread and credit makes up 27% or 22 basis points. Thus, investors and creditors in general do not believe in the existence of such a guarantee.

JEL Classification: G12, G23, H74

Keywords: Municipality bonds, risk premium, credit risk, liquidity risk, yield spread

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1. Introduction

Sweden has recently been the focus of an international discussion. High levels of immigration and unemployment, an aging population and a housing shortage are factors which are putting a strain on the Swedish social welfare system. Future financial and fiscal challenges will undoubtedly have a disproportional impact on Swedish sub-sovereigns (municipalities and counties) due to the decentralized nature of the Swedish social systems. Therefore, an investigation of the cost of funding of Swedish local governments becomes important. The primary source of funding aside from taxes is issuing debt contracts, either directly or through the local government funding agency Kommuninvest of Sweden (hereafter referred to as Kommuninvest). In an effort to minimize funding costs it is important to identify the market perception of the sector's intrinsic risks. The 1992 central government bailout of the municipality of Haninge contradicted the newly revised Local Government Act (Kommunallag (1991:900)) and introduced an ambiguity in the assessment of credit risk of Swedish municipalities.

The purpose of this paper is to investigate if the capital market believes in the existence of a central government guarantee of Swedish municipalities and if this can be observed in the municipal bond yield spread. More specifically, if the credit risk premium is zero when the spread between bonds issued by Kommuninvest and the Swedish central government is decomposed. Kommuninvest is here used as a proxy for the Swedish municipal sector as a whole and is the best representation of the sector's combined creditworthiness. We derive a more generalized version of the liquidity augmented CAPM first presented in Acharya and Pedersen (2005) to guide us in constructing our model. We then estimate liquidity and credit risk premiums by variance decomposition in a vector autoregressive setting. This is a novel approach which, to our knowledge, has not been previously suggested in this area. There are benefits in investigating yield spreads in a dynamic manner. For instance, changes in market wide liquidity and credit risk are likely to manifest at different rates in the municipal and government bond yields which has mainly to do with differences in liquidity between the markets and that it takes some time for investors to rebalance their portfolios. This difference in the rate of adjustment between bond yields is easier to control for in a dynamic model. Furthermore, in the single equation setting the issues related to spurious regressions are usually dealt with by differencing the variables to achieve stationarity. However, previous authors argue that the differencing of variables discards important information and that the issues associated with spurious regressions are greatly diminished in a VAR setting (Sims (1980), Sims, Stock and Watson (1990), Enders (2014)). The matching of bond maturities becomes problematic due to issued bonds being relatively few and therefore a smoothing spline approach is employed for estimating yield curves and consequently the Kommuninvest yield spread.

A number of empirical studies have decomposed yield spreads into different risk premiums for a number of different markets. However, there has been no consensus regarding the importance of credit vs. liquidity. Michaud and Upper (2008) attempt to estimate the liquidity premium for the US interbank money market in a time series setting without achieving statistically significant results. Similarly, Taylor and Williams (2009) estimated the risk premiums of the spread between the LIBOR and the over-night interbank rate during the 2007-2008 financial crisis. They found that credit risk is the key factor explaining the widening of the spread during this period and that Term Auction Facility had no significant effect on the spread. Schwarz (2018) on the other hand finds that liquidity is the most important factor when investigating the EURIBOR and the overnight-indexed swap rates. Fukuda (2012) investigates the comovement of the TIBOR and LIBOR during the financial crisis and finds that credit and liquidity risk differs between currency denominations. Market-specific credit risk increases the difference across markets, whereas liquidity risk causes the difference across currency denominations. Alexius *et al.* (2014) focus on the Swedish interbank risk premium and show that international variables such as the US and euro area risk premiums are the most important explanatory variables, whereas standard domestic measures of credit and liquidity risk are not statistically significant. The work of Schwert (2017) is argubly the closest related to this paper. The author uses three different empirical approaches of estimating the risk premiums of US municipal bonds and finds that 74 to 84 percent of the average spread is explained by credit risk after adjusting for tax-exempt status. He argues that the typical municipal bond investor is a buy-and-hold retail investor, entailing that trading intensity is low in this market which leads to a high liquidity risk premium. From an academic point of view the investigation of the Swedish municipal bond market is a “cleaner” endeavor relative to that of the United States due to the absence of locally issued tax exemptions which benefit local investors.

The main results show that approximately 62% of the Kommuninvest yield spread is explained by the chosen liquidity and credit variables. Liquidity explains approximately 35% of the spread which amounts to 28 basis points, credit amounts to 27% or 22 basis points and the remaining 38% or 30 basis points remain unexplained by the chosen liquidity and credit variables. The results suggest that there is a discrepancy between the perceived credit risk of the municipal sector and the Swedish government which indicates that the capital market in general does not believe in the existence of a central government guarantee.

The remainder of the paper is organized as follows. In Section 2, the Swedish municipal bond market, Kommuninvest and the difficulties of assessing the credit risk of the sector are briefly discussed. In Section 3, a risk premium augmented theoretical asset pricing model is presented. Section 4 summarizes the yield spread estimation method followed by an overview of the main data. Section 5 presents the chosen variables and the main vector autoregressive models. In Section 6 the results are presented and discussed followed by a sensitivity analysis. Finally, Section 7 concludes.

2. Kommuninvest and the Swedish Municipal Bond Market

Swedish public goods and services are primarily supplied at the local level (municipalities) with the exception of health care which is supplied on the regional level (counties). This decentralized structure is extended to the taxation system; as such Swedish sub-sovereign governments are autonomous with a constitutional right to self-governance and to levy taxes. In recent years the Swedish municipal bond market has grown substantially and is rapidly becoming one of the major sources of financing utilized by the sector. Kommuninvest is a local government funding agency which issues bonds on the global capital markets with the goal of supplying the sector with reliable and cost efficient financing. The agency is owned and jointly guaranteed by its members which as of March 2018 are made up of 277 member municipalities (out of 290 in total) and 11 member counties (out of 21 in total) (Kommuninvest of Sweden, 2018). Membership in Kommuninvest is open for all Swedish sub-nationals but not compulsory. As of 2006 Kommuninvest has been assigned the highest long-term senior unsecured debt and issuer rating by Standard & Poor's (AAA) and likewise by Moody's rating house (Aaa) from 2002. Swedish sub-nationals have historically utilized three financing channels: direct funding by issuing bonds, loans from the major Swedish banks and loans from Kommuninvest. As of 2012 Kommuninvest is the sector's main source of funding and for the year 2017 loans from Kommuninvest made up over 50 percent of the total outstanding debt (Kommuninvest of Sweden, 2017). The high creditworthiness of Kommuninvest is primarily due to the joint guarantee of its members who in turn have taxing power with a substantial share of the Swedish tax base. From a risk perspective Kommuninvest is the best representation of the Swedish municipal sectors combined creditworthiness.

However, a sequence of events occurring in the early 1990s would prove to make the pricing of Swedish municipal bonds somewhat problematic. In 1991 the Swedish Local Government Act (Kommunallag (1991:900)) was revised which resulted in financial deregulation of Swedish municipalities. Financial requirements were removed and replaced by a set of housekeeping requirements which forced municipalities to undertake more stringent financial planning and a more responsible use of resources. The overarching theme of the legislation was to increase municipal accountability in a number of areas. Management of liabilities and other financial risks was further decentralized, signaling that creditworthiness of municipalities should be determined on a case by case basis by creditors and investors. In 1992 the municipality of Haninge faced unforeseen financial difficulties due to miscalculated costs of one of its subsidiaries which resulted in insolvency. The ordeal was resolved by a central government bailout of Haninge through an acquisition of the subsidiary. Consequently, the bailout contradicted the newly implemented legislation and introduced an ambiguity in the assessment of creditworthiness of Swedish municipalities. On the one hand, the revised Swedish Local Government Act signals that the assessment of risk falls on creditors and investors and should be done on a case by case basis. On the other hand, the bailout of Haninge signals that if insolvency occurs in the sector it will be resolved by the central government, thus implying an implicit central government guarantee. If the prior is the predominant view held by creditors and investors then the credit risk premium should differ between the different levels of government with municipal bond yields being higher compared to those of the central government. If the latter is the predominant view then liquidity should account for the whole Kommuninvest yield spread since the credit risk of the municipal sector and the central government are viewed as being one and the same.

3. Credit and Liquidity Risk Augmented Asset Pricing Model

We derive in this section an asset pricing model related to the liquidity augmented CAPM first presented in Acharya and Pedersen (2005), but we follow a different line of argument. In this way, we are able to generalize to an asset pricing model with credit risk. The purpose of such an exercise is primarily to guide our decisions in selecting the appropriate credit and liquidity variables as well as choice of model. We assume that there are no arbitrage opportunities and that markets are complete. This implies that a unique stochastic discount factor m exists, so that all asset prices are determined by expected discounted payoffs (Cochrane, 2005). In order to prevent arbitrage, all future cash-flows of the same size and risk must have the same price today. In equation (1) p_t is the asset price at period t and x_{t+1} is the payoff at period $t+1$:

$$p_t = E_t[m_{t+1}x_{t+1}] \tag{1}$$

$$1 = E_t\left[m_{t+1}\frac{x_{t+1}}{p_t}\right] \tag{2}$$

Equation (2) follows from dividing equation (1) by p_t. Using the fact that $\frac{x_{t+1}}{p_t} \equiv 1 + r_{t+1}$ we get the following expression.

$$1 = E_t[m_{t+1}(1 + r_{t+1})] \tag{3}$$

$$1 = E_t[m_{t+1}] + E_t[m_{t+1}r_{t+1}] \tag{4}$$

Equation (4) follows from the fact that the expectation operator can be applied separately on every term of a summation. The relationship must hold for all assets including the risk-free asset. Since the asset is risk-free we know its future value with certainty and thus we can move r_f outside of the expectation operator. For the risk-free asset, equation (4) becomes:

$$1 = E_t[m_{t+1}] + E_t[m_{t+1}]r_f \tag{5}$$

Subtracting (5) from (4), we get:

$$0 = E_t[m_{t+1}r_{t+1}] - E_t[m_{t+1}]r_f = E_t[m_{t+1}r^e_{t+1}] \tag{6}$$

where $r^e_{t+1} = r_{t+1} - r_f$. Hence, expected discounted excess returns are zero. The market price in the absence of arbitrage is zero for a strategy that borrows at r_f and buys a risky asset that has a return r_{t+1}, since it is a zero net investment. Furthermore, this implies that:

$$0 = E_t[m_{t+1}r^e_{t+1}] = E_t[m_{t+1}]E_t[r^e_{t+1}] + Cov(m_{t+1}, r^e_{t+1}) \tag{7}$$

We assume that the risk-free rate is close to zero over short time interval and therefore we can approximate the expected discount factor by unity, i.e. $E_t[m_{t+1}] \approx 1$. Furthermore, we acknowledge that the risk-free rate has no covariance with the stochastic discount factor. Hence, we can write:

$$E_t[r_{t+1}^e] = -Cov(m_{t+1}, r_{t+1}) \tag{8}$$

$$E_t[r_{t+1}^e] = -\frac{Cov(m_{t+1}, r_{t+1}^e)}{\sigma_m^2}\sigma_m^2 \tag{9}$$

If we assume that the stochastic discount factor can be approximated by a linear function of aggregate wealth growth (the market return):

$$m_{t+1} = a - br_{t+1}^M \tag{10}$$

We get the following expression for Equation (9):

$$E_t[r_{t+1}^e] = \frac{Cov(r_{t+1}^M, r_{t+1}^e)}{\sigma_M^2} b\sigma_M^2 \tag{11}$$

We can now write the expression in equation (11) in the usual beta notation since the risk-free rate has zero covariance with the market, so that beta is defined in terms of covariance and variance with the market return and denoting $\lambda = b\sigma_M^2$:

$$E_t[r_{t+1}^e] = \beta\lambda \tag{12}$$

The beta for the market is equal to unity since by definition the market is the weighted average portfolio. Hence, we can identify $\lambda = b\sigma_M^2$ as the market excess return, i.e. the market risk premium:

$$E_t\left[r_{t+1}^{M,e}\right] = b\sigma_M^2 \tag{13}$$

Hence, the market risk premium is determined by the market variance times a parameter measuring the impact of market returns on the stochastic discount factor. Furthermore, expected individual asset returns are equal to market risk measured by beta times the market risk premium.

We assume now that investors in equilibrium care about asset returns net of costs, as proposed in Acharya and Pedersen (2005). In our framework this implies that the stochastic discount factor m_{t+1} can be linearly approximated by the market return net of transaction costs. At this point we deviate from Acharya and Pedersen (2005) and propose to see costs as a more general cost from holding a risky asset which incorporates both transaction costs (liq) and expected costs from credit loss (def). More specifically, we assume that the stochastic discount factor can be approximated as:

$$m_{t+1} = a - b_M r_{t+1}^M - b_{liq} liq_{t+1}^M - b_{def} def_{t+1}^M \tag{14}$$

Note that this implies that expected excess returns are now defined as $E_t[r_{t+1}^e] = E_t[r_{t+1} - liq_{t+1} - def_{t+1}] - r_f$, since investors in equilibrium care about asset returns net of transaction costs and credit losses, i.e. $r_{t+1} - liq_{t+1} - def_{t+1}$. Substituting (14) into (8) we get:

$$E_t[r_{t+1}^e] = -Cov\left(a - b_M r_{t+1}^M - b_{liq} liq_{t+1}^M - b_{def} def_{t+1}^M, r_{t+1} - liq_{t+1} - def_{t+1}\right) \tag{15}$$

Since covariances are additive, we can conclude:

$$\begin{aligned} E_t[r_{t+1}^e] = {} & b_M Cov(r_{t+1}^M, r_{t+1}) + b_M Cov(r_{t+1}^M, liq_{t+1}) + b_{liq} Cov(liq_{t+1}^M, r_{t+1}) \\ & + b_{liq} Cov(liq_{t+1}^M, liq_{t+1}) + b_M Cov(r_{t+1}^M, def_{t+1}) \\ & + b_{def} Cov(def_{t+1}^M, r_{t+1}) + b_{def} Cov(def_{t+1}^M, def_{t+1}) \\ & + b_{liq} Cov(liq_{t+1}^M, def_{t+1}) + b_{def} Cov(def_{t+1}^M, liq_{t+1}) \end{aligned} \tag{16}$$

By multiplying (16) with $1 = \sigma_m^2 / \sigma_m^2$ we get the usual beta notation:

$$\begin{aligned} E_t[r_{t+1}^e] = {} & \beta_{r(M),r} b_M \sigma_m^2 + \beta_{r(M),liq} b_M \sigma_m^2 + \beta_{liq(M),r} b_{liq} \sigma_m^2 + \beta_{liq(M),liq} b_{liq} \sigma_m^2 \\ & + \beta_{r(M),def} b_M \sigma_m^2 + \beta_{def(M),r} b_{def} \sigma_m^2 + \beta_{def(M),def} b_{def} \sigma_m^2 \\ & + \beta_{liq(M),def} b_{liq} \sigma_m^2 + \beta_{def(M),liq} b_{def} \sigma_m^2 \end{aligned} \tag{17}$$

In a more compact notation, with λ_M, λ_{liq} and λ_{def} denoting the risks associated with aggregate wealth growth, liquidity and credit, respectively, we get:

$$\begin{aligned} E_t[r_{t+1}^e] = {} & \beta_{r(M),r} \lambda_M + \beta_{r(M),liq} \lambda_M + \beta_{liq(M),r} \lambda_{liq} + \beta_{liq(M),liq} \lambda_{liq} + \beta_{r(M),def} \lambda_M \\ & + \beta_{def(M),r} \lambda_{def} + \beta_{def(M),def} \lambda_{def} + \beta_{liq(M),def} \lambda_{liq} + \beta_{def(M),liq} \lambda_{def} \end{aligned} \tag{18}$$

Equation (18) is the credit and liquidity risk augmented asset pricing model with 4 liquidity betas and 4 credit betas besides the usual market beta. We also have 3 different risk premiums, for bearing the risk of low market returns, high market-wide transactions costs and high market-wide credit losses, respectively.

