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MEASURING LIQUIDITY ON THE CORPORATE BOND MARKET

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CHAPTER 1: BACKGROUND AND SUBJECT OF THE STUDY

1.1. WHAT IS LIQUIDITY?

In finance, the word "liquidity" is a catch-all term that can refer to the liquidity of a security, the liquidity of a market, the liquidity of a fund or portfolio, or even the liquidity provided by a central bank. While these definitions of liquidity are of course linked, particularly through various transmission channels (see [74] on this subject, for example), when it comes to liquidity, it is always wise to clarify exactly what you are talking about.

In this study, conducted by researchers commissioned by the Institut Louis Bachelier, the issue of corporate bond liquidity is explored – both the liquidity of securities and that of the corporate bond market as a whole resulting from the liquidity of these securities. The liquidity of securities is not easy to define, as it is a multi-dimensional concept. In a few words, and from a qualitative viewpoint, a security might be said to be liquid if it can be bought and sold in large quantities in a relatively short time, without affecting its price (excessively).

When assessing the liquidity of securities, it is usual to look at four components – width, depth, immediacy and resiliency – which are not necessarily sufficient to capture every aspect of liquidity. The first component, width, represents the cost of the immediate consumption of liquidity. This is usually measured through a bid-ask spread, a natural measure that is relatively easy to calculate on certain markets such as the major equity markets, but is more complex to calculate (or even to define) on other markets, especially OTC (over-the-counter) markets such as the European corporate bond market (a point that we will come back to). The second component, depth, represents the liquidity – here meaning the volume – that is easily available. This may be measured by the volume of the orders posted at the best limits on markets organised around order books, but it is only a proxy, as there is no reason for the volume potentially available to be disclosed/revealed (through limit orders, for example), hence the often-used concept of the latent order book. Like the previous component, it can be very difficult to measure on OTC markets. The third component, immediacy, is more complex and aims to measure the time required for the reasonable execution of a large order. The fourth component, resiliency, which is also dynamic, represents the market's capacity to return to its initial state, or more generally to a state of equilibrium, after liquidity has been consumed. Through this breakdown we can therefore see that the concept of liquidity combines (i) cost (and therefore price) considerations, (ii) volume considerations, and (iii) time-based considerations. It is also important to note that, when talking about the liquidity of a market as a whole, another component, known as breadth, is also referred to, which measures the number of liquid securities. We will return to the concept of breadth, which is not currently taken into account in many liquidity measures and is nevertheless a key aspect in the liquidity of a market if systemic risk is to be avoided.

Although liquidity has been vital to the operation of the financial markets since they came into existence and became accessible to the general public, as it guarantees the current and future possibility of trading, the need to accurately measure liquidity was late to emerge, with the development of literature on optimal execution and market impact at the end of the 1990s (see [58] for an historical perspective). Numerous liquidity measures of course existed prior to this literature and we will take a look at these in this document. It is important to note, however, that most liquidity measures originate from the equity markets, mainly due to the greater availability of data, and are therefore not necessarily suitable for every market, and particularly the corporate bond markets. This is because they are still OTC markets on both sides of the Atlantic, despite technological changes described later in this study. The availability of data on the US corporate bond market since the advent of TRACE files (see [40], for example) and Enhanced TRACE files (see [41], for example), has enabled the emergence of empirical literature on this market's liquidity; literature that may be useful, by analogy, for analysing the European corporate bond market. The purpose of this report is precisely to measure the liquidity of the European corporate bond market, a market that is lagging the US market by 15 years in terms of post-trade transparency, but for which the AMF, like other regulators, has transaction data.

1.2. THE CORPORATE BOND MARKET

The corporate bond market is an OTC market that traditionally operates through dealers providing liquidity on the one hand, and clients consuming this liquidity on the other. It is extremely important for the financing of the economy.[1]

Marked for a dozen or so years now by economic, technological and regulatory changes, and a low interest rate universe that cannot last for ever, on both sides of the Atlantic the corporate bond market is attracting the attention of both bankers and asset managers, and regulators and various financial associations (see [13], [17], [76] and [87], for example)[2] on the lookout for signs of a (market) liquidity crisis that could have potentially systemic consequences.

1.2.1. The economic and regulatory environment

Since the 2007-2008 crisis, we have seen several related phenomena on the corporate bond market. Firstly, the monetary policy of central banks, by imposing a low short-term interest rate environment (which has spread along the curve), and by directly acting on the markets through large-scale securities purchase policies, has resulted in a large number of bond issuances, allowing companies to finance themselves at a low cost (see [75], for example, for a worldwide perspective). This low interest rate environment has also prompted investors/savers to look to riskier assets for a return, enabling more risky companies to access the bond market (see [26] and [75], for example). These various effects have caused an unprecedented increase in the size of the corporate bond market, far beyond the simple mechanical effect of the increase in prices, throughout the world.

Whereas the primary market has developed considerably since the crisis, the situation is more mixed for the secondary market. Numerous reforms were introduced in both the US and Europe following the crisis, including Basel 3, the Volcker rule and the Dodd-Frank Act. The banks' deleveraging after the crisis was therefore reinforced by successive regulations, reducing the intermediation capacities of many players on either side of the Atlantic.

The impact of the various post-crisis regulations on the documented fall in dealers' inventories (see inset) and on market liquidity has been analysed in a multitude of studies, research papers and commentaries, with a focus on the US market.[3]

On the fall in inventories

Many studies and research papers, particularly regarding the US market, point to a fall in dealers' inventories on the corporate bond market due to a tightening of regulatory constraints. Specifically, one chart that has been widely circulated (see [5] or [7], for example) shows the corporate bond inventories of broker-dealers on the US market and the sharp drop that they experienced at the time of the crisis, without subsequently rising to pre-crisis levels. This alarming chart has been widely discussed, but Goldman Sachs published a report (see [96]) suggesting that the chart was incorrect, as the data (obtained from the Fed) did not just include corporate bonds, but also MBS inventories, and that, in reality, even though inventories have fallen, this fall is not accurately reflected by the widely discussed chart and is in fact less extreme. The Goldman Sachs report issues a harsh verdict on studies suggesting an increase in liquidity (particularly the Fed's studies [4], [5] and [9]), however, and is very pessimistic about the inventories of US dealers. It particularly emphasises the fact that the immediacy traditionally ensured by dealers is now faltering (see the discussion on the switch from a principal trading model to a riskless principal trading model in the next subsection).

[1] For an overview of the corporate bond market in the US and Europe, see [12], [70], [72] and [75], for example.
[2] Also see [24] and [74] for a liquidity analysis that is not limited to the corporate bond markets.
[3] We believe that many findings relating to the US market validly apply to the European markets.

For instance, [10] documents the difference between dealer inventories before and after the crisis and shows that the fall in these inventories is greater for dealers subject to the new rules/regulations. One of the authors of [10] nevertheless demonstrates, with other co-authors, in [6], that the fall in inventories is not solely due to the regulations, but is also largely linked to the post-crisis deleveraging, which predated the regulatory pressure, and to other effects such as the electronification of the corporate bond market (see Section 1.2.2). Other papers, such as Duffie's (see [45]), more specifically implicate the Volcker rule, and it is notable that the Fed showed in [18] that when there have been stress events, like downgrades of corporate bonds that have led to sell-offs, the fall in US dealers' inventories has been attributable to the Volcker rule to a much greater degree than to Basel III or the Comprehensive Capital Analysis and Review (CCAR). [20] is also an important reference for a much wider perspective on the link between capital and market making, including a discussion on the new role of dealers. Another aspect for analysis, which has been little explored but often emerges in discussions with professionals (see the recent Goldman Sachs report [96], for example), is that the possibility of carrying corporate bond inventories has been eroded by the fall in liquidity on the CDS market, which is the natural market for hedging the risk borne by dealers.[4] The CDS market's liquidity is in fact closely linked to the liquidity of the bond market and the effects of the new regulatory frameworks on the CDS market's liquidity therefore have an indirect impact on dealers' corporate bond inventories (also see [85] on the protective role of a functional CDS market in periods of stress).[5]

A new fear: ETFs and other ETPs

The fear of a liquidity crisis on the bond market is shared by many market participants given the prospect of an inevitable rise in rates, which would have a dramatic impact if they rose too quickly. Whereas bonds are traditionally held indirectly through funds that do not always offer immediate liquidity, some of which propose protective redemption mechanisms, a fear expressed by a growing number of market participants relates to new assets or investment vehicles, namely bond ETFs (and other ETPs). While they account for only a small percentage of bond outstandings in Europe (see [14] particularly for the situation in France), bond ETFs could pose a threat to liquidity or, more specifically, be a crisis accelerator. Although they are fundamentally based on relatively illiquid assets, they in fact offer investors considerable liquidity. The analyses carried out in [27], [38] and [103] using traditional measures of liquidity lead to varying conclusions on the impact of ETFs on liquidity, but the issue of what would happen if there was a liquidity shock or large-scale redemption requests is not explored due to a lack of data. It is sometimes claimed that the issue of ETFs is mitigated, especially in the US, by the existence of in-kind mechanisms for many of them (see [27] in which the "taper tantrum" of 2013 and Bill Gross's departure from PIMCO in 2014 are analysed), but the market can still find itself in tight situations (e.g. Citigroup's problems during the "taper tantrum" [14]). Even though we believe, at least when it comes to Europe, that bond ETFs are not currently a major issue, there is clearly a need for high bond market liquidity, so that a system comparable to the transformation of illiquid assets into liquid assets does not seize up.

As multi-factor as it may be, and despite the controversies, the fall in dealers' inventories is a major subject of concern for regulators and industry on both sides of the Atlantic. As dealers see their intermediation capacity decline, there is a real risk of a liquidity crisis emerging if there is a rise in rates and a large-scale need for liquidity on the market, with potential systemic consequences. However, many papers suggest, using some liquidity measures that are debatable within the current framework (see Section 2.2), that despite the fall in dealers' inventories, market liquidity is still satisfactory and is even increasing. There have been many studies of the US market, including [4] (supported by [9]), [5], [16] and [104]. There have been fewer studies of markets outside the US, but one of these is a study [17] (dating from 2016) that uses data from the FCA for the 2008-2014 period and finds that, despite the fall in dealers' inventories, the liquidity of the UK corporate bond market has in fact not only not deteriorated, but has actually improved. A second, more recent study by the FCA [48] shows a

[4] Dealers wishing to reduce their exposure to the risk associated with a bond (and therefore an issuer) have several possibilities: (i) reducing their position in the security (but the low liquidity may make selling difficult and/or costly), (ii) reducing their position in another bond issued by the same issuer that has similar characteristics (maturity, seniority, etc.), or (iii) buying a CDS covering exposure to the issuer if this type of derivative is available.

