FI Analysis

New liquidity indicators for the fixed-income market

No.21
30 June 2020

Summary

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This analysis has presented at an internal seminar at FI. It has been approved for publication by an Editors' Board.

*The authors thank Johan Berg, Klas Granlund, Nikita Koptyug, Julia Rådahl and Michael Andersson for valuable feedback.

The Swedish fixed-income market – which includes the bond market, the money market and interest rate derivatives – is important for the government, municipalities, banks and firms to be able to finance their operations and manage risks. It is therefore of central importance to understand how these markets function and, more specifically, how liquid they are. This FI Analysis presents a new method for measuring market liquidity that focuses on government bonds and covered bonds.

This new method captures more dimensions of market liquidity than the methodology that Finansinspektionen used in the recent past (see Finansinspektionen, 2015). Thus, it describes how the market liquidity has changed over time in a deeper and more comprehensive manner than the earlier method. We also construct an aggregate measure that summarises information from the individual indicators. The aim is to provide a general overview of market liquidity. The aggregate measure can be used to follow the development of market liquidity, and analyse which factors are affecting market liquidity on the fixed income market.

The aggregate liquidity measure shows that liquidity in government bonds improved after the sovereign debt crisis in 2012 and was then stable until 2018, with the exception of temporary episodes in 2015 and 2016 when the market became more illiquid. Then, in 2018, liquidity deteriorated significantly once again and has stayed at this lower level since then. For covered bonds, the historical pattern is not as clear even if it does show that liquidity improved until the end of 2019 and then deteriorated. The aggregate liquidity measures for both government and covered bonds also show a clear deterioration in liquidity on the market in conjunction with the outbreak of the coronavirus in March and April 2020.

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FI Ref. 20-15313

Introduction

The fixed-income market plays a critical role for liquidity and risk management in the financial system. In order for the economy to function and grow, it is important that the fixed-income market is stable and well-functioning. The government, municipalities, banks and firms, among others, finance their operations by issuing bonds. For example, banks finance a large portion of their lending for households' mortgages by issuing covered bonds. The banks are also large investors in these instruments.[1] In order for Finansinspektionen (FI) to be able to achieve its goal of financial stability and well-functioning markets, it is important to follow the development of systemically important markets such as the fixed-income market.

The objective of this analysis is to present a new method for measuring market liquidity on the fixed-income market by focusing on government bonds and covered bonds. This new methodology uses several indicators that capture different dimensions of liquidity and therefore describes more thoroughly how liquidity changes over time. The method is an upgrade of an earlier tool that FI developed in 2015 (see Finansinspektionen, 2015). We also introduce a way to combine the information from each individual indicator to create an aggregate measure. The aim is to provide a general overview of market liquidity. The indicators and the aggregate measure can be used on an ongoing basis to follow market liquidity and analyse what is influencing liquidity on the bond market, for example regulatory changes, various measures, or structural changes on the market.

Liquidity and its dimensions

The term *liquidity* can be used in general to describe how easily an asset can be converted into cash. However, the concept is complex and can manifest itself in different ways.[2] The International Monetary Fund (IMF, 2015) describes three different types of liquidity: funding liquidity, market liquidity and monetary liquidity.

Funding liquidity describes how easily and inexpensively a market participant can finance their business or financial positions. A normal way for financial institutions and firms to finance their business is to issue securities in the form of shares or bonds or by raising loans (credit). Low funding liquidity can make it more expensive or more difficult to issue securities or borrow money and therefore restricts economic activity and the function of the financial markets.

Market liquidity is the possibility of easily and quickly selling a security at a price that is close to the market price just before the transaction takes place. If market liquidity is good, the holder of an asset can convert it to cash quickly, in large volumes, at a low transaction cost, and with little impact on the price, even under stressed market conditions. If market liquidity deteriorates, it becomes more difficult to quickly and efficiently sell large volumes of the financial instrument

1 For a general description of covered bonds and the covered bond market in Sweden, see Sandström et al. (2013), Finansinspektionen (2015b), and Hellström et al (2019)

2 See Brunnermeier and Pedersen (2009), IMF (2015), Finansinspektionen (2015b), and Bonthron et al. (2016) for a more in-depth analysis of the various ways.

without the transaction having a negative impact on the market price. Holders of instruments with low market liquidity may need to accept a significantly lower ask price than the current market price to sell the instrument. To hold illiquid instruments, investors will therefore require compensation that corresponds to the risk of not recouping their money if they choose to sell the instrument. Higher compensation requirements mean that the issuer will need to pay a higher interest rate to investors or the seller will get a lower price when selling the instrument on the secondary market.

Market liquidity is also important for price discovery, i.e. the process through which the prices on instruments are set. In a market with poor liquidity, the number of transactions is usually lower and fewer actors are prepared to provide reference prices for an instrument.[3] This impairs the price discovery process, in part through a larger spread between bid and ask prices. In markets with low liquidity, there is a greater risk for larger and more dramatic price movements, particularly given stressed market conditions. This could potentially give rise to serious consequences in the form of major losses for instrument holders and negative contagion effects for similar instruments.

Finally, monetary liquidity is the liquidity a central bank injects into the economy in the form of various facilities. Two such examples are repurchase agreements and quantitative easing through the purchase of securities.

The different types of liquidity influence one another. Changes in monetary liquidity can impact, for example, funding liquidity: lower repo rates or quantitative easing that lowers interest rates in general (including the financing rate) can decrease the cost of financing for market participants. Funding liquidity can also influence – and be influenced by – market liquidity through margin requirements. For example, market participants experiencing high costs to finance their holdings may need to reduce their positions. Falling prices caused by selling pressure in an illiquid market can influence in turn the value of remaining positions and collateral.[4] This leads to even higher margin requirements, and creates a negative spiral, where financing and market liquidity influence one another negatively.

This FI Analysis focuses on market liquidity and how it can be measured.

WHAT CAN AFFECT MARKET LIQUIDITY?

Market liquidity can be affected by financial cycles, changes in regulation and monetary policy.[5] After the financial crisis in 2008, legislators raised the requirements on banks' capital and liquidity. Theoretically, the stricter requirements could impair the banks' funding liquidity (see Brunnermeier and Pedersen, 2009) since the banks now need to hold more capital than before for their trading book and finance their trading book with longer maturities. Both of these factors are associated with a cost, which in turn can have a negative impact on market liquidity. Monetary policy can also impact market liquidity and

3 See, for example, Chordia et al. (2001).

4 Higher market volatility leads to higher margin requirements and larger valuation haircuts on collateral that is approved to cover the requirements.

5 See IMF (2015) for more on this.

funding liquidity. Since 2015, the Riksbank has lowered the repo rate and simultaneously implemented quantitative easing by purchasing government bonds. As market rates have fallen, the value of market makers' trading books has most likely increased, which might have boosted their profitability.[6] Market makers typically finance their trading books with short maturities. Due to lower short-term rates, the costs of financing trading books has decreased. This in turn can improve market liquidity. Quantitative easing, however, can also have a negative impact effect on market liquidity. When the central banks' increase their bond holdings, the volume that is available for other market participants decreases. On some occasions, quantitative easing can thus contribute to lower trading activity, which in turn can lead to less efficient price discovery, higher transaction costs, and lower market liquidity (see Han and Seneviratne, 2018).

A high competition between market makers can also affect market liquidity. When competition is high, it might be harder for market makers to raise the prices they charge their customers, for example with wider bid–ask spreads. Furthermore, banks themselves in their role as market makers can face incentives to promote liquidity in order to lower their financing costs, for example being more active on the secondary market for covered bonds (see Finansinspektionen, 2015).

MARKET LIQUIDITY IS MULTIDIMENSIONAL

Market liquidity is a complex term that is difficult to define. A market with high liquidity is often characterised by low transaction costs and the possibility of quickly executing large transactions with low price impact. These characteristics can be formulated as different *dimensions* in order to describe market liquidity. The academic literature suggests five dimensions: tightness, immediacy, depth, breadth, and resilience (see Sarr and Lybek, 2002).