The expected return of a risky asset (net of holding costs) is determined by the asset's market beta, but is also determined by how the asset's transaction costs varies with the market return, how asset returns vary with market transaction costs and how the asset's transaction costs vary with market transaction cost. Analogously, expected returns are moreover determined by how the asset's credit losses vary with market returns, how the asset's returns vary with market-wide credit losses and how the asset's credit losses vary with market credit losses.

Interestingly, we find two more channels through which credit and liquidity can affect asset prices: expected returns are also determined by how the asset's credit losses vary with market liquidity, and by how an asset's transaction costs vary with market-wide credit risk. This seems reasonable, since in bad times when liquidity in the market dries up, we prefer assets that have low credit losses at the same time as market-wide transactions costs are rising. Analogously, we prefer assets that have low transaction costs (e.g. are easy to sell) at the same time as market-wide credit losses are rising.

Equation (19) leads to insights about the different channels through which liquidity and credit risk affect asset returns. Considering that there is a possible correlation between liquidity and credit risk might explain the somewhat contradictory evidence in the previous literature, which seems to suggest it is difficult to disentangle credit and liquidity risk. We can write Equation (19) as:

$$E_t[r_{t+1}^e] = (\beta_{r(M),r} + \beta_{r(M),liq} + \beta_{r(M),def})\lambda_M + (\beta_{liq(M),r} + \beta_{liq(M),liq} + \beta_{liq(M),def})\lambda_{liq} + (\beta_{def(M),r} + \beta_{def(M),def} + \beta_{def(M),liq})\lambda_{def} \quad (19)$$

In order to further evaluate the theoretical model, we aggregate over betas (since betas are additive) without restricting the channels through which market risk factors affect individual asset returns, and get the following empirically testable equation:

$$E_t[r_{t+1}^e] = r_f + \beta\lambda_M + \beta_{liq}\lambda_{liq} + \beta_{def}\lambda_{def} \quad (20)$$

Analogous to λ_M, which is the market risk premium, λ_{liq} and λ_{def} are risk premiums for holding liquidity risk and default risk, respectively. Both factor risk premiums can be approximated by so-called factor portfolios with high loadings on liquidity and credit risk and low loadings on other factors. Since r_{t+1}^e=$r_{t+1} - r_f - liq_{t+1} - def_{t+1}$, we get:

$$E_t[r_{t+1}] - r_f = E_t(liq_{t+1}) + E_t(def_{t+1}) + \beta\lambda_M + \beta_{liq}\lambda_{liq} + \beta_{def}\lambda_{def} \quad (21)$$

The fact that expected liquidity and credit loss costs are included together with systematic risk costs is consistent with the fact that investors do not care about asset specific volatility, so that only the marginal effect on a well-diversified portfolio is considered in market equilibrium. That is, idiosyncratic volatility in liquidity and credit risks are disregarded. Equation (21) is our main theoretical model which gives us guidance in constructing the empirical methodology, more specifically in selecting the appropriate risk factor variables. It gives us a factor pricing model in terms of risk factor sensitivities and factor risk premiums. For highly liquid, AAA-rated government bonds, where the average investor (although not all) are buy-and-hold, we would expect the asset specific liquidity and default costs to be negligible but they still might exhibit covariance with market-wide liquidity and credit risk.

The variation in returns can stem from the cross-section of asset returns, that is, variation caused by assets' differing risk factor exposure. The variation can also stem from time series of asset returns, that is, variation caused in a conditional model by time-varying factor betas or time-varying risk premiums.

The main difference between the model presented here and the liquidity augmented CAPM is that the latter assumes that asset markets are in equilibrium and as a result liquidity costs must matter in equilibrium. We assume instead that markets do not have riskless arbitrage opportunities, which is less restrictive. It follows that a unique stochastic discount factor exists which can be approximated by the risk factors market, liquidity and credit employing a statistical approach based on observed variation in asset prices. A crucial difference in model predictions in addition to the credit-related channels affecting asset prices, is that in Acharya and Pedersen (2005) the risk premium is the same for holding market risk and liquidity risk. In contrast, in our model the risk premiums for market, liquidity and credit risk are differing and determined by the data.

To summarize, the main model implications are:

- Credit losses and transaction costs have a direct effect on asset returns.
- Systematic risk matters - not only the correlations with market returns, but also correlations with market-wide liquidity risk and credit risk affect asset returns.
- There are different channels through which credit risk and liquidity risk affect asset prices.
- In many cases, correlation with market credit losses and market liquidity costs might be more important than individual credit risk and transaction costs; from a portfolio perspective it is important to control non-diversifiable risk.
- Since the risk-free asset by definition has zero correlation with the market, a positive correlation of a bond with market credit risk is evidence of credit risk.
- By definition, $r_f + CDS = E[r]$ in the absence of transaction costs, or equivalently, $E[r] - r_f = CDS$. The CDS-rate therefore both contains expected credit loss (the hazard rate multiplied by 1 minus the recovery rate) and systematic risk, that is, how asset returns are correlated with both market returns and market credit losses. This is evident when comparing historical default probabilities and default rates implied by CDS-rates: for AAA-rated bonds the historical default probabilities are close to zero, whereas the implied default probabilities from bond CDS is around 0.5%, about 17 times the historical risk (Hull, 2017). Thus, systematic credit risk costs are generally higher than expected credit loss based on empirical evidence. Timing with bad times matters; when government bonds default it is at times that investors really do need a safe haven the most. It also implies that we need to control for the apparent credit risk in government bonds to discern credit risk in other bonds.
- Notice that the market comprises all public and nonpublic assets regardless geographical boundaries, since all financial markets are closely interlinked today. That is the deep notion of systematic risk; even the US credit spread is expected to explain Swedish municipal bond returns as long as they are exposed to credit risk.

4. Data

4.1 Yield Spread Estimation

In this part of the section we outlay the estimation methodology of the Kommuninvest yield spread. The focus will be on investigating the spread at 5 year residual time to maturity. The 5 year bond is close to the mean of the maturity structure of the Kommuninvest funding portfolio and thus yield anomalies occurring at the ends of the term structure due to, for instance repurchasing of bonds, will be of less concern. Due to the number of issues being relatively few the direct matching of residual bond maturities becomes problematic and therefore yield curves of both Kommuninvest and Swedish government bonds are estimated using the smoothing spline approach. Using spline-based techniques for estimating term structures have a long history and have been investigated by numerous researchers (McCulloch (1971), McCulloch (1975), Fong and Vasicek (1982), Shea (1984), Fisher, Nychka and Zervos (1995)). The smoothing spline is a modified version of the cubic spline with an added smoothing component which stiffens and reduces the wiggle of the cubic spline function.[1] This is of benefit for the estimation of the Kommuninvest yield in particular since the portfolio consists of bonds issued both in Sweden and Luxembourg which periodically leads to bonds with similar residual maturities having slightly different yields. Increasing the smoothing of the function reduces the impact of this difference on the curve. As discussed by Fong and Vasicek (1982) the stiffening of the curve reduces the oscillation of short term forward rates which was a shortcoming of the cubic spline regression method of McCulloch (1975). However, this also results in mispricing of short term bonds as shown by Bliss (1997). Nevertheless, these problems are of little concern for the applications in this paper. The yield curve and spread estimation methodology is further discussed in appendix A.

The benefits of a spline based approach over a parametric bond pricing models such as Nelson and Siegel (1987) and Svensson (1994) has mainly to do with accuracy since the parametric family of models forces a specific functional form to the data. This is by construction, since a limited number of parameters will limit the accuracy of the function when the number of observations increase. This point is also discussed in the original work of Nelson and Siegel (1987), the fact that the number of parameters in the cubic spline exceeds the number of observations ensures a good fit and maximizes smoothness.[2] The characteristics of the Nelson and Siegel model can be beneficial when yield curves are estimated for portfolios with a large number of bonds and issuers where the conditional variance in the yields is large. In addition, from a policy perspective there are benefits in terms of communication of using parsimonious models with easily interpretable parameters, whereas a spline can in many ways be perceived as a black-box. We recognize the benefits and the wide use of these models and therefore perform a sensitivity analysis on yield spreads

[1] See Waggoner (1997) for a discussion regarding the benefits and shortcomings of the smoothing spline approach.

[2] Notice, introducing a smoothing parameter to the standard cubic spline will increase smoothness but also reduce accuracy of the function. In addition, some spline techniques entail selecting fewer knot points than in the standard case and thus the number of observations may exceed the number of parameters. Adams and van Deventer (1994), van Deventer and Imai (1997) and van Deventer *et al.* (2004) define accuracy as an exact fit to all “good” data and argue that it is a mathematical fact that the smoothest line which can be fit to four yield curve points is the cubic spline.

estimated by the Nelson and Siegel (1987) model. Figure A1 and A2 in appendix A depicts the yield curves estimated by both methods with 180 day increments starting at 3rd of October 2011 and ending at 12th of October 2016.

In the next part of this section the main price and yield data cleaning method is overviewed followed by a brief summary of the data.

4.2 Price Data Cleaning and Summary

The data presented in this part of the section are of a daily frequency whereas the data used in the main analysis are of a monthly frequency. The reason for this is that some liquidity measures used for the risk premium decomposition are not available with a daily frequency which forces us to either interpolate data intra-month or to reduce the frequency of the price data. We have chosen to do the latter since it does not introduce artificial autocorrelations. Nevertheless, we feel that presenting the data at a daily frequency is more informative to the reader and in order to determine whether a lower frequency leads to smoothness and thus lower variability in the data.

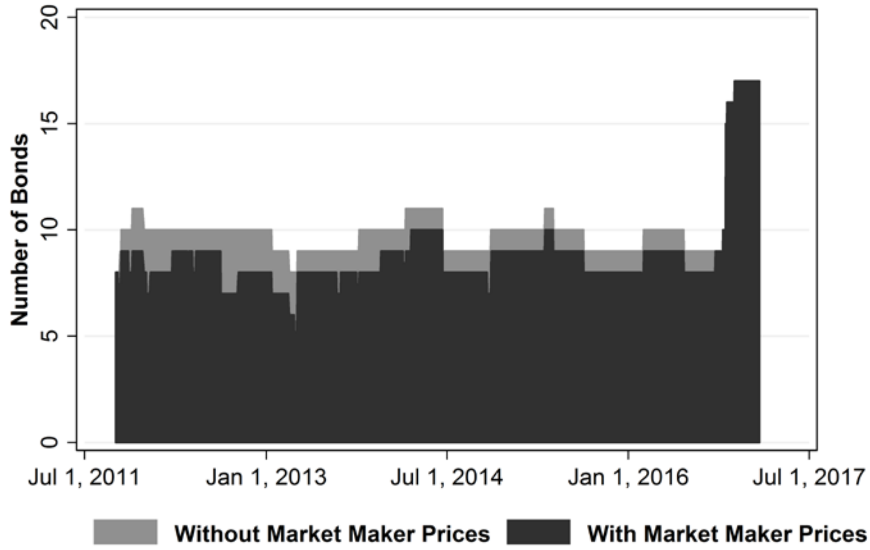
The main data on Kommuninvest bonds consist of daily closing prices for all SEK denominated, fixed coupon bonds available from Bloomberg between 3rd of October 2011 and 31st of January 2017. In total there are 30 bonds issued, 12 in Sweden and 18 in Luxembourg. We primarily use daily prices listed by one of the four major Swedish banks and Danske Bank.[3] The banks all have market maker agreements with Kommuninvest which implies that trades are executable at the listed prices.[4] If more than one market maker price is listed then the mean price is calculated. If no market maker price is listed then the Bloomberg generic price (BGN) is used, which is a weighted average of price sources available to Bloomberg. Finally, if BGN is not available then the Bloomberg evaluated pricing service (BVAL) is used, which utilizes reference data to price fixed income securities.[5] Since bid-ask spreads can differ across price sources we use mid-prices, defined as the midpoint in the bid-ask interval. These turn out to be relatively stable across price sources in our sample. The number of bonds with listed prices has stayed relatively stable over the sample period with the exception of the period following the 21st of October 2016 when Kommuninvest issued 5 bonds with the same coupon rate and consecutive maturity dates. Figure 1 depicts the number of bonds by price availability across time.

[3] Realized trade data would be the preferred choice, unfortunately this type of data is unavailable to us.

[4] The market maker agreements particularly applies to the 11 Kommuninvest benchmark bonds issued in Sweden.

[5] In this setup we primarily treat BVAL as preferable to interpolation. For further discussion of the use of BVAL prices see Arsov *et al.* (2013).

Figure 1 Number of Kommuninvest Bonds per Price Source,
3rd of October 2011 to 31st of January 2017, Daily Frequency

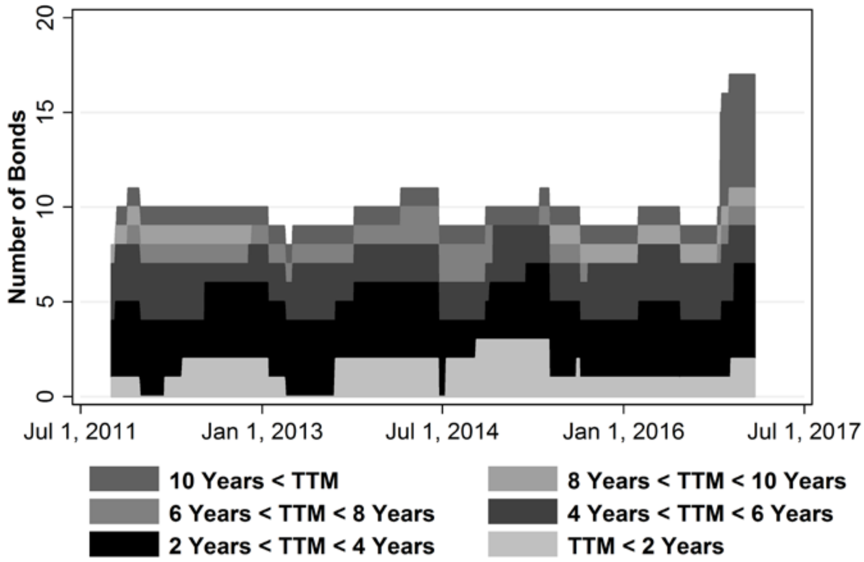


The data has been cleaned by removing any prices reported prior to the issue date and prices of bonds with residual maturities less than 12 months. The reason for this is that Kommuninvest typically issues a refunding provision to repurchase issued bonds during the last 16 months of maturity which significantly impacts the yields. However, typically the volumes repurchased increase closer to maturity and therefore the impact on the yield during the initial 4 months is small relative non-repurchased bonds. In addition, these bonds help us tie down the short end of the yield curve. Thus, there is a tradeoff between retaining as many bonds as possible in the data without jeopardizing the estimation due to wide yield fluctuations at the short end of the yield curve. We have further removed prices from sources that periodically deviate from both their own previous and following prices, as well as from prices from other available sources.[6] For the daily data set a total of 53 such exclusions have been made. These types of deviations are probably due to registration errors. Using trade dates as reported by NASDAQ we have 1338 trade dates and 13439 observed prices on Kommuninvest bonds.

