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The Impact of MiFID II/R on Market Liquidity

A quantitative analysis of secondary corporate bond markets

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Abstract

In this thesis, we investigate effects on market liquidity in the secondary corporate bond market in Norway, following MiFID II/R. To measure market liquidity, we use Roll's approximation to bid-ask spreads, Amihud's illiquidity estimator, the market efficiency coefficient, and trading volume. We use difference-in-differences estimation to obtain the average effect of the directive on corporate bonds subject to the directive over a six-month period and a two-year period after the implementation of the directive. In the six month period, we find a decrease in trading volumes of 11,8 per cent, significant at the 95 per cent confidence level, and an increase in bid-ask spreads of 8,56 per cent, significant at the 90 per cent confidence level. In the long term, none of these effects persist. We do, however, find a decrease in the market efficient coefficient of 8,4 per cent, significant at the 95 per cent confidence level, and a decrease of 19,4 per cent in Amihud's liquidity estimator, also significant at the 95 per cent confidence level. Regarding the total liquidity effects, these results are inconclusive.

Acknowlegements

This master's thesis concludes our Master of Science in Economics and Business Administration with a major in Financial Economics at the Norwegian School of Economics (NHH).

Given our interest for the financial markets, we found it interesting to investigate how MiFID II/R affects market liquidity. The writing process has provided us with valuable knowledge and insight.

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Contents

1. Introduction

In November 2007, the original Markets in Financial Instruments Directive (MiFID I) went into effect. The financial crisis of 2008 exposed weaknesses in the original directive. One of them was focusing too narrowly on stocks and ignoring other financial securities such as fixed income instruments. Markets in Financial Instrument Directive (MiFID II) is a revision of the original directive implemented on January 3, 2018, consisting of a comprehensive legislative framework which outlines the rules of the Markets in Financial Instrument Regulation (MiFIR). The framework is instituted by the European Union (EU) to strengthen investor protection and improve the functioning of financial markets making them more efficient, resilient and transparent (European Commission, 2011).

The objective of this thesis is to analyze whether MiFID II/R have influenced the market liquidity in secondary corporate bond markets. We conduct a quantitative analysis on the differences in liquidity between two portfolios consisting of Norwegian and American corporate bonds in the period from two years prior to the implementation of the directive to two years after implementation. The reason for the choice of portfolios, is that Norwegian bonds are affected by MiFID II/R through legislations in the European Economic Area (EEA), whereas US bonds are reasonably unaffected by this legislative framework.

Markets' purpose, at root level, is to function as a platform where buyers and sellers efficiently can trade assets at prices believed to reflect the true value of the asset. With efficiency, we mean the degree of which the market prices reflect all the relevant information determining the value of an asset. The connection between a market's efficiency and liquidity is well-founded. Kyle's (1985) model of price formation under asymmetric information shows how characteristics of liquid markets are similar to the underlying features of a continuous equilibrium market price. Foucault et al. (2013) extend Kyle's model, creating a theoretical framework on how illiquid markets are subject to asymmetrical information, and hence are inefficient. Chordia et al. (2006) analyze this connection between efficiency and liquidity empirically, proving that liquid markets enhance the market efficiency. We therefore believe the anticipated changes in the markets should be reflected in common measurements of market liquidity in markets subject to the directive if successfully implemented.

A central distinction between MiFID I and II are the types of financial instruments incorporated by the directives' directions. The original directive included equity-based instruments, whereas the revised version expanded to all fixed income instruments and derivatives traded in EEA. It is therefore likely that effects on equity-based instruments had already taken place in connection with MiFID I. We prefer to exclusively use bonds as the subject of our analysis. The reason for this has to do with the mentioned effects from MiFID I on equity instruments. Because derivatives, such as options and futures contracts, are in many cases derived from equity prices, it is likely that MiFID I to some extent affected the liquidity in derivatives markets. For example, if an underlying stock became significantly more liquid because of the directive, resulting in prices reflecting all information on its current value, the predictability of future prices is also likely to increase, indicating less uncertainty surrounding an option's true value, thus increased liquidity in this market. We further limit the scope of our analysis exclusively to corporate bonds. The reason for this is the structural differences in trading between types of bonds (Ødegaard, 2017), potentially leading to different liquidity effects following the changes imposed by MiFID II/R.

These motivations can be summarized into the research question of this thesis: *How has MiFID II/R affected the liquidity in secondary corporate bond markets?*

To answer this question in quantitative terms, we will perform an analysis using a difference-in-differences (DID) methodology, using corporate bonds with primary listing in Norway as the group subject to MiFID II/R and American corporate bonds as the control group. Because of the comprehensive structural market changes following the directive, we have reasons to believe that the effects on secondary markets emerge gradually rather than immediately after its implementation. It is therefore of interest to conduct separate analyses of the impact both over a short-term period, and a long-term period, after the implementation. We will use data over six months prior to and after the implementation for the short period, and two years for the long period.

There is no widely accepted single metric used to measure market liquidity. Although multiple researchers have proposed such measure, they generally consist of weighted combinations of measurements for different dimensions of liquidity. Because the dimensions are not related to each other in a fixed way, such measurements are necessarily designed with discretion. We will therefore perform separate analyses of four measurements which together reflect all liquidity dimensions. This may give ambigous answers to the research question, assuming the dimensions are not affected in the same way, but it allows for a broader economic interpretation of the results.

In section 2 we will review theoretical and empirical literature relevant to the research question, and formulate our hypothesis based on the literature. Section 3 presents the datasets used in the analyses, and how they are collected and prepared. Section 4 describes our methodology approach. The regression results are presented in Section 5 and discussed in Section 6. Section 7 consists of the conclusions of the analysis.

2. Literature review

In this section the central aspects of the research question are explained. We start off reviewing theoretical literature. First, we briefly define what corporate bonds are. Then we present definitions of market liquidity and how this is measured in the literature and discuss these in relation to our analysis. We outline the parts of the directive relevant to our study before this is set in context of how market liquidity is presumed to be affected. Then, we review the anticipated effects of the directive considering theories on market liquidity.

The second part consists of reviews of the empirical literature directly and indirectly connected to the research question. Because the directive was implemented recently, not many analyses relevant to the research question are currently available. Although not directly attributable to our research, we review reports on MiFID I's impact on market liquidity in secondary equity markets, as regulations in these markets are comparable to those in secondary fixed income markets following MiFID II/R. We continue reviewing two reports published by the The International Capital Market Association (ICMA), which examine the impact and challenges of the directive, the first and second year after implementation. Based on the literature, we construct our hypotheses on the outcome of our analysis.

2.1 Corporate bonds

O'Sullivan and Sheffrin (2004) define bonds as securities that are issued in connection with a borrowing agreement, where the borrower issues a bond to the lender for some amount of cash. In return, the issuer is obligated to make specified payments to the bondholder on specified dates. The distinguishable feature attributed corporate bonds is that the issuers are companies. This aspect of corporate bonds is not subject to further discussion in the thesis, as we focus on corporate bonds specifically, combined with the fact that all fixed income instruments, including corporate bonds, are treated the same way under the MiFID II/R regime. Throughout the literature review, we will thus clarify the implications of the directive on fixed income in general.

2.2 Liquidity

Liquidity, as an economic concept is multifaceted, which in broad terms describes how convertible an asset is. In security markets, liquidity is important as it determines the efficiency of markets (Muranaga & Shimizu, 1999), where security prices in highly liquid markets tend to reflect all available information affecting the fundamental value of the security.

In this thesis, we focus only on market liquidity. While market liquidity is a commonly used term in the literature, there are no widely accepted definition of it. Foucault et al. (2013, p. 8) defines it as "a market's liquidity is defined as its ability to trade a security quickly at a price close to its consensus value". Muranaga and Shimizu (1999) use a more elaborate definition, defining liquid markets as "markets where large volume of trades can be immediately executed with minimum effect on price". A common approach used to describe market liquidity is to define distinct characteristics present in liquid markets, rather than using one clear definition of the term. Sarr and Lybek (2002) present five dimensions of liquidity: tightness, immediacy, depth, breadth, and resilience. Tightness refers to low transaction costs, defined as the costs of simultaneously buying and selling the same asset at the current lowest ask price and the highest bid price, respectively. Immediacy represents the order execution speed. Depth refers to the existence of abundant orders above and below the security's trading price. Breadth refers to the aggregated volume of orders. Lastly, resilience is a market characteristic in which new order flows are quickly to correct order imbalances.

Huang and Wang (2010) investigate the drivers behind liquidity, observing that full market participation is at the heart of liquidity. They argue that when all potential market participants can trade without constraints and frictions, they always face the full supply and demand of the security. In this scenario, prices only depend on the expected payoffs and investor preferences. The only sources of market illiquidity are thus factors preventing fully participation in the market. This affects all mentioned dimensions. All potential participants place their quotes, creating a deep and broad market. Following this, an equilibrium price is determined by supply and demand, resulting in minimal differences between bid and ask prices. As all potential participants has placed their orders, trades happen immediately when orders are matched. The same goes for the resiliency, where any buy/sell orders placed above/below the current ask/bid price immediately are absorbed by the market, correcting the imbalance that occurs.

Because of the multidimensional definition of market liquidity, it cannot be quantified using one single metric, so we aim to measure the effects on the five dimensions indicating liquidity. Sarr and Lybek (2002) propose four categories of measurements to capture all liquidity dimensions: (1) Transaction cost measurements, (2) volume-based measurements, (3) measurements based on equilibrium prices, and (4) measurements of price impact. Although these measurements are not unequivocally connected to the liquidity dimensions, the combination of them covers all dimensions. We therefore seek to use one measure within each of the four categories.

2.3 MiFID II/R

In this part, we will outline the institutional effects on secondary bond markets following MiFID II/R. We start by explaining how the structure of corporate bond markets has shifted from primarily over the counter (OTC) trading to a higher degree of trading in regulated venues. Then, we will point out the key requirements imposed by the directive, relevant for secondary corporate bond markets.

Prior to the implementation of the directive, trading of corporate bonds mainly happened on OTC markets (European Commission, 2017). These markets are characterized by their bilateral nature, where dealers sell bonds to investors on their own account, meaning investors themselves are not directly involved in the trading of bonds. Instead, trading happens between dealers on marketplaces exclusive to them. Before MiFID II/R, the reporting requirements in these markets were lacking as they were entirely self-regulated (Casey & Lannoo, 2009). For investors, the information available were therefore minimal, with no access to information on historical transactions in the dealer market or currently placed orders. The low transparency following this market structure is expected to result in low liquidity, because of the asymmetry in information between dealers and investors (Foucault et al., 2013, p. 31). Dealers have an advantage knowing the current quotes and prices of previous trades and can exploit by selling/buying bonds at inflated/deflated prices to investors, which increases investors' transaction costs. Green et al. (2010) find a positive correlation between markets' transparency and price discovery. This gives implications on effects in the other liquidity dimensions: if there is no consensus value of the bond, markets are less likely to immediately correct for imbalances in the price, affecting both resiliency and immediacy. A third consequence, is that the number of market participants is lower in less transparent markets (Goldstein, Hotchkiss, & Sirri, 2007), affecting markets' liquidity.

To increase market transparency, MiFID II/R changes fixed income markets in three distinct ways (ICMA, 2017). The first is to change the structure of markets to reduce the amount of OTC trading in favour of more regulated marketplaces. Secondly, OTC markets themselves have become more regulated through new reporting standards. Lastly, dealers are required to distinguish between prices paid for bonds in dealer markets and other costs when giving their quotes to investors.

2.3.1 Market structure

MiFID II/R separates the system of organized transactions into different trading venues and systematic internalisers (SI). The trading venues consist of regulated markets (RM), multilateral trading facilities (MTF) and organized trading facilities (OTF). The new trading venue, OTF, offers inter alia trading in fixed income securities. For businesses to act as organized trading facilities, they need permission and fulfillment of certain criterias regarding organization. We will briefly outline the types of venues after the implementation of MiFID II/R in accordance with ICMA (2017), before comparing the pre- and post-MiFID II/R market structures.

Regulated Market (RM)

A regulated market (RM) is a multilateral trading venue operated by non-discretionary market operators connecting buyers and sellers without being involved in the trade themselves. These are typically centralized authorized exchanges on national levels. RMs, as well as MTFs, are both neutral transparent venues which can offer both equities and non-equities.

Multilateral Trading Facility (MTF)

Before the introduction of MTFs in MiFID I, multilateral trading was primarily centered on RMs. MTFs provides an alternative platform for investors to trade financial instruments, where private investment firms can operate them. Apart from this, they are subject to the same rules as RMs. The introduction of these allows for more competition between multilateral platforms.