Tightness refers to transaction costs, which normally are measured by the bid–ask spread. The lower the spread, the lower the cost to execute a transaction. This means higher liquidity.

Immediacy refers to the time needed to execute a transaction, i.e. how long it takes to buy or sell a certain volume of a security. The shorter the time, the higher the liquidity. Market makers are an important source of immediacy since they set the bid and ask prices that other market participants use for trading. Immediacy can be measured directly using order data for instruments traded in an order book by calculating how long it takes to match an order. For bilateral trade (over-the-counter, OTC), immediacy can be measured indirectly, for example by measuring how often an instrument is traded or calculating the share of instruments in a certain category that are not traded at all during a day.

Depth refers to various prices, both above and below the market price, where bid and ask orders are available. The market is considered deep when there is an abundance of buy and sell orders and a constant interest in trading. Depth is measured primarily through the volumes

6 A market maker is a contracted actor who in exchange for compensation commits to continuously provide bid and ask prices for the borrower's security to maintain liquidity in the instrument. The market maker uses an inventory of financial instruments, called a trading book, to bridge temporary imbalances between buyers and sellers.

that are available in the order book, but trading volume and the turnover ratio can also be used as indicators if there is no order book. Depth can also be estimated from how much a given transaction affects the current price.

Breadth is about the number and size of the volumes that are available in the order book at a certain price level for both bid and ask prices. If there are multiple orders on the market, a large transaction can be executed without having a major impact on the price. The terms *breadth* and *depth* are similar, but they describe slightly different aspects of liquidity in the order book. Depth describes price level where there is an interest in trading, while breadth describes how strong this interest is.

Resilience is the market's ability to correct an imbalance through supply and demand so that bid and ask prices quickly return to their previous levels. In a market with good resilience, new information is reflected immediately in the prices without major disruptions. Resilience can be measured by comparing short-term and long-term price volatilities. In a resilient market, the price recovers quickly to its equilibrium after large transactions.

Method for liquidity indicators

Market liquidity is not directly observable, and it is difficult to measure using a single indicator. In 2015, FI analysed market liquidity for covered bonds and government bonds using the yield impact liquidity indicator, which reflects the cost of trading bonds. The conclusion of the analysis indicated that it was difficult to measure market liquidity with only a single price-based indicator. In 2017, FI and other members of the European Securities and Markets Authority (ESMA) conducted a joint analysis of the liquidity of the EU's corporate bond market.[7] The analysis focused on a selection of liquidity indicators based on MiFID I transaction data.[8] Some of these indicators are only appropriate for measuring liquidity in bonds that are traded at a high frequency. Therefore, some of the indicators performed poorly for many Swedish corporate bonds since they are not traded every day. These indicators are instead more suitable for benchmark bonds (see *Benchmark bonds – the bonds with highest turnover*).

In general, the choice of liquidity indicators depends on both the type of the financial instrument and the market where it is traded. For instance, if trade is bilateral and there is no order book, it is not possible to directly measure depth or breadth. Other indicators can then be used to indirectly estimate these two dimensions. Liquidity indicators may also need to be adjusted to be able to apply them to different financial instruments. Unlike in the case of shares, a bond's residual time to maturity affects how actively the bond is traded on the market. Some indicators are more appropriate for instruments that are traded daily while others work best for instruments that are traded less frequently. There can also be problems with data availability. In order to be able

Benchmark bonds – the most-sold bonds

On the Swedish bond market, there are bonds that meet a certain standard and are traded in large volumes. These bonds are called benchmark bonds. The aim of benchmark bonds is to have reliable market-based reference prices for pre-determined maturities. Benchmark bonds include both covered bonds and government bonds, which means they meet well-defined and standardised conditions for outstanding volume and maturity. For example, covered benchmark bonds usually have a maturity of between one and six years while nominal government bonds can be issued as so-called on-tap issues. This makes it possible to increase outstanding volumes as needed or depending on demand. There is an established repo market for benchmark bonds, and there are also reliable repo facilities at the issuers. Dealers of benchmark bonds undertake to provide upon request tradeable prices for a bond when it meets the benchmark criteria. Given these binding agreements and the bonds' characteristics, benchmark bonds are normally traded more frequently than their respective non-benchmark bonds.

7 Several supervisory authorities have analysed the liquidity on the fixed-income market. See, for example, Autorité des Marchés Financiers (2015), Aquilina and Suntheim (2016), Cambón Murcia et al. (2017), and De Renzis et al. (2018).

8 See Appendix A for more information about the MiFID data.

to obtain a comprehensive overview of the market liquidity of a specific instrument, it is therefore necessary to use a number of different indicators based on the characteristics of the market. The indicators are chosen, in other words, according to the instruments that will be studied, the type of data that is available, and the dimensions of market liquidity that are intended to be captured.

This analysis further develops the liquidity indicators that FI, ESMA, and other supervisory authorities within the EU have developed earlier. We introduce new indicators that together capture the dimensions of liquidity that are mentioned above. We present ten different liquidity indicators that we calculate using transaction data reported to FI in accordance with the MiFID I and MiFID II regulations.[9] The indicators can be broken down into three groups based on the data that is used to calculate them: transaction-based, turnover-based, and price-based. Transaction-based indicators measure whether a transaction has occurred without using other information about the transaction. Turnover-based indicators use information available about transaction volumes. Price-based indicators are calculated using the price information for each transaction.

All indicators are summarised in Table 1 below:

Table 1. Individual liquidity indicators and their characteristics

Indicator		Category	Frequency	Dimension
Number of transactions	NrT	Transaction-based	H and L	I
Zero-trading days	ZTD	Transaction-based	L	I
% non-traded instruments	NTI	Transaction-based	L	I
Turnover per day	TURN	Turnover-based	H and L	B, D, I
Turnover per transaction	ATV	Turnover-based	H and L	B, D, I
Turnover ratio	TR	Turnover-based	H and L	B, D, I
Yield impact	YI	Price-based	H	T
BPW indicator	BPW	Price-based	H	T, R
Market Efficiency Measure	MEC	Price-based	H	R
Volume-Adjusted Intraday Volatility	VAIV	Price- and Turnover-based	H	B, D, T

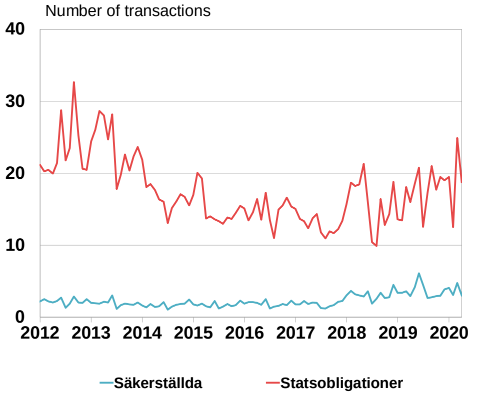
Note: *Category* refers to the information/variable the indicator is based on, *Frequency of data* describes whether an indicator is better suited for bonds that are traded daily (H) or less frequently (L). *Dimension* refers to the dimensions primarily captured by the indicators. The dimensions are tightness (T), immediacy (I), depth (D), breadth (B) and resilience (R).

TRANSACTION-BASED INDICATORS

Transaction-based indicators focus on whether a security is traded, but they do not require any additional information about the transaction itself. For this reason, they are easy to develop and interpret when transaction data is available. One limitation is that they do not use available information about price and volume. Transaction-based indicators are

9 See Appendix A for a description of MiFID I and MiFID II and a more detailed definition of all indicators expressed in mathematical formulas. Note that we focus solely on transactions that occur on the secondary market, which means that we do not consider sales when bonds are issued. We do so since the aim of this analysis is to describe market liquidity on the secondary market.

