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Liquidity in the Norwegian and Danish Covered Bond Markets

An empirical study comparing the liquidity in the secondary covered bond markets in Norway and Denmark from 2010 to 2021

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Abstract

In this paper, we analyze and compare the liquidity in the Norwegian and Danish secondary covered bond markets using transaction data from 2010 to 2021. With sparse transaction data, measuring liquidity in the two markets is no easy exercise. We employ two trading activity variables and two liquidity measures suitable for the data available.

Although the bond market in Norway is generally seen as less liquid compared to other markets, we do not find sufficient evidence to conclude that the liquidity in the Norwegian covered bond market is lower than the Danish. In addition, our study investigates how liquidity in the two covered bond markets is affected during stressed market periods. In Norway, we conclude that the market liquidity is significantly worsened during stressed market periods compared to normal market periods. We do not find sufficient evidence for a similar conclusion in Denmark.

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1 Introduction

The Norwegian market for credit bonds is generally recognized as being less liquid than other comparable European bond markets. However, academic research investigating the statement is limited. Beyond specific professional fixed-income communities, there is surprisingly little knowledge about the cost of trading bonds, considering the importance of bond funding in economies (Edwards et al., 2007). The limited knowledge of the Norwegian secondary bond market liquidity motivates us to write about the topic.

We want to examine the general perception that the Norwegian bond market is less liquid than other markets. Limiting the scope to the secondary covered bond markets in Norway and Denmark, our study will compare the liquidity in the two markets based on transaction data from 2010-2021. In addition, the study will investigate how the liquidity in the two markets is affected during stressed market periods.

Covered bonds are debt instruments issued by credit institutions and secured by a separate pool of high-quality assets (The European Commission, 2015). Covered bonds are considered very safe, often referred to as a substitute for government bonds. With rapid growth over the last two decades, covered bonds have become an essential source of financing for Norwegian banks. The Danish covered bond market is the world's largest. While the Danish market is more mature, the market mechanisms are generally the same in Norway. Therefore, the Danish covered bond market serves as a helpful benchmark.

The two covered bond markets mainly attract institutional investors, such as banks, insurance companies, pension funds, and mutual funds. Investors considering buying or selling securities are exposed to liquidity, or more precisely, the lack of it (Mahanti et al., 2008). Consequently, transaction costs are incorporated in covered bond investors' investment decisions. From the perspective of professional investors in the covered bond markets in Norway and Denmark, a well-functioning secondary market is essential. The investors want to hold securities that can easily be traded, even when markets are stressed.

Measuring liquidity in bond markets is a challenging exercise. Trading in the Norwegian and Danish secondary bond markets is mainly carried off-exchange, which reduces the availability of data. For instance, we do not have access to order-based data such as bid-ask quotes. The transaction data we have available limits us to perform only trade-based measures of liquidity.

We measure the liquidity in the two covered bond markets using both trading activity variables and liquidity measures. Bonds are traded relatively infrequently in our transaction data, especially in the Norwegian covered bonds. While the two liquidity measures we employ initially are designed for frequently traded securities, we make certain adjustments to make the measures suitable for our sparse transaction data.

We aggregate our chosen liquidity proxies to monthly numbers for each market to define the markets' liquidity. We then compare the two markets' liquidity to each other, in order to interpret which is the most liquid. In addition, we run regressions with time event dummies to test whether the liquidity in the markets changes significantly during stressed market periods.

Our analysis does not find sufficient significance to conclude that either of the covered bond markets is more liquid than the other. In addition, we do not find evidence that the Danish covered bond market's liquidity significantly worsens during the stressed market periods we have defined. However, for the Norwegian market, we conclude that the liquidity has been significantly lower during the stressed market periods.

The rest of this thesis is structured as follows. Section 2 presents an overview of the literature that has inspired our study. Next, section 3 presents the covered bond markets in Norway and Denmark. Section 4 describes the transaction data we have obtained for our study and the data treatment and filtering process. Further, section 5 explains what is meant by the term liquidity and introduces the liquidity measurements used in our study. Section 6 develops the two hypotheses we will test. Section 7 presents our results, while section 8 discusses weaknesses and suggestions for further research on the topic. Lastly, we will conclude our findings in section 9.

2 Litterature Review

Research covering the liquidity in Norway and Denmark's secondary covered bond markets is limited. In general, secondary bond market liquidity in Norway has received little attention, while the Danish bond market is slightly more studied. In international literature covering bond liquidity, the U.S. fixed-income market has received the most attention.

In our search to find an appropriate way to measure liquidity with relatively sparse transaction data, we have been inspired by literature comparing liquidity measures computed based on different granularity of data.

For the U.S. fixed-income structured product market, Friewald et al. (2017) find evidence that liquidity measures that use dealer-specific information can be efficiently proxied by means of measures that use less detailed information. An example is the imputed roundtrip cost measure, introduced by Feldhütter (2012), which allows estimating roundtrip costs without dealer information. In our study, we employ the imputed roundtrip cost measure as a proxy for measuring bid-ask spreads, using only price and volume information from our transaction data.

Schestag et al. (2016) find that most low-frequency liquidity proxies, including Amihud's (2002) measure, generally measure transaction costs well, based on daily transaction data from the U.S. corporate bond market. Our study employs a price impact measure similar to Amihud's (2002) measure as one of our two designated liquidity measures.

To our knowledge, Rakkestad et al. (2012) and Ødegaard (2017) are the only[1] academic papers using transaction data to analyze Norwegian secondary bond market liquidity. When measuring liquidity, the two papers employ trading activity variables, such as trading frequency and turnover, and liquidity measures, such as Amihud's (2002) price impact measure. The two papers also investigate whether the transaction data available is feasible to measure liquidity in the Norwegian bond market. Both papers conclude that the low trading activity in Norwegian corporate bonds makes it challenging to produce reliable liquidity indicators. However, Ødegaard (2017) observes an increased activity in covered bonds in recent years, making it the second most actively traded bond class after Treasury securities. With the rise in activity, Ødegaard (2017) argues it is feasible to

[1] Beyond theses written by students.

construct liquidity indicators for Norwegian covered bonds.

Our work builds on the works of Ødegaard (2017), who encourages further research of liquidity in the growing Norwegian covered bond market. We add value to Ødegaard's work in several ways. First, our transaction data is more complete. While Ødegaard only had access to daily transaction data, we have intraday data on realized transactions. Our dataset is also extended with the years 2017-2021. Second, we apply a particular focus on how liquidity is affected during stressed markets. Lastly, the liquidity is put in context by comparing it with the Danish covered bond market, which is the the world's largest.

Dick-Nielsen et al. (2015) compare the liquidity in Denmark's secondary covered- and government bond markets with transaction data from 2007 until 2011. This is one of few papers providing an empirical study of the Danish covered bond market liquidity. The results suggest that Danish covered bonds are as liquid as Danish government bonds, including during the financial crisis when markets were stressed.

Our empirical test strategy is inspired by the work of Dick-Nielsen et al. (2015). First, we employ the same price impact measure as a proxy for market liquidity in our study. However, we extend our research to include three additional proxies for liquidity. Second, to test whether liquidity in the Norwegian and Danish covered bond markets significantly decreases during stressed markets, we replicate the regression setup with time event dummies for stressed market periods. While Dick-Nielsen et al. (2015) have access to transaction data in the period 2007-2011, our study is extended with transaction data until 2021, starting from 2010.

3 Covered Bonds

Covered bonds are debt instruments issued by credit institutions and secured by a separate pool of high-quality assets (The European Commission, 2015). The cover pool, which bondholders have direct recourse to as preferred creditors, usually consists of high-quality assets such as residential and commercial mortgages or public debt. If liquidation of the cover assets does not fully settle the bondholders' claim in the event of issuer default, investors remain entitled to a claim against the issuing entity as ordinary creditors. The double claim against both the cover pool and the issuer is referred to as the "dual recourse" mechanism.

Covered bonds possess multiple strengths, making them attractive to investors searching for a reliable investment. The dual recourse mechanism means that bondholders can expect a higher recovery in the event of an issuer's failure (ECBC[2], 2021). Compared to unsecured debt, covered bonds have both higher ratings and higher rating stability.

The following two subsections will introduce the covered bond markets in Norway and Denmark, respectively.

3.1 The Norwegian Covered Bonds

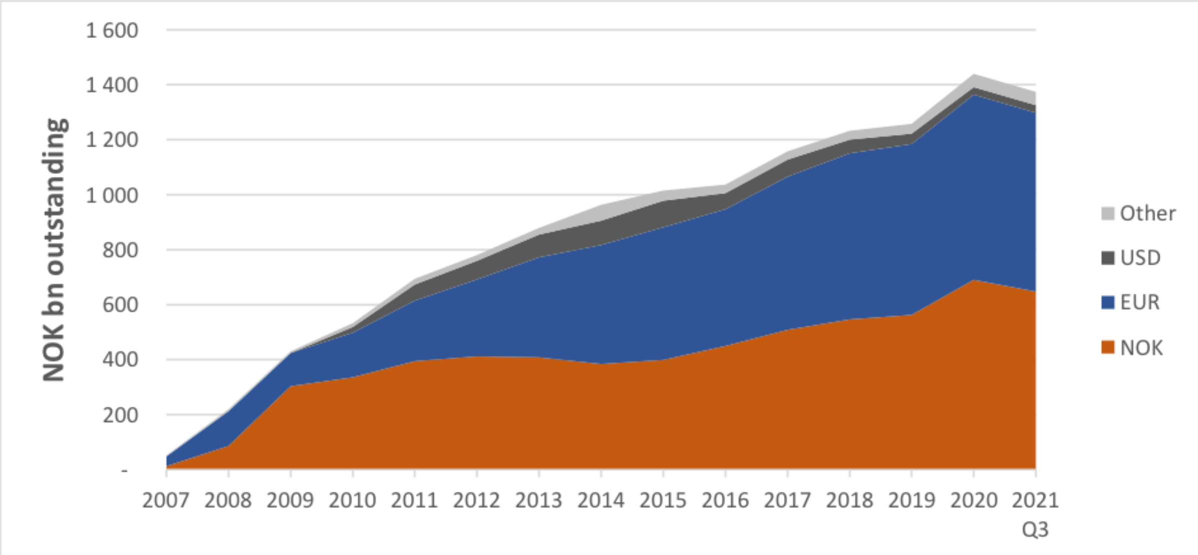
Norwegian covered bonds, denominated "Obligasjoner med fortrinnsrett" (OMF), are perceived among the best in class of European covered bonds (Finance Norway, 2018). According to a report from Finance Norway (2018), investors have not experienced a single loss on a Norwegian covered bond since the first issuance in the second half of 2007. The instrument's legal framework is considered solid, supported by Norway's robust macroeconomic position. The mentioned report also states that the secondary market of covered bonds is considered liquid by the market participants.