Organized Trading Facility (OTF)

While the original MiFID directive only covered MTFs, OTFs were introduced as a part of MiFID II/R. OTFs are trading venues focused on non-equity trading, including fixed income markets. The primary objective of this trading venue is transparency and structure in OTC trading. Unlike MTFs, orders executed on an OTF are carried out on a discretionary basis, where investors do not place orders at a specific price, but rather a window of prices the market operator can execute at.

Systematic Internaliser (SI)

Systematic Internaliser (SI) was introduced under the original MiFID directive, and expanded to fixed income markets under MiFID II/R. An SI is an investment firm which deals on its own account when executing client orders outside the trading venues, dealing on a bilateral basis, meaning the operator is the counterparty to investors when trading, and not a third party bringing buyers and sellers together.

Table 1: Market structure post-MiFID II/R (ICMA, 2017, p. 7)

	Regulated market (RM)	**Multilateral Trading Facility (MTF)**	**Organized Trading Facility (OTF)**	**Systematic Internaliser (SI)**
Operator	Market operator	Investment firm or market operator	Investment firm	Investment firm
Financial instruments	Equities and non-equities	Equties and non-equities	Non-equities	Equities and non-equities
Execution	Non-discretionary	Non-discretionary	Discretionary	Discretionary

Use of proprietary capital	Prohibited	Prohibited	Prohibited, with some exceptions	Expected
Matched principal trading	Prohibited	Prohibited	Permitted on instrument under certain obligations, with client consent	Only in exceptional circumstances

The introduction of SIs and OTFs was instrumental to limit the extent of OTC trading. Looking at table 2, in the absence of these new venues, the gap between OTC trading and trading on either RMs or MTFs were large. Most noticeably, is that neither of the regulated venues offer discretionary trading, limiting the freedom of brokers on behalf of their clients' capital. The same goes for the prohibition of proprietary and matched principal trading. Proprietary trading means that dealers gain profit from trading on their own account in the market, while matched principal trading denotes situations where dealers simultaneously buy bonds and sell them at a profit margin. These three factors are all sources of profitability for dealers, and abolishing OTC trading without structural changes in the market would reduce the profitability of dealers.

One could argue that abolishing OTC trading in favour of RMs and MTFs would harm the market liquidity. This is because dealers play a significant role of providing liquidity to illiquid markets, shown by Foucault et al. (2013, p. 23). Because their profitability is partly due to their informational advantage over investors, markets become more resilient as informed dealers' profits from pricing imbalances, by placing orders correcting for the mispricing. From this, the immediacy of trade execution will also provide liquidity in the market. Hence, the increased liquidity from shifting OTC trading to RMs ant MTFs may not exceed the liquidity provided by dealers in otherwise illiquid assets and markets. This underlines the necessity of OTFs and SIs, ensuring more transparent markets without making dealers redundant.

2.3.2 Transaction reporting

When MiFID I was introduced, a central goal was to increase the post-trade transparency of equity trading. Several new reporting requirements were introduced, which included standardized post-trade reporting standard and enhanced market data reporting (AFME, 2017). The post-trade reporting requirements set standardized rules for information that must be reported, such as transaction price, time of transaction, and the volume of the transaction. Additionally, clear guidelines were set regarding which part of the transaction responsible for publishing the report, and deadlines for publishing. With the change in the market structure, described in section 2.3.1, these reporting requirements were extended to include corporate bonds, with certain sets of requirements attributed to the different types of trading venues. For OTC trading, similar requirements were introduced in MiFID II/R, where investment firms are required to publish transaction data in real-time.

MiFID II/R has also made new requirements for pre-trade reporting in trading of corporate bonds. Here, trading RMs, MTFs, OTFs and SIs are required to continuously publish current orders, including order sizes and the bid- and/or ask-prices (ESMA, 2018).

The new reporting requirements are expected to lead to more transparent markets, as previously unavailable information now is available to all market participants in real-time. Gains of those in possession of asymmetrical information are now limited, as any orders placed by them carry some information previously unavailable for those who are not informed (Foucault et al., 2013, p. 2).

2.3.3 Research unbundling

OTC bond trading has historically been influenced by bundled pricing, meaning the prices paid by investors to investment managers reflect both the cost of the investment and the research costs of managers. Investors can therefore not know the actual market price of the bond purchased. This is not desirable for two reasons. One is the potential principal-agent problems that may arise when investment managers hold more price information than the investors. The other is the low degree of transparency in these markets. MiFID II/R resolves this problem by requiring managers to unbundle prices, separating the transaction price of the bond from the price paid to the investment manager.

2.4 MiFID I

Because MiFID II/R is a continuation of the original directive, expanding the requirements to non-equity markets, reports on MiFID I's effects on liquidity can give relevant insight on what we can expect to observe in secondary corporate bond markets. Although results of analyses of stocks subject to MiFID I do not directly transfer to our research question, they provide some insight for two reasons. One is that the requirements from MiFID I on equity markets are generally the same as the requirements MiFID II/R imposes non-equity markets. The second is that market mechanics to a large degree are equal across all financial instruments, regarding how trades are executed and the factors affecting trading decisions.

Aghanya et al. (2020) use a difference-in-differences model to examine effects on liquidity and price informativeness of stocks across 28 countries subject to MiFID I, with American and Canadian stocks as the control group. They found evidence of increased liquidity due to the increased flow of information following more transparent markets.

However, a significant difference between equity and fixed income markets, weakening the applicability of these results to our research, revolves the structural differences between equity markets pre-MiFID I and fixed income markets pre-MiFID II/R, where equity trading traditionally been traded significantly more on regulated venues than fixed income instruments (Sundaresan, 2009). The study substantiates this as the impact of MiFID I was bigger in less regulated markets prior to the directive. It is therefore fair to assume the impact from the structural changes in markets has had a bigger impact on fixed income instruments through MiFID II/R, than on equity instruments through MiFID I, meaning results of equity-based studies of MiFID I may be underestimated when attributing them to expected effects on fixed income instruments.

2.5 ICMA reports

MiFID II/R and the bond markets: the first year (ICMA, 2018)**:**

A year after the implementation of MiFID II/R ICMA published a report on the impact and challenges of the directive on the bond market. We will focus on the parts relevant for our paper, the impacts on the secondary market regarding liquidity.

The conclusion of the report regarding market liquidity, was that the responding firms on the survey remained largely unaffected across all bond asset classes. Transparency appeared to be mostly unchanged. Respondents suggests that post trade transparency had not improved because of the regulation, although it seems to be a degree of optimism that this could improve over time.

MiFID II/R and the bond markets: the second year (ICMA, 2019)**:**

In December 2019 following ICMA's first report, they published an analysis on the impacts of the implementation of MiFID II/R on the bond market after the second year. They state in the report that the corporate bond liquidity changes in the second year after implementation is hard to attribute causality regarding the impact of the directive, as there is a confluence of factors impacting market liquidity. From the report it is apparent that there is a continued lack of transparency in the fixed income markets.

As outlined in the two reports of ICMA, the impact of MiFID II/R on the secondary bond market liquidity appears to be minimal, but the effects on liquidity and transparency may appear to a larger degree in the years to follow.

Based on the provisional reports on MiFID II/R we would expect the change in liquidity on the secondary corporate bond markets following the implementation of the directive to be currently non-significant. Hence, we arrive at the following hypotheses:

H1: MiFID II/R has not had a significant impact on the market liquidity in the secondary corporate bond markets.

However, the theoretical literature suggests that increased market participation leads to increased market liquidity. In the context of the objective of increased market transparency due to MiFID II/R, and therefore lower barriers for potential investors to enter the market, thus increased participation, it is likely that market liquidity is affected by the directive.

H2: MiFID II/R has had a significant impact on the market liquidity in the secondary corporate bond markets.

3. Data

In this section, we describe the methods used to collect and prepare daily price and volume data. Then, we present the liquidity measures used in the analysis, and show how these are derived from the initial dataset. In the end, we present and comment on the summary statistics for each market in the short period of one year and the long period of four years.

3.1 Data sample construction

Constructing the data sample requires two corporate bond portfolios. One from markets subject to MiFID II/R, and one not subject. Initially, we wanted to include as many countries as possible in both groups. This way, by controlling for any country specific effects, the estimated effects of the directive would have a high degree of reliability. However, this resulted in problems regarding availability and consistency of data. Not all countries have available data. This could lead to selection bias in the analysis, assuming some correlation between the availability of market data and the markets' liquidity. Additionally, there were consistency issues due to differences in trade reporting both within and between countries regarding the frequency of trade volumes reporting, with some markets missing volume data completely. Our treatment group is thus limited to a portfolio of corporate bonds listed on Oslo Børs. The control group is a portfolio of American corporate bonds traded by institutions in USA. Results from the broader dataset will still provide some insight regarding price-base measures, as daily pricing data is available. We will thus include insights from these when evaluating the results from the analysis of Norwegian data.

Choosing these groups for the analysis relies on the institutions trading the bonds, as the directive focuses on the dealers trading the bonds, rather than the countries of the bonds' primary listing. Hence, trading of bonds listed on Oslo Børs must be subject to MiFID II/R to a larger extent than those listed in USA. Oslo Børs requires all SIs and sellers in over-the-counter markets to report trades by submitting Approved Publication Arrangements (APAs) to the exchange, which are reported in correspondence with the requirements of the directive, while RMs, OTFs, and MTFs publish trades directly in accordance with the directive (Oslo Børs, 2019). The American bonds in our dataset are exclusively traded through American institutions, and are not subject to MiFID II/R. They are, however, subject to similar regulations through The Trade Reporting and Compliance Engine (TRACE), introduced in

2002, requiring all American institutions selling USD denominated bonds in over-the-counter markets to report transaction information (FINRA, 2017). Although the introduction of TRACE is likely to have impacted market liquidity, we do not see this as a possible source of bias in our analysis. For this to be the case, these regulatory changes would have to impact the liquidity differently over the analyzed period. As we analyze the period from 2016-2019, we assume any liquidity changes due to the introduction of TRACE to already have taken place, and any persisting effects to be permanent over the period.

3.1.1 Treatment group

The Norwegian dataset is collected from Børsprosjektet NHH, using data from the Amadeus 3.0 database. This dataset includes 2,367 unique corporate bonds with primary listing on Oslo Børs between 01.01.2016 and 31.12.2019. The total number of transactions is 734,724. Each observation is daily data for a single bond listed on Oslo Børs, excluding bonds listed on Nordic ABM not subject to the regulations imposed by the directive. Price data is the latest reported execution price of the day, expressed as the percentage of its par value, while volume data is the day's aggregated NOK par value turnover for each bond.

3.1.2 Control group

The American dataset consists of bond trades eligible to TRACE-reporting on a per-trade basis, collected from Wharton WRDS' database, including the transaction price and the volume in par-value (UBS Financial Services, 2017). We use all obtainable data from the same period as for the treatment group and collect data from 14,014 unique corporate bonds with a total of 10,448,049 transactions. Unlike the treatment group, these are not data from a single exchange, but from corporate bonds traded through any broker-dealers subject to TRACE reporting.

3.1.3 Data adjustments

Both price-based measures are sensitive to sudden price changes. The dataset shows two specific cases where this occurs. One is outlier observations, where the price one day suddenly changes by an extreme amount, before returning to the normal price range. It is hard to formally identify outliers, as some bonds fluctuate more in price than others. As only a few bonds are subject to outliers, we identify sequences of two days with large fluctuations, and graphically evaluate the price time series. We cautiously remove the most severe cases.

Similarly, cases where the price suddenly changes, but remains within the new price range, affects the measurements. These price changes are not presumed to stem from irregularities in the datasets. Exact reasons for the changes are hard to determine, but presumably not connected to liquidity in any way. However, our liquidity measurements derived from price changes assume they do, resulting in short-term extreme estimates. As with the outliers, these are removed with discretion. In total, 37 individual bonds are dropped from the dataset due to these two issues, whereof 14 in the American dataset, and 23 in the Norwegian.

In the Norwegian dataset, trading volume in days without trading is, in most cases, given a value of zero rather than missing. Although this is not a problem by itself, it makes the two datasets incomparable. As we will elaborate in section 3.1.2, the American dataset is constructed using data on a per-trade basis. By collapsing these data into daily observations, days without trading are excluded altogether. Any interpretation of volume measurements is thus based on days where the bond is traded, and all zero-volume observations are replaced by missing value in Stata.

Using Stata 16, we convert the per-trade data from the American dataset to daily data by collapsing the data set, keeping the last price of each trading day and the aggregated volume per day. In 1,86 % of the observations, the reported volumes are not numeric values, but text values rounded down to the nearest million, e.g. “5MM+”. With no way of knowing the exact volume of these trades, we replace with numeric values to the nearest million. Although this is the lowest possible volume, we do not want to speculate on the correct values as there is no information on the factual values. Normally, an arguably better approach would be to remove the data of such bonds entirely, under the assumption that text reporting happens randomly across bonds. This is, however, not the case. According to FINRA (2001), such reporting is allowed for bonds of which the initial issuance size is above either USD 1 or 5 billion, depending on the bond’s investment grade.