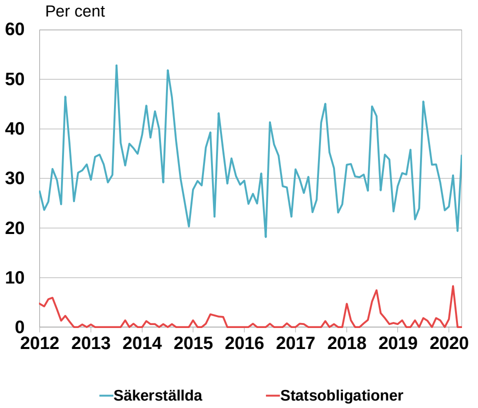
Diagram 1. Number of transactions (NrT)



Source: FI's own calculation, Refinitiv Eikon, Swedish National Debt Office, and Svenska Handelsbanken Bond Indices.

Note: The daily number of transactions (average per month) for covered bonds and nominal government bonds with benchmark status. Higher values correspond to higher liquidity.

Diagram 2. Zero-trading days (ZTD)



Source: FI's own calculation, Refinitiv Eikon, Swedish National Debt Office, and Svenska Handelsbanken Bond Indices.

Note: The percentage of zero-trading days (the average in each instrument group per month) for covered bonds and nominal government bonds with benchmark status. Higher values correspond to lower liquidity.

more suitable for measuring liquidity in instruments that are traded less frequently. In general, transaction-based indicators can be used to estimate the immediacy dimension since they describe how long it takes to buy or sell a certain volume of a security.

We construct three different transaction-based indicators:

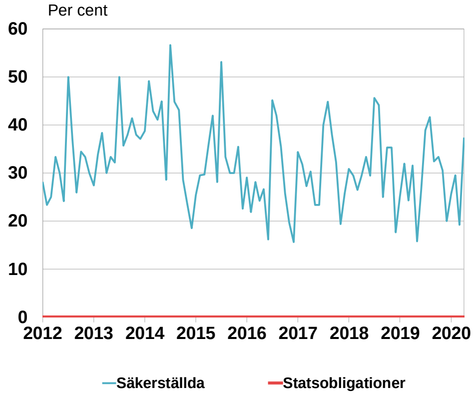
- *Number of transactions* (NrT) is the simplest indicator. It shows how many times a security has been traded on average during a certain period of time. A low value is a sign of low liquidity. For government bonds, the average number of transactions per day fell during the period 2012–2017 and then rose slightly, particularly in the past two years. In contrast, the average number of transactions for covered bonds was stable during the period 2012–2017 and then increased since 2017, just like government bonds (Diagram 1). The indicator therefore shows that liquidity in government bonds and covered bonds has improved in recent years.
- *Zero-trading days* (ZTD) are calculated as the percentage of days a security is not traded during a given period of time (see Dick-Nielsen et al., 2012). This indicator calculates how difficult it is for a market participant to quickly find a counterparty. The higher the value, the lower the liquidity. The indicator is suitable for securities that are not traded daily, for example covered bonds or real government bonds, but it is less suitable for measuring liquidity of securities that are traded very rarely or very frequently.[10] In these cases, the value of the indicator will not change over time, which is manifested, for example, as a low, constant value for government bonds. The indicator for covered bonds points to a decrease in liquidity during the period 2012–2014 since the percentage of zero-trading days per month increased from 30 per cent on average in 2012 to around 40 per cent in mid-2014. Since 2015, the percentage of zero-trading days stabilised at around 30 per cent (Diagram 2). It is worth noting that the indicator is clearly influenced by seasonal effects since the percentage of zero-trading days increases substantially during the summer.
- *Non-traded instruments* (NTI) are calculated as the percentage of securities within a certain instrument category that are not traded during a given day.[11] There is a large number of instruments on the fixed-income market that are not traded frequently. Trading in each instrument category is normally concentrated to a few securities while the remaining instruments in the same category are significantly less liquid. This applies primarily to trade in corporate bonds, but covered bonds and nominal, non-benchmark government bonds are also traded less frequently than corresponding bonds with benchmark status.[12] The indicator measures how difficult it is to find a counterparty for a specific type of security. A high value is a

10 The indicator is constant at 100 per cent if they are never traded. If they are traded daily, the indicator stays at 0 per cent.

11 We calculate NTI daily and aggregate per month by taking the median value. See Appendix B for more information. More details on NTI can also be found in Cambón Murcia et al. (2017), which applies the measure to Spanish bonds.

12 See the box on benchmark bonds.

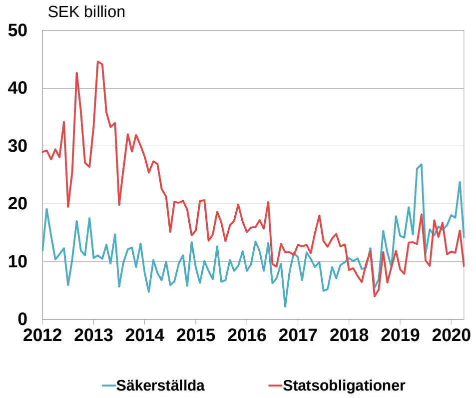
Diagram 3. Share of non-traded instruments (NTI)



Source: FI's own calculation, Refinitiv Eikon, Swedish National Debt Office, and Svenska Handelsbanken Bond Indices.

Note: Percentage of covered bonds and nominal government bonds with benchmark status that are not traded per day (median per month). Higher values correspond to lower liquidity.

Diagram 4. Turnover per day (TURN)



Source: FI's own calculation, Refinitiv Eikon, Swedish National Debt Office, and Svenska Handelsbanken Bond Indices.

Note: The daily trading volume (average per month) for covered bonds and nominal government bonds with benchmark status. Higher values correspond to higher liquidity.

sign of low liquidity. Just like the percentage of zero-trading days (ZTD), the percentage of securities that are not traded is a suitable indicator for measuring liquidity in an instrument category where there are differences in how often different securities are traded. If an instrument category only consists of securities that are traded daily or very rarely, the value at the category level will be more or less constant. Nominal government bonds are one example of this since they are traded daily and therefore have a value that is constantly zero (Diagram 3). In contrast, the indicator can be used to analyse the liquidity of covered bonds. For example, the value of covered bonds increased from around 30 to 50 per cent during the period 2012–2014, which indicates that the liquidity in these bonds decreased during the same period. The indicator has been stable at around 25–30 per cent the past few years despite some seasonal variation since there are some covered bonds with benchmark status that are not traded during the summer when trading activity is lower.

TURNOVER-BASED INDICATORS

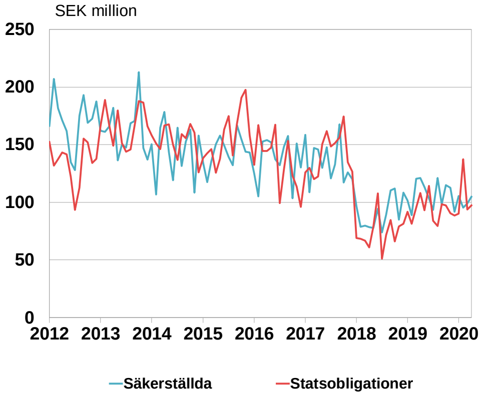
Turnover-based indicators are based on information about transaction volumes. Normally, turnover-based indicators only require data at the aggregate level, which is often available for several instrument categories. In general, high turnover is a sign of a liquid market, which means the higher the turnover, the higher the liquidity. However, this correlation does not necessarily apply under all market conditions, as demonstrated by the outbreak of the coronavirus pandemic in March 2020.[13]

We measure liquidity using three different turnover-based indicators.

- *Total trading volume per day* (TURN) indirectly measures the depth and breadth of the market and shows the market's ability to absorb large volumes. We measure the indicator by aggregating daily transaction volumes per instrument and instrument category. High values indicate higher liquidity. As shown in diagram 4, the indicator's value for government bonds has fallen over the past seven years. This is a sign of impaired liquidity on the market even if the value began to increase again after 2018. The daily trading volume in covered bonds has been more or less constant during the period 2012–2015. The turnover for covered bonds increased more than for government bonds after 2018, which indicates that liquidity for covered bonds improved slightly during the past two years, even compared to nominal government bonds. It is interesting to note that since 2018 covered bonds have had higher turnover than nominal government bonds. This can be due in part to the fact that total outstanding volumes for covered bonds have increased constantly over time. It is possible to take this effect into account by adjusting the turnover with

13 One example is the Flash Crash that occurred on 6 May 2010 on the U.S. stock market when Dow Jones fell by 9 per cent for just over 30 minutes due to a series of automated sales of large share volumes. The trading volumes were then high despite the poor liquidity on the market.