Since the legislation of covered bonds in Norway entered into force in 2007, the market has grown rapidly to be an integral part of the Norwegian financial system. Covered bonds listed domestically amount to nearly 30% of the total outstanding amount in the Norwegian bond market (Finance Norway, 2021). In terms of outstanding volume, the

[2]European Covered Bond Council.

Norwegian covered bond market was the tenth largest globally in 2020 (ECBC, 2021).

Figure 3.1: Outstanding volume in the Norwegian covered bonds



Source: Finance Norway

Figure 3.1 shows the development of the outstanding volume disaggregated by issuance currency. Norwegian covered bonds are issued in both domestic and international markets. Domestically, the vast majority of the covered bonds listed are issued in NOK. In foreign markets, the bonds are typically listed in EUR or USD. Our study will focus on covered bonds denominated in NOK and issued in the domestic market.

Covered bonds issued domestically in NOK are all listed on the main market Oslo Stock Exchange (OSE) or the Alternative Bond Market (ABM)[3]. Approximately 84 % of the outstanding amount of covered bonds outstanding is listed on OSE, the remaining amount on ABM. In general, the larger and most actively traded covered bonds are listed on OSE.

Corporate bonds in the Norwegian secondary bond market, including covered bonds, are mainly traded "over the counter" (OTC) (Norges Bank, 2021b). Although listed bonds can be traded through Oslo Stock Exchange's electronic system, which allows for direct trading between investors, the exchange trading system is only used to a small extent (Norges Bank, 2021b). Instead, covered bonds are traded OTC, either via phone or with electronic posting of trading interest (Ødegaard, 2017). OTC transactions must

[3]The Alternative Bond Market, established and managed by Oslo Stock Exchange, is an unregulated marketplace not subject to the Stock Exchange act, with less extensive listing and reporting processes. Nevertheless, ABM's system and trading rules are similar to OSE (Ødegaard, 2017).

be reported to the exchange by the end of the trading day, according to the reporting rules of the Oslo Stock Exchange.

Unlike trading through an organized exchange platform, OTC transactions are bilateral agreements between buyers and sellers (Norges Bank, 2021b). The buyer and seller will agree upon volume, price, settlement date and other conditions. The transactions often occur through an intermediary bond broker, helping investors find counterparties for their trades. The brokerage house may also operate as a "market maker", acting as a counterparty for the investor until they find another investor for the opposite side of the trade. The brokerages will often quote indicative prices, suggesting the price they could be willing to buy and sell bonds. The customer must contact the broker to get accurate price quotes to complete a trade (Norges Bank, 2021b).

The Norwegian legislation allows only specialized credit institutions to issue covered bonds. At the end of 2020, there were 25 such credit institutions (Norges Bank, 2021b). Some Norwegian banks own credit institutions in cooperation with other banks, while the major banks control their own mortgage companies.

Institutional investors dominate the Norwegian covered bond market. By the end of September 2021, the ownership breakdown of NOK denominated covered bonds was as follows (Norges Bank, 2021a). Banks and mortgage credit institutions own 62% of the bonds. Insurance companies hold 13%. 7% are held by mutual funds and 4% by public administration. Foreign investors hold the remaining 14%.

The vast majority of Norwegian covered bonds have maturities between 1 and 10 years. The bonds are issued with both fixed and floating coupons (Finance Norway, 2018). Most of the bonds have soft bullet conditions, meaning the bonds have extendable maturity features. This means that the covered bond issuer has the option to defer the repayment of the principal to a later date. Usually, the extended maturity date is one calendar year after the scheduled maturity date. By the end of 2017, soft bullet bonds with extendible features accounted for approximately 93% of the outstanding Norwegian covered bonds (Finance Norway, 2018). The remaining 7% were traditional hard bullet bonds without extendible options.

3.2 The Danish Covered Bonds

Danish covered bonds are considered high-quality and liquid securities. With 437 EURbn outstanding volume by the end of 2020, the Danish covered bond market is the world's largest (ECBC, 2021). The major issuers in Denmark all have AAA-rated bonds, which attracts investors in a shrinking universe of AAA-rated securities (Nykredit Markets, 2020). No Danish issuers have ever defaulted on a covered bond[4]. The Danish covered bonds are priced and traded as very safe and liquid bonds in the market (Finance Denmark, n.d.). Even during the financial crisis in 2008 and 2009, Danish covered bonds were in demand.

Most Danish covered bonds are issued through mortgage credit institutions[5]. As the specialized institutions are not allowed to receive deposits, they sell covered bonds to fund the mortgage lending (Danmarks Nationalbank, 2020). Furthermore, the mortgage institutions are subject to the balance principle by Danish legislation, which states that the institutions' debtor- and creditor sides must balance within certain limits. Therefore, the mortgage credit institutions must sell bonds on a running basis to finance their disbursement of new loans or the conclusion of fixed-rate agreements. In practice, this regulatory restriction requires the mortgage institutions to issue bonds with cash flow fully matching the underlying mortgage loan until maturity. The balance principle distinguishes the Danish mortgage credit model from the Norwegian one, where mortgage loans are not as closely linked to covered bonds.

The vast majority of the Danish covered bonds are issued domestically and denominated in DKK. Bond maturities range from 1 to 30 years. As in Norway, most Danish covered bonds are carried out outside the organized trading platforms, either OTC or through systematic internalisers[6] (DFSA, 2021). Of the traded volume in 2020, 59% was through systemic internalisers, 30% OTC and only 11% through trading venues. Trades in Danish covered bonds, including OTC trades and excluding repos, are reported to the Danish exchange, Nasdaq OMX Copenhagen (ECBC, 2021). The market is price-driven, heavily

[4] A late payment occurred in the 1930s (Nykredit Markets, 2020).

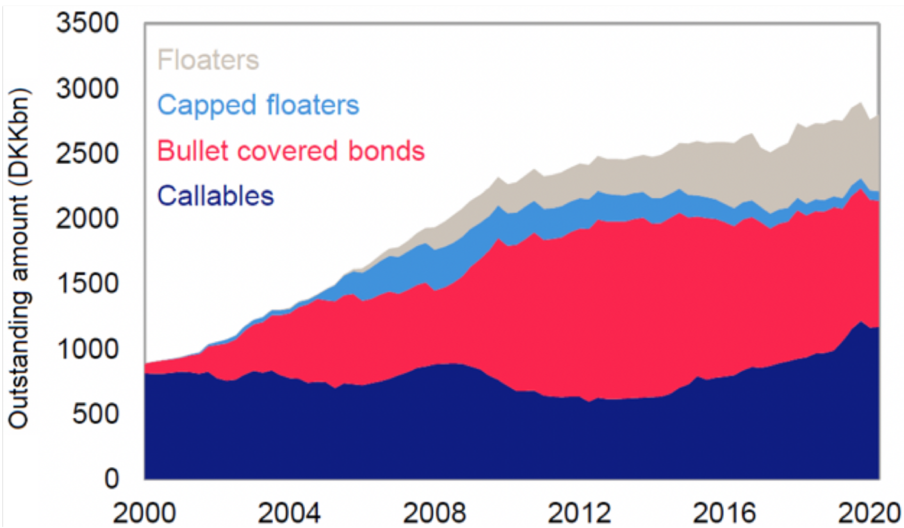
[5] The Danish Legislation also allows universal banks to issue covered bonds, but this option is only used by one issuer, Danske Bank. The remaining issuers are specialized credit institutions (Nykredit Markets, 2020).

[6] According to the Danish Financial Supervisory Authority (DFSA), a systemic internaliser is an "investment firm that deals on an organised, frequent, systematic and substantial basis on own account when executing client orders outside the organised trading platforms".

dependent on market makers who quote prices and mediate trades.

The Danish covered bond market can be split into three major segments: callable bonds, fixed-rate bullets and floaters (Nykredit Markets, 2020). As Figure 3.2 shows, the bullet bond and callable segments constitute the larger part of the market. Bullet covered bonds typically have short-term maturities of up to 5 years. The callable segment mainly consists of long-term fixed rate bonds, typically with maturities of 30 years. Figure 3.2 visualizes the rapid growth of the Danish covered bond markets over the last two decades. From 2000 to 2020, the outstanding amount in the major covered bond segments has approximately tripled.

Figure 3.2: Development in outstanding amount for the major Danish covered bond segments

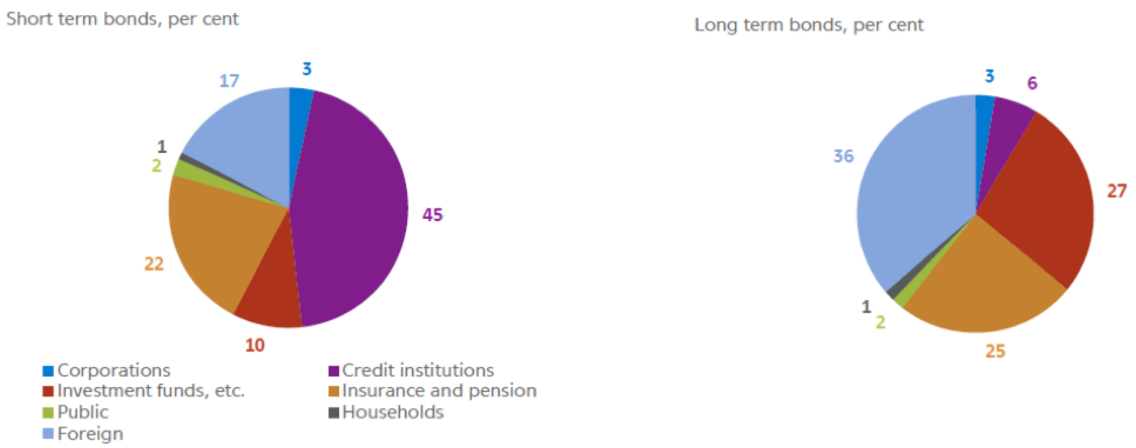


Source: Nykredit Markets

The investor side in the Danish covered bond market is dominated by institutional investors, as in Norway. The institutions trade in large blocks, typically between DKK 20 million and DKK 500 million (DFSA, 2021). There are also retail investors in the market, typically trading at amounts up to DKK 10 million. Our study will focus on institutional investors.