3.2 Dependent variables

In the following parts of this section, we present the measurements and the formulas used to compute these using the collected data. Variables p and v represent price and volume, respectively. Subscription variable i denotes unique bonds, and t trading dates.

3.2.1 Roll's measure

To measure transaction costs, the bid-ask spread is typically used. The spread is the difference between the lowest price a seller wants to sell a security for on the market, and the highest price a buyer wants to pay for the security. In terms of the liquidity dimensions, the bid-ask spread therefore directly covers the tightness but also gives supporting indications of breadth and depth (Sarr & Lybek, 2002, p. 20). To obtain comparable values between securities, the spread relative to the average of the bid- and ask-price is commonly used.

Computing the relative bid-ask spread directly requires data on the highest bid prices and lowest ask prices for predetermined time intervals. Considering the datasets used, such data is only available in the Norwegian dataset. To approximate the transaction costs, Roll (1984) proposes a measure deriving the bid-ask spread based on transaction prices instead of continuous bid- and ask-prices. The intuition of the method is explained by using a sequence of three trades that yields the combined joint distribution shown in table 2 of successive price changes expressed by the number of spreads (s). Because of the assumption of equal probabilities, the eight possible outcomes have equal probabilities. Note that two consecutive price changes in the same direction cannot happen as the estimated spread is constant over the period, implying constant bid and ask prices. Thus, a price change in the first period cannot be followed by another change in the same direction as the current price is already at either the bid or ask, giving probabilities of zero. The case with no change in either period accounts for both outcomes, where all three trades are executed at the same price, i.e. either bid or ask. Because the covariance of the price changes is known and can be expressed by the spread, restructuring the covariance formula can give an approximation of the spread.

Table 2: Possible outcomes in price over a sequence of three periods

		Δp_t		
		-s	0	+s
	-s	0	1/8	1/8
Δp_{t+1}	0	1/8	1/4	1/8
	+s	1/8	1/8	0

The measurement relies on four assumptions. One is balanced order flows, meaning the probability of a market order is equally likely to be a buy or sell order. Secondly, there must be no autocorrelation in orders. An order placed at a specific time will not affect the probability of future orders are buy or sell orders. The third assumption is that the markets orders have no effect on the mid-quote, which in practice means that orders does not contain information on the bonds fundamental value. Lastly, it is assumed that expected return is constantly equal to zero. Stoll (2000) tests the Roll's measure against empirical bid-ask spreads using daily covariances, confirming that the assumptions do not hold in practice, and that the measure consistently underestimates the spread. Despite its shortcomings, it is still a commonly used metric when comparing markets' tightness.

We calculate Roll's measure as follows:

$$Rolls_{it} = \frac{2\sqrt{-cov(p_{it+1} - p_{it}, p_{it} - p_{it-1})}}{p_{it}}$$

The measurement requires the covariate of an interval of prices. This should be short, as we want to capture short term price changes. However, too short intervals overestimate daily variations. Working with daily data, Roll (1984) found 21 days per interval to be appropriate. To account for the possibility of different expected price changes over the weekends than between weekdays, we choose periods of four weeks, equal to 20 business days. The covariances are determined by moving intervals. That is, when the time changes by one day, the observations determining the covariance also change by one day.

3.2.2 Market efficiency coefficient (MEC)

The intuition of using price changes as measurements of liquidity, is that in periods of no new information of the intrinsic values of a bond, the short-term price changes that may occur in this period is a sign of illiquidity in the market. In our case, measuring these price movements of periods without new information precisely is unrealistic, due to the amount of individual bonds used in the analysis and the complexity of determining the equilibrium price reflecting the bond's true value at any point in time. However, Hasbrouck & Schwartz (1988) proposes the market efficiency coefficient (MEC), a generalized measure to capture the extent of equilibrium price variations in periods without new information. The measure consists of the relationship between short- and long-term price variations, expressed by the variance. Over a given period, the variance of long-term price changes relative to the short-term changes gives information on how stable the price is in shorter trading periods compared to what is expected of the bond over time.

A crucial assumption when using this measure is that short-term price variations are expected to reflect new information to a lesser extent than in the long run in illiquid markets. That is, the long-term price changes in liquid markets are expected to be continuous over longer periods, while illiquid markets experience more price variations over the same period. Then the relative difference between the variances is interpreted as the extent of which the prices vary within the long periods compared to between long periods. To illustrate, we assume a constant price change each month. If the daily prices also change by a constant amount, this will result in a market efficiency coefficient of one, after multiplying the short-term variance by the number of short periods within one long. In this scenario imbalances do not occur, meaning the market is perfectly resilient. On the other hand, if the daily variations are high, but monthly still constant, resulting in a low MEC, there would be continuous market imbalances, giving low market resilience.

We measure the bonds' daily MEC based on variations in daily prices. The returns are the logarithmic change in price between two points in time. *rt* is the short time return, of which we use daily returns. Rt is the long-term return, where we use four business weeks (20 days). The relative difference between a short and a long period, N, equals 20. In accordance with Sarr & Lybek (2002, p. 14), the covariances are calculated on a moving average basis, where the included prices used to determine the covariances change along the time dimension. We use a rolling interval of 20 days. Hence, $Var(r_t)$ is the variance of daily prices over 20 days, and $Var(R_t)$ of monthly prices. The reason behind choosing a 20-day interval has to do with the ability to differentiate daily MECs. As the measure is used on a floating average, shorter intervals would reduce the number of days, giving rt a bigger impact on MEC. With longer intervals, the effects of daily changes in return decrease. As we analyze daily data, shorter intervals are preferable. At the same time, we seek to find consistent estimates on how much daily returns varies relative to monthly returns. Using too short time intervals would result in MECs heavily affected by extraordinary daily fluctuations. Averaging by 20 return observations will smoothen the effects of any daily price shocks, allowing us to compare the MECs across time, while still correcting for monthly price fluctuations.

$$MEC_{it} = \frac{Var(R_{it})}{N \times Var(r_{it})}$$

Where

$$Var(R_{it}) = Var\left(ln\left(\frac{p_{it}}{p_{it-19}}\right)\right)$$

$$Var(r_{it}) = Var\left(ln\left(\frac{p_{it}}{p_{it-1}}\right)\right)$$

$$N = 20$$

To avoid observations derived from too few price observations, i.e. periods with only a few price observations, we set the limit for the minimum number of price observations within the short and long periods at 15. Including intervals with few price observations would give misleading MEC estimates, as it implies missing observations in the price data.

3.2.3 Amihud's illiquidity

A measurement commonly used in measuring the price impact is the Amihud's illiquidity estimator (ILLIQ) (Amihud, 2002), which measures absolute return in comparison to trading volume, giving information mainly along the breadth and depth dimensions, as it measures to what extent the order book is able to execute large order volumes without changing the price. The measurement focuses on price changes over a period, such as one trading day. Price changes relative to the trading volume will indicate how market prices are affected by trading. The intuition is that low volume but bigger changes in the price indicates illiquidity, since the market then are not capable of processing orders without impacting the price significantly. There are other drivers of the returns, so it must be mentioned that the rate itself on a given point of time provides little informational value on the liquidity. Nevertheless, the daily rates over time on the different bonds will provide informational value.

The measure is commonly used over longer periods, such as months and years, taking the average of daily values (Ødegaard, 2018). This is done to obtain one comparable measure across markets and individual bonds. Using data from multiple time periods reduces the impact of short-term fluctuation in prices and volumes. These fluctuations can have different reasons, not always related to liquidity. If over a period of months, a significantly different return-to-volume ratio one day would not imply an illiquid bond. Are fluctuations more common, the implications on illiquidity would be stronger. Hence, averaging results over longer periods would give more fitting single values for individual bonds over a period. As evident in section 4.1, using periodic averages is in our analysis not necessary given the methodology used, where daily values are used to compute the averages of the two groups in two predetermined periods, making the use of longer periods to compute Amihud's ILLIQ redundant.

When calculating the measure, we need to make an assumption regarding the trading volume. We notice a handful of observations with artificially low volumes. Had there been a common trend within certain bonds, the individual fixed effects estimator, described in section 4.5, could be sufficient to resolve this problem. However, the low-volume observations happen at random points in time and is not repeated within individual bonds. Hence, when calculating this measure, we require the daily trading volume, $v_{it} \times \frac{p_{it}}{100}$, to be at least 5 USD. To avoid any potential selection bias from requiring different relative values in the two datasets, we use the NOK equivalent to 5 USD based on yearly averages[1]. Following this, 944 daily observations are excluded from the calculation.

The formula used for daily calculations is:

$$ILLIQ_{it} = \frac{ln\left|\frac{p_{it}}{p_{it-1}}\right|}{v_{it} \times \frac{p_{it}}{100}}$$

3.2.4 Trading volume

When using volume-based measurements, Sarr and Lybek (2002) specifically point at effects on market breadth and depth. Higher trading volumes indicate broad markets, as high trade volumes necessarily require high order volumes surrounding the current mid-price. Because both markets used in the analysis allow for limit orders (Oslo Børs, 2020) (Schmidt, 2011), broad markets are expected to also be deep, as orders at a given price will also be executed at better prices from the perspective of market participant placing the order. To achieve high immediacy of trades, a prerequisite is that markets are continuously broad, reflected by the volume. Hence, the trading volume directly covers these three dimensions. It also gives anecdotical indications in the three remaining dimensions, as order books contain information on the fair price of a bond (Foucault et al. 2013, p. 79), which in turn reduces the degree of asymmetric information. If all market participants are fully informed, a consensus price is established. Then the market will be tight, and any imbalances are immediately corrected for as informed investors will profit from these, increasing resilience. In respect to market

[1] Yearly average conversion rates are collected from www.ofx.com.

liquidity, the trading volume is a useful measure, but cannot be attributed specific dimensions to the same extent as the other measurements discussed.

As our volume-based measure, we use average daily volumes. These are computed using the local currency; NOK for bonds primarily listed on Oslo Børs, and USD for bonds primarily listed in USA. We transform the par-value volume intro currency denominated trading volume, using the following formula:

$$Volume_{it} = v_{it} \times \frac{p_{it}}{100}$$

3.3 Summary statistics

Tables 3 and 4 show summary statistics for the Norwegian dataset, and 5 and 6 for the American, for both pre- and post-MiFID II/R periods over the one-year period. Similarly, for the four-year period, tables 7 and 8 show summary statistics for the Norwegian dataset, and 9 and 10 for the American dataset. For detailed summary statistics of the whole dataset, se Appendix 1.

3.3.1 One-year period

Table 3: Norway pre-MiFID II/R (6 months)

Variable	Obs	Mean	Std.Dev.	Min	Max
Price	27522	82.97446	208.8293	.01	3550
Volume (mNOK)	27509	22.7	104.0	.000064	3.00e+09
Roll's	16143	.0355631	.0611669	0	2.891367
MEC	19728	.4925635	2.564066	.0169261	224.1004
ILLIQ	19668	0.000023	.0002530	4.69e -13	.013574

Table 4: Norway post-MiFID II/R (6 months)

Variable	Obs	Mean	Std.Dev.	Min	Max
Price	26666	90.02354	267.1949	.01	4900
Volume (mNOK)	26657	33.6	157.0	.0004	8.52e+09
Roll's	16267	.0392521	.0663635	0	1.219674
MEC	19404	.5007346	1.702739	.0035637	94.64374
ILLIQ	19666	.0000178	.0001801	2.43e-13	.0080786

Table 5: USA pre-MiFID II/R (6 months)

Variable	Obs	Mean	Std.Dev.	Min	Max
Price	134539	103.7419	22.55303	.09	1228.31
Volume (mUSD)	134539	2.2	24.5	1.2342	8.69e+09
Roll's	124779	.0108582	.0146344	0	1.355493
MEC	101957	.1014505	.2894768	.00005381	39.42335
ILLIQ	131971	6.05e-07	.000055	1.14e-15	.0186883

Table 6: USA post-MiFID II/R (6 months)

Variable	Obs	Mean	Std.Dev.	Min	Max
Price	136135	100.6475	16.97018	.12	1403.5
Volume (mUSD)	136135	2.5	6.4	2.88e-5	2.55e+08
Roll's	124178	.0119585	.0149869	0	.8723081
MEC	104653	.1230601	.1499105	.0021011	10.66434
ILLIQ	133730	4.56e-07	.0000301	2.45e-15	.0108931

3.3.2 Four-year period

Table 7: Norway pre-MiFID II/R (2 years)