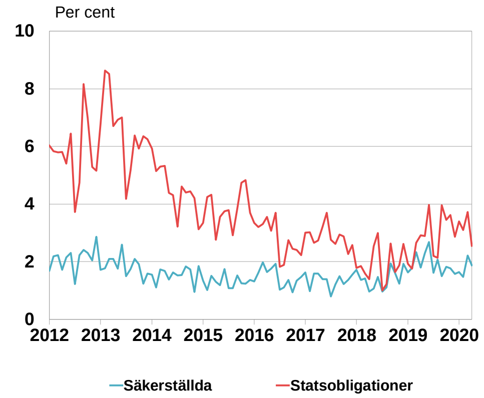
Diagram 5. Average transaction volume (ATV)



Source: FI's own calculation, Refinitiv Eikon, Swedish National Debt Office, and Svenska Handelsbanken Bond Indices.

Note: The daily trading volume per transaction (average per month) for covered bonds and nominal government bonds with benchmark status. Higher values correspond to higher liquidity.

Diagram 6. Turnover ratio (TR)



Source: FI's own calculation, Refinitiv Eikon, Swedish National Debt Office, and Svenska Handelsbanken Bond Indices.

Note: The turnover ratio (average per day) for covered bonds and nominal government bonds with benchmark status. Higher values correspond to higher liquidity.

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the total outstanding volume; see the turnover ratio indicator below.

- *Average transaction volume* (ATV) describes the average size of the transactions that are completed and indirectly captures immediacy. We measure the indicator per instrument and instrument category. A high value means in general that it is possible to trade large volumes in a single transaction. This, in turn, indicates high liquidity. The average volume per transaction and total turnover per day can generate different views on liquidity, even if the two indicators often follow one another. This is because a decrease in the total turnover does not necessarily mean lower volumes per transaction (and vice versa). Since 2012, the average volume per transaction for covered bonds decreased gradually, followed by a clear drop at the beginning of 2018 in conjunction with the introduction of the MiFID II regulations. Government bonds follow a similar pattern. The decrease in the average size of transactions points to a drop in liquidity in these markets even if there are signs of moderate improvement since 2019.
- *Turnover ratio* (TR) is calculated at bond level as turnover in relation to the total outstanding volume. The indicator shows the share of the total outstanding volumes that is traded on average during a given time interval. The turnover ratio differs from total turnover per day and average volume per transaction since it also takes into account the bond's total outstanding volume. The higher the value, the higher the liquidity. For government bonds, the turnover ratio gradually decreased during the period 2012–2018, which indicates a deterioration in liquidity on the market (Diagram 6). For covered bonds, the turnover ratio instead remained relatively constant during the same period. Over the past two years the turnover ratio has improved in particular for government bonds, even if the indicator, just like trading volume per day and average volume per transaction, shows a potential sharp deterioration in March and April 2020 in conjunction with the outbreak of the coronavirus.

PRICE-BASED INDICATORS

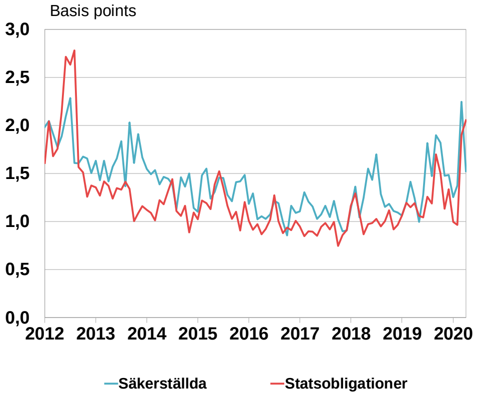
Price-based indicators are calculated using information about transaction prices. In general, they are more difficult to calculate than transaction- and turnover-based indicators since they require both a high frequency of transactions and more data processing. Price-based indicators are therefore appropriate for securities that are traded frequently, both during a given period of time (week, month, quarter) and during a single day (if the indicator is based on intraday data). Price-based indicators are necessary to capture the tightness, breadth, depth, and resilience liquidity dimensions, which cannot be measured using transaction-based and turnover-based indicators.

We construct three different price-based indicators and one indicator that uses both price and volume information:

- *Yield impact* (YI) is a modified version of the price impact indicator in Amihud (2002). Amihud's price impact captures the tightness dimension on the stock market. In general, a

Diagram 7. Yield impact (YI)

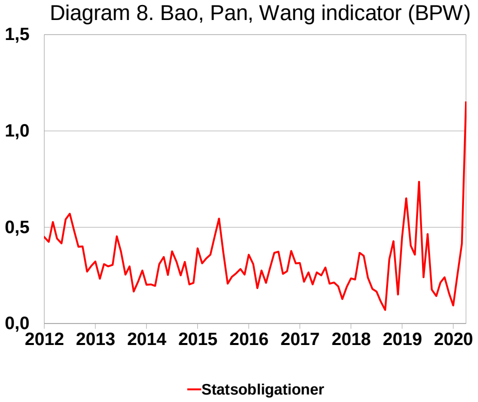
Basis points



Source: FI's own calculation, Refinitiv Eikon, Swedish National Debt Office, and Svenska Handelsbanken Bond Indices.

Note: The yield impact in basis points (average per month) per transaction for covered bonds and nominal government bonds with benchmark status. Higher values correspond to lower liquidity.

Diagram 8. Bao, Pan, Wang indicator (BPW)



Source: FI's own calculation, Refinitiv Eikon, Swedish National Debt Office, and Svenska Handelsbanken Bond Indices.

Note: BPW indicator (average per month) for nominal government bonds with benchmark status. Higher values correspond to lower liquidity.

high value of Amihud's indicator indicates that a transaction had a large impact on the price of a stock. This means that the transaction cost is high and the stock is illiquid.[14] We choose to use the yield impact, which is adjusted for the remaining maturity of the bond, instead of the transaction volume.[15] Yield impact for a bond measures the transaction costs by describing how many basis points are needed to buy and then immediately sell a bond. The higher the value, the lower the liquidity. Diagram 7 shows that the value of the indicator decreased slightly between 2012 and 2018 for both government bonds and covered bonds, with some temporary increases for government bonds in mid-2015. After 2018, the value increased for covered bonds more sharply since 2019. This is a sign that the absolute cost in basis points for trading these bonds decreased slightly through 2018 and then began to rise again, particularly in the past year.[16] Thus, the liquidity on the market for covered bonds has decreased since 2018. The impact of the outbreak of the coronavirus can be observed by looking at the yield impact in March and April 2020, which is historically very high for both government bonds and covered bonds.

- *Bao, Pan, Wang indicator* (BPW) measures market liquidity by calculating how much bond price varies over a short interval of time.[17] Bond prices are influenced by both new information about the fundamental value and different frictions related to how difficult and costly it is to trade the bond. The larger the frictions, the lower liquidity on the market. Theoretically, when the interval of time is short, the price is impacted more by the frictions since there will most likely not be much new information about the fundamental values. These frictions then are the main driver behind price fluctuations. It is then possible to measure market liquidity by calculating how much prices have changed over the short time interval. The indicator is linked to the tightness and resilience dimensions of liquidity. We calculate the indicator at intraday frequency, which means it needs a large number of daily transactions. This limits our analysis to government bonds.[18] A high BPW indicator indicates that liquidity on the market is low. The indicator for government bonds has varied during the period 2012–2018, with a temporary but significant increase at the beginning of 2019. The value also increased sharply in March and April 2020, which confirms the view that liquidity in government bonds deteriorated in conjunction with the outbreak of the coronavirus (Diagram 8).

14 See Finansinspektionen (2015b) for more detailed information about YI. In this analysis, however, we use an improved process for filtering data, which makes it possible to include more data in our analysis.