The face value of the bonds issued varies from 50 million SEK (5.6 million USD) to 32 billion SEK (3.6 billion USD) with an average issuing volume of 9 billion SEK (996 million USD). The bond term ranges from 2 to 25 years with an average of 8.8 years. Figure 2 depicts the number of bonds categorized by residual maturity across time.

[6] The omission-threshold is a minimum of 20 basis points deviation in all dimensions.

Figure 2 Number of Kommuninvest Bonds per Residual Time to Maturity, 3rd of October 2011 to 31st of January 2017, Daily Frequency



The estimated yield curves suggest that there are some differences in yields between Kommuninvest bonds issued on the Swedish and Luxembourg markets. These differences can be the result of differences in market factors such as liquidity but also due to structural differences between the two countries. In addition, bonds issued in Sweden are also part of the Kommuninvest benchmark program which implies that the general volumes issued are larger which in part could explain this difference. However, cross-sectional difference between Kommuninvest bonds are negligible in comparison to the yield spread between Kommuninvest and the Swedish government. The estimated yield curves depicted in Figures A1 and A2 in appendix A illustrate these slight cross-sectional differences. Government bond prices have been collected from Bloomberg for all available fixed coupon, non-inflation adjusted Swedish government bonds. Over the sample period there are 14 bonds available with maturities ranging from less than 1 year to over 10 years. Figure 3 depicts the evolution of the Kommuninvest and government 5 year yields and Figure 4 depicts the evolution of the spread. Figure A3 and A4 in appendix B show the evolution of the variables when yields are estimated by the Nelson and Siegel (1987) model.

Figure 3 Evolution of Kommuninvest and Government Yields Estimated by Spline, 3rd of October 2011 to 31st of January 2017, Daily Frequency

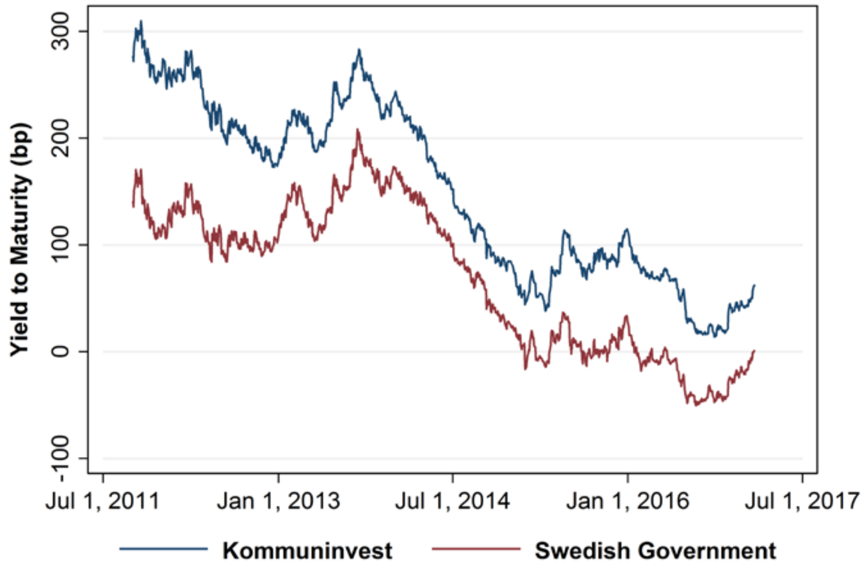
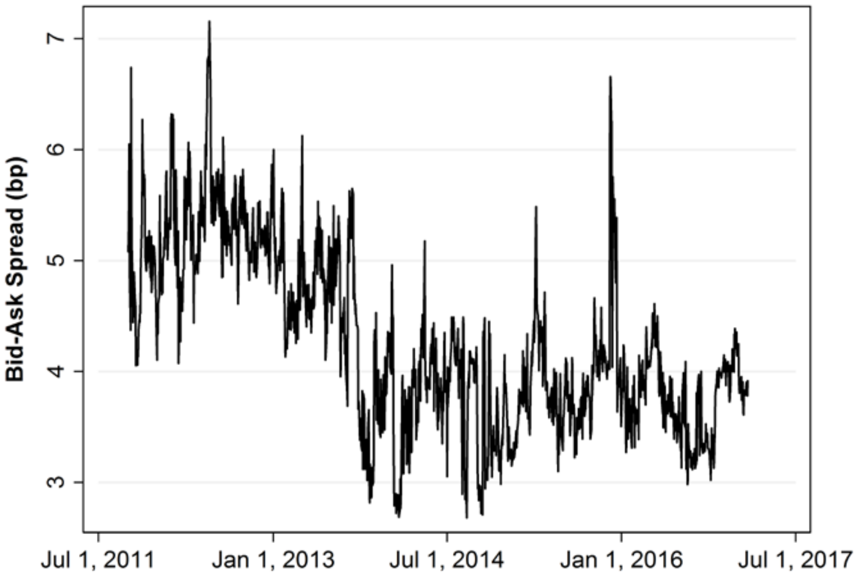


Figure 4 Evolution of Kommuninvest Yield Spread Estimated by Spline, 3rd of October 2011 to 31st of January 2017, Daily Frequency

Bid-ask spreads vary considerably across pricing sources for the same bond. To avoid noise and to get a comparable estimate the bid-ask spread reported in BVAL is used, which is the only price source that has data for all dates and bonds. We conclude that given the variability in the other price sources choosing the BVAL measure is the best option available to us. The evolution of the bid-ask spread is depicted in Figure 5.

Figure 5 Evolution of Kommuninvest Mean Bid-Ask Spread, 3rd of October 2011 to 31st of January 2017, Daily Frequency



Tables 1 and A1 in appendix B summarize the price and yield data on monthly and daily basis for both estimation methods and the results are quite similar. The variable value on the last trade day of the month becomes the corresponding observation of that month when moving from daily to monthly frequency. The average Kommuninvest yield is 80.3-83.4 basis points above the government yield depending on the estimation method chosen.

Table 1 Summary Statistic for Price and Yield Data, October 2011 to January 2017, Monthly Frequency

Variable	Average	Standard Deviation	Min	Max	Observations
Kommuninvest 5 Year Yield (‱) (Spline)	149.180	83.509	14.252	301.403	N = 64
Government 5 Year Yield (‱) (Spline)	68.923	70.405	-47.413	183.298	N = 64
Kommuninvest Yield Spread (‱) (Spline)	80.257	25.727	45.838	150.203	N = 64
Kommuninvest 5 Year Yield (‱) (Nelson-Siegel)	154.758	83.165	21.654	299.049	N = 64
Government 5 Year Yield (‱) (Nelson-Siegel)	71.362	70.122	-47.415	185.488	N = 64
Kommuninvest Yield Spread (‱) (Nelson-Siegel)	83.396	26.362	36.259	146.004	N = 64
Bid-Ask Spread (‱)	4.226	0.833	2.690	6.194	N = 64

As of the 18th February, 2015 the Riksbank announced that the policy rate would be lowered to -0.1 percent. This effect can also be observed in Tables 1 and A1 since the minimum government yield is negative which is also illustrated by Figure 3. The government bond yields are periodically negative from 12th of February to 31th of May for the year 2015, at which point this becomes more frequent. The summary statistics show that the data is quite stable when the frequency is changed from daily to monthly and notably, the standard deviations are almost unchanged despite the vast reduction of number of observations, which is beneficial for our analysis since we intend to explain variations in the data.

In the following section the chosen liquidity and credit variables are presented followed by a discussion regarding the methodology.

5. Methodology

In this section the credit and liquidity variables are presented followed by an outline of the model of choice.

5.1 Credit Variables

Estimating the Kommuninvest specific credit risk becomes quite difficult in this setting for a number of reasons. The method chosen only allows for estimation in the time dimension. Thus, using cross sectional variation in credit ratings as a proxy for credit risk is not possible. In addition, the credit rating of Kommuninvest has been constant during the sample period.

Credit Default Swap Spread

We follow the example of Longstaff *et al.* (2005), Michaud and Upper (2008), Alexius *et al.* (2014) and Schwert (2017), amongst others, and attempt to estimate the Kommuninvest specific credit risk premium using CDS spreads. Unfortunatly, there exists no traded CDS on Kommuninvest issued securities. As a second best option we calculate the 5 year CDS spread between the mean CDS rate of the four major domestic Swedish banks and Danske Bank and the CDS rates of the Swedish government. This approach is somewhat different from previous research but makes sense due to Kommuninvest being a hybrid between a public institution and a financial credit institution. On the one hand, the high creditworthiness of Kommuninvest is primarily due to the tax base of its members which comprise a large share of the Swedish national tax base and that the institution is guaranteed by its members which have taxing power. From this perspective the foundation of the Kommuninvest creditworthiness is not that different from that of the Swedish central government. On the other hand, Kommuninvest is required to abide by the same financial legislation, both domestic and international, as other financial institutions and is competing on the same international credit markets. Thus, it is expected that the hypothetical Kommuninvest CDS rate should reside somewhere in between the government and the mean bank CDS rates. The CDS rates are highly correlated with a coefficient of 0.92 which indicates that the variables capture the market-wide credit risk and according to the theoretical model of Section 3, both market-wide (systematic) risk and idiosyncratic expected losses of default are priced. Furthermore, the correlation between Kommuninvest yield and government CDS rate is higher than the government yield and CDS rate correlation by a factor of approximately two, 0.473 and 0.247 respectively. This is in line with the argument in Amihud (2002), i.e. a security which is risky in one dimension will also be sensitive to variation in that particular risk factor. This validates our approach to use the CDS spread between the Swedish banking sector and the Swedish government and we expect that the spread is a good predictor of the Kommuninvest specific credit risk. The CDS spread is expected to have a positive impact on the yield spread since an increase in systematic credit risk is expected to have a greater impact on more risky securities, implying that Kommuninvest yield will increase more than the government yield, widening the spread. All CDS rates are collected from Bloomberg where Figure A5 and A6 in appendix C show the evolution of these on a daily frequency.

Bankruptcies

The monthly number of bancruptcies of Swedish limited liability companies is collected from Macrobond, published by Creditsafe. This measure is a cumulative variable which sums all bancruptcies at the end of each month and is intended to more clearly capture the systemic risk of default. Although the variable is in levels and not represented as a ratio of all Swedish companies we expect it to be relatively stable due to the short time-span. This implies that we expect the total number of Swedish companies to be relatively stable over the period so that the number of bancruptcies reflects the probability of default. The yield spread is expected to be positively correlated with the number of bancruptcies since an increase in the latter would indicate an increase in default risk in the economy. Figure A7 in appendix C depicts the evolution of the measure and concludes that it is relatively stable.

Leverage Ratio

Finally, we follow the example of Nielsen *et al.* (2012) and calculate a monthly leverage ratio using funding, lending and investment data provided by Kommuninvest. The measure is calculated as the ratio between Kommuninvest debt and the sum of loans to Swedish sub-sovereigns and investments. Unfortunatly, there is no availible monthly data on Kommuninvest equity since there are no traded shares and the assets of Kommunivest are the face-value instead of the market value of loans. Thus the measure we use is a combination of the leverage ratio and debt to asset ratio. Nevertheless, we expect the measure to capture the degree of leverage of the organization sufficiently well and thus to be positively correlated with the yield spread. The evolution of the measure is depicted by Figure A8 in appendix C.

5.2 Liquidity Variables

Liquidity is a multifaceted phenomenon which is difficult to control for. Sarr and Lybek (2002) argue that liquidity can be characterized by 5 different characteristics: tightness, immediacy, depth, breadth and resilience, at least three of which are controlled for by the following liquidity variables. In the following part of the section the liquidity variables are presented and briefly discussed.

Yield Impact

The first liquidity measure is a yield adjusted version of the modified Amihud measure developed by Dick-Nielsen et al. (2012b), based on the work of Amihud (2002). Calculation of the Amihud measure requires transaction prices which are not available to us. Instead the measure is provided by the Swedish financial supervisory authority, Finansinspektionen. It is calculated for Swedish government bonds and published semiannually in a financial stability report (Finansinspektionen, 2015). By convention bonds on the Swedish credit market are typically traded on yield rather than on price and therefore the original modified Amihud measure is slightly adjusted to account for this. The measure captures the impact of changes in liquidity on government bond yields. Yield impact is calculated as the absolute return differences of two successive transactions. A high yield impact indicates that the yield of the asset is substantially affected by an additional transaction, which in turn indicates a high transaction cost and that the asset may be illiquid. In our setting the idea is that the measure captures the underlying market liquidity and therefore is highly correlated with Kommuninvest specific liquidity. The Kommuninvest yield has a higher correlation with all credit and liquidity measures compared to the government yield. Additionally, Kommuninvest securities are together with Swedish government bonds considered as level-1 assets (highest quality) in both domestic and European legislation regarding liquidity coverage ratios. This indicates that both securities are considered substitutes from a legislative perspective and that banks should be indifferent between the two with respect to abiding by the legislation. Thus, the legislation should affect both securities uniformly and the yields of both are expected to respond similarly, although not identically, to changes in market liquidity. As discussed previously, since there is a mismatch between the frequencies of the price and yield specific variables and the yield impact measure we have chosen to reduce the data to a monthly basis. The evolution of the average monthly yield impact is depicted in Figure A9 in appendix C. An increased yield impact implies lower liquidity and therefore it is expected to have a positive effect on the yield spread.