Variable	Obs	Mean	Std.Dev.	Min	Max
Price	98894	74.23765	185.3135	.01	3550
Volume (mNOK)	98855	23.4	103.0	.000012	4.79e+09
Roll's	58923	.0397757	.0901745	0	2.891367
MEC	68836	.5415575	4.233611	.0002872	359.4315
ILLIQ	70244	0.0000372	.0004055	1.64e-13	.0433781

Table 8: Norway post-MiFID II/R (2 years)

Variable	Obs	Mean	Std.Dev.	Min	Max
Price	110464	90.66893	227.8134	.001	4900
Volume (mNOK)	110390	30.6	137.0	1.00e-6	8.52e+09
Roll's	66284	.0426657	.0817915	0	2.94392
MEC	80128	.4983917	2.837462	.0013905	328.5845

ILLIQ	80683	.0000324	.0002633	2.43e-13	.0128798

Table 9: USA pre-MiFID II/R (2 years)

Variable	Obs	Mean	Std.Dev.	Min	Max
Price	510587	104.3506	33.94999	.09	2219.36
Volume (mUSD)	510587	2.6	14.0	1.2342	8.69e+09
Roll's	471235	.0126198	.0164913	0	1.761245
MEC	361098	.130023	.5671223	.0000499	60.04217
ILLIQ	500793	1.03e-06	0.0000981	1.03e-15	.0448879

Table 10: USA post-MiFID II/R (2 years)

Variable	Obs	Mean	Std.Dev.	Min	Max
Price	559504	100.8837	17.25771	1.00e-06	1403.5
Volume (mUSD)	559504	2.5	6.3	.02	4.06e+08
Roll's	506073	.0122474	.017492	0	1.696292
MEC	428890	.1634817	.3051653	.001107	29.13711
ILLIQ	547992	6.12e-07	.0000447	1.24e-15	.0297803

3.3.3 Comments

Looking at the number of observations, we see some differences in reporting between the two datasets. As the American data is derived from trade reports subject to FINRA's guidelines, all observations necessarily include both price and volume data. This is not the case for the Norwegian dataset. Here, the volume observations are consistently more frequent than price data. The reasons for this are unclear. However, Oslo Børs (2019) lists exemptions to the price reporting requirements and seems to be the probable cause. This reporting inconsistency will not affect any of the liquidity measurements and is thus not accounted for.

The liquidity measurements give some general insight on the trends in the markets. In Norway, we do notice minor differences with regards to liquidity between the periods. Roll's measure is slightly increasing, indicating lower liquidity. Consistently lower means in the short-term period additionally indicates a dip in the measure in around the time of implementation. This pattern is also present in the market efficiency coefficient, although the implications on liquidity are the exact opposite than for Roll's measure. Amihud's ILLIQ indicate a slightly lower price impact of trades, and the same pattern of a dip in the short period surrounding the implementation. The NOK denoted turnover indicate some increase in liquidity, it does not take inflation into account, and the real differences is hard to evaluate based on averages. This measure seems to vary less over time, not showing any clear patterns in the short-term period relative to the long-term period. For American bonds, the same pattern seems to be present in Amihud's ILLIQ and MEC. As the changes are similar in the relative change, this indicates that the dip has nothing to do with short-term liquidity changes explained by the directive, but rather general trend in all markets explained by some unrelated factor.

We notice several permanent differences between the markets. Even when accounting for currency differences, the average daily trading volume for a given bond is larger in Norway, both before and after the implementation. Also, MEC is larger in Norway, showing less short-term price movements. The relative bid-ask spreads and Amihud's ILLIQ both indicate better liquidity in the American market, and the differences seem somewhat constant between the periods, indicating fundamentally better liquidity in USA, and not necessarily increasing liquidity relative to Norway over the observed period.

4. Methodology

Our research question is whether MiFID II/R has had an impact on the liquidity of Norwegian corporate bonds. Before determining the methodological approach of the thesis, we transform the research question into a target estimand to give an understanding of exactly what we want to analyze, in quantitative terms. We define the estimand as the average difference of the liquidity measurements after MiFID II/R was implemented minus the average difference of the liquidity measurements had MiFID II/R not been implemented. This can be generalized as the average effect of treatment on the treated group (ATT).

The goal of this chapter is thus to find an appropriate estimator of ATT. First, we will outline our methodological approach, discuss the rationale behind choosing this method for the analysis, and describe the assumptions of this methodological approach. Secondly, evaluate and correct for potential biases in coefficients and standard errors. Lastly, we will develop a model for the analysis.

4.1 Difference-in-differences

Difference-in-differences is a quasi-experimental method used in panel data analyses to determine the effects of some treatment on one group at a specific point in time. Hence, the model requires at least one experimental group receiving the treatment and one control group that does not. The second prerequisite is to include two time periods, where one is the period before the treatment occurs, and the second after. In our case, the treatment variable is determined by bonds regulated by MiFID II/R, and the time variable by the date of which the directive was implemented in the markets. In the model, these two requirements are represented by dummy variables. Any bonds subject to MiFID II/R is assigned a value of one in the treatment variable, and zero otherwise. The time dummy takes a value of one for observations in the post-implementation period, and zero prior to the implementation.

Interpreting the dummy variables' coefficients in regression models, analyzing the four liquidity measurements discussed in section 3.2, gives information on the differences in liquidity between Norwegian and American corporate bonds, and equivalently differences between the pre- and post-implementation periods. Taking the product of these variables gives a third dummy variable, the DID estimator. This variable takes value one for bonds affected by the directive at a time of which the directive has been implemented, and zero if not. In an unbiased regression model, the coefficient of this variable is interpreted as the effect of the directive on the different liquidity measurements, i.e. the ATT, and hence the true effects of MiFID II/R on liquidity.

Figure 1 illustrates the principles behind the method, showing how the coefficients of the variables are estimated. They are in all cases the average difference between the two binary values. The inclusion of the interaction variable in the model will, however, affect the interpretation of the group and time variables. Isolated, the group effect takes the whole period into account, meaning the effects caused by MiFID II/R influence the coefficient. Similarly, the time effect is the average difference between the two periods unaffected by the separation of groups, meaning the effects of the directive also influence this coefficient. The ATT variable changes this interpretation, as effects attributed the directive are captured by this variable. Then, the group and time effect reflect differences in absence of the directive. Practically, this means that group differences only take the pre-implementation period into account, while the time effects only consider the control group.

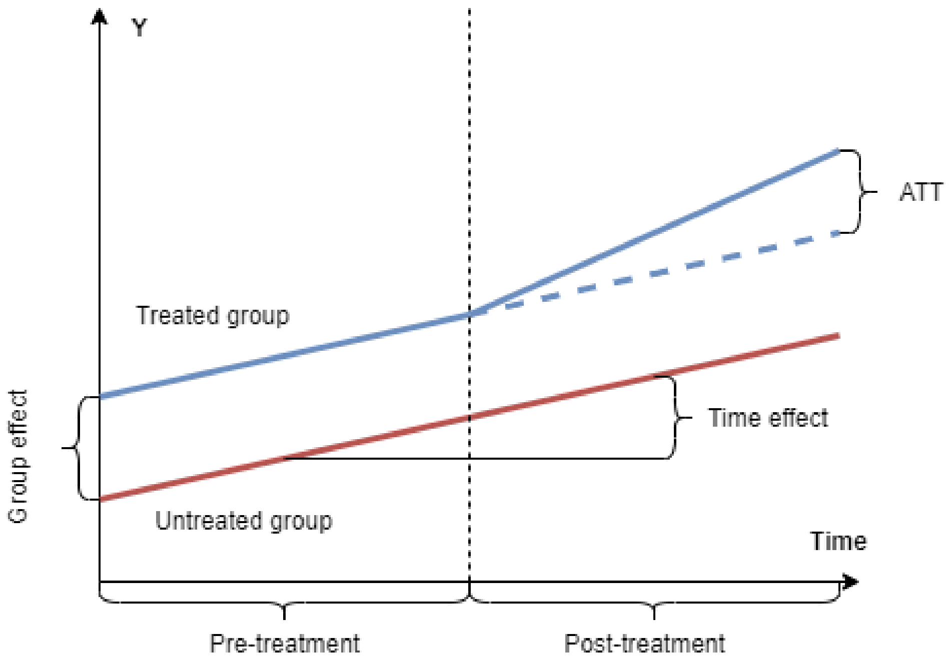

Figure 1: Intuition behind difference-in-differences estimation

4.1.1 Assumptions

Performing an analysis using DID models, it is assumed that both the treatment group and the control group follow the same linear time trend for the dependent variable had the treated group not been subject to the directive. As we cannot observe the trend in Norwegian bonds not affected by the directive in the post-implementation period, the assumption practically means that the difference between the groups is constant in the pre-implementation period. To explain the reason for this assumption, we look back at the explanation of coefficients. Because these are average values, the group effect would not reflect the true effect if, for example, Norwegian bonds increased in the outcome variable at a constant rate through both periods higher than American bonds. In this case, the time effect representing the changes unaffected by the treatment becomes too low for Norwegian bonds, as the lower growth rate in USA reduces the coefficient. The group effect is the average difference, which means the increasing difference is not accounted for, and thus underestimates the true group difference in the period after implementation. These two factors combined result in a positive estimated ATT, even though the directive has no impact. This assumption is thus crucial to hold to obtain unbiased coefficients and is subject to further testing in section 4.2.

The second assumption is that assignment to treatment is independent from the post-treatment outcome of the dependent variable. This assumption would be violated if issuers listed corporate bonds in another primary market based on anticipated effects of MiFID II/R; if issues intended for the Norwegian market was listed on American exchanges, or the opposite way around, in anticipation of market changes the directive brings. Additionally, these bonds' liquidity in the secondary market must be systematically different than the other bonds in the dataset for this to cause biases in the coefficients or standard errors. There is no easy way of testing whether this assumption holds. However, we argue that any significant violation of this assumption is unlikely for two reasons. Firstly, ICMA (2019) found no significant impact of the directive on primary markets with regards to costs. Secondly, a currency risk arises if corporate bonds are listed in markets with different currencies than needed for the purpose of the loan. The effects of the currency risk seem to outweigh the potential gains from speculating on the effects on the primary markets.

A third assumption is no spillover effects. That is, the implementation of MiFID II/R has not had any impact on the control group. This is unlikely to hold due to the interactive nature of financial markets across borders and is presumed to cause some bias to the coefficients. At the same time, we seek to analyze the effects on European markets, and not the absolute effects of the directive itself, meaning the consequences of this assumption not holding only affect the interpretation of the analysis. Therefore, we are looking at the effects on affected markets relative to markets not subject to the directive.

4.1.2 Rationale

Over the last decades, the DID approach has become a widespread method of evaluating the causal effects of single events on some quantitative measure (McKenzie, 2020). In the field of economics, the method is typically applied to evaluate a change in policy. Thus, after eliminating the time effect, and any fundamental differences between the experimental and control groups, through the treatment and time variables, it is possible to draw conclusions about the policy change's causal effect.

There are two main reasons why we choose a DID model in relation to our research question. One revolves the inclusion of the control group. This removes endogeneity problems that typically arise when making comparison between heterogenous individuals (Bertrand, Duflo, & Mullainathan, 2003). Without the control group, the possibility of endogeneity due to omitted variable bias would by high (Meyer, 1995). When these omitted variables are expected to behave in a similar way in both groups, the differences between the groups are not affected. The other reason revolves the time aspect. Including two periods separated by the time of implementation of MiFID II/R is necessary to derive any causal relationships from the analysis. An alternative would be to perform separate analyses on differences between the two markets before and after the implementation, but this could only yield some understanding of the correlation of the markets through the periods rather than causal effects from the directive.

4.2 Evaluating the parallel trends assumption

As outlined in section 4.1.1, the estimand's internal validity relies on the dependent variables' collinearity between the two markets prior to the implementation of MiFID II/R. The assumption certainly does not hold completely, given the sheer amount of observation and the variations that occur specific to either single markets or individual bonds. Our focus in this section is thus to take measurements to minimize the biases stemming from the violation of this assumption. We start off analyzing the trends graphically. Figures 2 to 5 show the monthly averages of each liquidity measure for both markets.