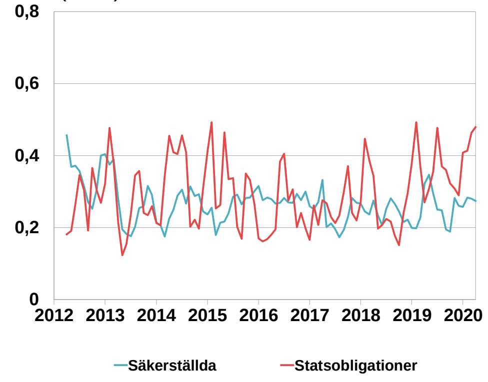
15 For a more in-depth description of why it is important to modify Amihud's price impact for bond data, see the description of YI in Appendix B and Finansinspektionen (2015b).

16 The relative transaction cost, i.e. cost in relation to the interest rate, has also increased due to the current low level of interest rates.

17 Roll (1984) developed the method that Bao et al. (2011) apply to corporate bonds. See Appendix B for more information about how the indicator is calculated.

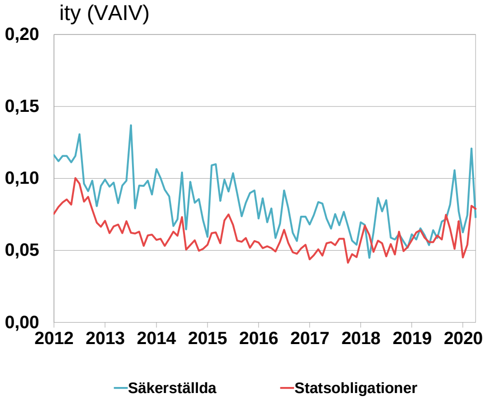
18 See Appendix B for a description of which restrictions were used to calculate BPW.

Diagram 9. Market Efficiency Coefficient (MEC)



Source: FI's own calculation, Refinitiv Eikon, Swedish National Debt Office, and Svenska Handelsbanken Bond Indices.
Note: The MEC indicator (average per month) for covered bonds and nominal government bonds with benchmark status. Higher values correspond to lower liquidity.

Diagram 10. Volume-Adjusted Intraday Volatility (VAIV)

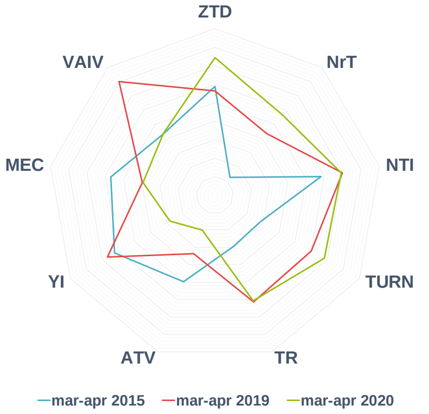


Source: FI's own calculation, Refinitiv Eikon, Swedish National Debt Office, and Svenska Handelsbanken Bond Indices.
Note: The volume-adjusted intraday volatility (average per month) for covered bonds and nominal government bonds with benchmark status. Higher values correspond to lower liquidity.

- *Market Efficiency Coefficient* (MEC) is linked to the resilience dimension (see Hasbrouck and Schwartz, 1988). The indicator is based on the assumption that prices in liquid markets vary at approximately the same rate over long periods of time. This means that when new information becomes available in a liquid market, it impacts the price quickly without needing multiple price adjustments. On the contrary, a less resilient market does not have good price discovery process. This means that new information that should impact the value of an asset takes a long time to be reflected in the price. This can cause temporary disruptions before new information is fully incorporated in new equilibrium prices. Our indicator proxies market resilience by identifying these disruptions, captured by comparing short- and long-term price volatilities. A high MEC indicates that liquidity is low.[19] The indicator requires that bonds are traded regularly, which limits the analysis to the most liquid bonds. Diagram 9 shows the value for both covered bonds and nominal government bond with benchmark status. The indicator, and thus the resilience, has fluctuated over the years, particularly for government bonds. During the period 2014–2015 and in mid-2018, the value increased for government bonds. There has also been a sharper increase since early 2019, which indicates that the market's resilience has decreased in recent years. The value for covered bonds, on the contrary, has held more constant, which could be due to the indicator not giving as much weight to the average effect of bonds that are not traded frequently.
- *Volume-Adjusted Intraday Volatility* (VAIV) is a price- and turnover-based liquidity indicator that measures how the price of a security moves over the period of one day in relation to the volume that is traded during that day (see Donier et al., 2015). According to the definition of tightness, the spread between bid and ask prices is low in a liquid market. If this spread is low, price volatility is usually also low since prices do not fluctuate as much between two consecutive closes. At the same time, it is normal for turnover to be high in a liquid market since there are more market participants who want to buy and sell securities in large quantities. The indicator considers how liquidity is reflected simultaneously in both prices and trading volumes and is calculated as a ratio between volatility over a period of one day (intraday) and the total daily turnover. One advantage of volume-adjusted intraday volatility is that it considers situations where volatility is low due to limited trade activity (which can indicate low liquidity) as well as situations where the turnover is high, but prices fluctuate sharply due to market frictions and inefficient price discovery (which also is a sign of low liquidity). One disadvantage of the indicator is that it can be difficult to compare levels of two instruments that are not traded with the same frequency. The calculation also requires a large number of transactions. The indicator is therefore only suitable for instruments traded daily and with high frequency. High VAIV indicate that liquidity is low. Volume-adjusted intraday volatility has decreased for covered bonds, and to less of an extent

19 See Appendix B for a detailed description of how MEC is calculated.

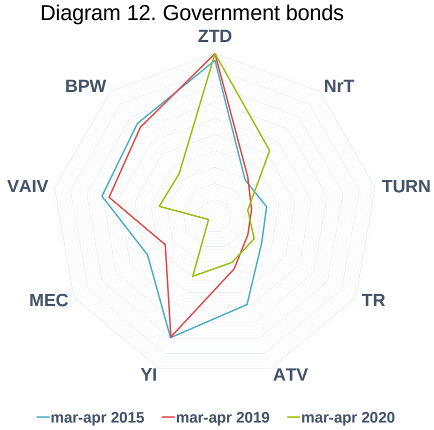
Diagram 11. Covered bonds



Source: FI's own calculation

Note: Average of normalised monthly values for relevant indicators for covered bonds with benchmark status. Larger areas correspond to higher liquidity. The values closer to the outer edge of the diagram correspond to higher liquidity.

Diagram 12. Government bonds



Source: FI's own calculation

Note: Average of normalised monthly values for relevant indicators for nominal government bonds with benchmark status. Larger areas correspond to higher liquidity. The values closer to the outer edge of the diagram correspond to higher liquidity.

also for government bonds, during the period 2012–2019, which indicates that liquidity has improved during this period. VAIV for both covered bonds and government bonds has increased since the beginning of 2020 – particularly between March and April – which once again indicates a deterioration in the liquidity on the market in conjunction with the outbreak of the coronavirus (Diagram 10).

Diagrams 11 and 12 describe visually how transaction-based, turnover-based and price-based indicators measure the market liquidity over three different time periods. For covered bonds (Diagram 11), market liquidity in general seems to have improved between 2015 and 2019, with the occasional outlier. However, during the outbreak of the coronavirus pandemic in March and April 2020, market liquidity deteriorated significantly according to price-based indicators (YI, MEC, VAIV). At the same time, however, transaction-based indicators (ZTD, NrT, NTI) and most of the turnover-based indicators (TURN, TR) show the opposite effect. This can indicate a deterioration in the tightness dimension in particular, which basically is captured by price-based indicators. For government bonds (Diagram 12), market liquidity deteriorated between 2015 and 2019 due to the turnover-based indicators. During the outbreak of the coronavirus pandemic, the price-based indicators contracted instead rather clearly.