[5] Another vital market is the repo market. The European repo market is very well described and analysed in [73].

moderate fall in liquidity starting from mid-2014. The situation in France was analysed by the AMF in [13], which arrives at the conclusion that the liquidity of the corporate bond market has improved[6], but there is room to doubt the robustness of this liquidity in the event of a crisis[7].

Although the results of many quantitative measures of liquidity, in both the US and Europe, seem to mitigate fears, they go against the general sentiment of professionals. Explaining this of course requires a critical reading of the liquidity measures used in the academic sphere and by regulators, and also, first and foremost, a finer understanding of the changes that have taken place in the (micro)structure of the corporate bond markets.

1.2.2. The current (r)evolution in the market structure

The electronification of the financial markets is a lengthy process that has spread, and will gradually continue to spread, to the majority of asset classes. The equity markets, with the creation of NASDAQ in 1971, for example, have played a pioneering role in this transition towards faster and less costly execution, and greater transparency, but many markets have since followed suit. The corporate bond market is currently undergoing electronification on both sides of the Atlantic in a process specific to this market (see, for example, the BIS's paper [23], McKinsey's report [86], or the article [101] on the launching of new platforms).

The electronification of the corporate bond market does not in fact imply a shift from an OTC market organised around dealers playing an intermediation role through their balance sheets, to a market based on order books (LOBs/CLOBs) that operates on the principle of all-to-all trading, as is mostly the case for the major equity markets (there are sometimes official market makers on equity markets, however, such as the Designated Market Makers on the NYSE). Due to its specific characteristics, and especially the large number of different securities and the now quite infrequent transactions carried out on many of them – although it might and should be asked whether buy and hold strategies are inherent to bond market participants or are a consequence of the market's structure –, it is difficult to imagine a corporate bond market organised according to the equity or US Treasury market model, or the model of the majority of the organised futures markets (see [21] for a historical perspective on the corporate bond market, however).

The electronification of the corporate bond market is dominated by operators such as Bloomberg, Tradeweb and MarketAxess, which offer platforms that allow clients to send the same request (RFQ) to several dealers simultaneously and therefore instantly put dealers into competition. In other words, despite the many efforts of entrepreneurs and major groups like BlackRock (see the withdrawal of Form ATS for the Aladdin platform referred to in [26]), there has been no paradigm shift for the corporate bond market from OTC to all-to-all trading/CLOBs.

The corporate bond market is therefore in a seemingly transitional situation, with, on the one hand, dealers who are supposed to play an intermediation role by carrying the risk associated with a principal trading model on their balance sheets, but who are reducing their inventories for cyclical economic reasons – and have been doing so for a long time now – and because of the regulations and, on the other hand, the emergence of all-to-all platforms offering a Copernican revolution, but that have not yet found their market (see [100] on the providing of liquidity by the buy side).

To be able to explain the corporate bond market's current operation, the paradigm shift in dealers' behaviour must be understood; in both the US and Europe they have partially switched from a traditional principal trading to a riskless principal trading model, whereby they no longer carry the natural risk linked to intermediation on their balance sheets, but instead put buyers in contact with sellers, which is not the expected role of a market maker.[8] In these circumstances, inventory size is of course not a good estimator of liquidity, and an increase in liquidity might be observed despite reduced inventories, but probably not by measuring bid-ask spreads if these no longer measure the complex risk combining volatility and liquidity that is generated by a market maker's

[6] In its 2017 risk map, the AMF indicates, however, that the change in its illiquidity indicator shows that liquidity decreased in 2016.
[7] We believe that the AMF is the most advanced and realistic regulator with regard to these issues.
[8] From this point of view, the growing role of sales in the corporate bond segment is quite pronounced on European trading floors.

traditional business (see [58, 59, 60], for example), but just a fee for the intermediation service (which should then be transparent – see [26])!

These factors affecting the market's structure are extremely important for discussing the relevance of liquidity measures, just as it is important to know that there are many trade throughs and much price discrimination on the bond market (see [62], [89] and [99], and [68] for a more theoretical viewpoint).

1.3. THE NEED FOR RELEVANT LIQUIDITY MEASURES

The current position of the corporate bond market is highly ambivalent, with asset managers testifying to the difficulty of trading, and even if trading is possible, the difficulty (sometimes) of ensuring delivery, while studies (see Section 1.2.1) carried out by academics, the Fed, international organisations and regulators in the US and Europe are almost all reassuring about the market's state of liquidity and are often even confident and optimistic.

This discrepancy creates a need for a critical reading of the liquidity measures used in the academic literature and the many studies listed in the bibliography. As these measures are most often inherited from organised markets, and more specifically equity markets, they are not necessarily suited to the corporate bond market, because of the very nature of the securities and the market's highly specific structure, also bearing in mind the economic and structural changes described in Section 1.2.2.

In the next chapter, we will therefore conduct a brief review of the literature on liquidity measurement and its traditional uses in the case of the corporate bond market. We also present a critical analysis of the main liquidity measures proposed historically, focusing particularly on their relevance to the French (or, more generally, European) bond market, given the nature of the reporting data belonging to the AMF.

Since MiFID came into force in 2007, the AMF has received information about all the transactions carried out in Europe for the securities for which it is the competent authority, in other words all the securities issued by issuers whose registered office is based in France. These reports are received daily and contain, for each transaction, a date and a time, a size, a price, the identity of the counterparty to the transaction, and the execution venue (where this is relevant). The theoretical analysis presented in Chapter 2 of this document has been carried out in view of the data available and their limited reliability.[9] Likewise, the proposals made in Chapter 3 and the empirical analysis given in Chapter 4 are the result of work carried out using the AMF's (anonymised) reporting data for the 2012-2016 period.

[9] The purpose of this document is not to reflect the data analysis that was carried out simultaneously with the study. The data are nevertheless not always amenable to analysis, with incorrect timestampings (e.g. reporting time instead of the transaction time), many reporting errors, a frequent confusion between the dirty price (i.e. the price including the accrued coupon) and the clean price (i.e. the price not including the accrued coupon), and so on.

CHAPTER 2: MEASURING LIQUIDITY

2.1. THE HISTORICAL REASONS FOR MEASURING LIQUIDITY

While the literature on precise measures of liquidity, and especially market impact measures, has recently multiplied, the measurement of transaction costs, which are a component of, or at least one of the factors determining, liquidity, has long been part of the academic literature. The measurement of sources of friction has always been vital in finance, for developing investment strategies, hedging derivative products, or dealing with more recent best execution issues.

2.1.1. Liquidity premia and bond spreads

In the case of bonds, and especially corporate bonds, for which buy and hold strategies are commonplace, it has long been crucial to measure the liquidity of securities in order to measure liquidity premia, which are in fact illiquidity premia. There is therefore a large body of literature that attempts to break down the yield spreads of risky bonds (usually yields to benchmark) according to the various risks borne by their holders in addition to the interest rate risk associated with the sovereign benchmark. The most obvious of these risks is the credit/default risk, but there is also the redemption risk, in the case of callable bonds, and liquidity risk, which is the focus of our interest (see [2], for example, for the theoretical impact of liquidity on expected returns). It is in fact worthwhile, for a long-term investor, or as part of a smart asset-liability management strategy, to carry a bond whose yield spread is higher because its liquidity premium is also higher (given an equivalent credit risk) if the security is supposed to be held until its maturity date.

The academic literature on liquidity premia mainly covers the US corporate bond market and uses numerous liquidity measures. In [19], the authors show that, over the 2003-2009 period, according to Roll's measure (see [97] and the next section), the liquidity of securities plays an important role in determining bond prices (and therefore yield spreads). They demonstrate particularly that the liquidity of bonds has a systematic component, in other words the liquidity of numerous bonds partly changes jointly.[10] They also show that the share of yield spreads attributable to liquidity depends on market conditions and, particularly, that it increases during periods of crisis. In [32], the authors use a battery of liquidity measures and show that liquidity is an important component of yield spreads. Similar conclusions are reached in [81] using the Amihud measure (see [15] and the next section) and the Pastor and Stambaugh measure (see [90] and the next section). The same finding is made using the initial TRACE data in [44] and a variant of the liquidity measure proposed by Amihud, and some simple measures such as volume, volatility/volume ratio and turnover. Again using the TRACE data, the authors of [53] demonstrate through traditional liquidity measures (bond characteristics, number of transactions, Amihud ratio, Roll's estimator, zero-return measure, price dispersion measure, etc.) that the changes in the liquidity of corporate bonds on the US market accounted for around 14% of the change in yield spreads over the 2004-2008 period. The authors of [53] also explore the change in liquidity and show that there is a flight-to-quality effect in stressed periods. Specifically, when the markets are tight, the liquidity of high-yield securities tends to disappear, which is a particularly interesting point proving that aggregating liquidity measures to measure a market's liquidity is not an effective solution, as it neglects the breadth component.

Other examples of articles, again exploring the US market, reach similar conclusions, but there would be little point in producing an exhaustive list (it suffices to say that some articles, depending on the bond universe in question, use econometric models to measure the share of the yield spread attributable to credit risk, while others, such as [82], use the CDS market). [31], however, uses a liquidity measure based on the difference between the theoretical price according to a model and the market price, which does not therefore require transaction data, and [30] uses an implied liquidity measure combining limited transaction data with data

[10] An important reference for the breakdown of the liquidity (of securities) into an idiosyncratic component and a systematic component, in the case of corporate bonds, is [65]. Within a more general framework, but for another asset class, also see [34].

regarding investors' portfolios. Other articles, like [39], also try to explain the share of bond spreads linked to the liquidity premium using liquidity indicators on other, related markets (US Treasuries and equities).

It is worth noting, however, together with the authors of [67], that although liquidity measures account for part of the bond spread component not explained by factors linked to credit risk, they do not explain the whole of what should, in many cases, only be the liquidity premium. A possible conclusion is that the liquidity measures commonly used are not sufficient to explain the entire liquidity premium (and especially its idiosyncratic aspect) or they are very noisy.

Most of the analyses presented in the literature cover the US market and this was already the case before the advent of TRACE. There have been some studies of the European corporate bond market, however. When it comes to the UK market, for instance, [17] claims that, regardless of the liquidity measure used, the liquidity premium's share in yield spreads is very low for investment grade bonds and low for high-yield bonds. The authors of [17] also show that there was a downwards trend in liquidity premia during the 2012-2014 period. The case of Norway is dealt with in [66] and the authors state here that it is difficult to find a component in bond spreads that is linked to liquidity, which of course raises the issue of liquidity measurement given the low volumes on the Norwegian market. The issue of liquidity premia is also tackled in [71] for a universe of euro-denominated bonds, and the authors of the article claim that, for these bonds, liquidity is effectively factored into bond spreads.

2.1.2. Liquidity, transparency and stress

Whereas, historically, liquidity measures have mainly been used to measure the liquidity premia in bonds spreads, liquidity measures are now more broadly used. As liquidity is now seen as a desirable property for markets to have, liquidity measurement has become important in itself. Many publications have therefore discussed the impact of certain events on the liquidity of the markets, and particularly the corporate bond market.