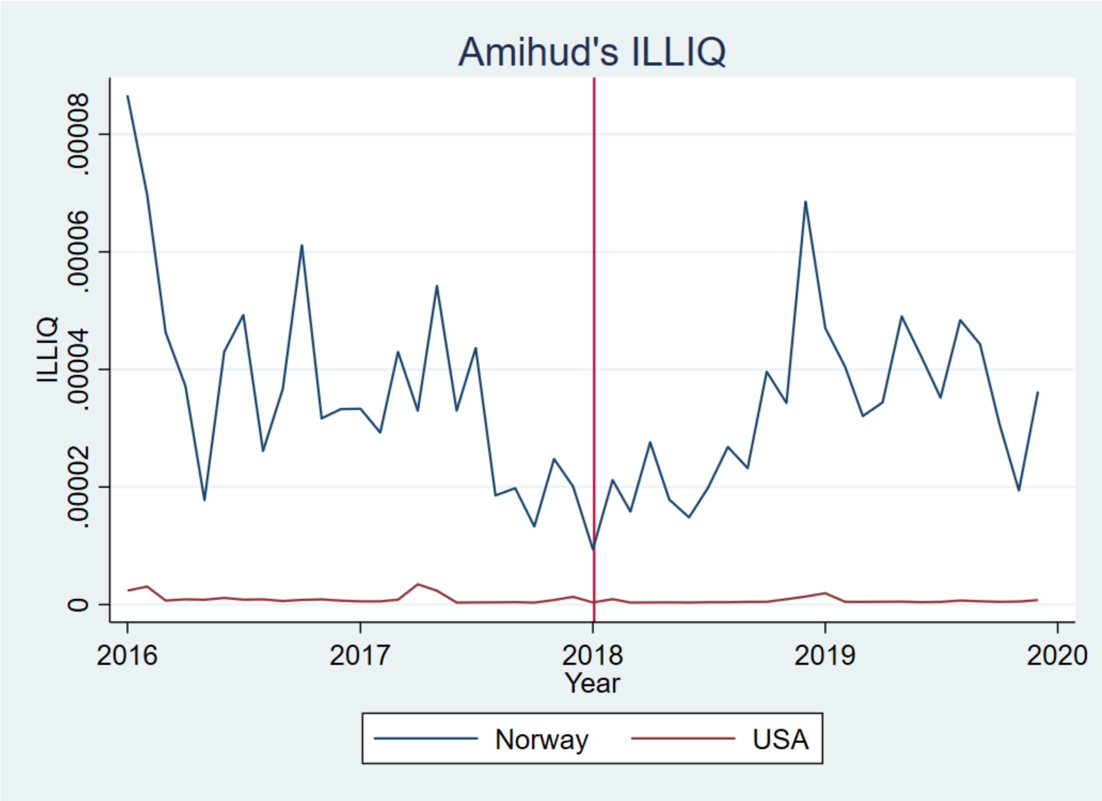

Figure 2 Time trends of monthly average ILLIQ

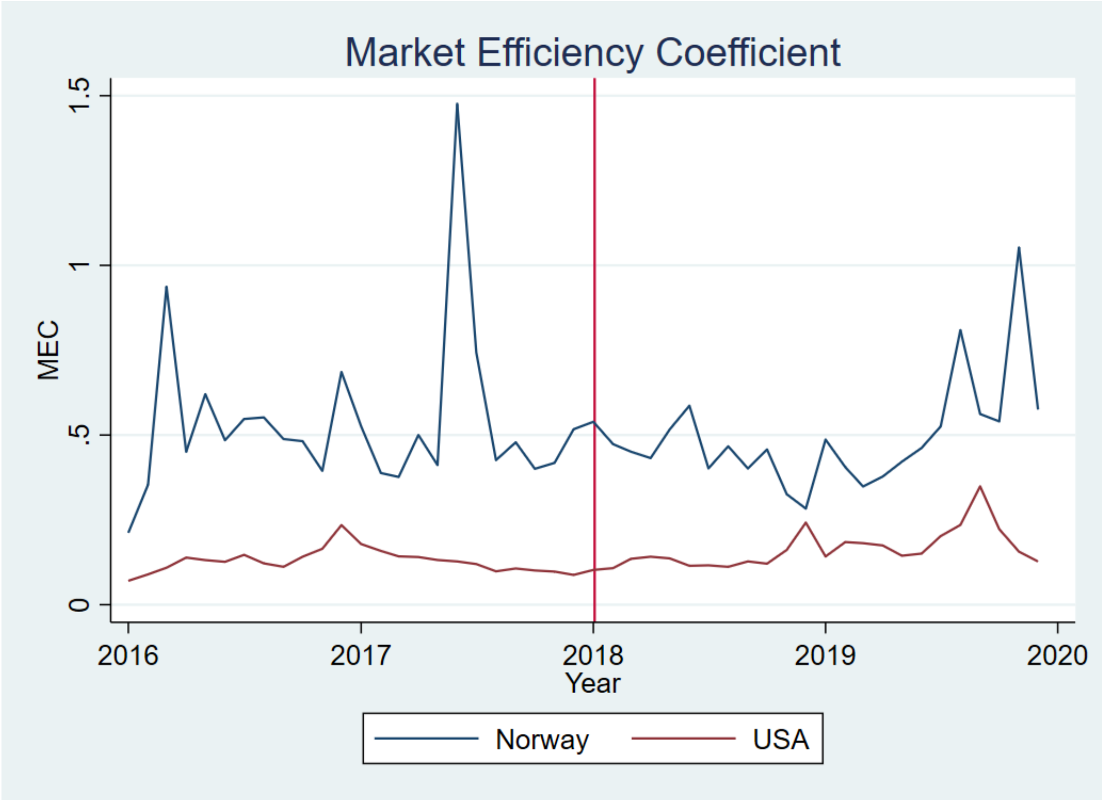

Figure 3 Time trends of monthly average MEC

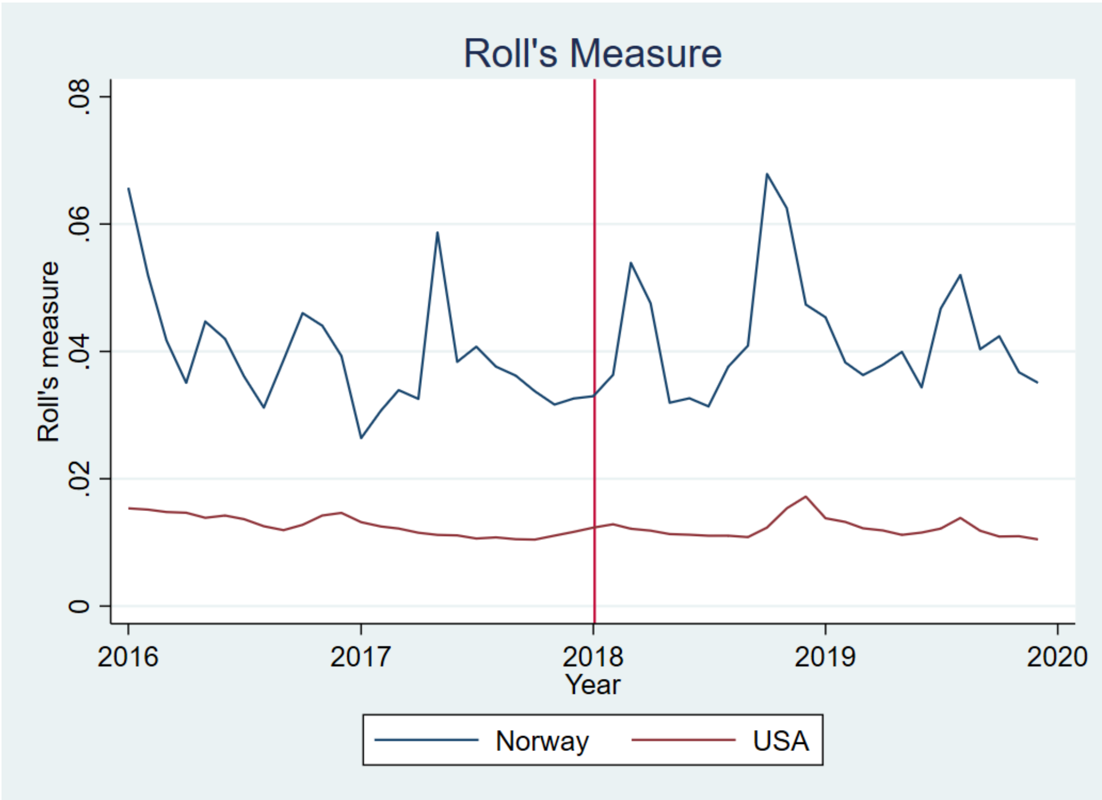

Figure 4 Time trends of monthly average Roll's measure

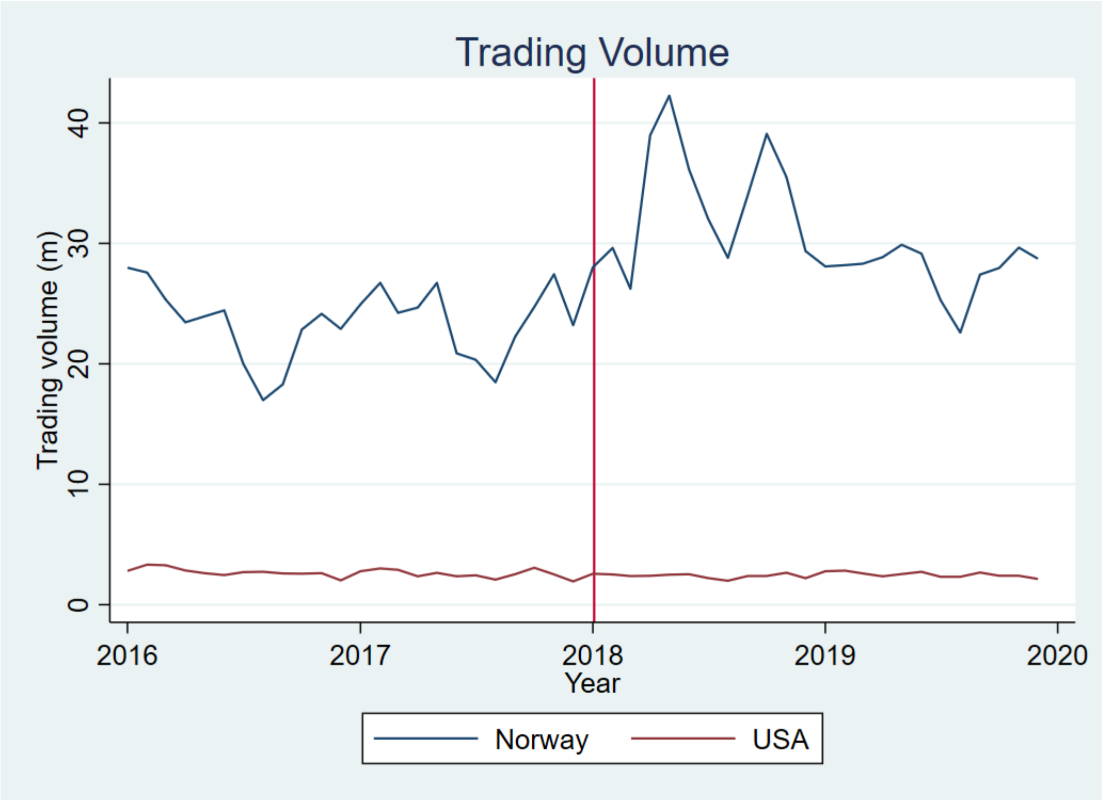

Figure 5 Time trends of monthly average trading volume

The time trends confirm that the assumption clearly does not hold. We do, however, notice three important patterns. Firstly, the Norwegian measurements are consistently above American, implying that there are constant group-effects in all measures. Secondly, the time-variant changes seem to go in the same direction, although not linearly as the model requires. Thirdly, these time-variant changes are consistently larger manifestations in the Norwegian measurements, indicating some common trend that is not linear. Thus, because the percentage rate of changes seems more alike in the groups than the absolute changes, transforming the measurements to logarithmic values may directly reduce the bias stemming from the violation of the assumption.

Time trends for log-transformed values are displayed in figures 6 to 10, and indicate that this is a better fit for the model than absolute values.