The different bond types attract different investor groups, which has implications for liquidity (Danmarks Nationalbank, 2020). In particular, short-term and long-term bonds attract different investor groups, as Figure 3.3 shows. For example, bank and mortgage credit institutions constitute 45% of the ownership of the short-term covered bonds, but only 6% of the long-term bonds. Banks typically buy short-term bonds with known cash flows as part of their liquidity portfolios. The long-term bonds have a callable option for early redemption, meaning that the expected cash flow for investors is unknown. Investment funds, foreign investors, insurance- and pension companies hold the majority of long-term bonds. These investors can undertake the higher market risk associated with the long maturity.

Figure 3.3: Investor breakdown for short- and long-term Danish covered bonds



Source: Danmarks Nationalbank

Approximately 75% of the trades in 2020 were less than 1 million EUR. However, these trades accounted for only 4% of the total traded volume. According to DFSA (2021), the small trades reflect the issuance of bonds matching cash flows of families' mortgages financing their homes. As our study focuses on professional investors in the covered bond market who typically trades in large sizes, these small trades will be removed from the transaction data.

4 Data

This section will present the data used in our study. We will present our data sources, the following data treatment and some descriptive statistics. At last, we will define our periods for stressed markets.

4.1 Data Sources

We have obtained transaction data for the Norwegian and Danish secondary bond markets. Ole Schjørn in Pareto Securities provided the Norwegian data, while we received the Danish data from Nasdaq OMX Copenhagen. From Stamdata[7], we have obtained bond reference data for both Norwegian and Danish bonds, which we merge with the bonds in the transaction data. The bond reference data contains information about bond characteristics such as sector class, outstanding volume and maturity date.

The bonds are identified with unique ISIN and ticker codes, enabling us to merge the transaction data with the bond reference data. The raw transaction data contain trades from all sector classes, meaning we must remove all observations in bonds that are not covered bonds. Both datasets contain transactions from January 2010 to September 2021. The data contains information about traded clean price, trade size and trade time for each transaction reported.

The raw transaction data received can be assumed to contain a substantial share, if not all, of the total transactions of bonds listed on an exchange, according to the data providers. As mentioned in the sections 3.1 and 3.2, all Norwegian and Danish covered bonds are listed on exchange.

Although the raw transaction data is assumed to be complete, our data sample might be incomplete due to missing bond reference data from Stamdata. According to our contact at Stamdata, the Danish bond reference data is incomplete before 2014. Danish bonds maturing before 2014 are, to a large extent, not included in the Stamdata reference data. As mentioned, we use Stamdata to identify the bonds classified as covered bonds in the transaction data. Transactions not identified as covered bonds are removed from our data

[7]Stamdata provides the most complete reference data for Nordic fixed income securities, both for active and matured bonds.

sample. As a result, our transaction data sample for Danish covered bonds is likely to be incomplete in 2010-2014 because not all Danish covered bonds during this period are included in the Stamdata reference data.

Similarly, according to our contact, Stamdata should have good coverage of Norwegian bonds starting from 2011. This means that the Norwegian data sample for 2010 may be incomplete.

4.2 Data Treatment

As mentioned in section 3.1, the vast majority of Norwegian covered bonds have maturities ranging from 1 to 10 years. While many Danish covered bonds also have maturities of 1 to 10 years, a large proportion of the bonds have maturities of 30 years. To ensure we compare apples to apples in the analysis, we only include bonds with maturity lower than ten years for both data samples. Long-term bonds generally tend to have lower liquidity than short-term bonds. Including Danish covered bonds with maturities up to 30 years in the data sample could give ambiguous results as nearly all Norwegian covered bonds have maturities below ten years.

Only bonds issued in domestic currency are included in our sample. In other words, we only include NOK denominated covered bonds for the Norwegian market and DKK denominated bonds for the Danish market.

Our analysis aims to determine the covered bond market liquidity from the perspective of institutional investors, who typically trade in large sizes. Therefore, we remove retail size trades as they will distort the analysis. Similar to the studies of Dick-Nielsen et al. (2015) and DFSA (2021), we remove all transactions with a nominal trade size of less than 10 DKKm for our Danish sample. While there are no retail investors in the Norwegian covered bond market, we remove all trades below 5 NOKm, to avoid small trades disrupting our analysis.

Outlier observations assumed to be error reporting are excluded to avoid noisy results. We remove transactions where the clean price traded is below 55 or above 160. Transactions outside these price limits are assumed implausible for covered bonds. Next, transactions where the nominal trade value is higher than the bonds' outstanding amount are removed.

We also remove Danish observations with trade size above 500 DKKm, as this number is the largest possible trade size on Nasdaq OMX, according to Danmarks Nationalbank (2020).

4.3 Descriptive Statistics

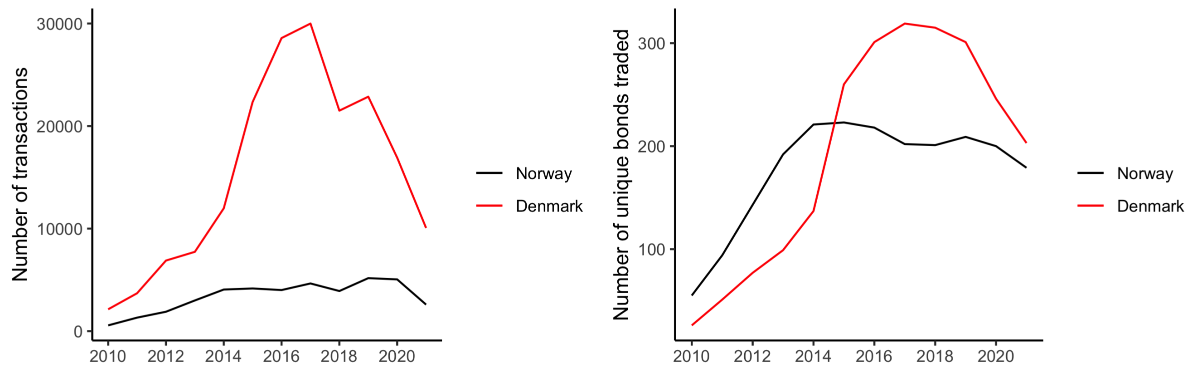
After the data filtering and cleaning process, our dataset samples consist of 40,369 and 184,704 transactions from the Norwegian and Danish covered bond markets, respectively. As mentioned, the observations span from January 2010 to September 2021. The Norwegian data sample consists of 473 unique bonds, while there are 612 unique bonds in the Danish sample. Table 4.1 below presents some descriptive statistics for our two data samples.

Table 4.1: Descriptive Statistics

Data sample variables	Norway	Denmark
Total sample observations	40,369	184,704
Average number of transactions per month	288	1,319
Average number of unique bonds traded per month	93	107
Average trade size	88 NOKm	85 DKKm
Median trade size	48 NOKm	55 DKKm
Average total traded volume per month	25 NOKbn	113 DKKbn

The descriptive statistics generally show that the Danish covered bond market is larger and more active than the Norwegian market. This comes as no surprise, as we know that the Danish covered bond market is the world's largest. We note that Denmark's monthly average traded volume is almost six times larger, adjusted for currency differences. While we notice more or less the same number of unique bonds traded every month in both samples, a unique Danish covered bond is on average trading four times more.

Figure 4.1: Yearly number of total transactions and unique bonds traded in the data sample



(a) Yearly number of transactions* **(b)** Yearly number of unique bonds traded*

*2021 only include observations until August 31st.

Figure 4.1a shows that the yearly number of transactions consistently is higher in the Danish sample. In the years before 2014, the number of Danish transactions is considerably lower, close to the Norwegian level. We suspect this is due to the lack of data from a number of Danish covered bonds during the period 2010-2014, regarding the incomplete bond reference data explained in section 4.1.

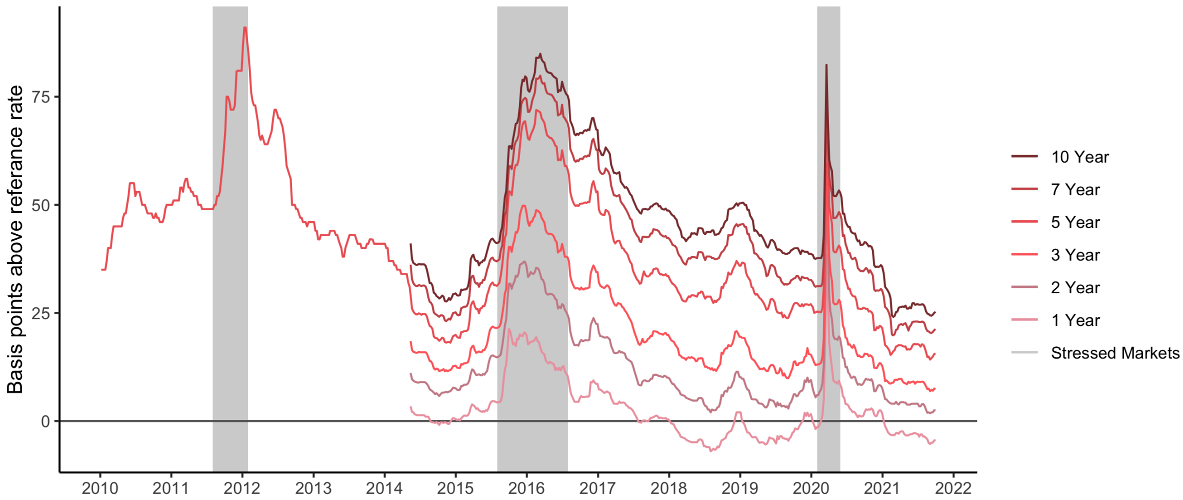
Figure 4.1b shows the number of unique bonds traded in the two markets in 2010-2021. In our data samples, there are more traded bonds in Norway before 2014, while Denmark takes the leading the years after. Although we do not precisely know how the graph should have looked in 2010-2014 with a complete Danish data sample, we suspect the yearly number of unique bonds traded in Denmark should be higher in this period.

4.3.1 Stressed Markets

In our study, we are interested in analyzing how stressed markets affect liquidity in the Norwegian and Danish covered bond markets. Therefore, we need to define the most significant periods of stress during 2010-2021.