This is the case in [46], for example, which, amongst other considerations, explores the impact on the liquidity of the US corporate bond market of the post-trade transparency that came about with TRACE, an impact considered to be very positive. Another article on this same theme of the link between transparency and liquidity is [55]. The authors conclude that the impact of transparency on liquidity is positive, especially in terms of costs and volumes. It is also noteworthy that the increase in liquidity is not uniform and is mainly seen for already liquid securities.

In addition to transparency, the studies mostly look at stress or shock events and we believe that this is of the utmost importance. It is indeed vital to be able to assess the likelihood of a market withstanding a shock to the demand or supply of securities. Studies of the corporate bond market have considered shocks of varying intensities as their starting point. One of the most frequent shocks occurs when a security leaves an index. Investors tracking the index must then immediately sell the security. In the case of corporate bonds, the effect of securities leaving indices is explored in [43] with very definite conclusions: since 2008, liquidity, here in its immediacy component, has substantially fallen, with a doubling of costs for investment grade bonds and a tripling of costs for high-yield bonds (costs being measured by a proxy of dealers' profits). Similarly, the authors of [18] show that the liquidity of US corporate bonds has decreased since the introduction of the Volcker rule by looking at a different type of shock: downgrades. These results may seem alarming, but other studies do not arrive at the same conclusions. In [16], for example, the authors analyse shocks such as an extreme increase in a yield or a downgrade, and find that the liquidity during periods of stress does not significantly change if pre- and post-crisis levels are compared. They note, however, that when there have been VIX shocks, the bond market's liquidity has deteriorated compared with the situation before 2007 (as the mechanism is not discussed, the effect's relevance is nevertheless debatable). Another, more specific, natural event, is the liquidation of corporate bond funds. In [8], the authors explore the case of the liquidation of the Third Avenue fund and show that liquidity was affected, but the market held up well. Several articles were of course produced following the 2007 crisis, including [53], which demonstrates that liquidity premia on the US corporate bond market increased during the crisis. On a related theme, it is also worth mentioning [1], which tackles the impact of liquidity shocks

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originating from the US equity and Treasury markets on the US corporate bond market. The authors in fact show that liquidity shocks on these markets have a different impact on investment grade bonds and high-yield bonds during periods of recession, particularly because of a flight-to-quality effect. Once again, we can therefore see that the liquidity of a market cannot be reduced to an "average" measure and "distribution" effects must be taken into account.

Measuring liquidity may be important, but knowing why it is being measured is vital. Is it worth knowing how liquidity fluctuates during periods of calm or do we want to know how liquidity will respond to a shock? What do we really want to measure: liquidity in all its components or merely the immediacy component, which will perhaps be the most important if a crisis is triggered? Do we wish to measure the liquidity of a market taking the breadth component into account, or simply measure the average liquidity of the securities? Although it is often difficult to answer these questions, they should be borne in mind when a liquidity measure is analysed.

The purpose of the next section is precisely to analyse the various liquidity measures proposed in the academic and professional literature, while focusing on the specific features of the French (or European) corporate bond market and the data available to the AMF.

2.2. CRITICAL ANALYSIS OF LIQUIDITY MEASURES FOR THE CORPORATE BOND MARKET

In this section we will be reviewing the majority (the aim is in no way to be exhaustive) of the liquidity measures proposed in the academic and professional literature. As we mentioned above, most liquidity measures were initially devised for the equity markets. They are therefore not necessarily applicable to OTC markets such as the corporate bond market, because of the absence of order books, or because the data available are of different kinds, or even because of the difference in the nature of equities and bonds, as very different bonds may be issued by the same issuer.

Many measures have nevertheless been used, sometimes after adaptation, especially on the US corporate bond market, for which transaction data are available through TRACE and Enhanced TRACE. The situation in Europe is more complicated as, before the arrival of MiFID 2, there was no post-trade transparency[11]. Transaction data are, however, available from local regulators (the AMF in the case that interests us), which systematically receive the transaction data for the corporate bond universe for which they are responsible (see Section 1.3).

The aim of this section is therefore to analyse the various liquidity measures conceivable in light of the French, and more generally European, corporate bond market's specific features and the data available.

2.2.1. Bid-ask spreads

In most of the articles and books comparing the various liquidity measures[12], applied to the equity or other markets (see [51], [52], [57], [74], [98] and [102], for example), one of the first ways to measure liquidity is to measure a bid-ask spread.

Quoted spreads

For markets organised around order books, measuring the bid-ask spread is usually not very complicated (even with the current fragmentation on the equity markets); you just consider the difference between the best ask

[11] And this was still very limited in May 2018; see the discussion on MiFID 2 in chapter 4.

[12] Liquidity measures that use the characteristics of securities are outside the scope of this discussion. We will also not be exploring the few approaches that measure liquidity by the difference between the theoretical price, according to a necessarily disputable model, and the transaction price (see Section 2.1.1 on liquidity premia). Finally, we will not be describing the simple measures that are sometimes used, such as volume or turnover, which are usually poor proxies for liquidity (e.g. a €10 million transaction has nothing in common, in terms of liquidity, with 10 transactions of €1 million that each involve different counterparties).

and the best bid. This type of bid-ask spread, which is also commonly known as the quoted spread, is a typical measure of the width component of liquidity.

There are executable quotes on the corporate bond market, but only for small quantities, and it is therefore not reasonable to use them to calculate bid-ask spreads. Due to the way the market is organised and the important role played by multi-dealer-to-client (MD2C) platforms like Bloomberg, MarketAxess and Tradeweb, most bid and ask quotes taken into account by asset managers are contributed quotes (streamed quotes), which are merely indicative of the price that would be offered by each of the dealers. These quotes are only available to all in an aggregated form and most financial operators take the aggregated prices, or CBBT (Composite Bloomberg Bond Trader), calculated by Bloomberg, as the bid and ask prices, by default.

We believe that calculating bid-ask spreads using these data is extremely risky. Firstly, these prices are only indicative and there is no guarantee that a request (RFQ) for the reference quantity will receive a quote equal to the streamed quote in response, or even that there will be any response from dealers who streamed quotes. Secondly, as these prices are only indicative, they are not necessarily up to date, although they increasingly are thanks to the automation of market making. In addition, given the paradigm shift in the behaviour of dealers, who are tending more and more to only carry out transactions if they already have a counterparty for them, there is no longer any real reason to link streamed quotes to liquidity, as with a traditional market maker. Lastly, in the limited documentation on the calculation of CBBT prices, Bloomberg does not explain exactly how these prices are calculated, but states that the algorithm may generate a bid price that is higher than the ask price, which casts doubt on the relevance of a bid-ask spread calculated from these data. For all these reasons, quoted spreads are not very appropriate liquidity measures for the corporate bond market and will probably become less so.

Effective spreads and realised spreads

More relevant bid-ask spread measures are often proposed in addition to quoted spreads. For instance, [52] defines the effective spread as the signed difference between the price of a transaction and the mid-price, the sign being dictated by the direction of the transaction. One variant is the realised spread, which also takes the impact of the transaction on the mid-price into account.

Other bid-ask spread measures are along the same lines, such as the adaptation by Schestag (see [98]) of the measure proposed by [99], which consists of considering the coefficient for the regression of the differences between the transaction price and a reference price (mid-price) on the direction of the transaction – ±1 in the case of a transaction between a dealer and a client (D2C) (depending on the direction) and 0 in the case of a transaction between dealers (D2D).

These measures are interesting theoretically, but they cannot be applied to the corporate bond market for at least two reasons. Firstly, it is difficult to determine what the mid-price should be. On this subject, it is worth noting that professionals view the CBBT (mid) as a default mid-price, but many of them try to establish a more relevant mid-price using publicly available data, data linked to their transactions and data linked to the RFQs that they receive.[13] Secondly, unlike the data present in most banks, the AMF's data do not indicate the direction of transactions.[14] Owing to the many price discriminations on the bond market, and the presence of D2D transactions and timestamping issues, it is not reasonable to use traditional Lee-Ready type algorithms to determine the direction of transactions, which means that almost all the liquidity measures that require data about the direction of transactions must therefore be eliminated (see [98], for example, for similar measures).

[13] The ILB has thus participated in several research projects aimed at obtaining a more relevant mid-price and bid and ask prices using filtering models (see [61], for example). Contrary to what was planned during initial exchanges with the AMF, similar approaches could not be applied to the AMF's data, due particularly, but not solely, to timestamping issues.
[14] The AMF's data make no distinction between seller-initiated and buyer-initiated transactions, or between D2C and D2D transactions.

Bid-ask spread proxies

In spite of these intrinsic limitations, as it only measures the width component of liquidity, the bid-ask spread has spawned a considerable amount of literature, especially on its estimation from different types of data.

One of the most well-known bid-ask spread estimators is Roll's [97]. This estimator uses the serial correlation of changes in transaction prices to deduce, thanks to the bid-ask bounce effect, the value of the bid-ask spread (which, according to robust assumptions, is a multiple of the square root of the opposite of the price change serial correlation). This measure may be highly disputable as a bid-ask spread estimator because of the underlying assumptions (no serial correlation of orders – an assumption known to be false –, no imbalance in the order flow, no impact of transactions on the mid-price, etc. – see the excellent work [52] co-written by Thierry Foucault for a complete analysis), but a negative serial correlation of yields is a clear sign of illiquidity (also see the Pastor and Stambaugh measure – [90]). In any case, for corporate bonds, the majority of securities have a very low trading frequency and it is therefore not very feasible to calculate a serial correlation of transaction prices.

Other measures have also been proposed aside from Roll's. The Corwin and Schultz measure [37] is often referred to, for example. This uses the maximum and minimum prices during a period (e.g. the highest and lowest prices in the course of a day) to estimate the bid-ask spread by eliminating the component linked to price volatility. This measure is interesting theoretically, but not very suited to our case, as it is very sensitive to price errors, which makes it inappropriate for use on AMF data because of the issues regarding the uncertain nature (dirty price or clean price) of the prices in the databases.

A last measure that should be mentioned, in the form of a dynamic generalisation of a bid-ask spread, is the imputed round trip cost. This measurement consists of searching the data for round trips (or data that might resemble round trips) by economic participants over short periods and measuring their cost. This type of measure can clearly only draw on limited data and is therefore of little interest for our bond universe.

2.2.2. Dispersion measures

The Corwin and Schultz measure estimates the bid-ask spread from the highest and lowest price in the course of a day (or, more generally, a given period). It therefore uses price dispersion, which is a joint measure of illiquidity and volatility, and attempts to separate the two components.