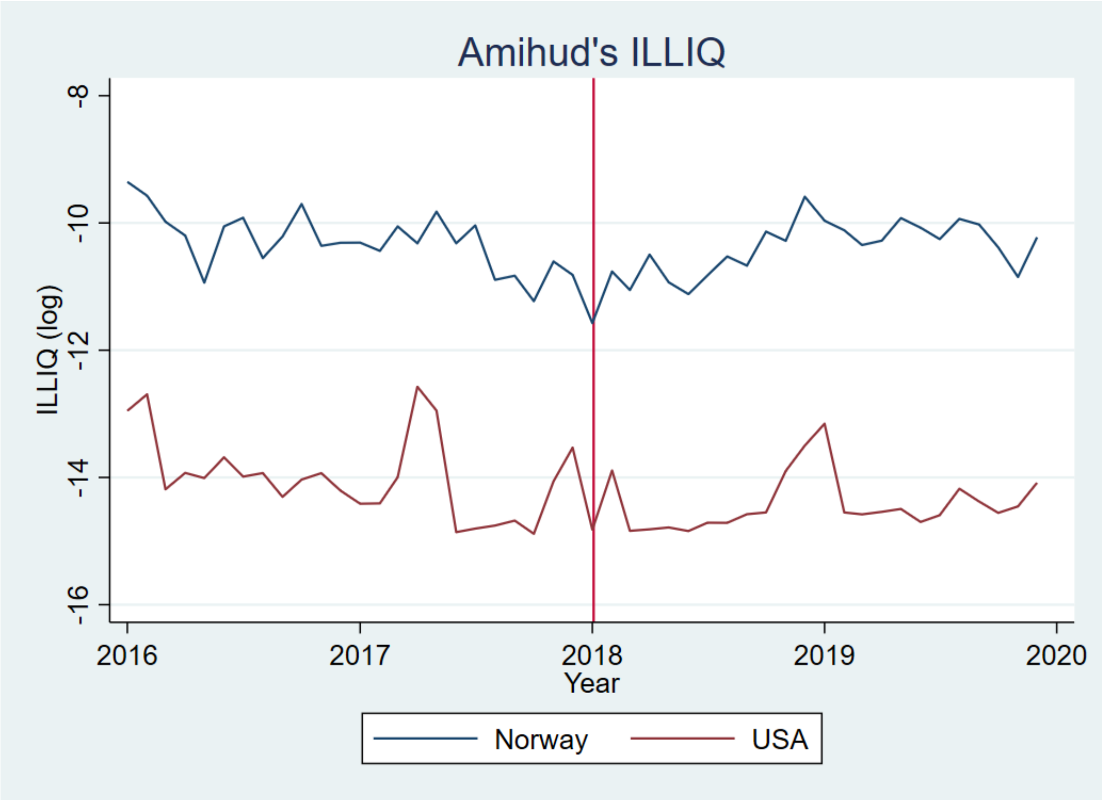

Figure 6: Time trends of monthly average logarithmic ILLIQ

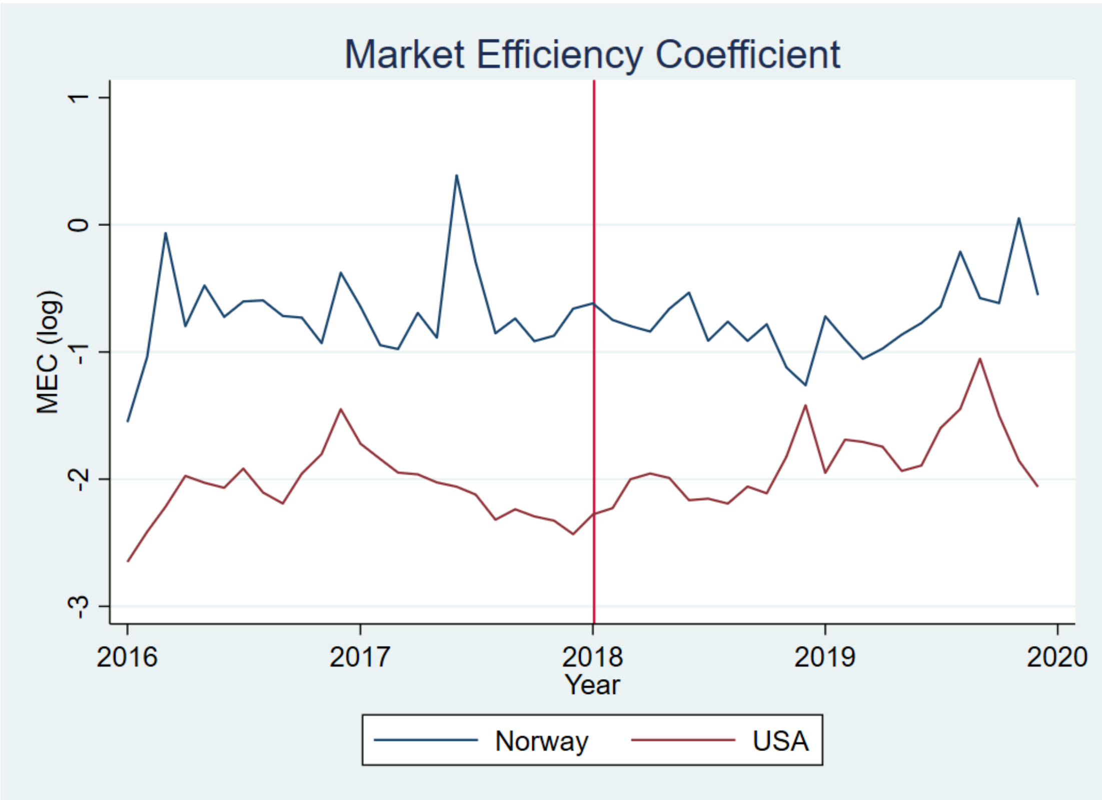

Figure 7: Time trends of monthly average logarithmic MEC

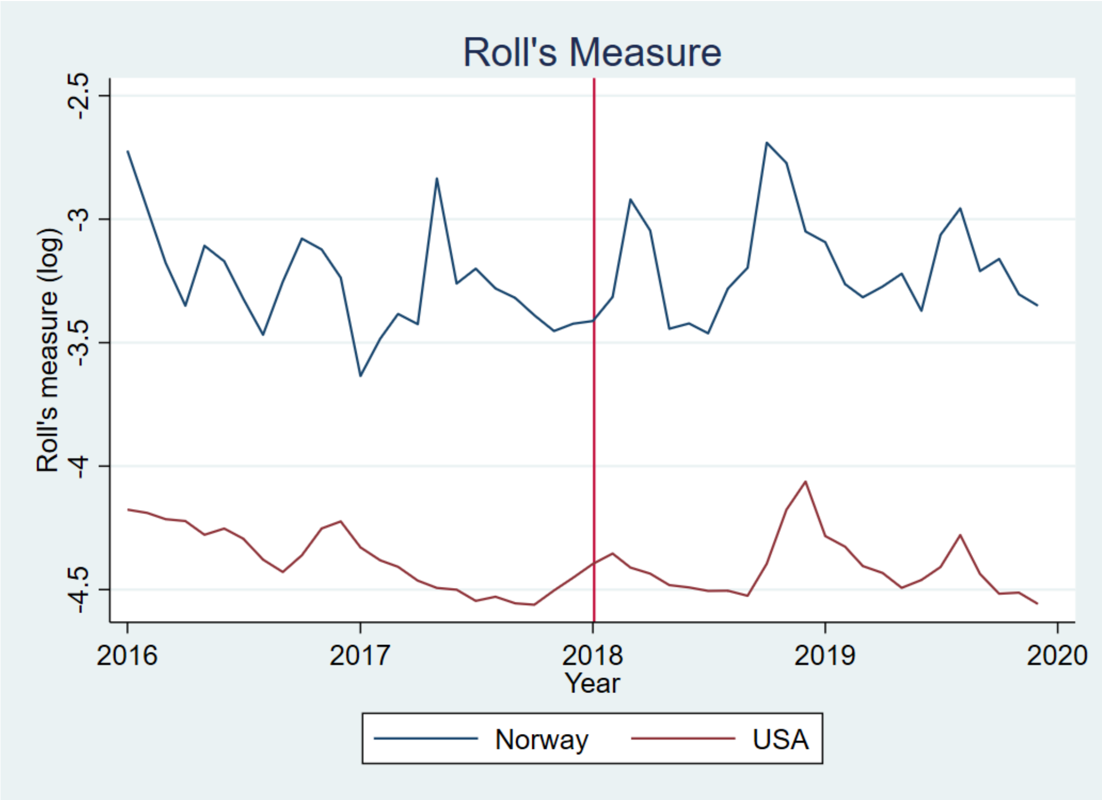

Figure 8: Time trends of monthly average logarithmic Roll's measure

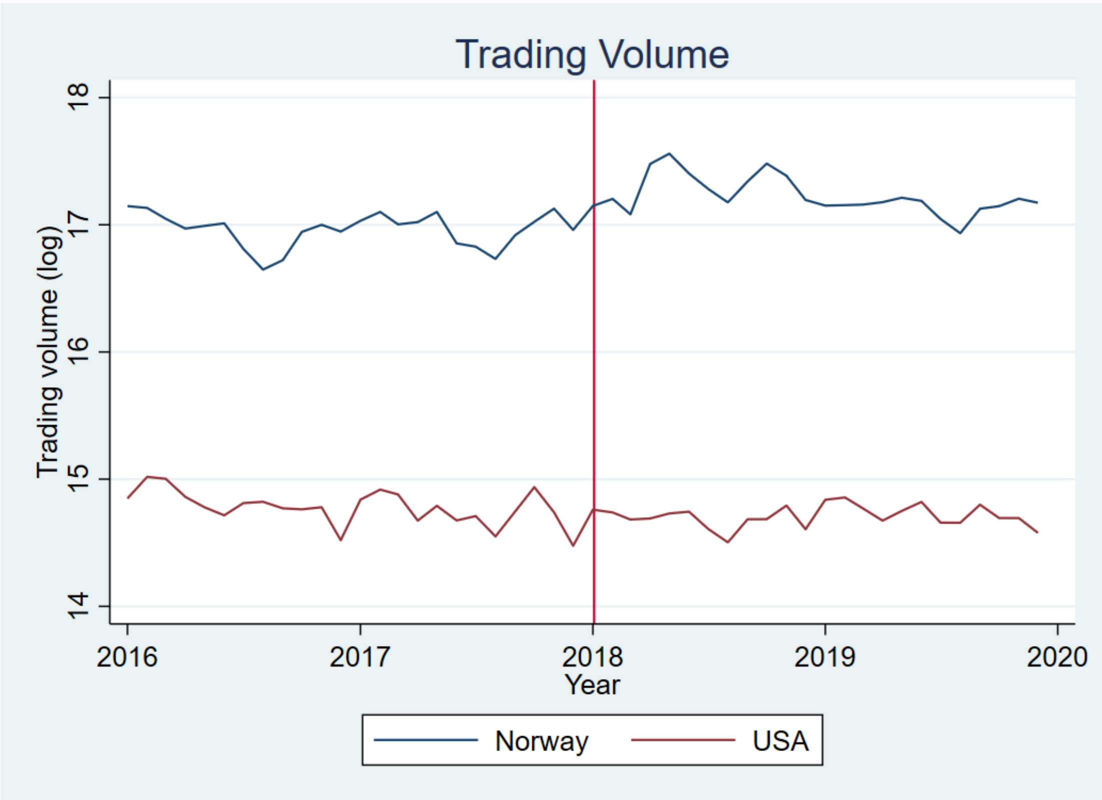

Figure 9: Time trends of monthly average logarithmic volume

The differences seem to be somewhat constant over time, although some deviations are present. This does not necessarily imply violations of the assumption, as the model only focus on the linear trends. Although the linear trends seem to go in the same direction in both groups, the slopes cannot be determined based on the graphs. To test whether the assumption holds, we regress each of the liquidity measurements on date, showing the daily linear trends. Because we do not know the trend for Norwegian bonds post-MiFID II/R had they not been subject to the treatment, the trends are estimated using pre-MiFID II/R data. Results are presented in table 11. Coefficients displayed are the OLS-estimates of a daily time variable.

Table 11: Time trends in the pre-implementation period

Six months	Trading volume	MEC	ILLIQ	Roll’s
USA	-.0007485	-.0012664	.0014318	.0006492
Norway	.0026434	-.0003422	-.0013793	-.0003934
Two years				
USA	-.0005881	-.0004039	-.0002966	-.0007912
Norway	.0004606	.0002273	-.0010994	-.0005997

The coefficients show that the time trends are not parallel, hence the basic DID model will give biased estimates of the ATT. To control for this, Mora and Reggio (2012) suggest including a group-specific linear time trend in the model. The intuition behind this, is that an interaction variable between time and the dummy for Norwegian bonds captures the time trend specific to Norwegian bonds, meaning the ATT coefficient is not affected by the time-invariant differences in trends between the groups. To obtain the group-specific time trend, a group-invariant time trend is also included to differentiate between trends only specific to the Norwegian market and trends across the markets.

Using the trading volume variable as an illustrative example, the developments in the exchange rates were not parallel relative to each other throughout the observed period. Although the dummy variable specific to Norwegian bonds partly capture this effect, it is only a constant representing the average exchange rate over the observed period. The group specific time effect will account for this by capturing the average daily trend in volume only present in the Norwegian dataset, affected by factors such as the continuous changes in the currency conversion rates.

4.3 Handling heteroskedasticity

A reasonable suspicion regarding the datasets, is that residuals within individual bonds are not independent from each other. That is, all corporate bonds cannot be assumed to be equally liquid in secondary markets. The reasons for this could be many, as bonds fundamentally differ from each other in many aspects. Presented in Appendix 2, we run Wald tests for groupwise heteroskedasticity in regression models of the log-transformed independent variables presented in section 3.2, with the groups being each individual bond. The null hypothesis of homoskedasticity is rejected in all cases.