Stressed bond markets are typically experienced in periods where the yield spreads are increasing. When the increasing trend reverses and the spreads start decreasing again, it typically signifies market normalization. Looking at the historical levels of yield spreads is therefore helpful when identifying market stress periods.

Figure 4.2: Yield spreads in the largest Norwegian covered bonds with different maturities



The selected bonds are in the category "OMFB1", which consists of the largest and typically most traded covered bonds in Norway. (Sources: Nordea Investment Management & Nordic Bond Pricing)

Figure 4.2 shows the yield spread curves for a selection of Norwegian covered bonds with different maturities. The three periods defined as stressed markets are shaded in gray. The first stressed period is set to 01.08.2011 – 31.01.2012. This period is related to the European Sovereign Debt crisis, where several countries experienced a collapse of financial institutions. The second period of stressed markets is set to 01.08.2015 – 31.07.2016 when bond markets across Europe were distressed. Lastly, the third significant period of stress was related to the COVID-19 pandemic. The period of stress in the bond markets after the virus outbreak was relatively short and is set to 01.02.2020 - 31.05.2020.

We apply the same defined periods of stress for both the Norwegian and Danish liquidity analyses. Although the stressed periods were defined based on Norwegian yield spread, the stress periods were prevalent across Europe and indeed also the Danish bond market. However, we keep in mind that the stressed markets periods may have affected the Norwegian and Danish covered bond markets to varying degrees.

5 Liquidity Measurement

This section will first clarify what is meant by the term liquidity and the implications of measuring liquidity in bond markets. Then, we will present the trading activity variables and liquidity measures employed in our study.

While there has been extensive research covering liquidity in financial markets, liquidity remains an ambiguous concept hard to define precisely in few words. Generally, previous literature agrees with Baker (1996), stating there is "no single unambiguous, theoretically correct or universally accepted definition of liquidity". In our study, we are interested in market-level liquidity. A liquid market can be characterized as "a market where a large volume of trades can be immediately executed with minimum effect on price" (Muranaga et al., 1999).

Harris (1990) defines four interrelated dimensions to explain the concept of liquidity: width, depth, immediacy and resiliency. Three decades later, Harris's definition is still frequently referred to as the most complete way to assess market liquidity. The first component, **width**, represents the cost of immediate execution of an order and is reflected by the difference between the highest bid price and lowest ask price, commonly known as the bid-ask spread. **Depth** reflects how much volume is available at a given price level. **Immediacy** refers to how quickly a large order can be executed. **Resiliency** reflects how fast the market can revert to its initial state after liquidity consumption temporarily has moved prices away from the equilibrium.

In markets with low transparency, observation of market activity and liquidity can be difficult. As bond markets are mainly traded OTC, transparency is limited to post-trade reporting (Ødegaard, 2017). Post-trade transparency refers to the availability of transaction information after a trade is conducted, such as prices and volume. Pre-trade transparency, on the other hand, is very limited in OTC markets. Pre-trade transparency refers to the availability of market information prior to a trade, such as bid-ask quotations and trade interest.

The available data limits us to perform trade-based liquidity measures, using variables such as trade size and transaction price. As we do not have any order book data, we are not able to perform ex-ante measures that capture liquidity supply directly.

In our study, we classify our proxies of liquidity into two groups: trading activity variables and liquidity measures. Trading activity variables are simple measures based on directly observable numbers, such as volume traded and trading interval. Higher trading activity will generally indicate higher liquidity. The liquidity measures are alternative ways of estimating transaction cost and market impact.

In the following, we will present the trading activity variables and liquidity measures applied in our analysis.

5.1 Trading Activity Variables

5.1.1 Turnover Ratio

The turnover ratio expresses how much a bond has been traded in a given period as a fraction of the bond's outstanding volume. The general intuition is that higher turnover indicates a higher level of liquidity.

Other factors than liquidity evidently affect the turnover rate (McCauley and Remolona, 2000), and there is debate on whether the turnover ratio is a good proxy for liquidity (Guo et al., 2020). Especially during stressed markets, measuring turnover ratio may give ambiguous results. For example, increased uncertainty may cause turnover to rise due to traders wanting to hedge their positions. Conversely, more uncertainty causing higher risk exposures may correspond to turnover declining.

Nevertheless, in our study, we will use the turnover ratio as a liquidity proxy, acknowledging the variable's potential weaknesses. We keep in mind that the variable does not capture all aspects of liquidity and we must be careful interpreting the results causally.

In the following, we will present how we employ the turnover ratio in our study. First, we calculate the turnover ratio for each bond in each month:

$$\text{TurnoverRatio}_{i,t} = \frac{\text{Total trading volume}_{i,t}}{\text{Amount outstanding}_i} \times 100\,, \tag{5.1}$$

where "Total trading volume" is the total volume traded in month t for bond i. "Amount outstanding" is the outstanding amount for bond i. For a given month t, only bonds that have been traded that specific month is included. We multiply the fraction by 100 in order to get the ratio as a percentage. Next, we calculate the markets' monthly turnover ratio by taking the average of the traded bonds' turnover ratio in each month:

$$\text{TurnoverRatio}_t^{\text{Market}} = \frac{1}{M}\sum_{i=1}^{M} \text{TurnoverRatio}_{i,t}\,, \tag{5.2}$$

where M is the number of bonds that are traded in month t.

5.1.2 Days with Zero Trading

The days with zero trading ratio (DZT-ratio) is the second trading activity variable we employ. We measure the DZT-ratio as the percentage of days during a month where a bond does not trade. Generally, liquid securities will trade more frequently. Thus, a low DZT-ratio may indicate higher liquidity for a specific bond.

It can be debated whether the DZT-ratio is a good proxy for liquidity. Although a bond is rarely traded, it does not necessarily mean that it is illiquid. In covered bond markets, trading activity is typically concentrated in a relatively small group of bonds. The rarely traded bonds are often perfect substitutes for the actively traded bonds. While trade-based measures such as the DZT-ratio may indicate low liquidity in rarely traded bonds, the liquidity of these bonds may be similar to the actively traded bonds.

While we acknowledge that the DZT-measure is simple and certainly does not capture all dimensions of liquidity, it does give an indication of the frequency of trading in the Norwegian and Danish covered bond markets. Used among other measures, it may help us explain the market liquidity.

For each bond and month, we calculate the percentage of how many days during the month the bond was not traded:

$$\text{DZT-Ratio}_{i,t} = \frac{\text{Days with zero trades}_{i,t}}{\text{Number of trading days in month}_t} \times 100\,. \tag{5.3}$$

We multiply the fraction by 100 in order to get the ratio as a percentage. The DZT-ratio are only calculated when the bonds are listed and available for trading.

We define DZT-ratio for the market by taking the average of all active bonds in each month:

$$\text{DZT-Ratio}_t^{\text{Market}} = \frac{1}{M} \sum_{i=1}^{M} \text{DZT-Ratio}_{i,t}\,, \tag{5.4}$$

where M is the number of bonds available for trading in month t.

5.2 Liquidity Measures

5.2.1 Price Impact Measure

Our first liquidity measure is a price impact measure used by Dick-Nielsen et al. (2015). The measure is closely related to Amihud's (2002) illiquidity measure, a measure popularly used in OTC markets due to its modest data requirement.

The price impact measure expresses how a single transaction moves the price. Therefore, a bond must be traded two times or more in a defined time window in order to calculate a price impact measure. In a liquid market, we would not expect consecutive transactions to move prices considerably. Contrary, a high price impact may indicate an illiquid market.

While Amihud's (2002) illiquidity ratio measures how much prices move as a response to trading volume, the modified measure we use does not scale the price impact by trading volume. Somewhat surprisingly, Dick-Nielsen et al. (2015) find no positive linear relationship between trading volume and price impact in the Danish covered bond market. We conclude similarly for both the Norwegian and Danish transaction data. This can be seen in Table A1.1 (in Appendix), which shows price impact measures by trade size. In fact, in most periods, larger trade sizes are associated with *lower* price impacts, indicating a negative relationship.

In the following, we will present how we employ the price impact measure in our analysis. For a given transaction, the price impact (PI) measure is defined as:

$$\text{PI}_{i,t,k} = \frac{|p_{i,t,k} - p_{i,t,k-1}|}{p_{i,t,k-1}} \times 10000\,, \tag{5.5}$$

where $p_{i,t,k}$ is the price for the kth transaction for bond i in month t. We multiply the fraction by 10,000 in order to interpret the price impact measure as price movement in basis points. Next, we define a monthly price impact measure for each bond. This is calculated as the average of price impact measures for the bond over a given month:

$$\mathrm{PI}_{i,t} = \frac{1}{N} \sum_{k=1}^{N} \mathrm{PI}_{i,t,k} \,, \tag{5.6}$$

where N is the number of price impact observations for bond i in month t. Finally, the monthly price impact measure for the market is defined as the weighted average across all bonds belonging to that market, with weights being the amount outstanding in the given bond:

$$\mathrm{PI}_t^{\mathrm{Market}} = \frac{1}{o_1 + \ldots + o_M} \sum_{i=1}^{M} o_i \times \mathrm{PI}_{i,t} \,, \tag{5.7}$$

where o_i is the amount outstanding for bond i, and M is the number of bonds traded in the market in month t. Trade sizes in smaller bonds are generally smaller compared to trades in larger bonds. By weighting the price impact measures by bond size, the importance of price impacts of smaller trades is appropriately reduced.

5.2.2 Imputed Roundtrip Cost Measure

Our second liquidity measure is a proxy for estimating bid-ask spreads, denoted imputed roundtrip cost (IRC) measure. The measure is proposed by Feldhütter (2012), whose intuition is in the following. After a period with no trades in a bond, we often see a corporate bond trading two or three times with the same trade size in a short time span. Such trades likely occur because one or two dealers match their customers' buy and sell orders. The dealer collects the bid-ask spread as a fee. Transactions defined as part of an IRT can be used to estimate a proxy for bid-ask spreads, i.e., the width dimension proposed by Harris (1990).

We do not have information about the sell- and buy-side identity in the trades in our transaction data. Therefore, the imputed round trip cost measure is useful, as it can proxy roundtrip cost without identity information.