AGGREGATION OF LIQUIDITY INDICATORS

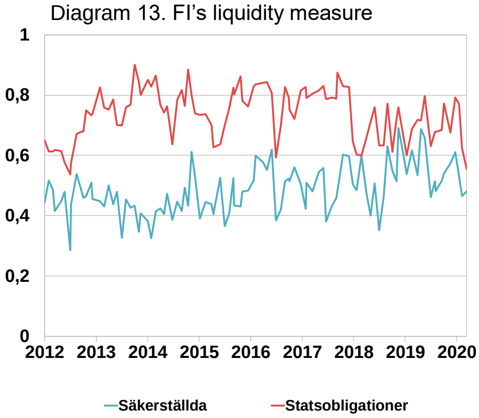
After having calculated the individual liquidity indicators, we construct an aggregate liquidity measure. The aim of this measure is to provide a general overview of liquidity that draws on the information from the individual indicators. The measure aggregates the various indicators to an index that varies between 0 and 1. A value of 0 means low liquidity and 1 high liquidity.

There are different ways to aggregate indicators. The simplest aggregation is an average with equally large weights. The benefit of the simple average is that it is both easy to calculate and consistent since the weights do not change over time. The downside of this aggregate method is that it does not consider potential correlation between various liquidity indicators. For example, two indicators could potentially measure the same liquidity dimension. If they are then included at the same weight as the other indicators, the aggregate measure will count some information twice.

Therefore, instead of using a simple average, we use a method from OECD (2008) and Nicoletti et al. (2000) to aggregate individual liquidity indicators. The method uses factor analysis and determines a weight for each indicator based on the historical movements of the indicators (see Appendix C). The method takes into account correlations between individual indicators and gives the highest weight to the indicator that contains the most unique information.[20] In this way, the aggregate liquidity measure considers the dynamics between the indicators and gives a better overall view of market liquidity. To compare

20 See OECD (2008) and Nicoletti et al. (2000) for detailed discussions about various aggregation methods.

Diagram 13. FI's liquidity measure



Source: FI's own calculation, Refinitiv Eikon, Swedish National Debt Office, and Svenska Handelsbanken Bond Indices.

Note: Liquidity measure as an aggregation of various individual indicators for covered bonds and nominal government bonds with benchmark status. Higher values correspond to higher liquidity.

the individual liquidity indicators before aggregation, we standardise the indicators (see Broto and Lamas, 2016).[21]

We aggregate our individual indicators by calculating the weights for each indicator according to the method described above and use monthly observations since 2012. We then calculate the aggregate liquidity measure for an interval set at three years (36 observations) and three factors. Therefore, the weights are calculated every month using the same number of observations. The weights vary during the period depending on the correlations between the various indicators over the previous three years.[22]

The aggregate liquidity measure shows that liquidity in government bonds improved after the sovereign debt crisis in 2012 and was then stable until 2018, with the exception of several temporary episodes in 2015 and 2016 when the market become more illiquid, after which it deteriorated significantly once again. For covered bonds, the historical pattern is not as clear, even if it does show that liquidity improved until the end of 2019 and then deteriorated during the year (Diagram 13).

Finally, it is possible to link the most recent deterioration in liquidity for both government bonds and covered bonds during March and April 2020, to the coronavirus outbreak. The turmoil created by the epidemic in all financial markets most likely had a negative impact on market liquidity as well.

Concluding remarks

The objective of this analysis is to present a method that has been developed to measure market liquidity for financial securities, and that focuses in particular on government bonds and covered bonds. This new method is a development of the previous tools FI developed in 2015. Using this method, we can study how market liquidity has changed over time and analyse, for example, how specific changes in regulation or market events have affected market liquidity.

In our analysis, we introduce a number of different liquidity indicators and calculate them using transaction data reported to FI in accordance with MiFID I and MiFID II. We show how our method can be used to describe the changes in market liquidity since 2012. It is interesting to note that the various indicators can give different indications on the status of market liquidity. This can happen, for example, when turnover and the number of transactions decrease without having a negative impact on prices. This type of situation can arise when market participants for different reasons become less active or reduce their traded volumes. Another example of when the indicators can show conflicting results could be linked to the current low interest rates. When interest rates are low, the relative transaction cost – that is the cost of trading in relation to the current yield – increases as interest rates fall

21 We use ten indicators for government bonds and nine indicators for covered bonds since there is no BPW indicator for covered bonds.

22 For example, the measure at the end of 2018 is based on the values of the various indicators between 2015 and 2018. Note that a sliding window of 36 months means in practice that the first value of the aggregate measure is calculated after three years of data. We chose to use the first weights retroactively on all indicators to fill the period 2012–2014 in Diagram 13. See Appendix C for a description of the method.

even if the bid-ask spread decreases or is constant. A higher relative transaction cost can reduce the incentive to trade despite a small bid–ask spread, and such reduction in trading activity indicates lower liquidity. These examples describe why it is important to follow market liquidity using multiple indicators that capture different dimensions of liquidity.

In order to have a general overview of market liquidity, we also construct an aggregate measure that summarises all the information from each individual indicator. The measure is easier to interpret if the goal is to summarise how liquidity has changed over time, but as a result some of the specific information included in the individual indicators is lost. The aggregate liquidity measure indicates that the difference in liquidity between government bonds and covered bonds has decreased slightly over the past three years. This is due in particular to the decrease in liquidity for government bonds after 2018, even if it improved again after the spring of 2019 and up to the outbreak of the coronavirus.

In this FI Analysis, we do not investigate further the causes for the deterioration in market liquidity during the period we have analysed. A possible explanation for the worsening of liquidity in the government bond market – which is mentioned by a majority of the market participants in the Riksbank's financial market survey – is the Riksbank’s purchases of government bonds since 2015 (see Riksbank’s Financial Markets Survey 2018, 2019a, 2019b)[23].

Another possible cause that might have affected liquidity for both government bonds and covered bonds could be the changes in capital requirements imposed on banks over the past seven years. These requirements might have affected banks’ risk appetite and thereby their desire to provide liquidity as market maker.

New regulations, for example MiFID II that was introduced at the beginning of 2018, can also affect liquidity through decreased transparency on the Swedish bond markets (see Finansinspektionen, 2019).[24] In a less transparent market, it can be more difficult and more expensive to gather information about underlying prices of securities, which means that price discovery becomes less efficient. This, in turn, makes it both more difficult to find a counterparty to trade with (lower depth and immediacy) and potentially more costly to trade (lower tightness). A market with low transparency can also be more sensitive to sudden disruptions (lower resilience).[25]

Our data includes the market uncertainty that arose in conjunction with the spread of the coronavirus in March and April 2020. The aggregate liquidity measures for both government bonds and covered bonds show a clear deterioration of liquidity on the market during this period. It is interesting to observe that this deterioration is captured

23 Several market participants raised the opinion that a less expansive monetary policy, particularly in the form of a decrease in purchases and holdings of Swedish government bonds, could help the market work better in the future.

24 According to FI’s analysis, this is primarily because the information is published in many different places and is difficult to access. Market participants executing transactions at a trading venue in another EU country are also able to defer the publication more frequently than what Swedish rules allow, which further decreases transparency.

25 For example, Goldstein et al. (2006) shows that there is a positive link between transparency and liquidity by studying how the implementation of the TRACE system (reporting of transactions to increase price transparency) improved liquidity on the US corporate bond market.

primarily by price-based indicators, and partly by turnover-based indicators, while transaction-based indicators indicate a marginal increase in market activity during the same period. A possible explanation for this is that more market participants chose to reallocate the positions in their portfolios at the beginning of the coronavirus pandemic in March 2020. Liquidity then worsened further in April 2020, possibly since it became both harder to find a counterparty and more expensive to trade. More studies are needed to pinpoint the exact cause for this deterioration.

Appendix A – Data

This analysis focuses on the Swedish bond markets and is based primarily on data from FI's transaction reporting system during the period January 2012–April 2020. We use external data sources (Swedish National Debt Office, Handelsbanken Bond Index and Refinitiv EIKON) to add further bond specific data, such as instrument category, maturity, issue date, and outstanding amount. In the analysis we focus on all covered bonds and nominal government bonds with benchmark status issued in SEK. We use benchmark data from the Swedish National Debt Office and Handelsbanken to identify these categories.