In the presence of heteroskedasticity, the assumption of constant variance does not hold, leading to biased standard errors. Although the coefficients are unaffected by heteroskedasticity, the biased standard errors may result in wrongful causal interpretation of them. To obtain robust standard errors across bonds, we cluster standard errors by individual bonds in the model.

4.4 Variable description

	Variable	Description	Unit
Dependent (Y)	Roll’s measure	Estimated relative bid-ask spread	%
	Amihud’s ILLIQ	Daily price change relative to daily trading volume	%
	Trading volume	Daily currency denominated trading volume	NOK/USD
	MEC	Variance of price changes over 20 days relative to the variance of daily price changes	%
Independent	Norway	Dummy variable equal to one if the bond is listed in Norway, and zero if listed in USA	0/1

	MiFIDII	Dummy variable equal to one is the observation is after the implementation of MiFID II/R, and zero before	0/1
	Norway*MiFIDII	Interaction variable equal to one if the observation is after the implementation of MiFID II/R and the bond listed in Norway, and zero otherwise	0/1
	Date	Linear time variable separated by trading days	Integer
	Norway*Date	Interaction variable, showing the linear time effect exclusive to Norwegian bonds	Integer

4.5 Regression models

The equation below shows the regression model used for both the one-year and the four-year periods, where Y represents the four liquidity variables, dependent on the independent variables. i and t indicate if the variables are determined by individual bonds and time, respectively. We will throughout this section provide a brief explanation of the interpretation of the constant, coefficients, and the error term.

$$ln(Y_{it}) = \alpha + \beta_1 Norway_i + \beta_2 MiFIDII_t + \beta_3 (Norway_i \times MiFIDII_t) + \beta_4 Date_t + \beta_5 (Norway_i \times Date_t) + v_{it}$$

Where

$$v_{it} = u_i + \varepsilon_{it}$$

The constant, α, shows the expected outcome in terms of the liquidity measurements when all the independent variables are equal to zero. In practice, this is interpreted as the estimated outcome for an American bond at time zero, i.e. the trading day before the observed period.

Coefficients β_1, β_2, and β_3 represent the standard DID regression model. β_1 is the average difference in outcome between the two markets unconditional on time. β_2 is the average difference in outcome between the pre- and post-MiFID II/R implementation periods, unconditional on which exchange the bond is primarily listed on. The interaction coefficient β_3 shows the estimated ATT, hence the main coefficient we seek to analyze.

β_4 and β_5 are the time trends mentioned in section 4.3. Here, β_4 shows the common linear time trend present in both groups, while β_5 those specific to Norwegian bonds.

The residual term, v_{it}, is split into two components. u_i is the component allowing for fixed effects in the model on an individual basis, which is a constant only attributed to each individual bond. With the same reasoning as for why we use clustered standard errors, we expect individual bonds to permanently differ from each other with respect to the outcome variables. If this is the case, a fixed effects model is preferred, because observations are not only affected by the stated independent variables, but also by which bond the observation belongs to. Performing Hausman tests, presented in Appendix 3, confirm that fixed effects is preferred in our model for all dependent variables. ε_{it} is the difference between the actual outputs and the outputs estimated by the independent variables.

Finally, we transform Y_{it} into logarithmic values. This has two key purposes. One has to do with the interpretation of the coefficients in the regression output, which becomes more intuitive when given as percentages compared to the units used for the individual measurements. The second is the econometrical purposes described in section 4.2.

5. Results and key findings

The results following are based on the data discussed in the preceding sections. First, we present the results and then investigate if MiFID II/R has influenced the liquidity in Norwegian secondary corporate bond markets. Then we interpret the coefficients and determine whether the coefficients are statistically significant. We present the regression outputs for the four liquidity measures, both in the short-term and the long-term periods.

Note that when using a fixed effects model, the group-specific variable Norway is omitted due to collinearity with the fixed effects estimator. This is because the dummy does not change value over time for an individual bond. Because the coefficient of the variable is time-invariant, i.e. has a fixed value over time, this effect is entirely captured by the bond-specific fixed effects.

5.1 Short-term results

The regression results from our empirical analysis is presented in the tables below. From the output we see that the results as to the effect of MiFID II/R are rather inconclusive. After presenting the combined main results in the tables below, we will separately present the results of each of the liquidity measurements.

Table 12 – DID model short-term regression results

Period: 1. July 2017- 31. June 2018

Variables	**(1)** **Roll's measure**	**(2)** **MEC**	**(3)** **ILLIQ**	**(4)** **Trading volume**
MiFID II/R	0.122*** (0.0162)	0.169*** (0.0190)	-0.0632*** (0.0220)	0.167*** (0.0170)
Norway	-	-	-	-
MiFID II/R*Norway	**0.0958*** (0.0498)	**-0.0189** (0.0593)	**0.00459** (0.0599)	**-0.118**** (0.0537)
Date	-0.0005*** (8.08e-05)	-0.0002** (8.93e-05)	0.0005*** (0.000116)	-0.0008*** (9.04e-05)
Date*Norway	0.0003 (0.000238)	-0.0006* (0.000312)	-0.0014*** (0.000387)	0.0014*** (0.000391)

Constant	4.029**	4.079**	-24.41***	24.21***
	(1.604)	(1.876)	(2.357)	(2.081)
Observations	281,021	245,742	305,035	324,840
Adjusted R-squared	0.006	0.012	0.001	0.001
Number of bonds	3,991	1,732	6,190	7,274

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

From the table above we see that Roll's measure has increased by 9,58 per cent in the short-term period, significant at the 90 per cent confidence level, implying increased transaction costs of trading, thus decreased liquidity. The MEC coefficient indicates a decrease of 1,89 per cent in the time-period. The change is not significant and provide us no meaningful interpretation to a change in liquidity caused by the implementation of the directive. Amihud's illiquidity estimator has increased by 0,5 per cent, hence indicating a slight decrease in the liquidity, but also these results are statistical insignificant. The trading volume coefficient indicates a negative change of 11,8 per cent, and the result is significant at the 95 per cent confidence level. Hence, the liquidity has significantly decreased based on this measurement.

5.2 Long-term results

Table 13 – DID model long-term regression results

Period: 1. Jan 2016- 31. December 2019

Variables	**(1) Roll's measure**	**(2) MEC**	**(3) ILLIQ**	**(4) Trading volume**
MiFID II/R	0.198***	0.0021	0.07***	0.105***
	(0.0107)	(0.0123)	(0.0180)	(0.0150)
Norway	-	-	-	-
MiFID II/R*Norway	**0.0333**	**-0.0840****	**-0.194****	**0.111**
	(0.0345)	(0.0396)	(0.0805)	(0.0794)
Date	-0.0006***	9.64e-05***	-0.0003***	-0.0003***
	(1.59e-05)	(1.76e-05)	(2.55e-05)	(2.01e-05)
Date*Norway	0.0003***	3.68e-05	0.0002	-8.32e-05
	(4.50e-05)	(5.73e-05)	(0.000142)	(0.000142)

Constant	7.415***	-4.288***	-12.69***	19.10***
	(0.312)	(0.359)	(0.598)	(0.598)
Observations	1,101,013	938,952	1,199,708	1,279,336
Adjusted R-squared	0.057	0.003	0.002	0.002
Number of bonds	7,093	2,437	11,756	15,811

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The estimated coefficient of Roll's measure is indicating a 3,33 per cent increase over the 4-year period. This change is not significant, and thus the interpretation is not valid to arrive to any meaningful conclusion on a change in liquidity based on this measurement. We see that MEC has had a change of negative 8,4 per cent. The result is significant at the 95 per cent confidence level. Hence, this indicates a decrease in the liquidity after the implementation of MiFID II/R. For Amihud's ILLIQ, the coefficient indicates a reduction in the measurement of 19,4 per cent. The coefficient is significant at a 95 per cent level. As ILLIQ measures the illiquidity, the negative coefficient represents an increase in the liquidity. Opposed to the result of MEC, this result indicates that MiFID II/R has led to a significant increase in liquidity if we solely interpret based on this measurement. The trading volume has a coefficient that indicate an increase of 11,1 per cent, but the result is not statistically significant. Thus, we cannot arrive to a meaningful conclusion of a change in liquidity based on this measurement.

5.3 Comparison and concluding remarks

Overall, the DID model regression results show inconclusive and ambiguous results as of the effect of MiFID II/R in the long-term period, but the indicate decrease in liquidity short-term. In the short-term results, we see a significant decrease in liquidity based on the results of Roll's measure and the trading volume. The other two measurements had insignificant effects, thus provide us no meaningful interpretations. Roll's measure and trading volume indicate an insignificant change in liquidity in the long term. Hence, these measurements affect the liquidity significantly in the short term, but not in the long term based on our results. The two other measurements indicate a significant change at the 95 per cent level in different directions long-term. All in all, we see no clear relationship between short- and long-term effects, and the conflicting behaviour of the measurements give no clear answers regarding the factual effects over the two-year period.

In the long-term model we see some conflicting results. ILLIQ indicates higher resiliency, as the impact of trades on prices are reduced. At the same time, MEC gives indications of lower resiliency, as short-term price fluctuations increase relative to those in the long term. Although there is an increase of short-term price variations compared to the control group, this effect is offset by a simultaneously increased trading volume. Thus, from an economic perspective, the directive has caused larger short-term price fluctuations but also higher trading volumes. What this means in terms of absolute market liquidity is not clear, because the effects on the different liquidity dimensions do not point in the same direction.

6. Discussion

Our results did not reject any of our hypotheses. The coefficients were ambiguous and did not provide any clear answers on the total liquidity effects, meaning the hypothesis of no effects cannot be rejected. On the other hand, there were some significant changes in our liquidity measures, meaning the hypothesis of liquidity effects cannot be rejected either. In this section we will discuss potential explanations to these results and clarify the weaknesses and limitations of the analysis. Finally, we compare the results with a similar analysis we have done with an expanded dataset regarding the price-based measures, to evaluate whether the Norwegian results can be attributed to other countries subject to MiFID II/R.

6.1 Economic interpretation

While the theoretical framework suggests that MiFID II/R increases the market liquidity through more transparent markets, there are several market considerations coming into play determining liquidity changes. We point specifically at the time aspect, as the analysed period can be considered short when determining causal effects of the directive. Additionally, we want to discuss potential reasons why the different liquidity dimensions are not expected to react in the same way following the implementation of the directive.

In the period around the implementation, there were no consensus perception on how exactly markets would be affected. This could be a source of uncertainty regarding the fair value of bonds. An implication of this, is that the informational component of bond prices was reduced, and hence the speculative component increased, deeming markets less efficient. This would give direct negative manifestations in the market efficient coefficient, with more price fluctuations although no new information on the fundamental value of bonds is added. Related to this, other liquidity dimensions may have been affected due to changed behaviour among market participants prior to the implementation. That is, the announcement of the market changes itself may have had impacts on liquidity before the directive was implemented.

Other economic considerations are the potential adverse effects following the directive. As outlined in section 2.3.1, dealers provide liquidity in over-the-counter markets. When their incentives are profit driven, they need to obtain an informational advantage to detect possible market imbalances of which they can profit from. Having an opinion of the fair value of bonds makes it possible to offer bid and ask quotes to investors of which dealers are expected to profit from. Hence, illiquid markets give incentives to obtain information to profit from the illiquidity, which in turn provide liquidity. While this market structure never bring perfect liquidity, as there will always be some transaction costs for investors when dealers profit from the difference between their offered quotes and the expected fair value of the bond, it is not intuitively clear if this source of illiquidity exceeds the liquidity they provide. We can trace this back to the dimensions of liquidity. On one hand, the transaction costs applied to investors is a source of illiquidity, but on the other hand, dealers facilitate immediate trading, market breadth and depth, and resilience. This market structure does, however, contradict the notion of liquidity stemming from the degree of market participation. In OTC markets, potential participants avoid entering the market knowing they have an informational disadvantage. In this sense, markets should be completely transparent to increase liquidity. Given the short period of time after the implementation analysed, we do not believe the positive liquidity effects of increased market participation to outweigh the negative effects from reducing dealer incentives of obtaining information. These aspects may explain the increased trading volume, as market participation is expected to have increased, while the market efficiency coefficient has decreased, as prices may be more speculative when less resources are used by dealers to estimate bonds' fair value.

Because of the comprehensiveness of the directive it is fair to assume there has been extraordinary costs to investment firms operating over-the-counter markets connected to the changes to the new, more regulated venues. These new venues do not change the core business, and their main source of profits is still the differences in bid and ask quotes offered to investors. A natural way of covering these costs would be to increase income from their customers, implying increased bid-ask spreads. This may provide some intuitive understanding as to why we see a short-term increase in the spread.