We measure imputed roundtrip cost (IRC) for bonds where there have been two trades with the same amount traded in less than five days. The IRC measure is formulated as follows:

$$\mathrm{IRC}_{i,t,k} = \frac{p_{max} - p_{min}}{p_{min}} \times 10000\,, \tag{5.8}$$

where $\mathrm{IRC}_{i,t,k}$ is the kth observation in month t for bond i. p_{max} is the transaction price for the one transaction with the highest price, while p_{min} is the transaction price for the transaction with the lowest price. Further, we calculate the monthly average imputed roundtrip cost for each bond as follows:

$$\mathrm{IRC}_{i,t} = \frac{1}{N} \sum_{k=1}^{N} \mathrm{IRC}_{i,t,k}\,, \tag{5.9}$$

where N is the number of IRC-observations for bond i in month t.

Next, the monthly IRC measure for the market is defined as the weighted average across all bonds belonging to that market, with weights being the amount outstanding in the given bond:

$$\mathrm{IRC}_t^{\mathrm{Market}} = \frac{1}{o_1 + \ldots + o_M} \sum_{i=1}^{M} o_i \times \mathrm{IRC}_{i,t}\,, \tag{5.10}$$

where o_i is the amount outstanding for bond i, and M is the total number of bonds with imputed roundtrip cost observations in month t. The arguments for weighting the IRC measure by amount outstanding are analogous to the arguments used for the price impact measure.

6 Hypothesis Development

As mentioned in the introduction, the Norwegian secondary bond market for credit bonds is generally perceived as less liquid than other European bond markets. According to our knowledge, no empirical studies have challenged this common perception. By narrowing the scope to the covered bond markets in Norway and Denmark, we want to test whether the general perception about the Norwegian bond market being less liquid holds true. Based on the common view, we formulate the following hypothesis:

Hypothesis 1: During the period 2010-2021, the Danish covered bond market has been more liquid than the Norwegian covered bond market.

The period 2010-2021 is divided into normal and stressed market periods. From the perspective of the participants in the covered bond markets, the stressed market periods are particularly interesting to analyze. It is during stressed markets that the uncertainty is greatest, and market participants have a greater need to be able to get in and out of positions quickly. Therefore, when comparing the liquidity measurements in the two markets, we will pay attention to who performs better during stressed market periods.

Another interesting aspect is how much market liquidity is affected during stressed periods, compared to normal periods. While the first hypothesis compares the liquidity in Denmark and Norway for each period, our second hypothesis compares the liquidity in normal and stressed periods *within* the same market. More precisely, we want to test, for each market, whether the liquidity is significantly worsened during stressed market periods.

Hypothesis 2: The market liquidity is lower during stressed markets, in both the Norwegian and the Danish covered bond markets.

7 Results

7.1 Methodology

As described in section 5, we employ both trading activity variables and liquidity measures to assess the liquidity in the Norwegian and the Danish covered bond markets. The trading activity variables we employ are a turnover ratio and a days with zero trading ratio. The liquidity measures applied are a price impact measure and an imputed roundtrip cost measure.

Inspired by Dick-Nielsen et al. (2015), we aggregate the proxies to monthly numbers to define the market liquidity in each month, as described in section 5. We use matched pairs t-tests to statistically test whether the monthly liquidity measurements are significantly different in the Norwegian and Danish covered bond market samples.

Furthermore, we run ordinary least square regressions with time event dummies to test whether the liquidity level significantly changes in stressed markets. The time event dummies are the three periods defined as stressed markets in section 4.3.1. We run the regression for each liquidity measurement on each market separately:

$$\begin{aligned}\text{Market Liquidity}_t = \alpha &+ \beta_1 \times \text{European Debt Crisis}_t \\ &+ \beta_2 \times \text{15/16-distress}_t + \beta_3 \times \text{Covid-crisis}_t + \epsilon_t \,,\end{aligned} \tag{7.1}$$

where t refers to the month t, α is the intercept and ϵ_t captures the unobserved factors in month t. The European Debt Crisis dummy gets the value 1 for the months between 01.08.2011 – 31.01.2012 and 0 elsewhere. The 15/16-distress dummy gets the value 1 for the months between 01.08.2015 – 31.07.2016 and 0 elsewhere. Lastly, the Covid-crisis dummy gets the value 1 for the months between 01.02.2020 - 31.05.2020 and 0 elsewhere.

To control for time trends in the markets' liquidity, we will also run regressions with a regressor capturing linear time trends:

$$\begin{aligned}\text{Market Liquidity}_t = \alpha &+ \beta_1 \times \text{European Debt Crisis}_t + \beta_2 \times \text{15/16-distress}_t \\ &+ \beta_3 \times \text{Covid-crisis}_t + \beta_4 \times t + \epsilon_t \,.\end{aligned} \tag{7.2}$$

In the analysis, we will assess each liquidity measurement one at a time and compare the two markets. For each measurement, the first part of the analysis will discuss which of the two markets have performed better during the period 2010-2021. The second part of the analysis will, for the specific liquidity measurement, explore whether the liquidity level changes significantly during stressed markets. In section 7.4, we will sum up the results from the four liquidity measurements and conclude on our two hypotheses.

7.2 Trading Activity Variables

7.2.1 Turnover Ratio

Figure 7.1: Turnover Ratio

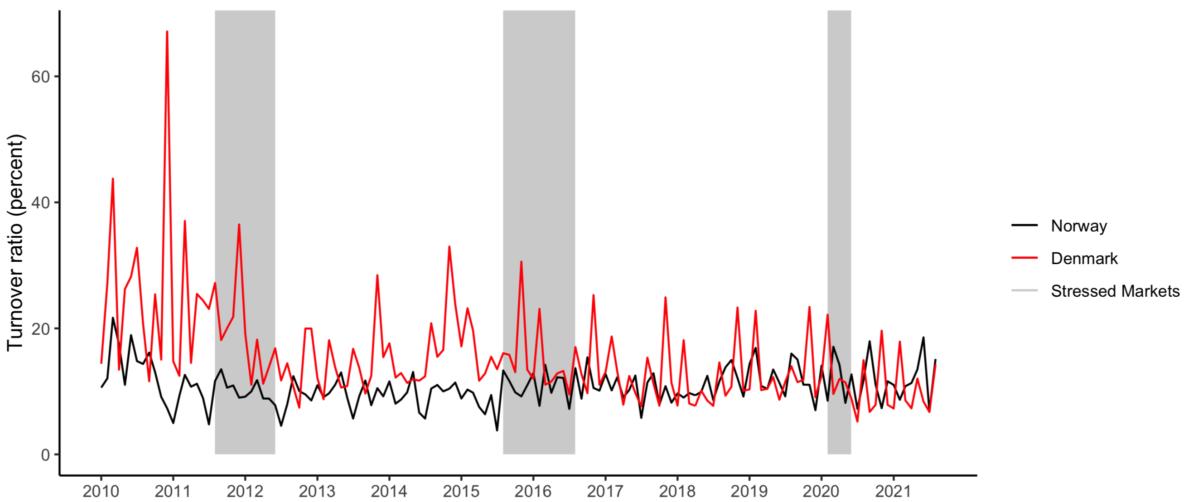


Figure 7.1 shows the turnover ratio in our transaction data samples from the Norwegian and Danish covered bond markets. The grey areas represent the periods defined as stressed markets.

Danish covered bonds' turnover ratio is generally higher than the Norwegian bonds in our data sample. Especially in 2010-2016, the turnover ratio in Denmark tends to be higher. We also register a negative trend in the Danish data, where the turnover ratio generally is higher in the earlier years. The turnover ratio in Norway is relatively stable the whole period.

Table 7.1: Monthly average turnover ratio for each period

	Total	Normal 1	European Debt Crisis	Normal 2	15/16-distress	Normal 3	Covid-crisis	Normal 4
Norway	*10.81*	12.06	10.81	9.29	10.93	11.28	12.00	**11.70**
Denmark	***15.61***	**25.14**	**23.81**	**15.23**	**15.19**	**12.70**	**13.79**	10.24
Significant difference*	Yes	Yes	Yes	Yes	No	No	No	No

All numbers are given in percent. The market with the best liquidity performance in **bold**.
*Based on matched-pairs t-tests. Thourough results available in Appendix.

Table 7.1 shows the monthly average turnover ratio for each period of normal and stressed markets. For the total period 2010-2021, the average monthly turnover ratio is 15.61% in Denmark and 10.81% in Norway. When statistically testing the difference between the two numbers, we find that the turnover ratio in Danish covered bonds is significantly higher.

Studying the numbers for each period, Denmark has a higher turnover ratio in every period, except for the last normal period. The differences are significant for the first two normal periods and the European Debt Crisis period.

Table 7.2: Regression Results - Turnover Ratio

	Norway		Denmark	
Regressor	**(i)**	**(ii)**	**(iii)**	**(iv)**
Intercept	10.7530***	7.0855	15.2929***	66.0419***
	(0.2790)	(3.7043)	(0.7452)	(8.9130)
European Debt Crisis	0.0557	0.3781	8.5218*	4.0597
	(1.2682)	(1.3092)	(3.3877)	(3.1501)
15/16-distress	0.1767	0.1590	-0.1044	0.1410
	(0.9182)	(0.9184)	(2.4527)	(2.2098)
Covid-crisis	1.2407	0.8895	-1.5016	3.3591
	(1.5407)	(1.5808)	(4.1155)	(3.8037)
Time Trend		0.0002		-0.0030***
		(0.0002)		(0.0005)
N	140	140	140	140
Adjusted R^2	-0.01704	-0.01715	0.09171	0.2089

* $p<0.05$, ** $p<0.01$, *** $p<0.001$
Standard deviations in parentheses.

Next, we want to determine whether the turnover ratio significantly decreases during stressed market periods. Table 7.2 shows the results when running the regressions from equations 7.1 and 7.2. The regression result on the Norwegian market without a time trend, regression (i), shows no indications of any significant movement in turnover ratio during stressed markets. Nor do we find any significant difference in turnover ratio during stressed markets in regression (ii), when we include a regressor capturing a linear time trend.

The regression on the Danish market without a time trend (iii) finds no significant results, except for the European Debt Crisis period, where the turnover ratio is significantly higher compared to normal periods. The significant result may be biased because the turnover ratio, in general, was higher in the earlier year in the Danish sample, as shown in Figure 7.1. Therefore, we also run a regression including a time trend variable.

When including a regressor for a linear time trend in the Danish regression (iv), we find a significant result for the time trend. Further, the time event dummy estimate for the European Debt Crisis is no longer significant. Therefore, we conclude there is no evidence of a significant turnover ratio change during stressed markets in our Danish covered bond market sample.

To summarize, the Danish covered bond market generally performs better in terms of turnover ratio as a proxy for liquidity. The turnover ratio in the Danish market is higher in all periods except for the last normal period. Further, we do not find evidence that the turnover ratio significantly changes during stressed markets for neither of the two markets.