Mean Bid-Ask Spread

A number of authors over the years have researched the connection between bid-ask spreads and asset prices but arguably the first authors to attribute this connection to liquidity was Amihud and Mendelson (1986). They argue that liquidity may be measured by the cost of immediate execution. An investor willing to buy or sell a specific asset has two choices. The investor can either accept the current bid-ask price and make the transaction or wait for prices to become more favorable to make the transaction. Thus, the spread between the two prices is a natural measure of liquidity. As discussed by Sarr and Lybek (2002), transaction costs can be distinguished between explicit costs such as order processing costs and taxes associated with the trade, and implicit costs. The bid-ask spread incorporates both of these types of costs and a low spread is typical for a deep, broad and rescilient market. Issuers may rely on one or more market makers to facilitate trades and uphold liquidity of the specific asset. Market makers hold a substantial share of bonds and are required to post daily bid and ask (offer) prices at which they are willing to execute trades. In this case the bid-ask spread represents the transaction cost of the market maker which in turn reflects the compensation for the risk of holding the asset an uncertain amount of time. Thus, a highly liquid asset will have a lower bid-ask spread since the average holding period of the market maker will be short and vice versa. In the case of the Kommuninvest Swedish benchmark issuance program all four major domestic banks and Danske Bank act as market makers. We use the daily reported BVAL spread from Bloomberg for all active bonds and calculate the mean bid-ask spread for each point in time. An increase of the bid-ask spread implies higher costs and lower liquidity which is expected to result in a widening of the yield spread.

Turnover Ratio

Finally, the ratio of monthly turnover to total outstanding Kommuninvest debt is calculated. This type of volume based measure is useful when measuring market breadth but is also highly correlated to market depth (Sarr and Lybek, 2002). Market breadth entails that the market is characterized by both numerous and large volume trades that have a limited impact on prices. Market depth implies that orders are abundant both above and below the current price. Market depth fosters breadth since large orders can be divided into several smaller orders. Monthly volume of all Kommuninvest bonds traded on the secondary market is published by the Riksbank and the monthly total outstanding Kommuninvest debt is published by Kommuninvest. Both are collected from Macrobond. An increase in the turnover ratio implies an increase in liquidity and consequently a reduction of the spread. Figure A10 in appendix C shows the evolution of the monthly turnover ratio.

5.3 Vector Autoregressive Model

Equation (23) is the main VAR(p) model used in this paper presented in general form. The 7-by-1 vector $\mathbf{y}_t$ contains the 5 year Kommuninvest yield spread and the abovementioned credit and liquidity variables, $\mathbf{c}$ is a 7-by-1 column vector of constant terms and $\{\mathbf{A}_1, \mathbf{A}_2, \ldots, \mathbf{A}_p\}$ is a collection of 7-by-7 matrices containing estimated autoregressive parameters.

$$\mathbf{y}_t = \mathbf{c} + \mathbf{A_1}\mathbf{y}_{t-1} + \mathbf{A_2}\mathbf{y}_{t-2} + \cdots + \mathbf{A}_{\boldsymbol{p}}\mathbf{y}_{t-p} + \mathbf{e}_t \qquad (23)$$

The vectors $\{\mathbf{y}_{t-1}, \mathbf{y}_{t-2}, \ldots, \mathbf{y}_{t-p}\}$ contain the lagged values of the seven variables and $\mathbf{e}_t$ is a 7-by-1 vector of error terms that satisfy the following conditions:

$$E(e_{i,t}) = 0 \quad \forall e_{i,t} \subseteq \mathbf{e}_t \qquad (24)$$

$$E(\mathbf{e}_t\mathbf{e}_t') = \mathbf{\Omega} \text{ is positive-semidefinite} \qquad (25)$$

$$E(\mathbf{e}_t\mathbf{e}_{t-k}') = \mathbf{0} \quad \forall k \neq 0 \qquad (26)$$

The necessary condition for the abovementioned system to be stable is that $\mathrm{N} \times \mathrm{p}$ eigenvalues lie inside the unit circle, where $\mathrm{N} = 7$ is the number of variables and equations in the system. Orthogonal impulse responses are estimated by Cholesky decomposition which are conditional on the ordering of the endogenous variables in the lower triangular matrix. This ordering is done by a decreasing order of exogeneity which is discussed in the following parts of the section.

5.4 VAR Variable Order

As stated previously, the ordering of variables in the VAR system is of importance for the Cholesky decomposition and consequently for estimating the impulse responses. A rule of thumb is that the variables in the system should be sorted in a decreasing order of exogeneity. This is difficult to test for and therefore we rely on theory and logical deduction to give us some insight. First we must distinguish between exogeneity which is due to the mechanical differences of the measures and "true" exogeneity. For instance, the number of bankruptcies (B), yield impact (YI) and turnover ratio (T) are cumulative variables which are calculated over the prior month whereas the CDS spread (CDS), the yield spread (S), the bid-ask spread (BA) and the leverage ratio (LR) are realized values at the specific day at the end of the month. Thus, the number of bankruptcies, the yield impact measure and the turnover ratio are the most exogenous by construction since the present cannot impact the past. It is assumed that the number of bankruptcies is the most exogenous variable since it being a cumulative variable and the variable which closest captures the systematic credit risk. Since the yield impact measure is calculated for government bonds and the turnover ratio is calculated for Kommuninvest bonds it is reasonable to assume that government bond liquidity reflects systemic liquidity to larger extent. Notice that these two liquidity variables are obviously highly correlated but it is reasonable to assume that Kommuninvest liquidity is less likely to impact government bonds than vice versa. Therefore, the number of bankruptcies is assumed to be the most exogenous, the yield impact measure the second most and the turnover ratio the third most.

In the case of the "spot" variables it is assumed that the CDS spread is the most exogenous since it is being calculated using CDS rates of the whole Swedish banking sector and the Swedish government whereas the remaining variables such as the yield spread, bid-ask spread and leverage ratio are Kommuninvest specific. The yield and bid-ask spread are tightly interconnected since market makers set bid and ask prices by observing prices and yields on the secondary market which in turn affects new prices and yields. Thus, there is a feedback loop between the two. However, it is assumed that bid-ask spread is the second least exogenous and that the Kommuninvest yield spread is the third least. An argument for this is that the yield spread is a combination of both the Kommuninvest and government bond yields and it is assumed that government variables are more exogenous. Therefore, the yield spread is more exogenous due to the inclusion of the government yields. Finally, the least exogenous variable is the Kommuninvest leverage ratio since it is an entity specific measure of a relatively small actor. Equation (27) summarizes the variable order in the VAR model.[7]

$$\mathbf{y}_t' = (B_t \quad YI_t \quad T_t \quad CDS_t \quad S_t \quad BA_t \quad LR_t)' \tag{27}$$

In the next section the main results and the results from the robustness test are presented.

[7] As a sensitivity analysis we shift the variable order in the VAR system. First, we test the variable order $\mathbf{y}_t' = (T_t \quad B_t \quad YI_t \quad LR_t \quad CDS_t \quad S_t \quad BA_t)'$ where the variable in the last/far right position within each block (cumulative and spot) is shifted to first/far left position within the same block. Second, we test the model when the variables are ordered from slow to fast, $\mathbf{y}_t' = (B_t \quad T_t \quad YI_t \quad LR_t \quad BA_t \quad CDS_t \quad S_t)'$, instead of by decreasing order of exogeneity. These results are briefly discussed in the next section.

6. Results

In this section the main results from the vector autoregressive model are presented where the yield spread is estimated using the smoothing spline approach followed by a sensitivity analysis where the yield spread is estimated by the Nelson and Siegel model.

6.1 VAR Results Using Spline Estimated Yield Spreads

The results from the Augmented Dickey-Fuller unit-root test (Said and Dickey, 1984) and the KPSS test (Kwiatkowski et al., 1992) where mean reversion around a constant level is tested for, is presented in Table A2 in appendix D where the lag length in the test equations was given by the Schwarz (1978) information criterion. Recall that the Augmented Dickey-Fuller test has a unit root under the null hypothesis, whereas the KPSS test has stationarity under the null. As can be seen by the results, the CDS spread, the bid-ask spread and the yield spreads estimated by both spline and the Nelson and Siegel model are non-stationary while the remaining variables are stationary at the 1% level according to the results from the Augmented Dickel-Fuller test. The KPSS test rejects the null for all variables except for the Kommuninvest leverage ratio. Notice, all non-stationary variables in the Augmented Dickey-Fuller test are either variables based on yields, bond prices or interest rate derivatives. Therefore, we will treat these non-stationary variables as being stationary. There is both empirical and theoretical support for this. Wu and Chen (2001) show that standard unit-root tests have low power and they find support for mean reversion in nominal interest rates when using panel unit-root tests. Furthermore, most macroeconomic models assume that interest rates have a long run equilibrium value. Bansal and Yaron (2004) show that there is evidence of mean reversion in consumption growth which in turn implies by the standard Euler equation that real interest rates are stationary. Consequently, nominal interest rates are also stationary given a stationary inflation target. Finally, Homer and Sylla (1996) illustrate that historic nominal interest rates have been in the range of 4 to 8 percent which is not consistent with a unit-root process. Table A3 in appendix D shows the summary statistics for the liquidity and credit variables. The lag length in the model is set to $p = 1$ as suggested by the Schwarz information criterion. Figure 6 depicts the unit circle and the estimated eigenvalues discussed in the previous section. All $N \times p = 7$ eigenvalues are inside the unit circle, suggesting that the system is stable.

Figure 6 Unit Circle and Estimated Eigenvalues, Yield Spread Estimated by Spline

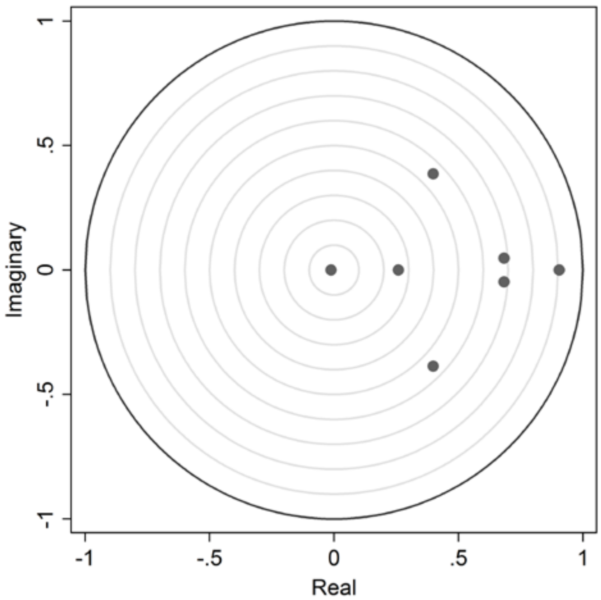
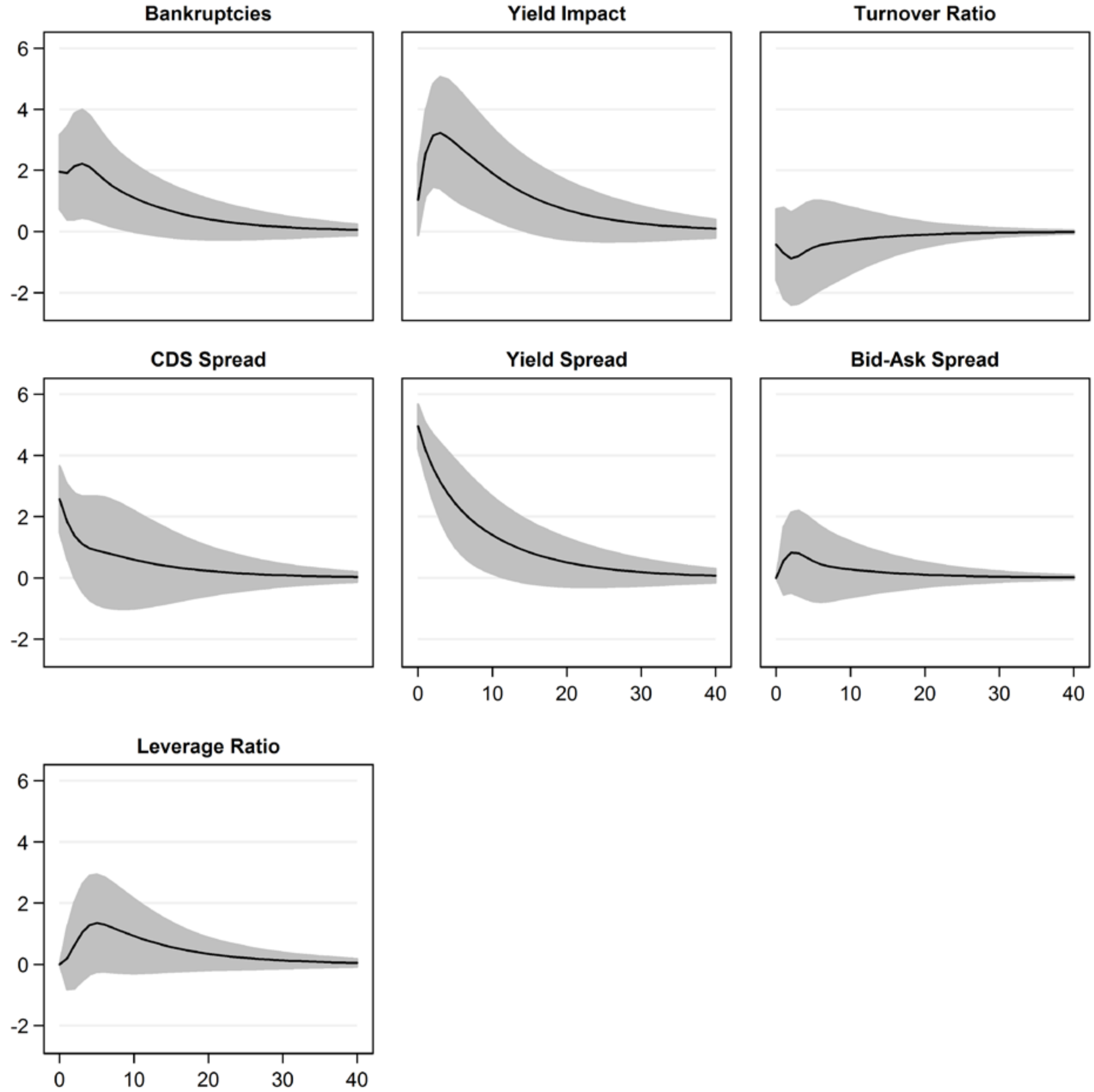


Figure 7 depicts the impulse responses of the Kommuninvest yield spread to shocks in the credit and liquidity variables.[8] All impulse responses are as expected and in line with previous literature. Most notably, the largest responses occur to changes to the systematic variables rather than to the Kommuninvest specific variables. The largest effect is explained by the yield impact measure where a one standard deviation shock to the measures has a statistically significant impact on the yield by approximately 3.25 basis points. A shock to the CDS spread results in approximately a 2.75 basis point statistically significant increase in the spread.

[8] When the variable order is changed to $\mathbf{y}_t' = (T_t \quad B_t \quad YI_t \quad LR_t \quad CDS_t \quad S_t \quad BA_t)'$ the results remain very similar. When ordering variables from slow to fast, $\mathbf{y}_t' = (B_t \quad T_t \quad YI_t \quad LR_t \quad BA_t \quad CDS_t \quad S_t)'$, results are similar but with some minor discrepancies. Notably, shocks to the bid-ask spread and the leverage ratio results in an initial negative response in the spread, although not statistically significant, and becomes positive after approximately three periods. These results are omitted from the paper but are available upon request.