6.2 Weaknesses and limitations

An important limitation of the study is that we only used data from one country in both the treatment group and the control group. Using only Norwegian data limit the interpretation of the absolute effects, as markets within EEA are presumed to not be identical in structure prior to the implementation. The results are thus only interpreted as the liquidity effects on Norwegian corporate bonds, and not the causal overall effects of the directive. Including only American corporate bonds in the control group appear as a weakness when estimating the effects. Any effects specific to this market are assumed to occur in all markets unaffected by the directive. Optimally, the control group should therefore consist of all countries not subject to directive, so any market-specific factors over the observed period could be accounted for. Although we attempted to construct a wider control group, the problems connected to reporting differences only left price-based measures comparable between markets.

Even when correcting for misspecification in the model and adding time trends specific to markets to the model, the assumption is still not likely to hold. While using robust standard errors account for the unbiased standard errors, thus ensuring reliable interpretations of causal effects, the same cannot be said for the coefficients. These are likely to be biased to some extent and cannot give conclusive answers regarding the exact effects of the directive. This is likely to be reflected in the coefficient, where they generally seem higher than economically feasible. Assuming the individual time effects do not entirely eliminate the peaks exclusive to Norwegian bonds in the pre-implementation period, shown in the graphs in section 4.2, the same graphs would indicate that similar peaks in the post-implementation are misinterpreted as effects from the directive, although they rather seem to be explained by generally larger fluctuations in Norway compared to USA.

There are some weaknesses arising when computing the liquidity measures. As shown in the regression outputs in section 5, MEC is based on significantly fewer individual bonds than the other measures. This has to do with the requirement of continuous daily data. Even though we allow for up to five days of missing data over the periods of 20 days, there are still numerous cases where this requirement is not met. When the omitted bonds are infrequently traded, implied by the relatively few omitted observations compared to the omitted bonds, it is implied that these are systematically less liquid than the other bonds. The alternative of allowing days without trading, thus using the same price for days without trading as the last trading day, the measure would indicate high liquidity in periods without trading, even though the opposite is likely to be the case. This problem is also apparent to a lesser extent in the computation of Roll’s measure.

In section 3.1.3, we had to assume the actual trading volumes of trades exceeding one and five million USD were in fact either one or five million USD. Assuming the average liquidity of the affected bonds do not follow the same time trend as the rest of the control group, the ATT coefficient will be biased. Even though the group specific effect will be somewhat biased in the model by not removing observations, we argue that the bias of the ATT will be less significant than by removing the affected bonds. This is because the likelihood of imprecise reporting does not vary across the time dimension, and the ATT coefficient should not be biased to the same extent. Since we cannot observe the actual volumes, it is still possible that there is a time effect on the differences between the approximated and actual volume. In this case the ATT coefficient will be biased. Unlike the problems mentioned in the paragraph above, this is a problem exclusively apparent in the American dataset, thus undoubtfully a source of biased estimates, as American average volumes are consistently underestimated. The effects on the ATT estimator is, however, unclear. This depends on the difference in the average deviations from the actual trading volumes between the two periods. If this is insignificant, only the country-specific coefficient is biased, but not the ATT.

When analyzing the effect of MiFID II/R on the market liquidity, we compared two time-periods pre- and post-implementation which are relatively short. Hence, it could be that the effect on the market liquidity could manifest over a longer time-period than two years. ICMA also states that it will take time for the benefits of the implementation of the directive to become manifest (ICMA, 2018). Several changes in the market structure, and firms needing time to adjust to the new rules of the directive, can indicate an effect on the market liquidity over a longer time-period. Hence, arguably we could capture the incremental effects of the implementation of the directive better over an analysis in a few years.

In three instances, we had to directly interfere with the dataset. The first was to exclude extreme price observations only occurring one day over the time series for an individual bond, presumably due to some extraordinary event or reporting mistakes. Secondly, were sudden permanent price changes occurring at one specific date, which in turn would give outlier observations when computing the daily values of the liquidity measures. While the number of dropped bonds was low, this may be a source of selection bias. However, we considered the biases stemming from outlier observations to be more impactful. The third instance was the unique observations dropped when computing Amihud's ILLIQ. While the reasoning here was similar, that even small price changes would result in unreasonably big impacts on the measure, we believe the bias from this was more significant than the two former instances. This is because the omitted observations show the same distinctive characteristic of low trading volumes. Investigating the dropped variables, show that they mostly are found within a few Norwegian bonds, indicating high probability of biased coefficients due to selection bias. However, the omitted observations are evenly distributed between the two periods, thus the bias in the estimator of liquidity effects following MiFID II/R is unclear.

6.3 Are the results robust across European countries?

Aghanya et al. (2020) suggested, that following MiFID I, the liquidity effects of the directive were dependent on the degree of regulations in the markets prior to implementation of the directive, thus the impact on one country would not necessarily transfer to another. Using data from Thomson Reuters/Datastream, we collected daily price data to investigate the average effects across several countries. The group subject to MiFID II/R consists of Norwegian, Swedish, British, French, German, and Spanish corporate bonds, and the control group of American, Canadian, and Australian corporate bonds. Due to missing and inconsistent volume data, these data could not give a complete image of the market liquidity, and we did not include it in our main analysis. However, the results from this broader dataset may give useful insight as to whether our findings in Norway are comparable with other European countries.

Conducting the analysis, we use the same model and follow the same econometric principles as the main analysis. An important difference from the main analysis, is that bid-ask spreads here are derived directly from daily closing bid and ask quotes, rather than approximated spreads using Roll's measure. Regression results are presented in table 14.

Table 14 – DID model regression results

Period: 1. Jul 2017- 31. Jun 2018 | Period: 1. Jan 2016-31. Dec 2019

Variables	**(1) Bid-ask spread**	**(2) MEC**	**(1) Bid-ask spread**	**(2) MEC**
MiFID II/R	0.0023 (0.0018)	0.1446*** (0.0087)	0.02523*** (0.0032)	0.0674*** (0.0064)
Europe	-	-	-	-
MiFID II/R*Europe	**0.0152*** (0.0057)**	**-0.1477*** (0.0189)**	**0.0145* (0.0077)**	**-0.0072 (.01464679)**
Date	-0.0002*** (.00001)	0.0005*** (.00005)	-0.0003*** (8.82e-06)	-0.0003*** (8.59e-06)
Date*Europe	-6.80e-06 (.00003)	0.0002* (.0001)	-0.00006*** (0.00002)	0.00005*** (0.00002)
Constant	-0.4209 (0.2927)	-12.98*** (1.0023)	1.6969*** (0.1870)	5.0698*** (0.1931)
Observations	1,851,341	1,978,800	6,951,572	7,426,993

Adjusted R-squared	0.0093	0.0000	0.0067	0.0045
Number of bonds	7,414	7,895	7,474	7,950

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Both the bid-ask spread and MEC give significant indications of reduced liquidity in the six-month period after implementation. Over the two-year period the coefficients indicate that the negative effects are declining, although not statistically significant. These results are especially interesting when put in the context of the discussion on the negative impact on dealers and the short-term uncertainty in markets following the implementation. While we cannot confirm if they are factual reasons for the short-term reduction in liquidity, they still give strong indications of some immediate negative liquidity effects vanishing over time.

Compared to the results in section 5, we see similar trends. Both measurements indicate reduced liquidity along the transaction price and resiliency dimensions. The main difference is that these results are significant in the European dataset over the six-month period, but not in the two-year period. This indicates some immediate effects following the implementation, which vanished over time. In the Norwegian dataset, we see similar results only in bid-ask spreads. Although these results cannot be used to confirm the results of the main analysis, they substantiate the findings of reduced liquidity according to the price-based measurements.

7. Conclusion

A key objective when introducing MiFID II/R was to increase the transparency in secondary fixed income markets. The aim of this thesis was to examine the causal effects on our four liquidity measures from the implementation of MiFID II/R, given the theoretical ties between market transparency and liquidity. We used two separate time periods to investigate if the directive had immediate effects vanishing over time, if the immediate effects persisted over time, or if the effects arose gradually over time.

We found that, in the short-term period, the liquidity was weakened in the Norwegian secondary corporate bond market, where we saw an increase in transaction costs and decreased average daily trading volumes, by 9,58 and 11,8 per cent respectively. None of these findings persisted over the longer period, where both coefficients were deemed insignificant. We did, however, find significant effects on the two remaining measures. The impact of trading on prices has decreased substantially by 19,4 per cent, while the monthly price variations relative to daily variations has decreased by 8,4 per cent. Regarding the overall effect on market liquidity, these results give ambiguous answers. While they give some evidence of causal effects on the liquidity measures, we cannot conclude whether the directive has improved market liquidity in secondary bond markets, and neither of the hypotheses are rejected.

Taking practical considerations and findings in other European countries into account, we still find the results interesting for two main reasons. Firstly, we acknowledge that the comprehensive changes following the directive take time to be fully manifested in markets. Over the analysed period other factors are likely to come into play, such as short-term loss of market efficiency due to uncertainty among market participants in the immediate period following the implementation, and expected costs to market participants due to the restructuring process. Secondly, the consistent results in Norway and other countries subject to the directive substantiate the indications of a short-term negative impact on liquidity that vanishes over time. We encourage further research to be done on this subject in the future to evaluate if this trend continues, and if we eventually see the anticipated positive liquidity effects following MiFID II/R.

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Appendices

A.1 Summary statistics

Complete summary statistics: one-year period

Variable	Obs	Mean	Std.Dev.	Min	Max
Price	324862	100.2985	99.58079	.01	4900
Trading vol. (NO)	54166	28.1	133	6.4e-11	8520
Trading vol. (USA)	270674	2.5	17.8	1.23e-06	8690
Roll's	281367	.0144028	.0270731	0	2.891267
MEC	245742	.1735794	0.9060303	.0005381	224.1004
ILLIQ	305035	3.09e-06	.0000893	1.14e-15	.0186883

Complete summary statistics: four-year period

Variable	Obs	Mean	Std.Dev.	Min	Max
Price	1279449	99.32574	88.26991	1.00e-06	4900
Trading vol. (NO)	209245	27.2	122	1.00e-12	8690
Trading vol. (USA)	1070091	2.5	10.7	2.00e-08	8690
Roll's	1102515	.0157066	.0343172	0	2.94392
MEC	938952	.2069121	1.478467	.0000499	359.4315
ILLIQ	1199708	5.07e-06	.0001391	1.03e-15	.0448879

A.2 Wald's test for heteroskedasticity

Modified Wald test for groupwise heteroskedasticity in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

Roll's measure

chi2 (7093) = 4.3e+31

Prob>chi2 = 0.0000

Turnover

chi2 (15811) = 2.0e+41

Prob>chi2 = 0.0000

MEC

chi2 (2437) = 1.7e+31

Prob>chi2 = 0.0000

Amihud's ILLIQ

chi2 (11756) = 5.1e+35

Prob>chi2 = 0.0000

A.3 Hausman tests

Roll's measure

	Coefficients			
	FE (b)	RE (B)	Difference (b-B)	S.E.
MiFID	.1982135	.0022615	.195952	.0024822
Norway*MiFID	.0332796	.0036179	.0296616	.0075295
Date	-.0006144	-5.00e-06	-.0006094	3.07e-06
Norway*Date	.0002979	-2.57e-06	.0003005	9.36e-06

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(4) = 65278.90

Prob>chi2 = 0.0000

MEC

	Coefficients			
	FE (b)	RE (B)	Difference (b-B)	S.E.
MiFID	.0020899	.00197	.0001199	.0000742
Norway*MiFID	-.0839964	-.0839401	-.0000562	.0002646
Date	.0000964	.0000984	-1.94e-06	1.52e-07
Norway*Date	.0000368	.0000346	2.23e-06	4.70e-07

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(4) = 223.86

Prob>chi2 = 0.0000

Amihud’s illiquidity

	Coefficients			
	FE (b)	RE (B)	Difference (b-B)	S.E.
MiFID	.0699537	.0715276	-.0015738	.000269
Norway*MiFID	-.1935099	-.1953752	.0018654	.0007229
Date	-.0003011	-.0002984	-2.76e-06	5.18e-07
Norway*Date	.0002239	.000205	.0000189	1.34e-06

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(4) = 510.54

Prob>chi2 = 0.0000

Trading volume

	Coefficients			
	FE (b)	RE (B)	Difference (b-B)	S.E.
MiFID	.1051625	.1034574	.001705	.000138
Norway*MiFID	.1105539	.1101563	.0003976	-
Date	-.0002962	-.0002935	-2.69e-06	4.11e-07
Norway*Date	-.0000832	-.0000441	-.0000391	8.52e-07

b = consistent under Ho and Ha; obtained from xtreg

B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(4) = 3294.46

Prob>chi2 = 0.0000

(V_b-V_B is not positive definite)