7.2.2 Days with Zero Trading

Figure 7.2: Days with Zero Trading

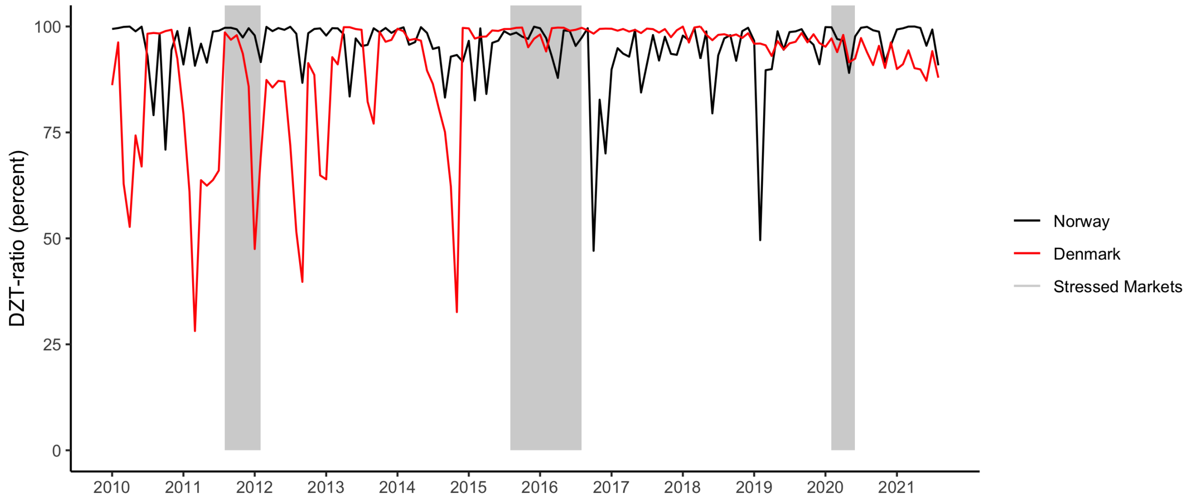


Figure 7.2 shows the Days with Zero trading (DZT) ratio level in the two markets in 2010-2021. As discussed in section 5.1.2, a high DZT-ratio may indicate low liquidity. A DZT-ratio of 100% means that no active bonds in the data sample are traded in the given month. In Norway, the DZT-ratio is close to 100% most of the time. However, we observe two marked drops in the middle of 2016 and the beginning of 2019, indicating more Norwegian covered bonds being traded in these periods.

In Denmark, the DZT-ratio was volatile from 2010 to the end of 2014, while the ratio was consistently close to 100% in 2015-2021. We must be careful interpreting the DZT-ratios in the earlier years. The incomplete Danish bond reference data in 2010-2014, explained in section 4.1, means that many Danish bonds are missing in this period. This likely explains the noisy DZT results in Denmark in 2010-2014. The DZT-ratios in 2015-2021, which consistently indicate few bonds are actively traded, are more likely to represent the actual state in the Danish covered bond market.

The descriptive statistics in section 4.3 showed there are, on average, more than a thousand transactions per month in our Danish data sample. As we still observe a high DZT-ratio in Denmark, we can assume the trading activity is concentrated in a small number of bonds, which in turn trade often. The same reasoning may apply to the Norwegian covered bond market.

Table 7.3: Monthly average of DZT-ratio for each period

	Total	Normal 1	European Debt Crisis	Normal 2	15/16-distress	Normal 3	Covid-crisis	Normal 4
Norway	*94.96*	94.67	98.93	95.94	**96.86**	**91.92**	95.64	97.76
Denmark	***90.34***	**76.28**	**86.73**	**86.34**	98.37	97.88	**95.18**	**92.08**
Significant difference*	Yes	Yes	No	Yes	No	Yes	No	Yes

All numbers are given in percent. The market with the best liquidity performance in **bold**.
*Based on matched-pairs t-tests. Thourough results available in Appendix.

Table 7.3 shows the monthly average DZT-ratio for each period of normal and stressed markets. For the total period 2010-2021, the monthly average DZT-ratio is 94.96% for Norway and 90.35% for Denmark. The difference between the two numbers is statistically significant.

We can then look at the periods after 2014, where we have more reliable data. In the last two stressed markets, the European Debt Crisis and the Covid-crisis, there is no significant difference in the DZT-ratios of the two markets. In the normal period between the two crises, Norway has a significantly lower DZT-ratio. In the last normal period, Denmark has a significantly lower DZT-ratio.

Table 7.4: Regression Results - DZT-Ratio

	Norway		Denmark	
Regressor	**(i)**	**(ii)**	**(iii)**	**(iv)**
Intercept	94.5385*** (0.7261)	98.438*** (9.671)	89.554*** (1.319)	2.214 (15.877)
European Debt Crisis	4.3941 (3.3010)	4.051 (3.418)	-2.820 (5.995)	4.859 (5.611)
15/16-distress	2.3216 (2.3900)	2.340 (2.398)	8.821* (4.341)	8.399* (3.936)
Covid-crisis	1.1024 (4.0102)	1.476 (4.127)	5.624 (7.283)	-2.742 (6.776)
Time Trend		-0.0002 (0.001)		0.0052*** (0.00094)
N	140	140	140	140
Adjusted R^2	-0.002995	-0.009202	0.01395	0.1894

* $p<0.05$, ** $p<0.01$, *** $p<0.001$
Standard deviations in parentheses.

Next, we want to determine whether the DZT-ratio significantly changes during stressed market periods. Table 7.4 shows the results when running the regressions from equations 7.1 and 7.2. When running the regression on the Norwegian data sample, we do not find evidence for significant change in days with zero trading during stressed periods, neither with nor without a linear time trend included.

When running the regression without time trend (iii) on the Danish data sample, we find that the DZT-ratio was significantly higher during the European Debt Crisis period, which may indicate lower market liquidity. We find no significant results for the other two stressed market periods. When running a new regression on the Danish data with a time trend (iv), we find the time trend to be significant. The significant time trend can be explained by the many low DZT-ratios in 2010-2014, probably due to the incomplete Danish data during this period. The time event dummy for the European Debt Crisis is still significant when including the time trend.

To summarize, the DZT-ratio is lower in Denmark in most periods, which means that days with zero trading are more frequent in Norwegian covered bonds. If days with zero trading are believed to be a good proxy for market liquidity, the results favor Denmark. Further, when assessing whether market liquidity is lower during stressed markets, we find that the DZT-ratio in Denmark significantly increased during the European Debt Crisis, implying that liquidity was worsened in the crisis. In the Norwegian market, we do not find any significant change in the DZT-ratio during stressed markets.

7.3 Liquidity Measures

7.3.1 Price Impact Measure

Figure 7.3: Price Impact Measure

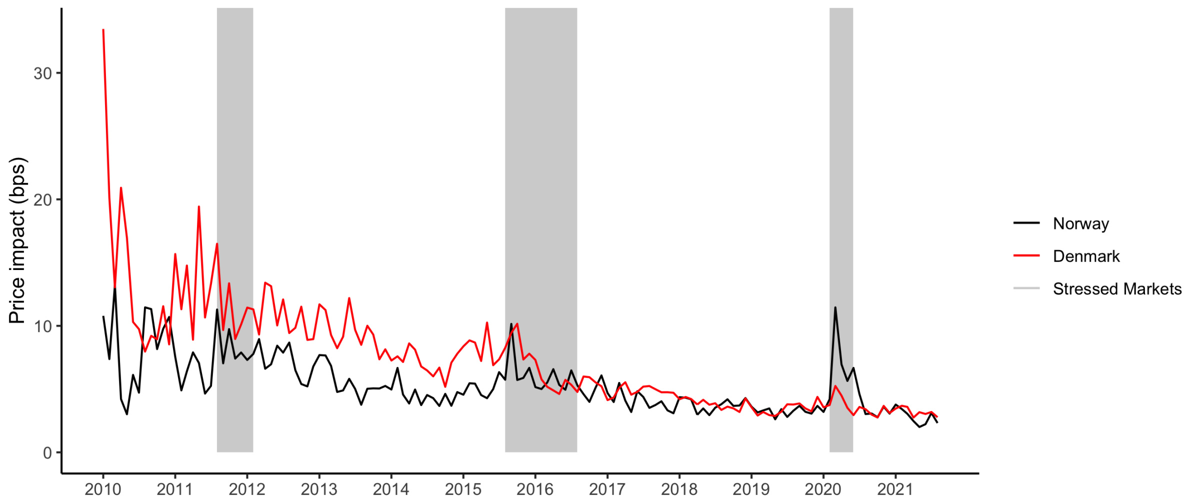


Figure 7.3 illustrates the monthly price impact measure for both markets in 2010-2021. Recall that a high measure of price impact may indicate lower liquidity.

We observe higher price impact measures in the Danish market from 2010 till the end of 2015. In 2016-2021, the level of price impact is similar in both markets. The Danish measures are noisy the first few years, with especially extreme measures in 2010.

The price impact measure is relatively stable in the Norwegian market. Even though the Norwegian results are not as unstable as the Danish, the graph shows some fluctuations the first couple of years before the measure stabilizes. In Norway, we observe some spikes during our defined periods for stressed markets, while Denmark seems to be less affected in stressed markets. Especially during the Covid-crisis, there is a clear spike in the price impact measure for Norway, indicating lower liquidity.

Table 7.5: Monthly average of price impact measure for each period

	Total	Normal 1	European Debt Crisis	Normal 2	15/16-distress	Normal 3	Covid-crisis	Normal 4
Norway	***5.3085***	**7.6093**	**8.4470**	**5.6176**	**6.0991**	**3.8413**	7.0673	3.2799
Denmark	*7.3821*	13.9371	11.6726	8.9308	6.8202	4.2050	**4.2492**	**3.2077**
Significant difference*	Yes	Yes	Yes	Yes	No	Yes	No	No

All numbers are given in basis points. The market with the best liquidity performance in **bold**.
*Based on matched-pairs t-tests. Thourough results available in Appendix.

Table 7.5 shows the monthly average price impact measure for each period of normal and stressed markets. For the total period, the price impact measure is higher in the Danish market than in the Norwegian, indicating lower liquidity in the Danish market. We notice that the difference is statistically significant.