Figure 7 Kommuninvest Yield Spread Impulse Responses, Estimated by Spline[9]



Comment: Basis points on the vertical axis and months on the horizontal axis. The coloured band is the 90% confidence interval. Size of impulse is one standard deviation.

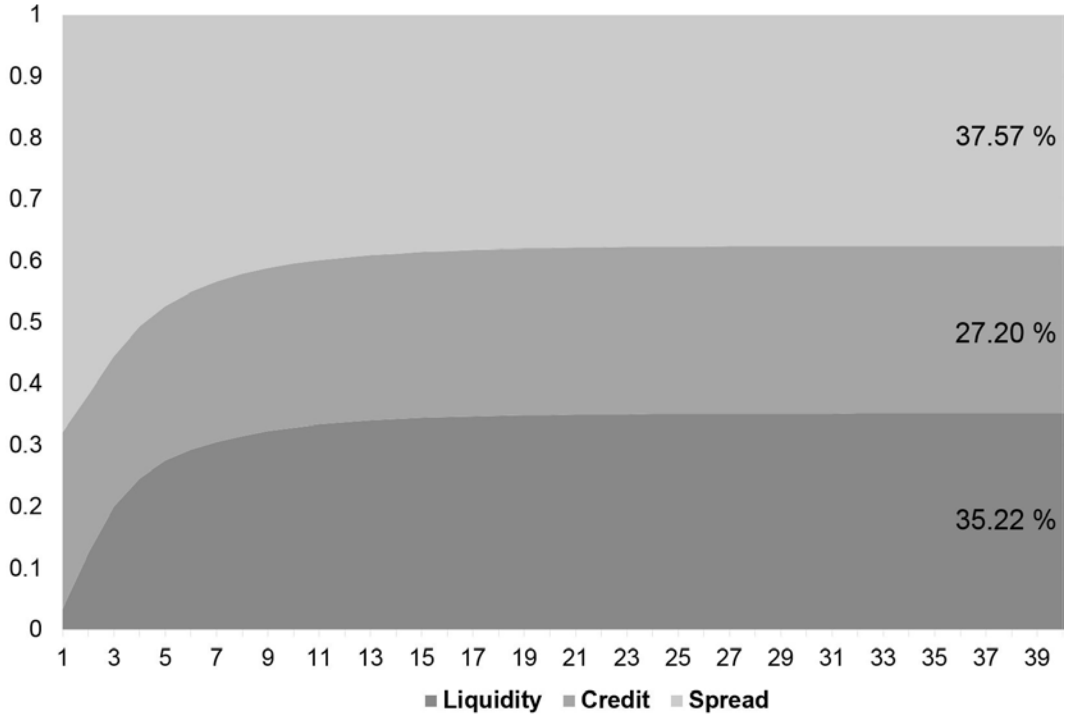
A shock to the bankruptcy variable results in a 2 basis points statistically significant response in the spread. Although the Kommuninvest specific bid-ask spread, leverage ratio and turnover ratio have the expected effects on the yield spread the effects are small and non-significant. A standard deviation shock to the bid-

[9] We perform an additional sensitivity analysis by adding three international variables to the original model as to investigate if the national effects are deluded. The excess bond premium based on the Gilchrist and Zakrajšek (2012) GZ credit spread index and the average distance-to-default index by Saldías (2013) are collected from Macrobond, published by the Board of Governors of the Federal Reserve System and the Cleveland Federal Reserves, respectively. Following the example of Alexius *et al.* (2014) the LIBOR OIS (Overnight indexed swap) rate spread is collected from Bloomberg. Results show that none of the shock results in a statistically significant response in the yield spread whilst the responses to the Sweden specific shocks remain unchanged. These results are omitted from the paper but are available upon request.

ask spread and the turnover ratio has approximately a 1 basis-point positive and negative impact, respectively. Finally, a shock to the leverage variable results in a 1.25 basis points response in the spread but is non-significant.

Figure 8 shows the results from the variance decomposition where the Kommuninvest yield spread is decomposed into different risk premiums. The variance decomposition is estimated over a 40 month period which is a relatively long time horizon. Approximately 35% of the variation of the spread is explained by the liquidity variables. This amounts to an average liquidity risk premium of approximately 28 basis points. The credit variables explain 27% which in turn amounts to a credit risk premium of 22 basis points. Thus, the liquidity risk premium is approxematly 8 percentage points larger than the credit risk premium. The results show that there is a substantial credit risk differential between Kommuninvest and the Swedish government even though the creditworthiness of both is based on similar factors. Furthermore, the results also suggest that the Swedish municipal bond market in general does not believe in the existence of an implicit government guarantee. The variance decompositions per variable are presented in Figure A11 in Appendix D. Shocks in the yield impact measure and the CDS spread explain a statistically significant share of the yield spread forecast error variance for the initial periods. However, one should keep in mind that the results depicted in Figure A11 cannot tell us anything in regards to the statistical significance of shocks in each variable block as a whole. It may be the case that a combined shock to all liquidity and credit variables respectively may yield statistically significant results even though shock to the individual variables do not. From Figure 8 we can see that approximately 38% of the yield spread is unexplained, i.e. explained by the yield spread lag, which amounts to 30 basis points. Theoretically, the unexplained portion of the spread should be comprised of either credit or liquidity, or a combination of the two. Assuming that the unexplained portion of the spread is comprised entirely of liquidity results a liquidity premium of 73%, which corresponds to 58 basis points. Assuming that the unexplained portion of the spread is comprised entirely of credit would result in a credit risk premium of 65% or 52 basis points. A more likely scenario is that the unexplained spread is made up of a combination of liquidity and credit. A scenario where the unexplained portion of the spread is shared 50/50 between liquidity and credit would result in a liquidity risk premium of 54% or 43 basis points and a credit risk premium of 46% or 37 basis points. Finally, assuming that the liquidity and credit risk premium shares estimated by the variance decomposition are representative for the unexplained portion of the spread as well would result in a liquidity risk premium of 56% or 45 basis points and a credit risk premium of 44% or 35 basis points.

Figure 8 Kommuninvest Yield Spread Variance Decomposition per Risk Factor Block, Estimated by Spline



Comment: Shares are calculated by summing the variance decomposition point estimates over all variable within each risk factor block.

These results implicitly gives Kommuninvest some policy suggestions. Increasing the number of members could potentially improve creditworthiness and reduce the credit risk premium. However, adding new members with worse creditworthiness relative to the weighted average of the existing members could in fact worsen the creditworthiness of Kommuninvest. It is also the case that liquidity is positively correlated with issuing volume and by increasing the number of members the required volume would increase and indirectly increase liquidity. Thus, focusing funding to one specific market may be beneficial in improving liquidity by increasing issuing volumes in that market but may be problematic in other aspects, for instance this strategy increases nation specific risk exposure. It is however unclear how large these synergistic effect would be. Arguably, a simpler and more immediate approach is to target liquidity directly. Some obvious suggestions for improving liquidity would be to increase awareness of the organization by focusing on investor relations and aim for inclusion into different fixed-income security indexes which would allow index tracking fund investors to hold Kommuninvest securities. In addition, increasing the number of market makers could potentially have a positive effect on liquidity.

6.2 Sensitivity Analysis Using Yield Spreads Estimated by the Nelson and Siegel Model

In this part of the section the results from the sensitivity analysis are briefly discussed. The model is now estimated by substituting the spline based yield spread with the yield spread estimated by the Nelson and Siegel (1987) model. Figures A12-A15 in appendix D present the VAR results. These results are similar to the main results and the VAR system is stable since all eigenvalues lie inside the unit circle as shown in Figure A13 in appendix D. Most notable is that the credit and liquidity risk premiums estimated by variance decomposition make up a smaller share of the yield spread variation compared to the main results. Approximately 27% or 22 basis points are explained by the liquidity variables, 32% or 26 basis points by credit and 41% or 35 basis points by the autoregressive yield spread term. In total only 59% is explained by the included variables. Contrary to the main results credit now makes up a majority of the explained spread. Nevertheless, the conclusions are the same, the fact that we observe a credit risk premium different from zero suggests that the capital markets in general do not believe in the existence of an implicit central government guarantee.

7. Conclusions

In this paper we have estimated bond liquidity and credit risk premiums of the Swedish municipal sector represented by Kommuninvest of Sweden. The method of estimating yield spreads by smoothing spline and estimating risk premiums in a VAR setting is quite novel and, to our knowledge, has not been previously suggested in this specific field. The main purpose of the paper was to assess whether the Swedish municipal bond market in general believes in the existence of an implicit central government guarantee, as suggested by the 1992 bailout of the municipality of Haninge. The results show that this is not the case. Shocks to all systemic variables generate statistically significant responses in the yield spread. In addition, the CDS spread and the yield impact measure are statistically significant in the variance decomposition. The liquidity risk premium amounts to 35% or 28 basis points of the yield spread, credit makes up 27% or 22 basis points and 38% or 30 basis points is explained by the spread own autoregressive term. Thus, investors and creditors in general do not believe in the existence of a central government guarantee due to the discrepancy in credit risk between the municipal sector and the central government.

These result have some important policy implications for reducing the municipal yield spread; improving creditworthiness is of equal importance as improving liquidity, although the latter may be the simpler and more direct approach. From a wider societal perspective improving the funding conditions of Swedish sub-sovereigns is exceedingly important as it has an impact on the population as a whole through the different social programs.

References

Acharya, V. V., & Pedersen, L. H. (2005). Asset Pricing with Liquidity Risk. *Journal of Financial Economics 77*, 375-410.

Adams , K. J., & van Deventer, D. R. (1994). Fitting Yield Curves and Forward Rate Curves with Maximum Smoothness. *The Journal of Fixed Income 4*, 52-62.

Alexius, A., Birenstam, H., & Eklund, J. (2014). The Interbank Market Risk Premium, Central Bank Interventions, and Measures of Market Liquidity. *Journal of International Money and Finance 48*, 202-217.

Amihud, Y. (2002). Illiquidity and Stock Returns: Cross-Section and Time-Series Effects. *Journal of Financial Markets 5*, 31-56.

Amihud, Y., & Mendelson, H. (1986). Asset Pricing and the Bid-Ask Spread. *Journal of Financial Economics 17*, 223-249.

Arsov, I., Brooks, M., & Kosev, M. (2013). New Measures of Australian Corporate Spreads. *Reserve Bank of Australia Quarter Bulletin (December)*, 15-26.

Bansal, R., & Yaron, A. (2004). Risks for the Long Run: A Potential Resolution of Asset Pricing Puzzles. *Journal of Finance 59*, 1481-1509.

Bliss, R. R. (1997). Testing Term Structure Estimation Methods. *Advances in Futures and Options Research 9*, 197-231.

Cochrane, J. (2005). *Asset Pricing*. Princeton, NJ: Revised edn. Princeton University Press.

de Boor, C. (1978). *A Practical Guide to Splines*. Berlin: Springer-Verlag.

Dick-Nielsen, J., Feldhütter, P., & Lando, D. (2012). Corporate Bond Liquidity Before and After the Onset of the Subprime Crisis. *Journal of Financial Economics 103*, 471–492.

Dick-Nielsen, J., Gyntelberg, J., & Sangill, T. (2012). Liquidity in Government Versus Covered Bond Markets. *BIS Working Paper 392*.

Enders, W. (2014). *Applied Econometric Time Series*. Hoboken, NJ: 4th edn. John Wiley & Sons Inc.

Finansinspektionen. (2015). "*Likviditeten I Marknaden för Säkerställda Obligationer*". Stockholm.

Fisher, M., Nychka, D., & Zervos, D. (1995). Fitting the Term Structure of Interest Rates with Smoothing Splines. *Finance and Economics Discussion Series 95-1, Board of Governors of the Federal Reserve System*.

Fong, G., & Vasicek, O. A. (1982). Term Structure Modeling Using Exponential Splines. *Journal of Finance 37*, 339-348.

Fukuda, S.-i. (2012). Market-Specific and Currency-Specific Risk During the Global Financial Crisis: Evidence From the Interbank Markets in Tokyo and London. *Journal of Banking & Finance 36*, 3185-3196.

Gilchrist, S., & Zakrajšek, E. (2012). Credit Spreads and Business Cycle Fluctuations. *American Economic Review 102*, 1692-1720.

Homer, S., & Sylla, R. (1996). *A History of Interest Rates*. New Brunswick: Rutgers University Press.

Hull, J. C. (2017). Options, Futures, and Other Derivatives. London: 10th edn. Pearson.

Khmelnitskaya, A. B., & Yanovskaya, E. B. (2007). Owen Coalitional Value Without Additivity Axiom. *Mathematical Methods of Operations Research 66*, 255-261.

Kommunallag (1991:900). (2017, February). *Dokument & lagar*. Retrieved from riksdagen.se: http://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/kommunallag-1991900_sfs-1991-900

Kommuninvest of Sweden. (2017). "*Local Government Debt*". Örebro.

Kommuninvest of Sweden. (2018). Retrieved from https://kommuninvest.se/en/

Kwiatkowski, D., Phillips, P., Schmidt, P., & Shin, Y. (1992). Testing the Null Hypothesis of Stationarity Against the Alternative of a Unit Root: How Sure are We That Economic Time Series Have a Unit Root?. *Journal of Econometrics 54*, 159–178.

Longstaff, F. A., Mithal, S., & Neis, E. (2005). Corporate Yield Spreads: Default Riskor or Liquidity? New Evidence From the Credit Default Swap Market. *Journal of Finance 60*, 2213-2253.

Lybek, T., & Sarr, A. (2002). Measuring Liquidity in Financial Markets. *IMF Working Paper 232*, 1-64.

MathWorks. (2018). *casaps*. Retrieved from MathWorks: https://se.mathworks.com/help/curvefit/csaps.html

McCulloch, J. H. (1971). Measuring the Term Structure of Interest Rates. *Journal of Business 44*, 19-31.

McCulloch, J. H. (1975). The Tax Adjusted Yield Curve. *Journal of Finance 30*, 811-830.

Michaud, F. L., & Upper, C. (2008). What Drives Interbank Rates? Evidence From the Libor Panel. *BIS Quarterly Review (March)*.

Nasdaq OMX Nordic. (2017). Retrieved from http://www.nasdaqomxnordic.com/

Nelson, C. R., & Siegel, A. F. (1987). Parsimonious Modeling of Yield Curves. *Journal of Business 60*, 473-489.

Said, S. E., & Dickey, D. A. (1984). Testing for Unit Roots in Autoregressive Moving Average Models of Unknown Order. *Biometrika 71*, 599-607.

Saldías, M. (2013). Systemic Risk Analysis Using Forward-Looking Distance-to-Default Series. *Journal of Financial Stability 9*, 498-517.

Schwarz, G. E. (1978). Estimating the Dimension of a Model. *Annals of Statistics 6*, 461-464.

Schwarz, K. (2018). Mind the Gap: Disentangling Credit and Liquidity in Risk Spreads. *SSRN*.