Other liquidity measures use price dispersion. A dispersion measure worth looking at in our case is the interquartile price range (as a percentage of the price), over a day, for example, as in [98], or over a longer period. For relatively liquid securities, or if we consider a sufficiently long period, this may be a useful measure, as the effects of dirty price vs. clean price errors can be limited due to the use of quartiles (behind which the incorrect data will be).

Other dispersion measures (see [77], for example) have been proposed, but (i) they usually require a mid-price – which is not necessarily very reliable (see Section 2.2.1 on this subject) – and (ii) they are sensitive to price errors. We do not recommend them given the nature of the errors in the AMF's reporting databases.

2.2.3. The market impact: from Amihud to precise models

The bid-ask spread is a static concept that only measures the width component of liquidity. When trying to measure the other components of liquidity, it is natural to wonder about the possible measures of the market impact. The market impact may in fact measure not just the width component, but also the depth component linked to the volumes available, and even the time-based components of liquidity, such as resiliency, using the most advanced methods.

The most well-known market impact measure is the Amihud measure [15], although it is not really designed for this purpose. The idea behind the Amihud measure, which is perfectly in line with the depth component, is to measure the sensitivity of prices to the volumes traded. Amihud's illiquidity measure therefore consists, for a given security and a given period, of establishing the ratio of the absolute value of the return of a security over a period to the transaction volumes for this security during the period in question.[15] The traditional interpretation of the relationship between Amihud's ratio and liquidity is as follows: the greater a security's liquidity, the greater the volume required to move the security's price, and therefore the lower Amihud's ratio. An alternative interpretation, that there is a causal link from theoretical returns (linked to fundamental value) to volumes, rather than from volumes to returns, is also possible, whereby the greater a security's liquidity, the smaller the change in its fundamental value required to cause changes in investment decisions and transactions, and therefore the lower Amihud's ratio.

These interpretations are of course open to criticism, for every asset class, as price changes are generated by supply-demand imbalances rather than the volumes themselves.[16] Corporate bonds pose a particular problem, however, as there may be tens, or even hundreds, of different bonds for the same issuer (which is not the case for equities, to which the Amihud measure is often applied). As such, if there is a change in the fundamental value of an issuer, the change in yields of the various bonds will be highly correlated (the more so if the characteristics of the securities, i.e. their maturity and seniority, are similar), but there is no reason for there to be a security-by-security link between these changes in yields and transaction volumes. Investors may often adjust their exposure to the risk associated with an issuer by trading one of the various bonds, at their discretion, according to their portfolio.[17]

Based on these observations, we believe that Amihud's ratio can only be meaningful at the level of each issuer, but it then becomes difficult to link this ratio to the securities' liquidity. We do not, therefore, recommend using Amihud's ratio to measure the global liquidity of the corporate bond market.

While Amihud's measure considers the volumes traded, most market impact models consider the signed volumes at the level of each transaction or the aggregated imbalance. [64], for example, proposes regressing the returns of securities (equities in this case, but the approach is the same) on the imbalance or, more precisely, in line with the largely documented market impact square-root law, on the imbalance divided by the square root of the absolute value of this imbalance, and considering the regression coefficient in relation to this variable to be a measure of illiquidity. As we do not know the transactions' signs, these market impact models are of course largely unusable.[18]

2.2.4. No-trade and zero-return measures

We saw in Sections 2.2.1 and 2.2.2 that bid-ask spreads and dispersion measures can theoretically be used to measure the width component, and that market impact measures also enable measurement of the depth component, or even the resiliency component in the case of advanced models (which unfortunately are not usable with the current data). All of these measures (apart from quoted spreads, but we saw that they served little purpose) use data linked to transactions, such as transaction prices and volumes. So what about transactions that do not take place because of the market's illiquidity? Is this not ultimately asset managers' main concern when they claim that dealers focus on the most liquid market segments? To really understand liquidity in all its aspects, the difficulty, or even impossibility, of finding a counterparty – which is a bit like the

[15] Note that, in [13], the AMF considered a variant of Amihud's measure by dividing not by the trading volume, but by the square root of the trading volume (in line with the square-root law).

[16] In a context where the direction of transactions is unknown, this is the only possibility, however, and the imbalance is usually proportional to the volume.

[17] Note that averaging Amihud ratios to get around the problem of multiple securities is not recommended. If we consider two almost identical securities with a return of 1% over a given period, of which a total volume *V* has been traded, the division of the volume between the two securities will have a huge impact on the calculation. If the volume is equally divided, the average is $\frac{1}{2}\frac{1\%}{V/2}+\frac{1}{2}\frac{1\%}{V/2}=\frac{2\%}{V}$, whereas in the case of a volume 95% allocated to the first security and 5% to the second, the average is $\frac{1}{2}\frac{1\%}{0{,}95V}+\frac{1}{2}\frac{1\%}{0{,}05V}\cong\frac{10{,}5\%}{V}$, resulting in a ratio of more than 1 to 5 between the two cases, even though the choice of one asset over the other may be arbitrary.

[18] Note that Eisler and Bouchaud succeed in [47] in applying the propagator method – one of the leading methods for measuring market impact and resiliency – to credit indices, although this involves an OTC market and no knowledge of the direction of transactions. As the market is more liquid, the direction of the transactions is easier to determine, however.

negative, in photographic terms, of immediacy – must also be measured, and this difficulty/impossibility cannot be determined from measures calculated based on transaction prices.

One of the measures proposed in the literature that can be used to measure the difficulty of completing transactions is the LOT measure – an acronym used by the authors of [80]. This measure, and those that derive from it, estimate the transaction costs and/or the bid-ask spread for each security, based on the number of days without price changes – this is also known as a zero-return measure.

In the case of corporate bonds, the AMF's reporting data give us access to all the transactions within a broad corporate bond universe, therefore making it possible to directly consider a no-trade rather than a zero-return measure.

It is probably wiser, in fact, to reverse the logic and count the number of securities for which there were transactions over a given period (and why not determine the ratio of this number to the total number of securities within the universe in question in order to take into account the bond market's growing size[19]). Furthermore, this measure allows us to directly see how the liquidity is changing within the bond universe under review, in other words at market level (see particularly the concept of breadth introduced in Section 1.1).

In the next chapter, we will illustrate this type of measure and we are confident in the relevance of the values that we will obtain, as the AMF's reporting data are deemed to be exhaustive and are seemingly free of errors that might be detrimental to this estimator's quality, although we suppose that some dates are incorrect (but only to within a day, which means there are no real issues).[20]

2.2.5. Concluding remarks about liquidity measures

Our analysis of the various liquidity measures, in view of the European corporate bond market's characteristics and the data available to the AMF, prompts us to be extremely cautious regarding liquidity measures and their uses. That said, some lessons might be taken away and some measures proposed.

Firstly, we saw that it was not desirable, given the context and the data available, to use a bid-ask spread calculation to measure the width component. We nevertheless believe that measures of bid-ask spreads originating from the main MD2C platforms, calculated based on RFQ data (which contain far more information than transactions), would be useful.[21] As matters currently stand, we suggest opting for an interquartile dispersion measure, for all the reasons explained above. We believe that this is the only feasible measure for measuring the width component using the available data, even though it also contains a component linked to volatility within it. We provide an example of the use of this type of measure in the next chapter.

As for bid-ask spread measures (based on transactions) and dispersion measures, note that these can only be applied, due to their nature, to the most frequently traded securities. This raises the issue of aggregation bias. If the number of liquid securities falls (the breadth component) then the aggregated bid-ask spread measure will automatically cover a smaller universe of securities and therefore more liquid securities (all things being equal), which will increase the impression of liquidity. We believe, moreover (see the next chapter particularly), that this effect plays an important role and that liquidity measures based on transaction prices may be illusory in some cases.

In addition to measures based on transaction prices, another measure that seems to us to be vital in this illiquid market is the number of different securities traded during a given period, as this provides us with information about market participants' difficulty finding counterparties with whom to complete transactions. This number

[19] Unfortunately, we do not have access to dynamic data on the market's size.

[20] Note that the data errors in the AMF's databases make it difficult to thoroughly "de-duplicate" transactions (if the two counterparties report the same transaction differently). This de-duplication is not necessary for no-trade measures, however.

[21] Note that, during our discussions with professionals, we learned about one of the major operators' plans to introduce such a measure.

may be analysed raw or as a proportion of the total bond universe covered.[22] This measure is market-wide by nature and is an indicator of the breadth component of liquidity.

Regarding the creation of a single measure based on various measures, we believe that this is a risky and counter-productive exercise (i) if the measures do not cover the same universes, and especially (ii) if they do not measure the same components of liquidity.

When it comes to units of measurement – which is an issue raised by the AMF –, in our view it may be advisable, particularly if the measure does not use a meaningful unit[23], to associate a value between 0% and 100% with the measure's values. This first requires verification that the measure always increases with liquidity, even if this means changing the sign or reversing it. There are then basically two useful techniques. The first consists of associating, with each value, its rank within the distribution of previous values (over a rolling or non-rolling period). For instance, a value of 20% indicates that, in the past, the measure's value was above the current value 80% of the time. If the measurement increases above its maximum, the associated value will of course be 100%, but this is not really a problem if you are trying to check that liquidity is not decreasing. A second possibility, which is in fact only a variant, consists of considering the ratio (capped at 100%) between the current value of the measure and a high quantile (95% or 99%) of the past distribution of the measure's values.

[22] Unfortunately, we do not have access to dynamic data on the market's size.
[23] The two measures that we propose in the next chapter have clear units, which means that this is not an issue.

CHAPTER 3: NUMERIC ILLUSTRATIONS BASED ON AMF DATA

3.1. ILLUSTRATION OF THE DIFFICULTY OF COMPLETING TRANSACTIONS

In order to illustrate our breadth component measure, we carried out the following exercise on the AMF's reporting databases. Firstly, we counted, for each day (excluding Saturday and Sunday), the number of different securities (in other words the number of different ISINs) for which a transaction took place in the course of the day.