Further, we notice that the Norwegian market performs better in the first five periods, of which four of them significantly. In the last two periods, including the Covid-crisis, Norway has a higher price impact measure. However, these differences are not significant.

Table 7.6: Regression Results - Price Impact Measure

	Norway		Denmark	
Regressor	**(i)**	**(ii)**	**(iii)**	**(iv)**
Intercept	5.0089*** (0.1921)	25.5804*** (1.8447)	7.3273*** (0.4002)	57.0008*** (3.1734)
European Debt Crisis	3.4381*** (0.8734)	1.6293* (0.6520)	4.3453* (1.8196)	-0.0222 (1.1216)
15/16-distress	1.0902 (0.6324)	1.1897* (0.4574)	-0.5071 (1.3174)	-0.2669 (0.7868)
Covid-crisis	2.0584 (1.0610)	4.0287*** (0.7873)	-3.0781 (2.2104)	1.6796 (1.3543)
Time Trend		-0.0012*** (0.0001)		-0.0030*** (0.0002)
N	140	140	140	140
Adjusted R^2	0.1122	0.5357	0.01395	0.6561

* $p<0.05$, ** $p<0.01$, *** $p<0.001$
Standard deviations in parentheses.

Next, we want to analyze whether the price impact measures change significantly during stressed market periods. Table 7.6 shows the results when running the regressions from equations 7.1 and 7.2.

The regression results for the Norwegian market, without a time trend (i), indicate that the price impact increased significantly during the European Debt Crisis period. Again, we recall that higher price impact measures may be associated with lower market liquidity. We also find positive coefficients for the 15/16-distress and Covid-crisis periods, meaning the price impact increased in these two crises as well. However, these increases are not statistically significant.

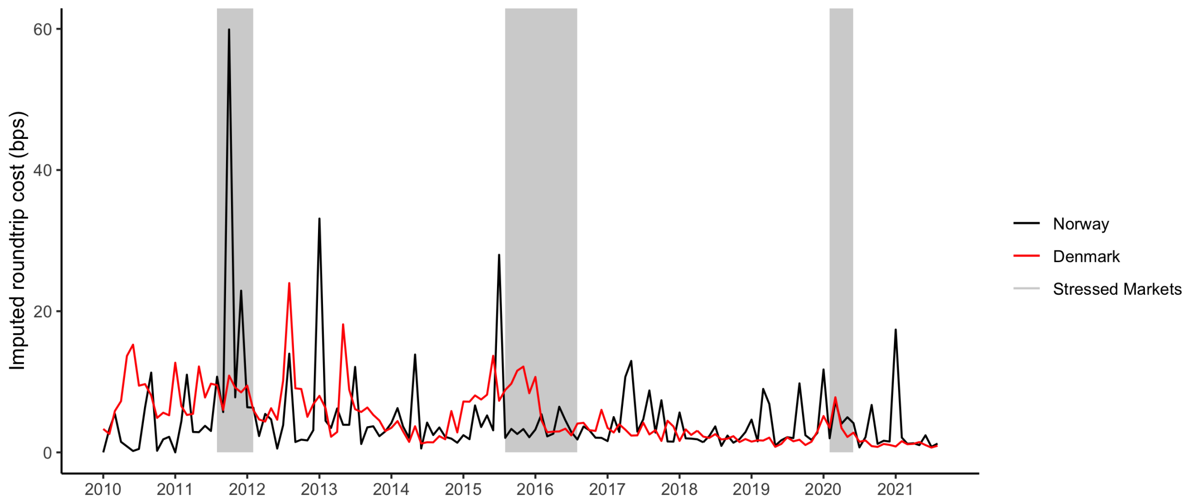
When we add a linear time trend to the regression (ii) for the Norwegian market, we find significance for all regressors. As suspected by looking at the graph, the regression suggests a decreasing linear time trend in the period. When accounting for the time trend in Norway, all the stressed market time event dummies become significant with a positive coefficient, indicating lower liquidity during stressed markets. We conclude that the price impact measure for the Norwegian market has a downward sloping trend through the total period, and that the price impact significantly increases during stressed markets.

We find no significance for the regression (iii) on the Danish market, except for the European Debt Crisis, where the regression results claim the price impact measure to be higher. As discussed, this is probably due to the price impact, in general, being higher at the beginning of the period. When adding a linear time trend to the regression (iv) on the Danish market, the result for the European Debt Crisis regressor is no longer significant. Therefore, when accounting for a time trend, we do not find any significant difference in the Danish market's price impact measure during normal and stressed periods.

To summarize, we find lower price impact measures in Norway compared to Denmark from 2010 until around 2016, indicating higher liquidity in the Norwegian market. Further, we find significant increases in the price impact measure during all stressed market periods for the Norwegian market, when taking a linear time trend into account. On the other side, there is no evidence that the price impact for the Danish market changes significantly during stressed markets when we control for a linear time trend.

7.3.2 Imputed Roundtrip Cost Measure

Figure 7.4: Imputed Roundtrip Cost Measure



From 5.2.2, we recall that transactions defined as part of an Imputed Roundtrip Cost (IRT) can be used to estimate bid-ask spreads. In other words, higher IRT measures indicate higher bid-ask spreads, which in turn indicates lower liquidity.

Figure 7.4 shows the monthly IRT measures in the two markets in 2010-2021. In the Norwegian covered bond market sample, we observe many spikes where the bid-ask spread is assumed to be higher. The spikes are observed in both the normal and stressed periods.

The measures in Denmark seem to be more stable. Although there are several spikes in the Danish data as well, the magnitude of the spikes is lower than in Norway. In 2015-2021, there are two spikes in Denmark which coincide with the two last periods of stressed markets.

Table 7.7: Monthly average of imputed roundtrip cost for each period

	Total	Normal 1	European Debt Crisis	Normal 2	15/16-distress	Normal 3	Covid-crisis	Normal 4
Norway	***4.7757***	**3.3835**	18.9086	**5.3188**	**3.4086**	3.8394	4.5744	3.0418
Denmark	*4.9309*	7.9277	**8.9264**	6.1809	6.7020	**2.6280**	**4.2334**	**1.2541**
Significant difference*	No	Yes	No	No	Yes	Yes	No	No

All numbers are given in basis points. The market with the best liquidity performance in **bold**.
*Based on matched-pairs t-tests. Thourough results available in Appendix.

Table 7.7 shows the monthly average IRT measures for each period of normal and stressed markets. For the total period, the imputed roundtrip cost is about the same in both markets, and we do not find any significant difference.

In the first normal period and during the 15/16-distress period, Norway performs better with significantly lower IRT measures. In the third normal period, Denmark performs significantly better. We find no significant differences for the remaining periods. While there is a considerable high IRT measure in Norway during the European Debt Crisis period, the difference to the Danish market is not significant.

Table 7.8: Regression Results - Imputed Roundtrip Cost

	Norway		Denmark	
Regressor	**(i)**	**(ii)**	**(iii)**	**(iv)**
Intercept	4.1981*** (0.5586)	8.8653 (7.4899)	4.4936*** (0.3401)	35.5490*** (3.6915)
European Debt Crisis	14.7106*** (2.5290)	14.2958*** (2.6202)	4.4329** (1.5401)	1.6734 (1.2914)
15/16-distress	-0.7895 (1.8314)	-0.7718 (1.8357)	2.2084* (1.1152)	2.3267* (0.9048)
Covid-crisis	0.3763 (3.0721)	0.8181 (3.1592)	-0.2602 (1.8708)	2.6795 (1.5570)
Time Trend		-0.0003 (0.0004)		-0.0019*** (0.0002)
N	140	140	140	140
Adjusted R^2	0.1859	0.1822	0.05874	0.3807

* $p<0.05$, ** $p<0.01$, *** $p<0.001$
Standard deviations in parentheses.

Next, we want to analyze whether the IRT measures change significantly during stressed market periods. Table 7.8 shows the results when running the regressions from equations 7.1 and 7.2.

The regression result for the Norwegian covered bond market, without a time trend (i), indicates that the imputed roundtrip cost significantly increased during the European Debt Crisis period. For Denmark, the regression without a time trend (iii) shows that the imputed roundtrip was significantly high during the European Debt Crisis and the 15/16-distress period.

We do not find any significant time trend when adding a time trend regressor to the regression for the Norwegian market (ii). For the Danish market, we find a negative linear time trend in the imputed roundtrip cost (iv). When a time trend is included, there is no longer a significantly higher IRT measure during the European Debt Crisis in Denmark. However, the IRT measure during the 15/16-distress remains significant.

To summarize, we do not find any apparent difference in liquidity between the Norwegian and the Danish markets when using the imputed roundtrip cost as a measure. We only find a significant difference during the 15/16-distress period, where Norway had a lower IRT measure, which indicates higher liquidity. Further, we find that the imputed roundtrip cost significantly increased in Norway during the European Debt Crisis, compared to normal periods in Norway. Similarly, in Denmark, imputed roundtrip cost significantly increased during the 15/16-distress period, accounting for the negative time trend.

7.4 Summary of Results

Up until now, we have analyzed and discussed the four liquidity measurements separately. In this subsection, we will conduct a joint assessment of the four analyses and conclude on our two hypotheses.

Hypothesis 1: During the period 2010-2021, the Danish covered bond market has been more liquid than the Norwegian covered bond market.

Based on the descriptive statistics, Denmark has a larger and more actively traded covered bond market compared to Norway. When analyzing the two trading activity variables, we find that the Danish market overall performs better. In contrast, when using the price impact measure, we find that the price impact measurement overall is higher in Denmark. A high price impact indicates lower liquidity, meaning that the price impact measure implies that the Norwegian market is more liquid. Furthermore, for the imputed roundtrip cost liquidity measure, we do not find evidence for any of the markets being more liquid than the other.

To summarize, the descriptive statistics and the measures of the two trading activity variables indicate the Danish covered bond market to be more liquid. On the other hand, one of the designated liquidity measures indicates the Norwegian market is more liquid, and the other finds no difference. Due to the weaknesses of the trading activity variables discussed in section 5.1, we emphasize the results from the designated liquidity measures somewhat higher. Given the divergent results, we cannot verify our hypothesis suggesting that the Danish covered bond market is more liquid compared to the Norwegian market.

Hypothesis 2: The liquidity is lower during stressed markets, in both the Norwegian and the Danish covered bond markets.