Schwert, M. (2017). Municipal Bond Liquidity and Default Risk. *The Journal of Finance 72*, 1683-1722.

Shea, G. (1984). Pitfalls in Smoothing Interest Rate Term Structure Data: Equilibrium Models and Spline Approximations. *Journal of Financial and Quantitative Studies 19*, 253-269.

Sims, C. A. (1980). Macroeconomics and Reality. *Econometrica 48*, 1-48.

Sims, C. A., Stock, J. H., & Watson, M. W. (1990). Inference in Linear Time Series Models With Some Unit Roots. *Econometrica 58*, 113-144.

Svensson, L. E. (1994). Estimating and Interpreting Forward Interest Rates: Sweden 1992-1994. *Centre for Economic Policy Research Discussion Paper 1051*.

Taylor, J. B., & Williams, J. C. (2009). A Black Swan in the Money Market. *American Economic Journal: Macroeconomics 1*, 58-83.

Waggoner, D. F. (1997). Spline Methods for Extracting Interest Rate Curves from Coupon Bond Prices. *Working Paper 97, Federal Reserve Bank of Atlanta*.

van Deventer, D. R., & Imai, K. (1997). *Financial Risk Analytics: A Term Structure Model Approach for Banking, Insurance, and Investment Management*. Chicago, IL: Irwin Professional Publishing.

van Deventer, D. R., Imai, K., & Mesler, M. (2004). *Advanced Financial Risk Management*. Hoboken, NJ: John Wiley & Sons.

Wu, J. L., & Chen, S. L. (2001). Mean Reversion of Interest Rates in the Eurocurrency Market. *Oxford Bulletin of Economics and Statistics 63*, 459-474.

Appendix A – Yield Spread Estimation

In equation (A1) S_j is the spline function represented by a specific piecewise cubic polynomial where x_i is the residual maturity of bond i and a_j, b_j, c_j are the parameters where $i = \{1,2, \dots, n\}$, $j = \{1,2, \dots, n-1\}$ and $n > 1$.

$$S_j(x_i) = a_j + b_j x_i + c_j x_i^2 + d_j x_i^3 \tag{A1}$$

Equation (A2) is the yield to maturity represented by the full spline function S and an i.i.d. error term ϵ with constant variance.

$$y_i = S(x_i) + \epsilon_i \tag{A2}$$

The spline parameters are estimated by the following minimization problem and conditions. This method is developed by de Boor (1978) where the term specific weights have been normalized to unity. Thus, the level of smoothing is applied uniformly over the whole yield curve.

$$\min_S \quad p \sum_{k=1}^{n} [y_k - S(x_k)] + (1-p) \int \left(\frac{d^2 S}{dx^2}\right)^2 dx \tag{A3}$$

$$s.t \qquad S_i(x_i) = y_i = S_{i-1}(x_i) \tag{A4}$$

$$\frac{\partial S_i}{\partial x_i} = \frac{\partial S_{i-1}}{\partial x_i} \tag{A5}$$

$$\frac{\partial^2 S_i}{\partial x_i^2} = \frac{\partial^2 S_{i-1}}{\partial x_i^2} \tag{A6}$$

$$\frac{\partial^2 S_1}{\partial x_1^2} = \frac{\partial^2 S_{n-1}}{\partial x_n^2} = 0 \tag{A7}$$

Condition (A4) simply states that two neighboring piecewise cubic polynomials should yield the same values when evaluated at the knot point x_i. Conditions (A5) and (A6) state that the slope and curvature of two neighboring piecewise polynomials should be equal at the knot. Finally, condition (A7) states that the first and last piecewise polynomial in the x-dimension should have zero curvature at the end points. In expression (A3) the parameter p controls the smoothness of the spline. Setting p equal to 0 maximizes smoothness and the spline function reduces to a straight line. A parameter value equal to 1 ensures that the function goes through all points in the data, however this can result in an oscillating function which in certain cases can lead to nonsensical yield curves.

The smoothing parameter is set equal to $1/(1 + h_t^3/6)$ where h_t is the average spacing of bond residual maturities at trade day t, i.e. the parameter is time varying although constant over periods where no bonds have matured and no new bonds have been issued.[10] Finally, the yield spread is estimated as shown by

[10] This is denoted as the "interesting value" of the smoothing parameter and is covered in the Matlab casaps function documentation (MathWorks, 2018).

expression (A8) by estimating the splines for both Kommuninvest and the Swedish government bonds for each trade day, evaluating both functions at residual maturity, x_i, equal to 5 years and then taking the difference.

$$\hat{Y}_t = S_t^{KI}(5) - S_t^{GOV}(5) \tag{A8}$$

Figure A1 Yield Curves Estimated by Smoothing Spline, 180 Day Increments

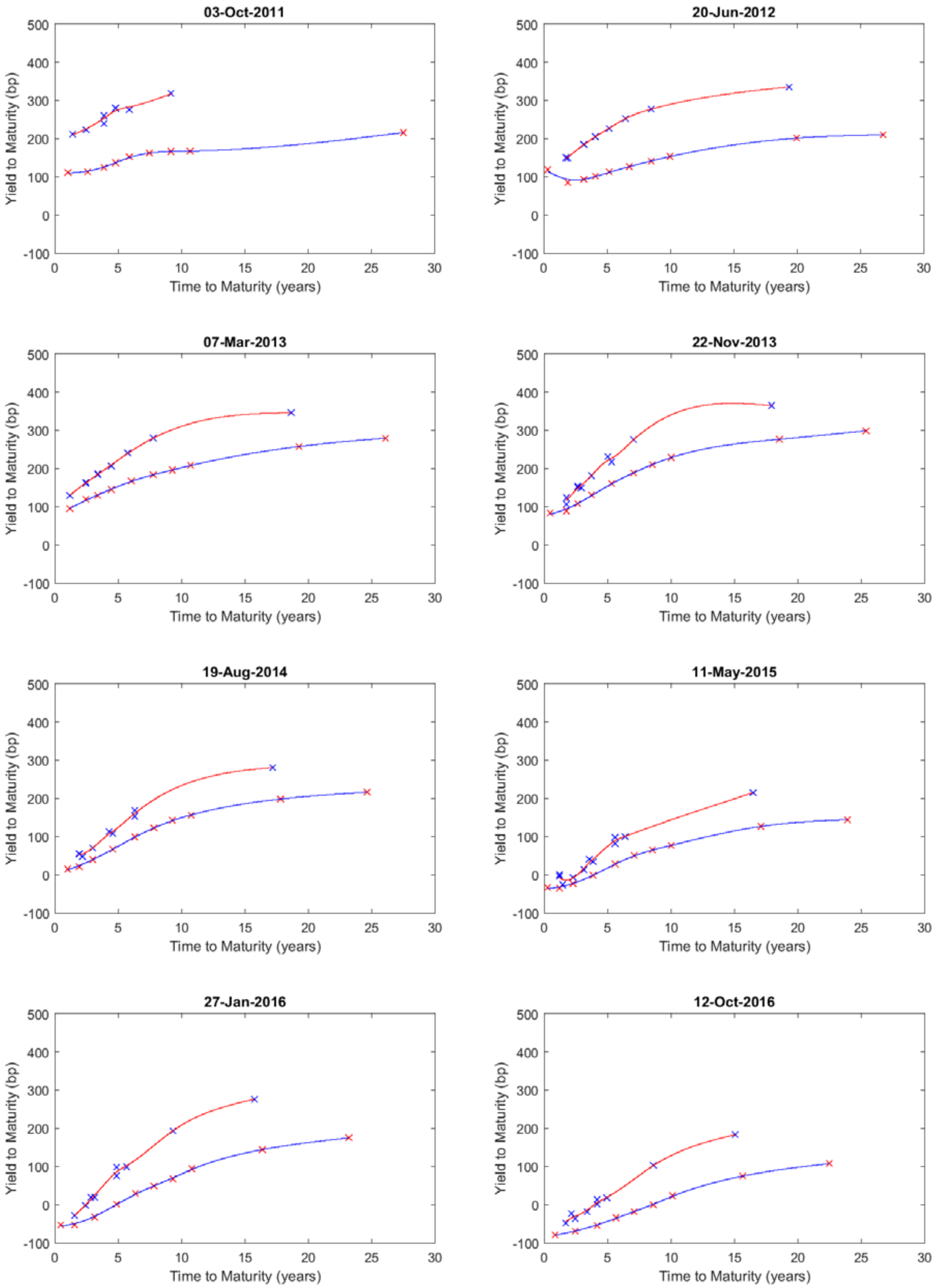
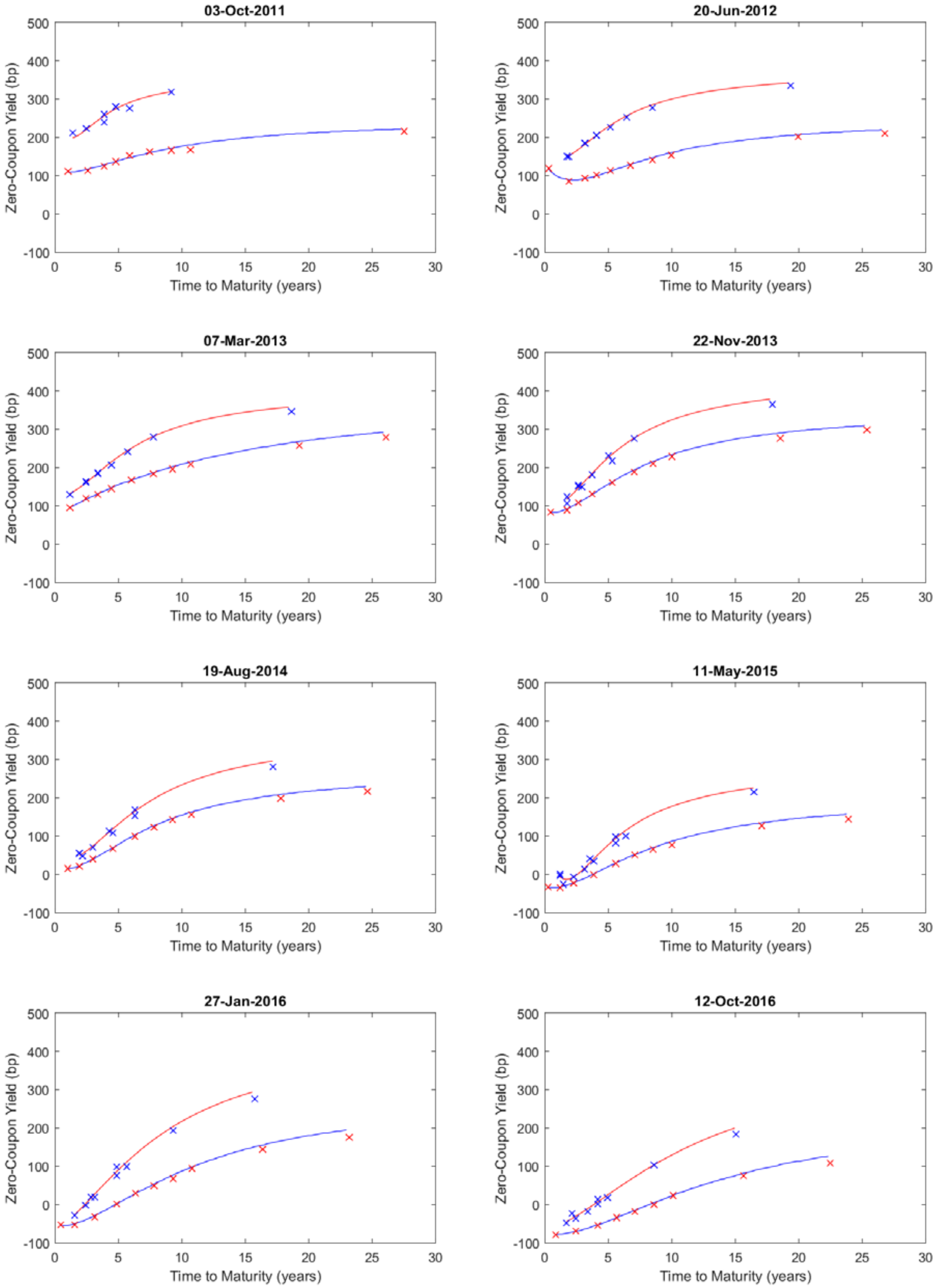


Figure A2 Yield Curves Estimated by Nelson-Siegel, 180 Day Increments



Appendix B – Price Data

Figure A3 Evolution of Kommuninvest and Government Yields Estimated by Nelson-Siegel, 3rd of October 2011 to 31st of January 2017, Daily Frequency

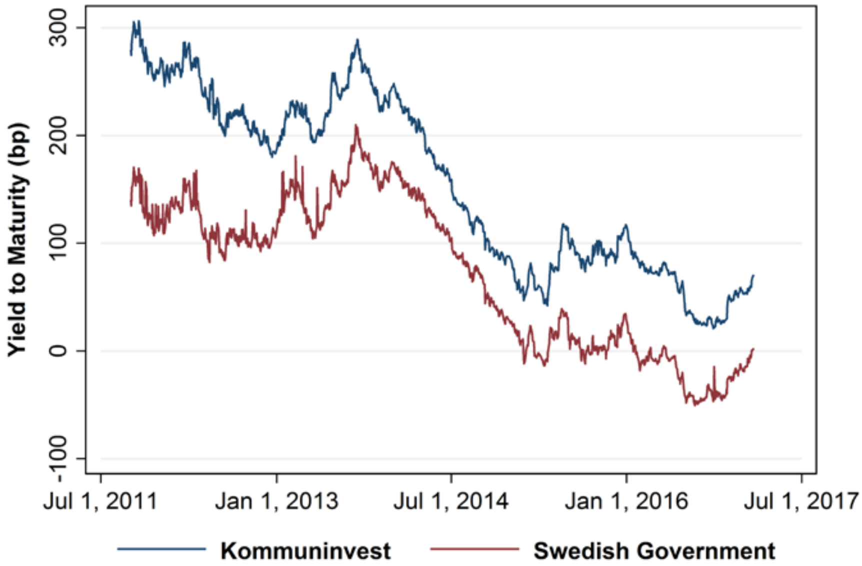


Figure A4 Evolution of Kommuninvest Yield Spread Estimated by Nelson-Siegel, 3rd of October 2011 to 31st of January 2017, Daily Frequency