Figure 3.1

Number of different bonds traded in the course of a day (raw data excluding weekends)

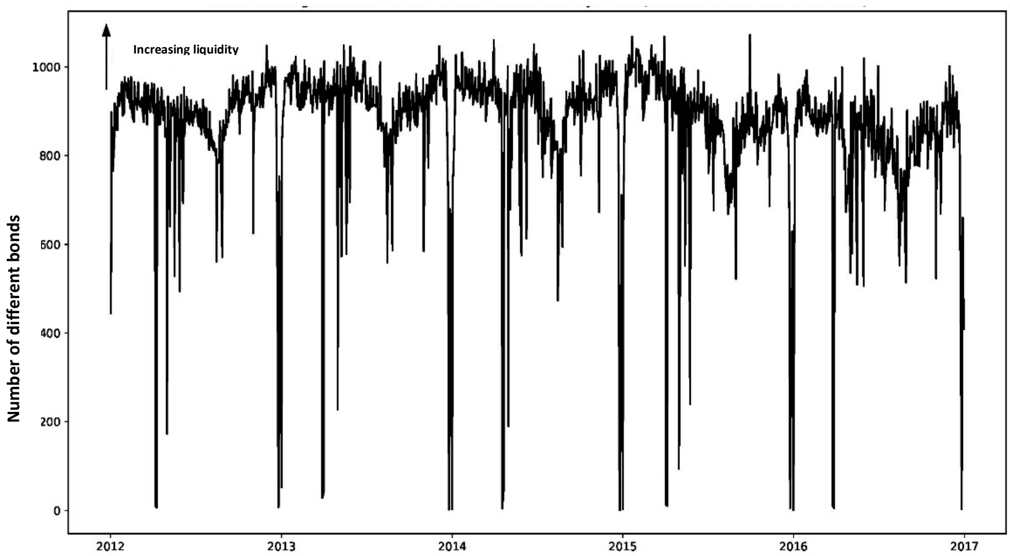


Figure 3.2

Histogram of the distribution of the number of different bonds traded in the course of a day (raw data excluding weekends)

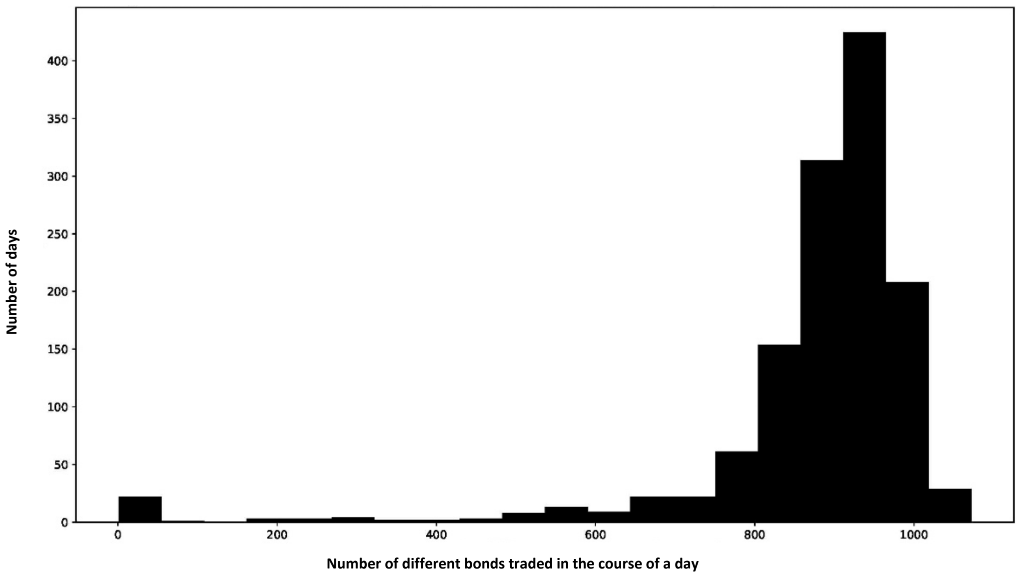
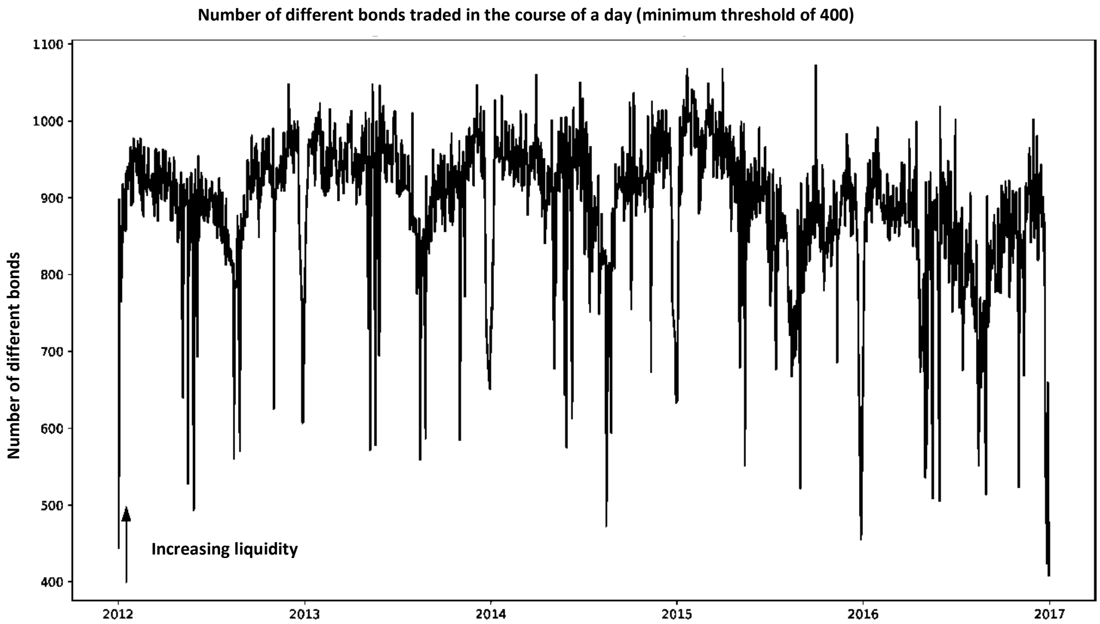


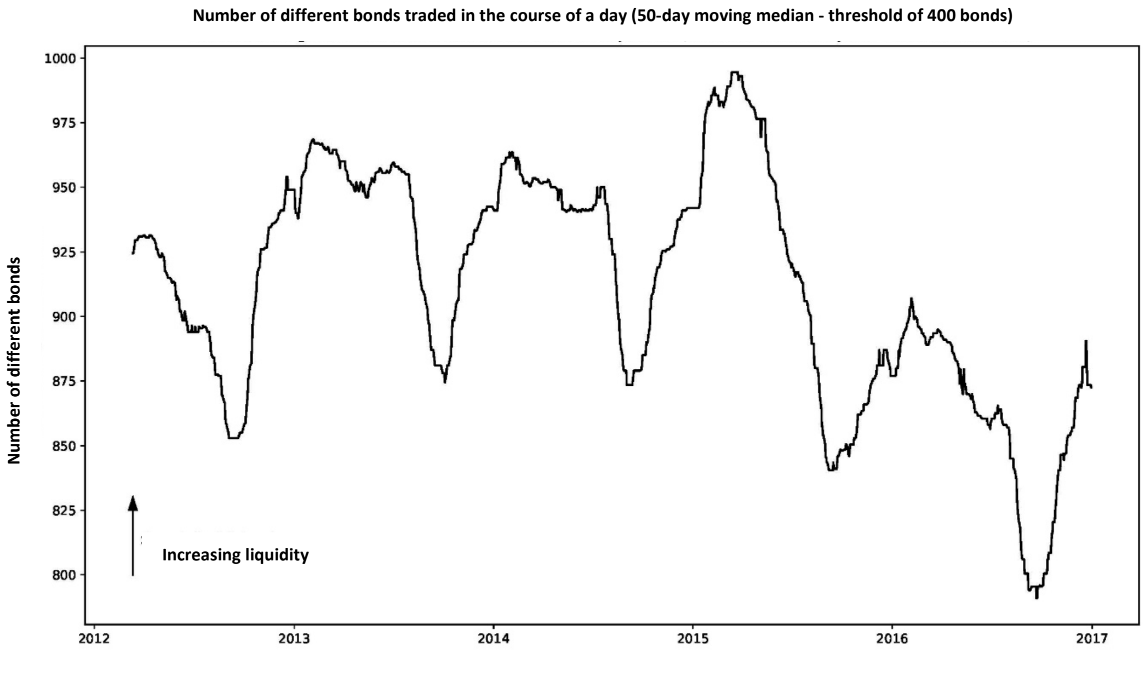
Figure 3.3



The raw data are shown in Figure 3.1 and the associated distribution is shown in the histogram in Figure 3.2. Two things emerge from these charts.

Firstly, there are a significant number of days when very few securities were traded. For easier analysis, and in light of the histogram above, from this point on we will remove from our time series the days when the number of different securities traded was less than 400 (see Figure 3.3).[24] There is also a seasonality effect, with a fall in the measure each summer, which can be seen more clearly in Figure 3.3.

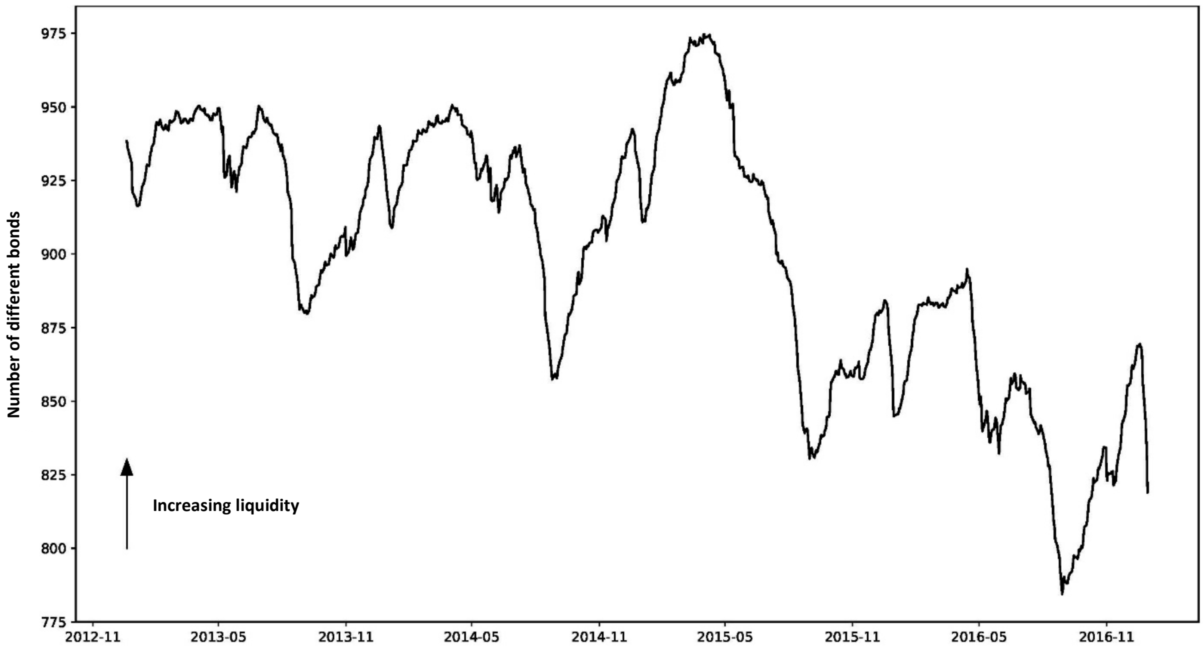
Figure 3.4



[24] The tests that we were able to conduct show that the conclusions that we draw are unaffected by a reasonable change of threshold.