To test our second hypothesis, we have run regressions to determine whether the level of the liquidity measurements changes significantly during stressed periods. For the Norwegian covered bond market, we find that the liquidity worsened significantly during the European Debt Crisis period when using the designated liquidity measures, i.e., the price impact measure and the imputed roundtrip cost measure. For the 15/16-distress period, we find a significant decline in liquidity only when using the price impact measure. Similarly, for the Covid-crisis, we find a significant worsening in liquidity when using the price impact measure.

Whenever there is a significant change in the liquidity measurements during stressed markets in Norway, the significant change is associated with a *worsening* of liquidity. The measurements generally also indicate a worsening of the market liquidity in Norway in the cases where the changes are not significant. For the Norwegian covered bond market, we conclude that we can verify the hypothesis that liquidity is lower during stressed markets.

In the Danish covered bond market, the regressions find a significant decline in liquidity during the 15/16-distress period for two of our liquidity proxy measures, namely the days with zero trading ratio and the imputed roundtrip cost measure. There is no significant change during the 15/16-distress period when using the turnover ratio and the price impact measure. For the two other stressed market periods, there are no significant results in the regressions on the Danish market when accounting for the time trend.

With the discussion above in mind, we conclude that we do not find sufficient evidence that the liquidity in the Danish covered bond market is significantly lower during stressed market periods.

8 Weaknesses and Further Research

Due to missing bond reference data from Stamdata, mentioned in section 4.1, our transaction data is incomplete in the first years. This applies in particular to the Danish transaction data in 2010-2014, where an unknown number of covered bonds are missing from our data sample. We observe some noisy results during this period, but we do not know to what extent the incomplete data affects the results.

As liquidity has several dimensions, there is no universally correct way of measuring liquidity in bond markets. The liquidity measurements used in our study are chosen based on the transaction data available. Alternative measurements may be more accurate for measuring liquidity in the covered bond markets in Norway and Denmark. Potentially, we could have reached other conclusions using alternative measurements.

Measuring liquidity is challenging when trading activity is low. Bonds are traded relatively infrequently in our transaction data, especially in the Norwegian covered bond market. The two liquidity measures we employ, price impact and imputed roundtrip cost, are initially designed for securities that trade more frequently. With sparse transaction data, certain adjustments of the liquidity measures are necessary. For example, the price impact measure is initially designed to capture the price impact of trades on a particular trading day. As the covered bonds in our data sample rarely trade multiple times during a day, we are forced to extend the time window from one day to one month. With an extended time window, other factors than liquidity may likely affect the price changes, which may bias the results.

To avoid problems arising from sparse transaction data, we have a suggestion regarding further research on liquidity measurement in the Norwegian and Danish covered bond markets. Dick-Nielsen et al. (2015) refer to the "unity market for Danish covered bonds", where similar covered bonds from different issuers serves as perfect substitutes and thereby can be treated as one bond. Covered bonds with matching cash flows and specifications will likely trade at the same price regardless of the issuer, as long as the differences in credit risk are perceived as minor. All major issuers in both Norway and Denmark are AAA-rated. We have talked to market participants in the Scandinavian bond markets, who support the view of a "unity market for covered bonds" existing in both Norway and Denmark. The number of observations per bond may greatly increase by pooling matching covered bonds into one bond. This will increase the accuracy of the liquidity measures.

For further research covering liquidity in the Norwegian market for credit bonds in general, we suggest considering an alternative way of measuring liquidity that does not involve using sparse transaction data. Specifically, an approach measuring *latent* liquidity would be interesting. Mahanti et al. (2008) define the measure of latent liquidity as the "weighted average turnover of investors who hold a particular bond, in which the weights are the fractional holdings of the amount outstanding of the bond". They argue the measure is suitable in markets with sparse transaction data, as we know is the case for the Norwegian bond market for credit bonds. Mahanti et al. (2008) use databases from a large U.S.-based custodial bank[8] to measure latent liquidity. As far as we know, there has been no research measuring latent liquidity in the Norwegian bond market. We suggest gathering data from VPS[9], which in practice operates as a custodial bank for all Norwegian bond market investors.

[8] The primary function of a custodial bank is to provide trade clearance and settlement, and hold customers' securities for safekeeping

[9] Euronext VPS, officially "Verdipapirsentralen ASA"

9 Conclusion

This study aims to answer two hypotheses concerning the liquidity in the Norwegian and Danish covered bond markets. First, we challenge the general perception that the liquidity in the Norwegian market for credit bonds is less liquid than other European bond markets. Specifically, we compare the liquidity in the covered bond markets in Norway and Denmark from 2010 until 2021. Second, we study whether the liquidity in the two covered bond markets is significantly worsened during stressed market periods.

Our analysis does not find sufficient evidence to verify the first hypothesis stating that the Danish covered bond market has been more liquid than the Norwegian in 2010-2021. To analyze the liquidity, we employ two trading activity variables and two liquidity measures suitable for our relatively sparse transaction data. While the Danish covered bond market is substantially larger, with bonds traded more frequently, our analyses give deviating results of which market is most liquid. The liquidity measurements in the two markets are compared for the total period and for each subperiod of normal and stressed markets. We statistically test whether the liquidity measurements between the two markets are significantly different.

The second hypothesis, stating that covered bond market liquidity is lower during stressed markets, has different conclusions for the Norwegian and Danish markets. In Norway, we conclude that market liquidity is significantly worsened during the stressed market periods compared to normal markets. We do not find sufficient evidence for a similar conclusion in Denmark. We run ordinary least square regressions with time event dummies for the defined stressed market periods to test whether the liquidity level significantly decreases during stressed markets.

With relatively sparse transaction data, measuring liquidity in the two covered bond markets is challenging. There are several different methods for measuring bond market liquidity in the literature, but there is no consensus on what is necessarily the best approach. While we find our methodology and liquidity measurements suitable for our available data, we acknowledge that we could have concluded differently with different methodologies and other liquidity measures.

The purpose of this master's thesis is to expand the audience's knowledge about a little-known topic, namely the liquidity in the secondary covered bond markets in Norway and Denmark. As transactions costs are incorporated in covered bond investors' investment decisions, the results in our study may serve useful for the professional market participants.

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Appendix

A1 Price Impact by Trade Size

Table A1.1: Price impact by trade size

Period	**Market**	**Trade Size Group**			
		Lowest (0%-25%)	Second lowest (25%-50%)	Second highest (50%-75%)	Highest (75%-100%)
Normal	Norway	5.22	4.59	3.90	3.22
	Denmark	6.05	5.23	5.54	4.29
European Debt Crisis	Norway	7.77	11.43	7.98	4.56
	Denmark	14.14	10.01	9.10	9.58
15/16-distress	Norway	6.58	5.39	5.66	4.65
	Denmark	6.56	5.44	4.86	6.26
Covid-crisis	Norway	9.25	8.58	7.41	6.80
	Denmark	5.62	5.18	4.54	4.40

Price impact measures are given in basis points.

A2 Results from Matched-pairs T-tests

Table A2.1: Matched-pairs t-test for turnover ratio

	Total period	Normal 1	European Debt Crisis	Normal 2	15/16-distress	Normal 3	Covid-crisis	Normal 4
Mean of differences (pp)	4.800297	13.08247	13.00605	5.939251	4.258751	1.420342	1.79757	-1.463997
P-value	6.013e-10	0.000651	0.01002	6.154e-09	0.05867	0.07429	0.7176	0.3703
t-statistic	6.6556	4.1144	4.0298	7.3041	2.1091	1.8316	0.39749	-0.92575
Observations (months)	140	19	6	42	12	42	4	15
Conclusion	Denmark more liquid. Significantly	Denmark more liquid. Significantly	Denmark more liquid. Significantly	Denmark more liquid. Significantly	Denmark more liquid. Not Significantly	Denmark more liquid. Not Significantly	Denmark more liquid. Not Significantly	Norway more liquid. Not significantly

Table A2.2: Matched-pairs t-test for DZT-ratio

	Total period	Normal 1	European Debt Crisis	Normal 2	15/16-distress	Normal 3	Covid-crisis	Normal 4
Mean of differences (pp)	-4.607715	-18.40057	-12.19891	-9.600378	1.514611	5.948907	-0.4636114	-5.682328
P-value	0.001553	0.003227	0.182	0.0006362	0.2495	0.001905	0.7627	1.005e-05
t-statistic	-3.2283	-3.395	-1.5494	-3.6989	1.2157	3.3187	-0.33063	-6.7032
Observations (months)	140	19	6	42	12	42	4	15
Conclusion	Denmark more liquid. Significantly	Denmark more liquid. Significantly	Denmark more liquid. Not significantly	Denmark more liquid. Significantly	Norway more liquid. Not significantly	Norway more liquid. Significantly	Denmark more liquid. Not significantly	Denmark more liquid. Significantly

Table A2.3: Matched-pairs t-test for price impact measure

	Total period	Normal 1	European Debt Crisis	Normal 2	15/16-distress	Normal 3	Covid-crisis	Normal 4
Mean of differences (bps)	2.073613	6.327776	3.225584	3.313146	0.721067	0.3637011	-2.818043	-0.07224376
P-value	3.2e-10	0.0009959	0.002029	2.2e-16	0.1849	0.002321	0.1028	0.8078
t-statistic	6.7774	3.9235	5.8747	13.367	1.4146	3.248	-2.3234	-0.24794
Observations (months)	140	19	6	42	12	42	4	15
Conclusion	Norway more liquid. Significantly	Norway more liquid. Significantly	Norway more liquid. Significantly	Norway more liquid. Significantly	Norway more liquid. Not significantly	Norway more liquid. Significantly	Denmark more liquid. Not significantly	Denmark more liquid. Not significantly

Table A2.4: Matched-pairs t-test for imputed roundtrip cost measure

	Total period	Normal 1	European Debt Crisis	Normal 2	15/16-distress	Normal 3	Covid-crisis	Normal 4
Mean of differences (bps)	0.09234793	4.225571	-9.982204	0.8620967	3.293412	-1.211442	-0.3409687	-1.787683
P-value	0.8749	0.002838	0.2789	0.4245	0.0284	0.02173	0.736	0.1347
t-statistic	0.15768	3.4844	-1.2142	0.80668	2.5214	-2.3861	-0.36998	-1.5878
Observations (months)	140	19	6	42	12	42	4	15
Conclusion	Norway more liquid. Not significantly	Norway more liquid. Significantly	Denmark more liquid. Not significantly	Norway more liquid. Not significantly	Norway more liquid. Significantly	Denmark more liquid. Significantly	Denmark more liquid. Not significantly	Denmark more liquid. Not significantly