MiFID I and MiFID II data

MiFID was introduced in Sweden at the end of 2007. Its objective was to strengthen the protection for investors and increase competition in trading with financial instruments on the securities markets. A new directive and a regulation on markets in financial instruments – MiFID II and MiFIR – were introduced in January 2018.[26] These place new requirements on transaction reporting throughout all of the EU, both in terms of who needs to report the transactions and which instruments must be included in the reporting.[27] The reporting has also become more comprehensive since more information must be provided.[28]

The period analysed in this report includes the periods prior to and following the introduction of MiFID II/MiFIR. To create our liquidity indicators, we include data from transactions reported under both MiFID I and MiFID II. We use the same data filter for both databases. We only choose to use reporting data under MiFID I from 2012 onward due to improvements that were made to the data quality then.

We only choose to use secondary market transactions since we are interested in studying liquidity on this market. We therefore exclude all transactions that occur between issuers and dealers, including when issuers increase the outstanding volume in a bond that has already be issued by selling bonds directly to dealers ("on tap").

Data cleaning

Our original dataset contains incorrectly reported transactions that can affect the results of our analysis. The most common errors are that interest rates or volumes are reported in the price field or nominal amounts are reported in the field for the transaction price. For each measure, we remove transactions from the database that were reported twice and excluded data that otherwise contains incorrect information. Since the indicators are based on information such as transactions, volumes and transaction prices, we adjust the data filters for each indicator to be able to use as many observations as possible. We use different filters based on price movements, volumes and counterparties in a transaction. Finally, we compare the turnover in MiFID I and MiFID

26 See https://www.fi.se/sv/marknad/vardepappersmarknad-mifidmifir/

27 See https://www.fi.se/sv/marknad/rapportering/transaktioner-mifid2-mifir/ för mer information.

28 New information about customer identification and notifications of short selling and transparency exemptions have been included.

II data with the Riksbank's SELMA data to ensure that the differences are not significant.[29]

29 To have a comparable database, we build a sample of MiFID I and MiFID II data that reflects the data in SELMA. We only consider, for example, transactions reported by official SELMA reporting entities, we include transactions on the primary market, and we exclude all transactions between banks' branches. To calculate all indicators in this FI Analysis, however, we use all reported transactions from all reporting entities, including those that do not need to report to SELMA, and we exclude all primary market transactions.

Appendix B – Liquidity indicators

We describe in detail in this appendix the liquidity indicators that we include in the main analysis.

Number of transactions (NrT)

NrT is defined as the average of the number of transactions that occurred during a given period of time, for example one day, in all bonds that belong to a specific instrument group.[30] We define the indicator per instrument group *j* and day as:

$$\mathrm{NrT}^j = \frac{1}{N}\sum_{i=1}^{N} \text{tot nr transactions}_i^j,$$

where $\text{tot nr transactions}_i^j$ is the total number of transactions for the given day for bond *i* that belongs to instrument *j*.

NrT captures the dimension immediacy since it shows how often bonds have actually been traded during a given day. The higher the indicators, the higher the market liquidity is expected to be. NrT is easy to calculate, but it does not provide any information about prices and volumes.

Zero-trading days (ZTD)

ZTD is described by Dick-Nielsen et al. (2012) among others and is calculated as the number of days during a given period of time (for example, one month) that a security is not traded. ZTD is defined as

$$\mathrm{ZTD}^j = \frac{1}{N}\sum_{i}^{N} \frac{\text{tot days without trade}_i^j}{\text{tot trading days}},$$

where $\text{tot days without trade}_i^j$ is the number of days without a transaction during the selected period of time for bond *i* that belongs to instrument group *j*, and tot trading days is the total amount of available trading days during the selected period.

ZTD captures the dimension immediacy since it shows how infrequently a bond has been traded during the period. The indicator is also an estimate of how difficult it would be for a market participant to find a buyer or a seller for a security. The higher the ZTD, the lower the market liquidity is expected to be.

ZTD is relatively easy to interpret and is effective for measuring liquidity of bonds that are not traded daily – for example covered bonds or inflation-linked bonds. The indicator is not suitable for measuring liquidity for bonds that are traded very infrequently or daily, since in these cases the value of ZTD becomes constant.

30 With the term *instrument group* we refer to, for example, benchmark covered bonds.

The number of non-traded instruments (NTI)

NTI is described by Cambón Murcia et al. (2017) among others and is calculated as the share of securities in an instrument category that are not traded during a given period of time. The indicator is calculated per day as follows:

$$\mathrm{NTI}^{j} = \frac{1}{T}\sum_{i}^{T}\frac{\text{tot bonds without trade}_i^j}{\text{tot active bonds}^j},$$

where $\text{tot bonds without trade}_i^j$ is the sum of bonds in group *j* that have not been purchased or sold during the day and $\text{tot active bonds}^j$ is the sum of bonds that are available for trade during the same day. In the analysis, we calculate NTI per day and instrument category and then take the median of NTI for each month. We choose to use the median instead of the average since the calculation method for our instrument categories in this specific case means that NTI and ZTD are perfectly correlated. They can differ in other contexts, however, and we therefore choose to compute the median in our analysis.

NTI captures the dimension immediacy since it shows how often a certain category of bonds is traded on average. The indicator is therefore an estimate of how difficult it would be to find an opposing interest for trading a specific type of bond. The higher the NTI, the lower the market liquidity is expected to be.

Just like for ZTD, NTI is relatively easy to interpret and is effective for measuring liquidity within a certain category of bonds where the number of bonds traded within the category varies between different points in time. The indicator is not appropriate for measuring liquidity in a category where the share of bonds that is traded is constant over time.

Total trading volume per day (TURN)

TURN is calculated as the average of the total trading volume per day for instrument group *j* as follows:

$$\mathrm{TURN}^{j} = \frac{1}{N}\sum_{i}^{N}\text{tot daily turnover}_i^j,$$

where $\text{tot daily turnover}_i^j$ is the sum of all traded volumes during the day for bond *i* that belongs to instrument group *j*. High TURN values indicate high liquidity.

Average transaction volume (ATV)

ATV is defined as the daily average of the volume per transaction for instrument group *j* as follows:

$$\mathrm{ATV}^{j} = \frac{1}{N}\sum_{k}^{N}\frac{\text{tot daily turnover}_i^j}{\text{tot nr transactions}_i^j},$$

where $\text{tot daily turnover}_i^j$ is the sum of all traded volumes during the day for bond *i* and $\text{tot nr transactions}_i^j$ is the total number of transactions for that day for bond *i*. High ATV values indicate high liquidity.

Turnover ratio (TR)

TR is described among others by Sarr and Lybek (2002) and is calculated as the total daily turnover in relation to the outstanding volume for bond *i*. The measure shows, in other words, the share of the issued amount that is traded during a given interval:

$$\mathrm{TR}^j = \frac{1}{N}\sum_{i}^{\mathrm{N}} \frac{\text{tot daily turnover}_i^j}{\text{total outstanding}_i^j},$$

The higher the TR, the larger share of the bond is traded per day, which means that market liquidity is also higher.