Figure 3.5

Number of different bonds traded in the course of a day (exponential smoothing λ = 0.97 - threshold of 400 securities)



To be able to more precisely observe the trends in the time series obtained, we (i) calculated a 50-day moving median (Figure 3.4) and (ii) applied traditional exponential smoothing with λ= 97% (Figure 3.5).[25]

The results unequivocally indicate that the number of different bonds traded in the course of a day has tended to decrease since the start of 2015, which clearly illustrates the increased difficulty, testified to by managers, of completing transactions across a broad corporate bond universe. This outcome is all the more striking as the literature simultaneously claims that there has been an increase in the size of the corporate bond universe.

These results clearly show that the liquidity of the corporate bond market, in its breadth component, is decreasing. In addition, as we saw in Section 2.2.5, this trend may generate misleading biases with regard to liquidity if said liquidity is measured based on transaction prices (which is often the case in the literature, through the recurring use of bid-ask spreads). It is therefore important to clearly separate the different measures and to take into account the breadth component in any analysis of the corporate bond market's liquidity.

3.2. ILLUSTRATION OF AN INTERQUARTILE MEASURE

We will now look at a second liquidity measure (combining liquidity and intraday volatility) based on the interquartile transaction price range in the course of a day.

We carried out the following exercise. Firstly, for every day, we defined a securities universe consisting of the 100 bonds[26, 27] that had been most frequently traded (defined by the number of days when a transaction took place)

[25] These smoothing parameter choices (50 days and λ = 97%) were made in order to smooth out the indicator and observe any trends. The conclusions arrived at in this document are not specific to the particular smoothing parameters chosen.

during the last 100 days. For these 100 securities, we then calculated (if there were at least three transactions on the day in question) the interquartile transaction price range (as a proportion of the median price). This produced a list of interquartile ranges, for each day, for the 100 currently most liquid securities – this list did not contain 100 securities if some did not undergo the three transactions required for the calculation of a relevant interquartile range.

Figure 3.6

Median interquartile time series for the 100 most traded securities (by number of days) in the last 100 days

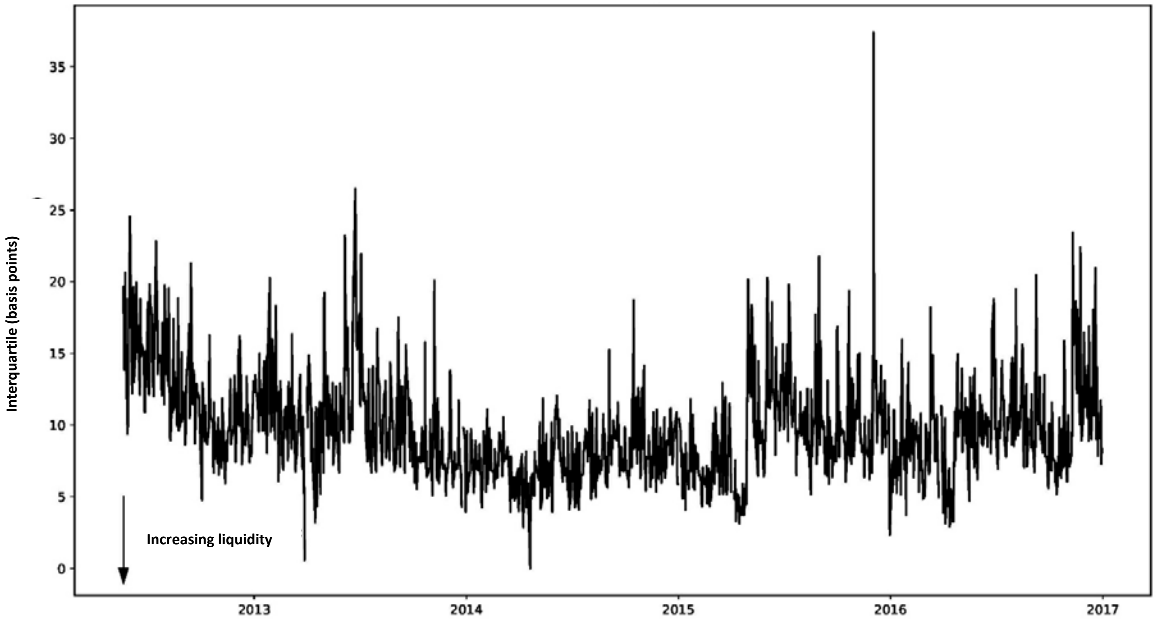
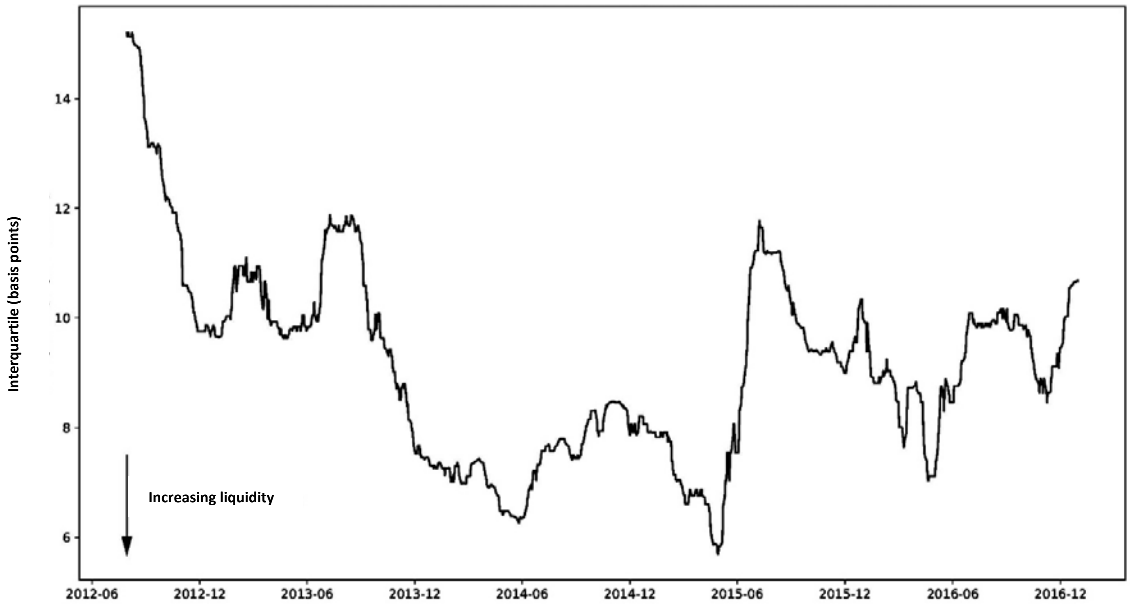


Figure 3.7

Median interquartile 50-day moving median time series for the 100 most traded securities (by number of days) in the last 100 days



[26] Setting the number of securities ex ante and restricting ourselves to the most liquid securities partly eliminates the biases documented in Section 2.2.5 in connection with the breadth component. Furthermore, restricting ourselves to the most liquid securities allowed us to focus on the cost component, independently of transaction volumes.

[27] Note that the same exercise applied to a universe of 50 and 150 securities leads to the same qualitative conclusions.

Based on these values, we were able to calculate a value representative of the width component for the market segment that was apparently the most liquid, for each day. This involved calculating the median for all the relevant securities for the day (Figure 3.6) and, to smooth out the chart – to be able to observe any trends –, we also showed the 50-day moving median for the time series (Figure 3.7). An alternative was also considered: calculating the average for all the relevant securities for each day after two-tailed Winsorisation at a 5% threshold. The 50-day moving median obtained for the time series is shown in Figure 3.8.

Figure 3.8

Average interquartile 50-day moving median time series (after Winsorisation at 5%) for the 100 most traded securities (by number of days) in the last 100 days

We can easily see that our measure of the width component of liquidity for the most liquid corporate bond segment fell sharply (reflecting an increase in liquidity) during the first half of the period under review. This trend ended in mid-2014, however, and was then followed by a reverse trend. In the second half of 2016, for example, liquidity levels were much lower than in 2014 and close to the levels at the end of 2012-start of 2013.

3.3. JOINT ANALYSIS OF THE TWO LIQUIDITY MEASURES

We proposed two liquidity measures above and, more precisely, two measures covering two components of liquidity: the breadth component and the width component.

In order to assess the simultaneous change in the two measures, we produced a scatterplot of the two measures (daily number of different bonds traded with a minimum threshold of 400 securities – see Figure 3.3 – and median value – for the most liquid bonds – of the interquartile transaction price range – see Figure 3.6), as shown below (Figure 3.9), adding the time dimension using a grey scale.

We can see that no correlation emerges from this scatterplot and the two measures seem to be independent. A quantitative analysis gives us a correlation coefficient of -6.3% and a Kendall τ of -7.5%. These low coefficients are, of course, also linked to the noise in the indicators. We therefore considered a scatterplot of the 10-day moving medians of the two measures with one point every 10 days (see Figure 3.10). The associated correlation coefficient was -23.3% and the Kendall τ was -19.2%. It is therefore apparent that the two measures are largely complementary and the negative correlation between them indicates that the two components of liquidity tend to be positively correlated. The measure of the breadth component increases with liquidity, whereas the interquartile measure linked to the width component is high when the market is illiquid.