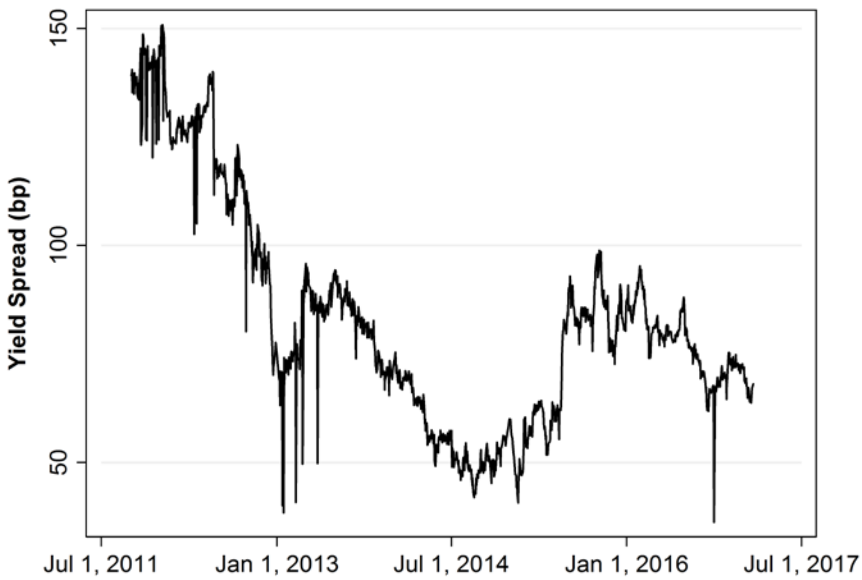


Table A1 Summary Statistic for Price and Yield Data, 3rd of October 2011 to 31st of January 2017, Daily Frequency

Variable	Average	Standard Deviation	Min	Max	Observations
Kommuninvest 5 Year Yield (‱) (Spline)	150.166	83.173	14.096	309.616	N = 1338
Government 5 Year Yield (‱) (Spline)	70.138	70.237	-50.305	208.544	N = 1338
Kommuninvest Yield Spread (‱) (Spline)	80.028	25.904	40.658	156.784	N = 1338
Kommuninvest 5 Year Yield (‱) (Nelson-Siegel)	155.618	82.882	20.933	306.192	N = 1338
Government 5 Year Yield (‱) (Nelson-Siegel)	72.572	70.905	-50.434	210.015	N = 1338
Kommuninvest Yield Spread (‱) (Nelson-Siegel)	83.046	25.710	36.259	150.840	N = 1338
Bid-Ask Spread (‱)	4.262	0.811	2.683	7.155	N = 1338

Appendix C – Methodology

Figure A5 Evolution of Bank and Government CDS Rates, 3rd of October 2011 to 31st of January 2017, Daily Frequency

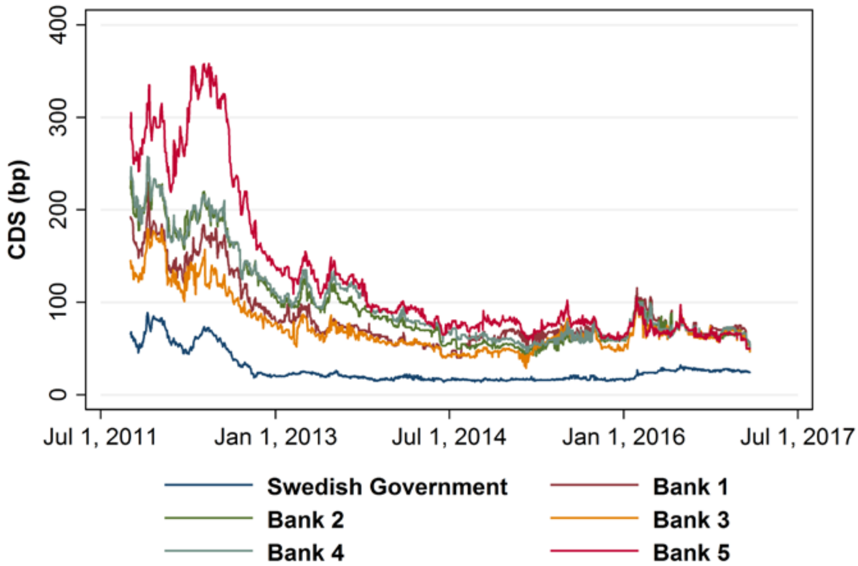


Figure A6 Evolution of Mean Bank and Government CDS Rates, 3rd of October 2011 to 31st of January 2017, Daily Frequency

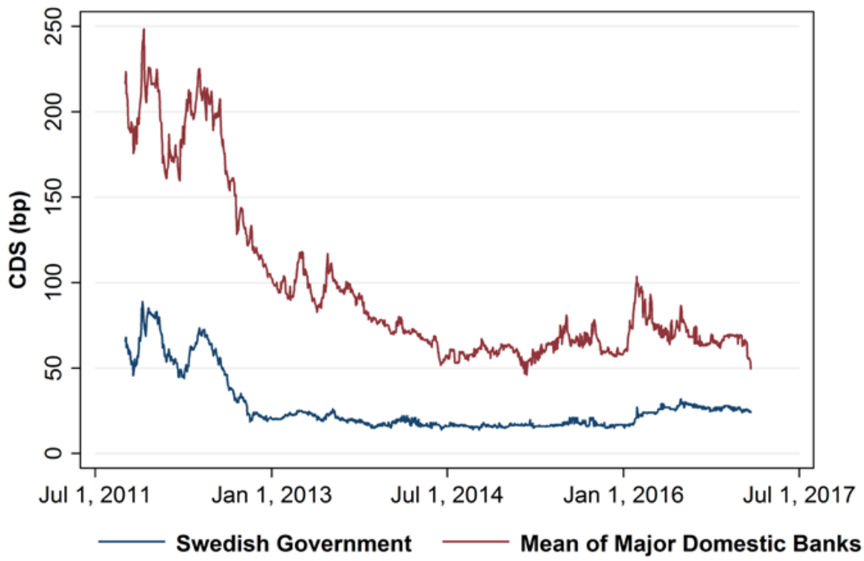


Figure A7 Evolution of the Total Number of Bankruptcies in Sweden, October 2011 to January 2017, Monthly Frequency

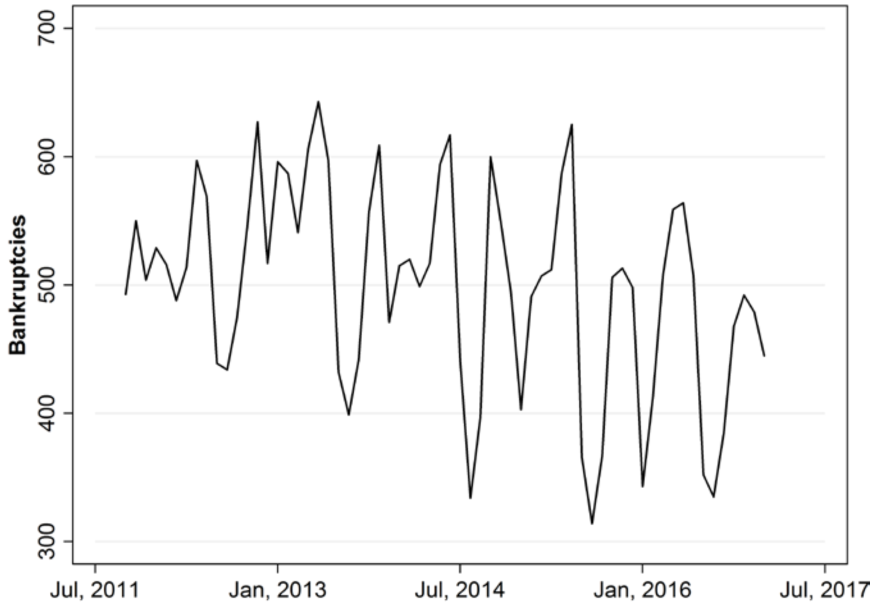


Figure A8 Evolution of Kommuninvest Leverage Ratio, October 2011 to January 2017, Monthly Frequency

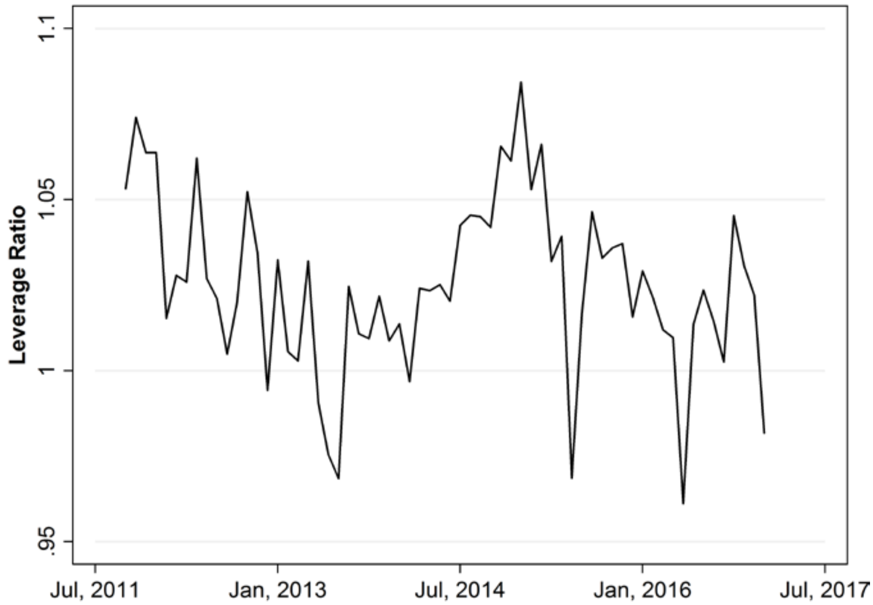


Figure A9 Evolution of Government Bond Yield Impact, October 2011 to January 2017, Monthly Frequency

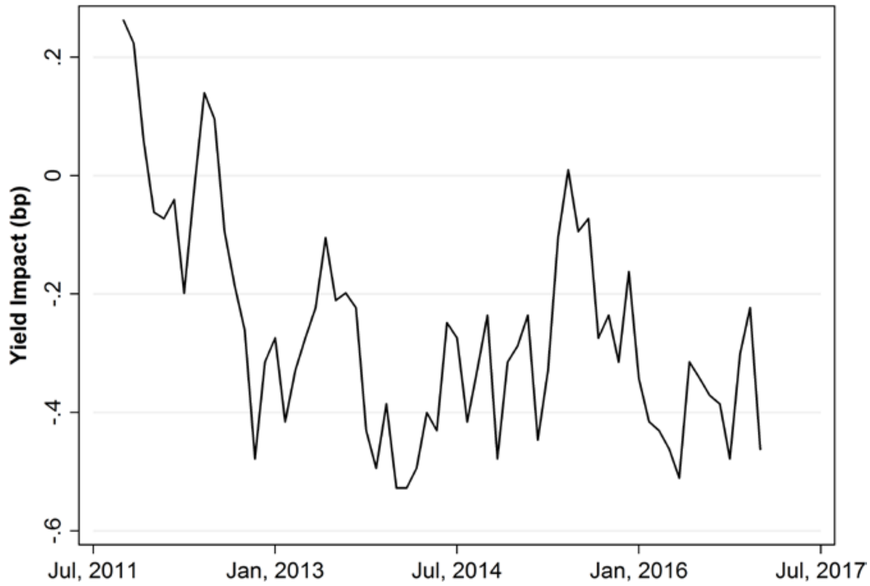
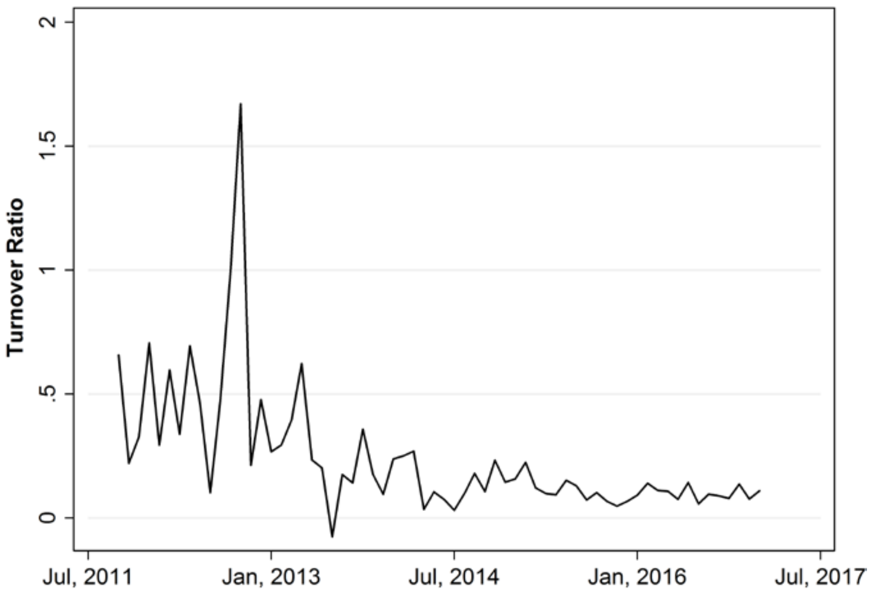


Figure A10 Evolution of Kommuninvest Turnover Ratio, October 2011 to January 2017, Monthly Frequency



Appendix D – Results

Table A2 Results from Unit-Root Tests, Monthly Frequency

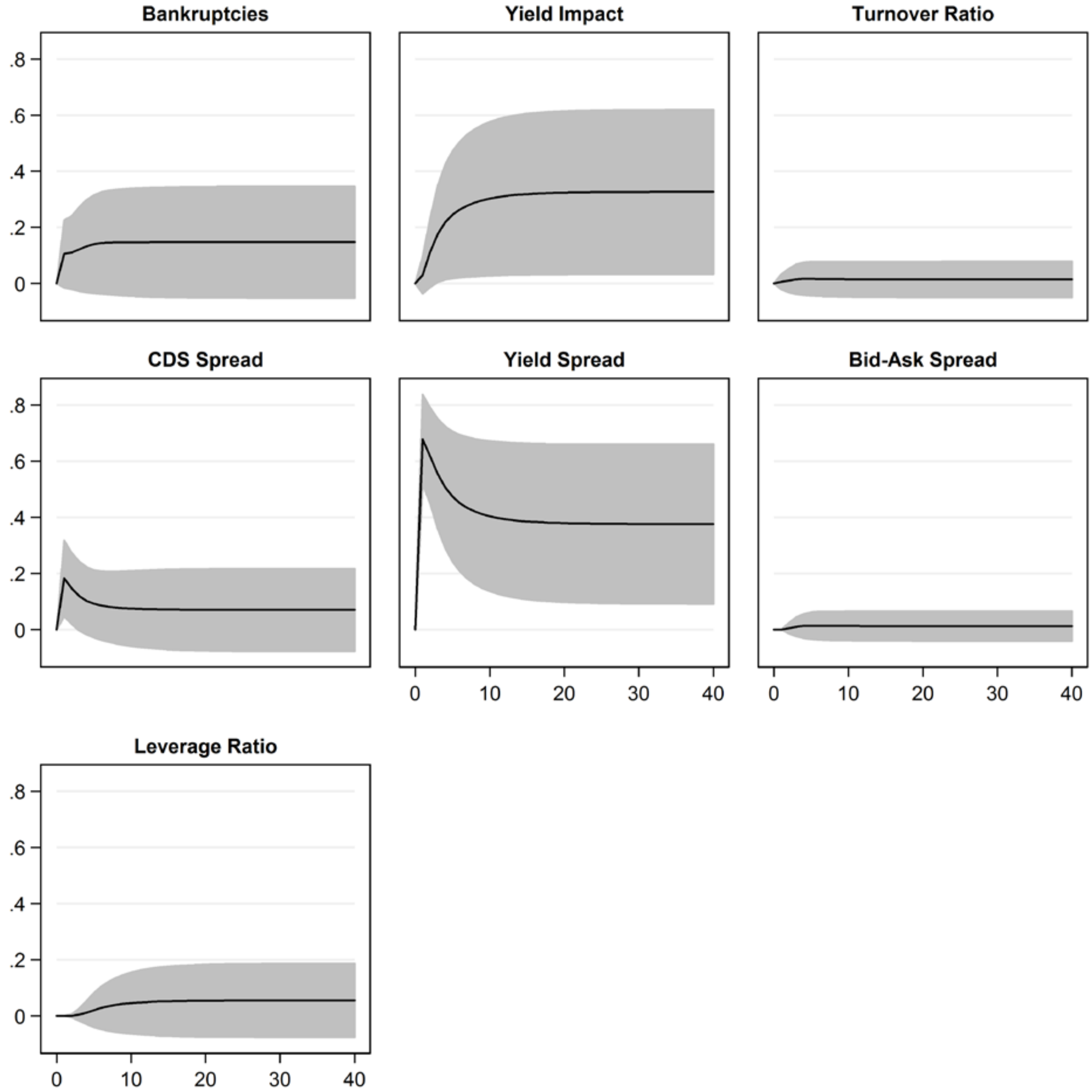
Variables	ADF	KPSS
Bankruptcies	-6.558***	0.656**
Bid-Ask Spread	-1.823	0.670**
CDS Spread	-1.872	0.937***
Leverage Ratio	-4.437***	0.131
Turnover Ratio	-4.839***	0.818***
Yield Impact	-3.596***	0.502**
Yield Spread (Spline)	-2.434	0.629**
Yield Spread (Nelson-Siegel)	-2.297	0.629**