FI's yield impact (YI)

YI is a modified version of the Price Impact (PI) liquidity indicator for the stock market in Amihud (2002). According to Amihud's indicator, it is possible to indirectly measure transaction costs for a stock by looking at the absolute return between two consecutive transactions, divided by the transaction volume. We choose to use a modified version YI, which is adjusted so the remaining maturity (time to maturity) of the bond is used instead of the transaction volume. We do this for two reasons. First, unlike in the stock market, there is no indication that larger transactions have a greater impact on price for OTC trades. There is instead a weak and negative relationship between volumes and the impact on price.[31] Second, we need to consider that bond prices in Sweden, by convention, are reported in basis points and not in absolute SEK. These basis points, which are usually called yield to maturity, correspond to the annual return the investor can expect from holding the bond until it matures. The duration describes how sensitive the price is to changes in the annual expected return. In general, the duration for long bonds is higher than for short bonds. Higher duration means a higher change in price as a result of a change in interest rates. We use time to maturity to adjust the returns since duration data is not directly available, and we define the daily YI indicator per instrument group *j* using the following equation:

$$\mathrm{YI}_d^j = \frac{1}{N}\sum_{i}^{\mathrm{N}} \mathrm{YI}_{d,i}^j$$

with

$$\mathrm{YI}_{d,i}^j = \frac{\mathrm{PI}_{d,i}^J}{(\text{time to maturity in yr})_{d,i}},$$

and

31 See, for example, Dick-Nielsen et al. (2012).

$$\mathrm{PI}_{d,i}^{J} = \frac{1}{N}\sum_{k}^{\mathrm{N}} \frac{\left|\mathrm{p}_{d,i,k}^{j} - \mathrm{p}_{d,i,k-1}^{j}\right|}{\mathrm{p}_{d,i,k-1}},$$

where $\mathrm{p}_{d,i,k}$ is the price of transaction k during day d for bond i in group j. YI measures the transaction costs by describing how many basis points are needed to buy and then immediately sell a bond. The measure therefore captures the dimension tightness. The higher YI, the lower market liquidity is presumed to be.

YI easily and effectively measures transaction costs by describing how many basis points are needed to buy and then immediately sell a bond. However, the indicator requires a certain number of transactions per day to be calculated. It is therefore particularly suitable for more liquid bonds that are traded daily, such as nominal and covered benchmark bonds.

Bao, Pan and Wang indicator (BPW)

The BPW indicator measures market liquidity by calculating how much bond prices vary over a short interval of time. Bond prices are affected by both new information about the fundamental value and market frictions that describe how difficult and costly it is to trade the bond. These frictions are linked to the liquidity, so that larger frictions mean lower market liquidity. Theoretically, when the time interval is short it is unlikely that market prices change due to new information. On the other hand, prices are continuously affected by market frictions. These frictions then lead to temporary fluctuations in bond prices. It is possible to estimate this temporary component using the following equation:[32]

$$\mathrm{BPW}^{j} = \frac{1}{N}\sum_{i}^{\mathrm{N}} -cov(r_{t,i}^{j}, r_{t-1,i}^{j})$$

where $-cov(r_{t,i}^{j}, r_{t-1,i}^{j})$ is the daily covariance between returns on two consecutive transactions (so-called autocovariance) in bond i belonging to instrument group j, and N is the number of observations per day.

To estimate BPW with sufficient precision, we choose to focus on bonds that have at least 10 transactions per day. The only bonds that are traded with a sufficiently high frequency to be included in BPW are thus nominal government bonds with benchmark status.

Market Efficiency Measure (MEC)

MEC was described first in Hasbrouck and Schwartz (1988) and is based on the assumption that price volatility is more or less constant in liquid markets, even when the prices is constantly – but temporarily – influenced by new information. The variance of daily prices changes therefore should not differ significantly from the variance of price changes over longer horizons. In other words, short and long term vol-

32 According to Bao et al. (2011) there are two components in price changes, a temporary component that affects liquidity and a permanent component that is controlled by fundamental information. See Bao et al. (2011) for a more in-depth description of underlying assumptions in the model.

atility tend to converge when markets are resilient. We build our indicators as the absolute difference between Hasbrouck and Schwartz's MEC indicator and 1, so that high values of MEC mean that the value is low:

$$\mathrm{MEC}^{j} = \frac{1}{N}\sum_{i}^{\mathrm{N}}\left|\frac{Var\ (R_{i,t}^{j})}{T * Var\ (r_{i,t}^{j})} - 1\right|$$

where $Var\ (R_{i,t}^{j})$ and $Var\ \left(r_{i,t}^{j}\right)$ are the variance of returns over a five-day period and variance of returns over a one-day period for bond *i*, and *T* is the number of short periods in each longer time period (which means that in our case T = 5). We calculate the variances over a period of three months to achieve sufficiently high precision in our estimates.

MEC measures how resilient a market is for sudden shocks. A higher MEC means lower liquidity, all else being equal. MEC does not need as many observations during one day as, for example, BPW. However, it is necessary to use daily returns of the same bond to compute the indicator, which limits the use of MEC to the most traded bonds with benchmark status.

Volume-Adjusted Intraday Volatility (VAIV)

VAIV is a modified version of the indicator described in Donier and Bouchaud (2015). Their indicator is based on the order book data, where trade is continuous. Liquidity can then be described as a reaction to imbalances in the order flows. We adapt Donier and Bouchaud's indicator for the bond market and define our liquidity indicator as

$$VAIV_{t}^{j} = \frac{1}{N}\sum_{i}^{\mathrm{N}}\frac{\sigma(r_{i,t}^{j})}{\log(\text{tot daily turnover})_{i,t}},$$

where $\sigma(r_{i,t}^{j})$ is the volatility of returns on bond *i* during day *t* and $\log(\text{tot daily turnover})_{i,t}$ is the natural logarithm of the total turnover of the same bond *i* during the same day *t*. We use return adjusted by the time to maturity to be able to have comparable measure of volatility between bonds with different maturities since bonds with lower maturity usually show higher price sensitivity and therefore higher price volatility.

VAIV is calculated as a ratio between the intraday volatility during a day and the total daily turnover. One advantage of VAIV is that it considers situations where volatility is low due to limited trade activity (which indicates low liquidity) as well as situations where the turnover is high but prices fluctuate significantly due to market frictions (which also is a sign of low liquidity). A disadvantage of VAIV is that it requires a large number of transactions. The indicator is therefore only suitable for instruments traded daily and with high frequency. High VAIV values indicate that liquidity is low.

Appendix C: FI's liquidity index

Factor analysis describes the covariation between individual variable using few underlying factors. We can write the factor model as

$$X_1 = a_{11}F_1 + a_{12}F_2 + \cdots a_{1m}F_m + \varepsilon_1$$

$$\dots$$

$$X_n = a_{n1}F_1 + a_{n2}F_2 + \cdots a_{nm}F_m + \varepsilon_n$$

where X_n is the normalised individual indicators in our analysis, F_m are joint factors, ε_n are idiosyncratic factors that differ for each individual indicator, and a_{nm} are so-called factor loadings (FL). FL capture the relationship between the individual indicators and the factors and is used to calculate the weights for each indicator that is included in the liquidity index. An advantage of the factor analysis is that the information included in several variables can be summarised using a few factors.

We follow the same method as in Holló et al. (2012) and normalise the individual indicators by calculating their cumulative distribution function (CDF) as

$$X_n = \begin{cases} \frac{r}{n}, f\ddot{o}r\ x_{[r]} < x_t < x_{[r+1]},\ \text{där}\ \ r = 1, 2, \dots T-1 \\ 1, f\ddot{o}r\ x_{[T]} \leq x_t \end{cases},$$

where x_t are the individual indicators [33] and $x_{[r]}$ are ranked observations of each indicator, where r is the place in the ranking, so that $x_{[1]} < x_{[2]} \dots < x_{[T]}$.

We construct the liquidity index in four steps. First, we calculate the correlations between the individual indicators. If the correlation is weak, this means that there is no joint factor that can explain the variation in the indicators. As a second step, we identify a number of factors that can describe the covariance between the individual indicators.[34] As a third step, we apply a so-called rotation (varimax), which changes both FC and each factor's contribution to the total explained variation. Finally, as a fourth step, we calculate the weights from the rotated FC, which are then used to weight our liquidity index.[35]

We compute the weights on the liquidity index based on the most recent 36 observations of X_n, so that the weights are allowed to change between different points in time and only consider correlations between indicators over the previous three years.

33 Before CDF is calculated, we invert some indicators so that a higher value means lower liquidity. For example, we multiply the TURN indicator by -1.

34 We decide the number of factors in this step, i.e. the value of m in equations. See OECD (2008) for details on how the number of factors should be chosen.

35 See Nicoletti et al. (2000) for details.

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