Figure 3.9

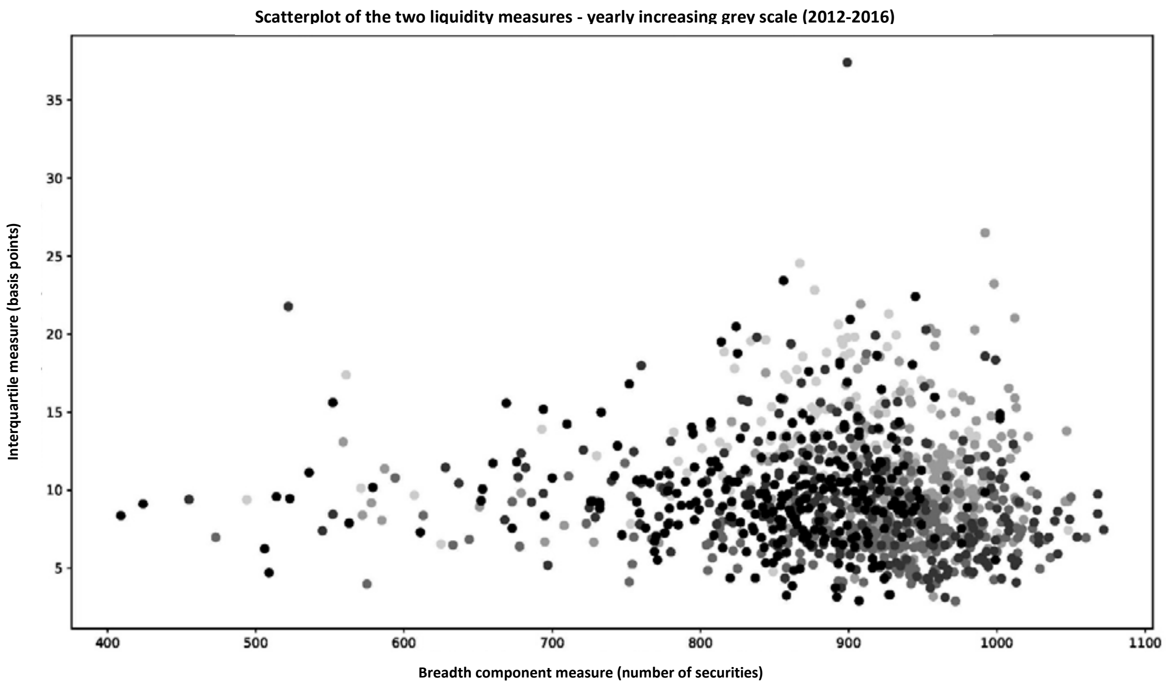
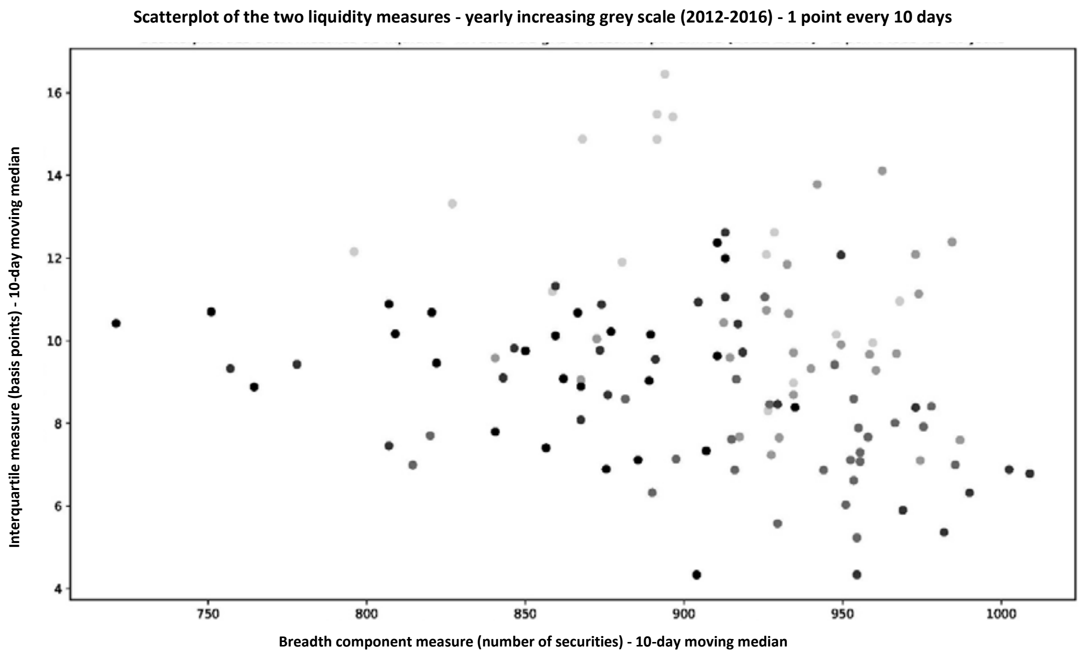


Figure 3.10



This joint analysis is particularly instructive as it goes against the "concentration" argument often heard (but never substantiated or demonstrated) during informal discussions on the liquidity of the corporate bond market. This argument consists of qualifying the supposed fall in liquidity by arguing that there has been an increase in liquidity in the most liquid market segment (hence the idea of a concentration of market participants on liquid securities). The negative correlation documented above, and the analysis of the changes in the two measures at the end of the period (low level of the breadth component and higher interquartile transaction price range values), clearly show that liquidity had deteriorated overall at period-end, and there was an evaporation rather than a concentration of liquidity.

Given the measures carried out above, and contrary to what is suggested by many analyses that in our view are disputable on theoretical grounds, we believe that there is reason for concern about the change in liquidity on the European corporate bond market. Although the situation is not yet alarming, it is important to monitor it and taking action to foster a return of liquidity should be a priority.[28]

[28] We suggest a few possibilities in the next chapter.

CHAPTER 4: UNDERSTANDING THE FACTORS DETERMINING LIQUIDITY

4.1. A SCIENTIFIC APPROACH

For a number of years now, the corporate bond market's liquidity has been a subject of concern for managers investing in this asset class and for regulators, on both sides of the Atlantic. We need measures to be able to analyse this liquidity, as with any economic analysis that claims to be scientific. We saw in the previous chapters (i) that measuring liquidity is not easy and that only a few liquidity measures were scientifically acceptable, and (ii) that the different acceptable measures did not transcribe the same aspects of liquidity.

In the last chapter, we showed that, over the 2015-2016 period, and compared with previous years, the corporate bond market overseen by the AMF experienced an evaporation of two aspects of liquidity, namely the breadth and width components. More specifically, our measures show (i) that the effective size of the market, measured by the number of different bonds traded daily, has reduced – in spite of the significant increase reported by the literature, in recent years, in the number of different bonds available – and (ii) that the intraday price variability has increased, which is usually a sign of a more volatile market and/or a market with greater frictions.

Looking beyond the facts, a legitimate scientific question is why. What, in fact, are the factors determining the liquidity of the bond market under review? What is behind the fluctuations in the various components? In addition to these questions about explanatory factors, but connected to them, is the issue of how the corporate bond market's liquidity might be acted upon.

To address these questions we will begin this chapter with our interquartile measure of the width component, which is more suited to econometric analysis, then we will discuss our measure associated with the breadth component.

4.2. THE WIDTH COMPONENT: SOME QUANTITATIVE FACTORS

The interquartile measure proposed in the previous chapter is a measure of the width component of liquidity, and therefore of the cost of the rapid consumption of liquidity. On consulting the literature on market making, we can see that this width component is linked to risk aversion and volatility, and also to the ability of market makers to find counterparties or take hedging positions (usually partial hedging).

In order to measure risk aversion and volatility, we considered the European equivalent of the VIX index (often referred to as the fear index), i.e. the VSTOXX. This index, based on the implied volatilities of options on the EURO STOXX 50, is of course an equity index rather than a bond index. However, the corporate bond market is far more closely linked to the equity markets than the sovereign bond market, and there is apparently no flight-to-safety from equities to corporate bonds, making our choice appropriate.

To measure the ability of market makers to reduce their risk exposure through hedging, we considered the spreads of the traditional European credit indices, in other words the iTRAXX Main and the iTRAXX Xover. These indices' spreads are in fact equivalent to an aggregated measure of the cost of hedging using derivative products.

Note that we also considered other variables linked to German bonds and European equity indices, but their explanatory power proved to be very limited or non-existent and our focus here is on factors that might offer explanations.

The interquartile measure shown in Figure 3.6 is extremely noisy and so we considered weekly averages of each of the variables in the statistical analysis that follows.[29] For the period under review, from the end of May 2012 to the end of 2016, we therefore have 240 points. The simultaneous changes of the different variables are shown in Figures 4.1, 4.2 and 4.3.