*Comment: The table gives the test statistics from the Augmented Dickey-Fuller and the KPSS tests. *** indicates significance at the one percent level; ** indicates significance at the five percent level; * indicates significance at the ten percent level.*

Table A3 Summary Statistic for Liquidity and Credit Variables, October 2011 to January 2017, Monthly Frequency

Variable	Average	Standard Deviation	Min	Max	Observations
Bankruptcies	498.328	82.307	314	643	N = 64
Bid-Ask Spread (‰)	4.226	0.833	2.690	6.194	N = 64
CDS Spread (‰)	69.132	35.417	25.518	172.084	N = 64
Leverage Ratio	1.025	0.026	0.961	1.084	N = 64
Turnover Ratio	0.243	0.268	-0.075	1.671	N = 64
Yield Impact (‰)	-0.262	0.185	-0.528	0.262	N = 64

Figure A11 Kommuninvest Yield Spread Variance Decomposition per Variable, Estimated by Spline



Comment: Share of variance in the forecast error on the vertical axis and months on the horizontal axis. The coloured band is the 90% confidence interval.

Figure A12 Unit Circle and Estimated Eigenvalues, Yield Spread Estimated by Nelson-Siegel

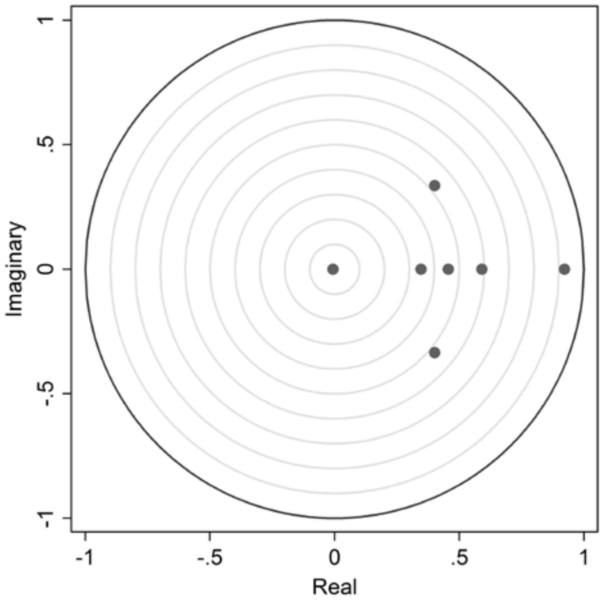
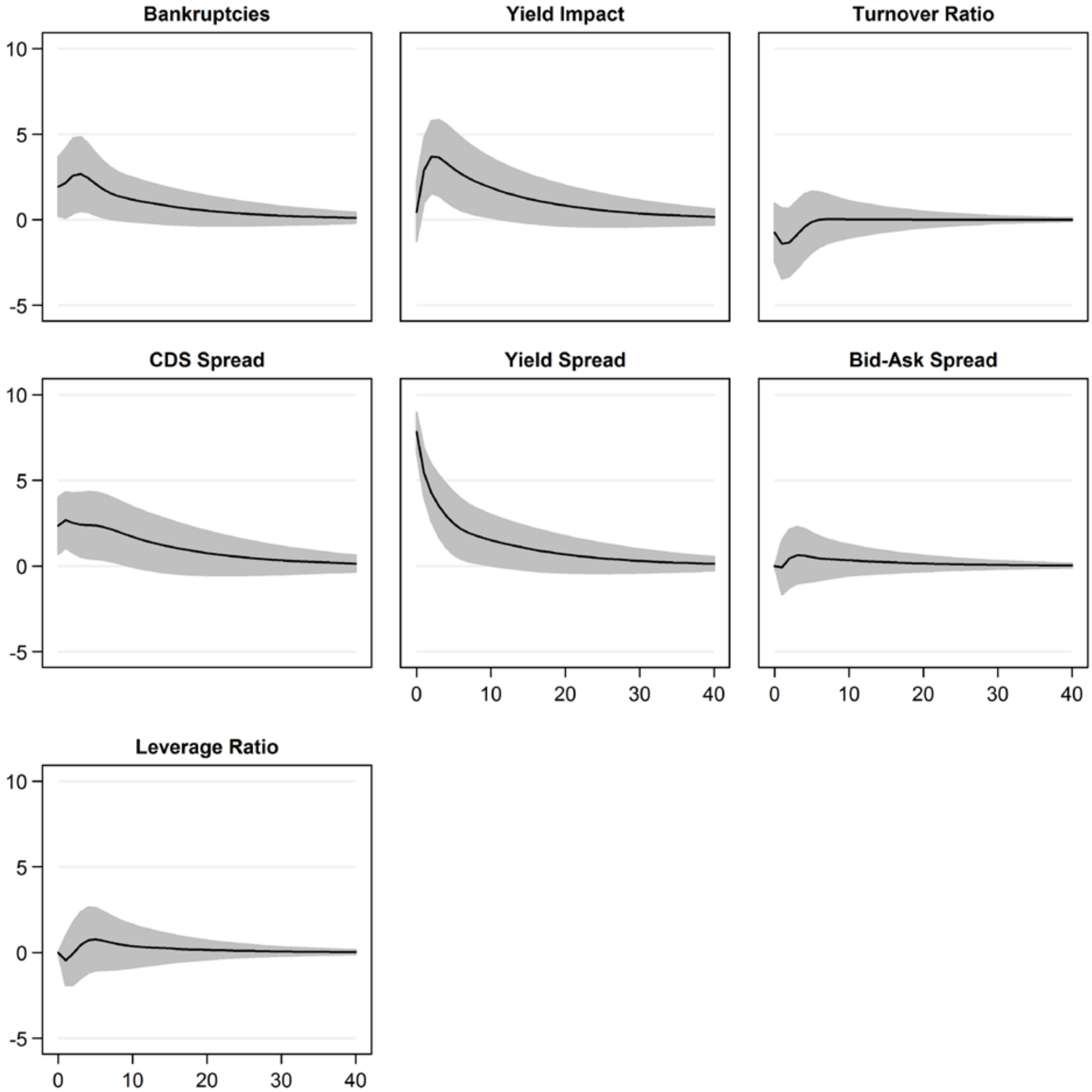
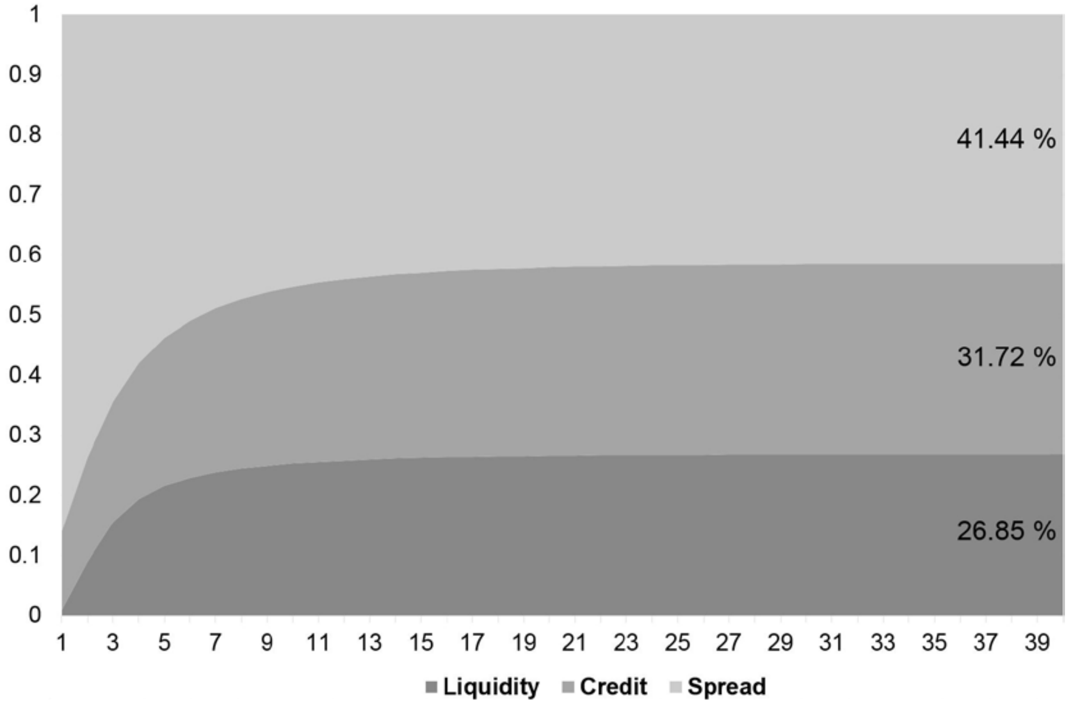


Figure A13 Kommuninvest Yield Spread Impulse Responses, Estimated by Nelson and Siegel Model



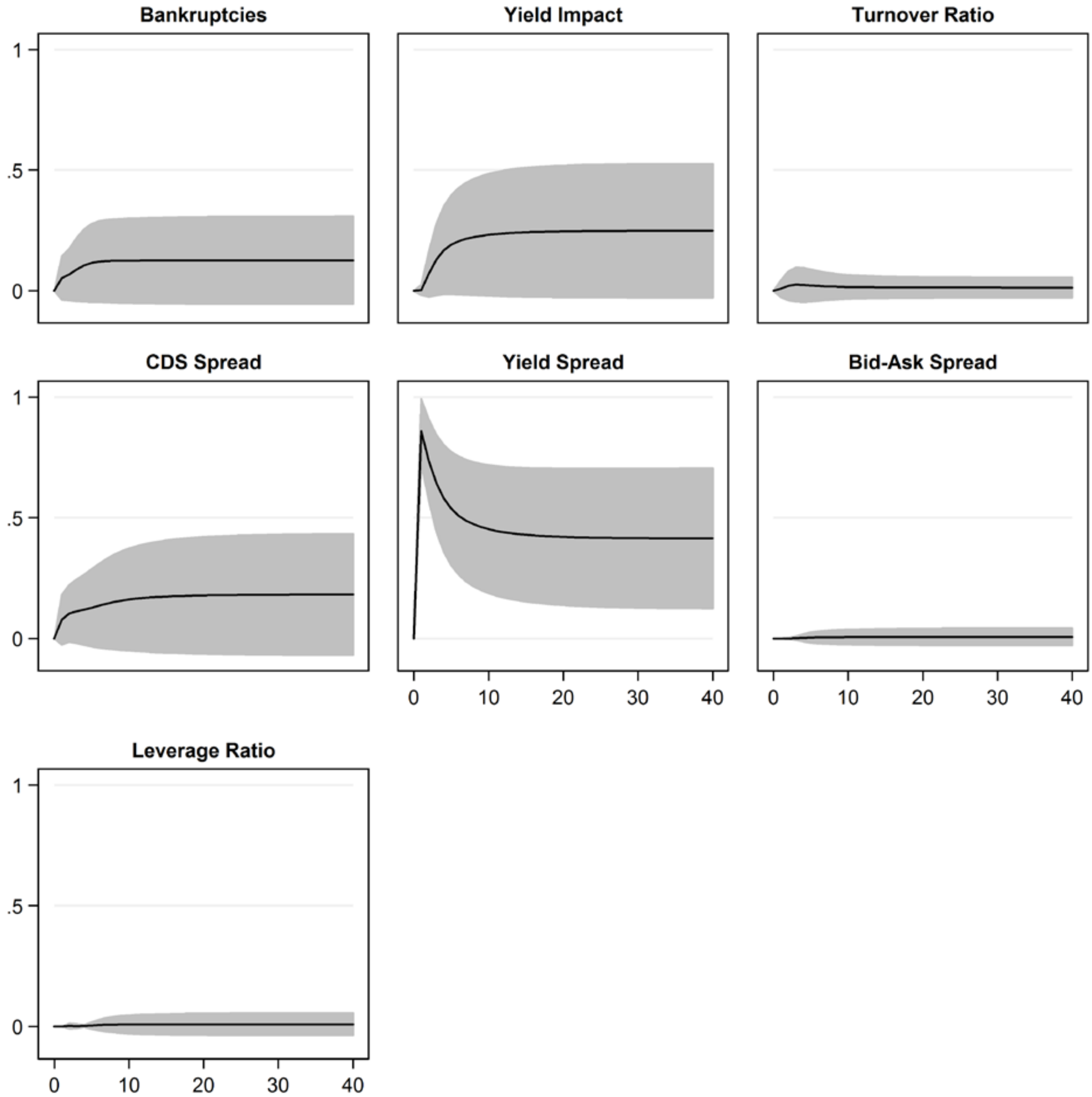
Comment: Basis points on the vertical axis and months on the horizontal axis. The coloured band is the 90% confidence interval. Size of impulse is one standard deviation.

Figure A14 Kommuninvest Yield Spread Variance Decomposition per Risk Factor Block, Estimated by Nelson-Siegel



Comment: Shares are calculated by summing the variance decomposition point estimates over all variable within each risk factor block.

Figure A15 Kommuninvest Yield Spread Variance Decomposition per Variable, Estimated by Nelson-Siegel



Comment: Share of variance in the forecast error on the vertical axis and months on the horizontal axis. The coloured band is the 90% confidence interval.