Figure 4.1

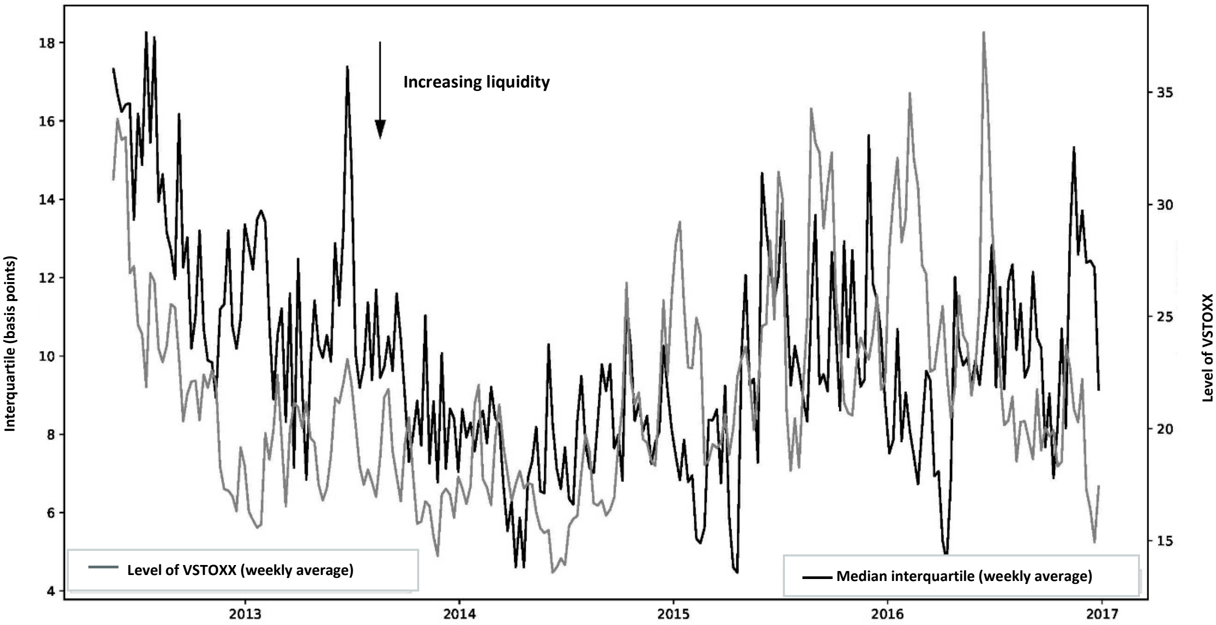
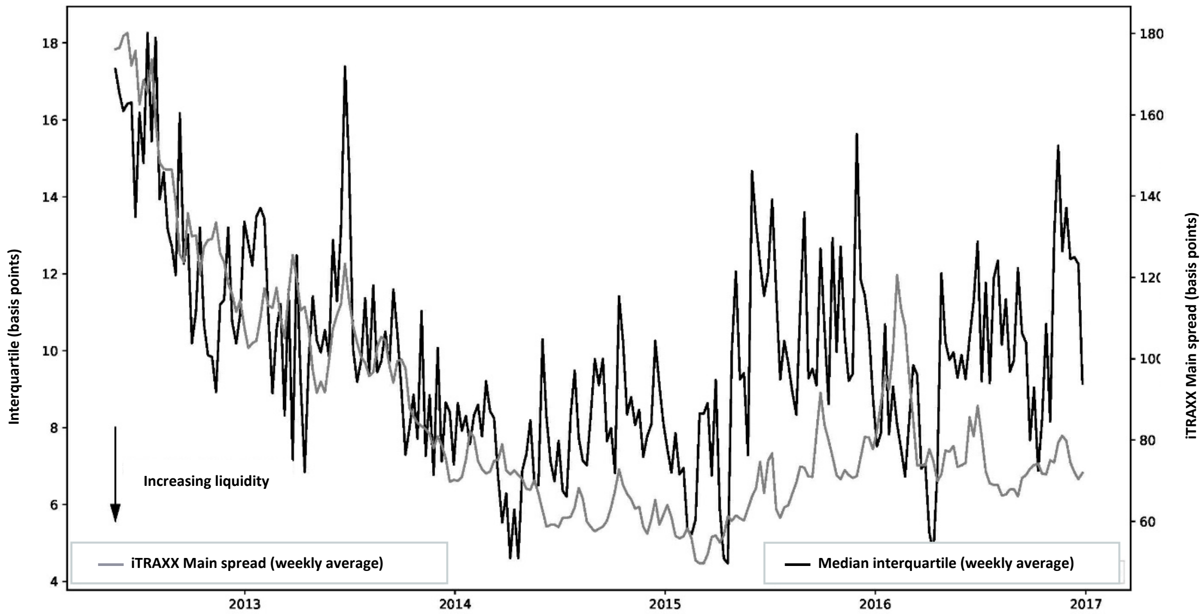
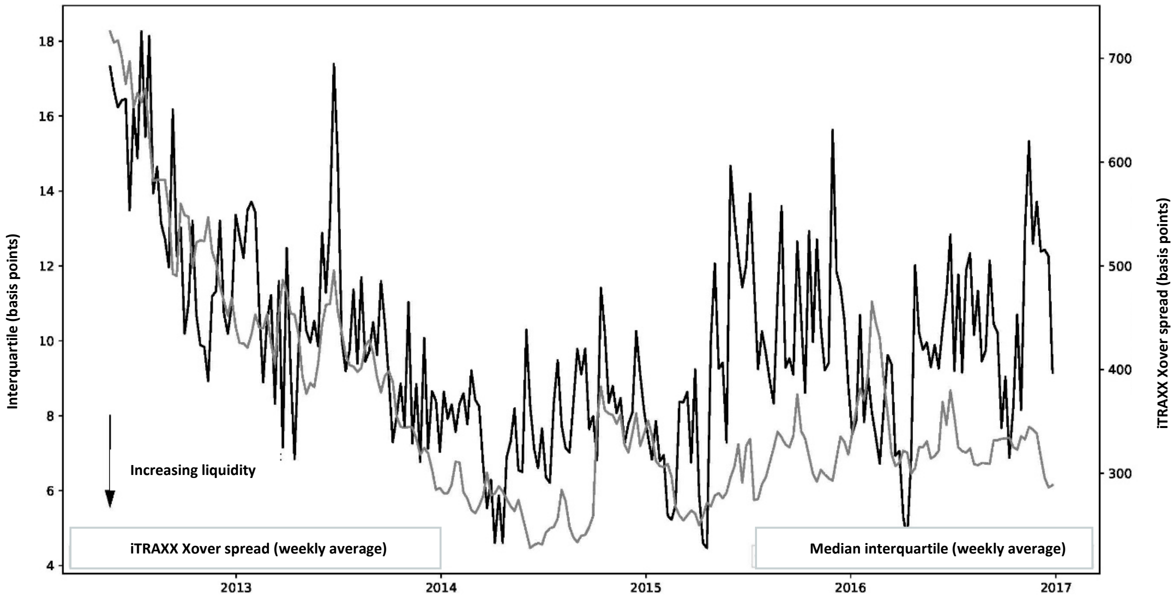


Figure 4.2



[29] We did not consider using smoothing over a longer period as in the previous chapter, where the aim was to carry out a (graphical) trend analysis. The objective here is to have enough points to conduct a statistical/econometric analysis.

Figure 4.3



The correlation matrix[30] is presented in Table 1 below.

Table 1: Correlation matrix

	Interquartile	VSTOXX	iTRAXX Main	iTRAXX Xover
Interquartile	1.000000	0.290857	0.622610	0.634950
VSTOXX	0.290857	1.000000	0.289992	0.361656
iTRAXX Main	0.622610	0.289992	1.000000	0.971949
iTRAXX Xover	0.634950	0.361656	0.971949	1.000000

An analysis of the correlations suggests a close link between our interquartile measure and the explanatory variables chosen, and a very high collinearity between the two credit indices' spreads.

We therefore carried out a linear regression (OLS) on the VSTOXX and the iTRAXX Main. The R^2 obtained was 40.1%. The regression coefficients and the associated statistics are presented in Table 2.

Table 2: Linear regression over the whole period

	coef	std err	t	P>|t|	[0.025	0.975]
const	3.5602	0.691	5.156	0.000	2.200	4.920
VSTOXX	0.0709	0.031	2.297	0.022	0.010	0.132
iTRAXX Main	0.0558	0.005	11.210	0.000	0.046	0.066

[30] Correlations of levels are referred to here rather than changes.

A naive econometric analysis might conclude that the level of the VSTOXX index and the spread of a credit index such as the iTRAXX Main are satisfactory explanatory factors for the width component. The R^2 is in fact high – given the noisy nature of the data – and the coefficients' signs are in keeping with economic intuition: an increase in risk aversion, volatility and the cost of hedging tends to increase the cost of liquidity.

An analysis over sub-periods suggests that the results obtained should be qualified, however. We completed the same regression on the first 120 points (Table 3) and the next 120 points (Table 4) and we arrived at respective values of R^2 of 67.8% and 4.0%.

Table 3: Linear regression over the first half of the period

	coef	std err	t	P>|t|	[0.025	0.975]
const	2.7216	0.883	3.080	0.003	0.972	4.471
VSTOXX	-0.0507	0.077	-0.660	0.511	-0.203	0.101
iTRAXX Main	0.0837	0.009	9.050	0.000	0.065	0.102

Table 4: Linear regression over the second half of the period

	coef	std err	t	P>|t|	[0.025	0.975]
const	7.0327	1.306	5.384	0.000	4.446	9.619
VSTOXX	-0.0250	0.057	-0.434	0.665	-0.139	0.089
iTRAXX Main	0.0433	0.022	1.983	0.050	5.93e-05	0.087

In addition to the explanatory nature of the model, which is not clear, we can also see, from the p-values in Tables 3 and 4, that the explanatory power of the VSTOXX should really be qualified.

So what might be concluded from this analysis?

Firstly, it seems possible to assert that the cost of hedging, measured by the iTRAXX Main spread, plays a natural role in the width component of liquidity: the more expensive it is for market makers to hedge their exposure, the higher the cost of liquidity (the width component). The bid-ask spread of the hedging instruments should, in fact, probably also be taken into account, the more so if market makers hedge their exposure using single-name CDSs. As discussed in Section 1.2.1, having a liquid CDS market is vital for bond market liquidity.

Secondly, we should recognise that, although the simultaneous change in the iTRAXX Main and iTRAXX Xover spreads and our interquartile indicator is clear until mid-2014, i.e. even though the change in the iTRAXX Main and the iTRAXX Xover probably explains the change in the width component for the first half of the period under review, the link, which is admittedly still positive, later becomes less clear. Figures 4.1 and 4.2 show, in fact, that the trends are still linked, but the noise in our weekly interquartile indicator, and potential lag effects, reduce the explanatory nature of the iTRAXX indices' spreads.

We believe, moreover, that the factors explaining liquidity may have changed in the latter years of the period under review due to the ECB's asset purchase programme and the many paradigm shifts on the part of market participants (see Section 1.2.2). In our opinion, these changes are also most likely to explain the changes in the breadth component seen since 2015.

4.3. THE BREADTH COMPONENT: STRUCTURAL FACTORS

The width component of liquidity, as measured by our interquartile measure, seems to have returned, at the end of 2016, to levels close to the end of 2012-start of 2013 (reflecting a fall in liquidity in the second half of the period under review). In addition, as we saw in the previous chapter (see Figures 3.4 and 3.5), the breadth component fell substantially over the 2015-2016 period (more than can be explained by seasonal effects).

We saw above that the 2015-2016 period was difficult to understand from a quantitative viewpoint and that a change of regime was probably taking place. More specifically, we believe that the recent changes in liquidity are largely linked to structural effects that cannot really be quantified or precisely dated, but have gradually occurred in recent years within investment banks, including a shift from principal trading to riskless principal trading, the gradual use of market making algorithms, and the change in the relationship between sales and traders. These effects and the failure (for the time being) of all-to-all platforms are, in our view, the cause of the current situation, far more than the effects linked to risk aversion or hedging costs.

Given the current regulatory universe, the majority of the main investment banks with a corporate bond market making activity have made major changes to their business models. The experiences of trading floors and the various scientific requests made by banks to the Institut Louis Bachelier show that two effects are at work. Firstly, there is a trend to automate market making from end to end (from streaming to trading). Secondly, there is a wish to keep risk to a minimum by trying to find counterparties for as many transactions as possible, and the increasing role of sales (assisted by quantitative methods) in achieving this is unparalleled.

Automation has been gradually taking place since 2014. The gradual nature of the process is due to the fact that some banks have made more progress than others, and the scope of the securities to which automation is being applied is gradually expanding within each bank. Some bonds are perhaps simply being abandoned by certain market makers until they are brought within the automatic market making scope, and this may be an explanation for the decline in the breadth component. The effect should only be temporary, but it may last for several years.

With regard to risk control, we spoke above about the shift from a principal trading model to a riskless principal trading model. The idea here is to keep inventories down to a minimum, by trying to find counterparties for as many transactions as possible.[31] This change in business model may also explain the fall in the breadth component if some securities were traditionally carried on balance sheets and (partially) hedged by reverse positions in securities with similar properties or by derivatives, whereas counterparties are now being sought for transactions.

The factors explaining liquidity may therefore perhaps be found in banks' structural responses to changes in the regulations. Although acquiring data to prove this econometrically is probably unrealistic, it is nevertheless a plausible hypothesis.

4.4. CONCLUDING REMARKS ABOUT THE FACTORS AFFECTING LIQUIDITY AND THE MEANS OF ACTING UPON IT

Finding the factors that explain a phenomenon allows it to be better understood and also, and above all, enables the making of predictions and extrapolations (with regard to both intended and unintended changes in the factors).

In the case of the corporate bond market's liquidity, we can assume that an increase in the iTRAXX Main (or Xover) spread will result in a fall in the width component of liquidity, and we are able to quantify this fall through our interquartile indicator and an econometric model like the one proposed above. At the moment, however, it

[31] It is noteworthy scientifical approaches have been developed to allow sales to successfully achieve this goal.

seems difficult to quantify the effect of the various measures that might be taken or to guess what would happen in the event of a shock.

What is more, even if we had more effective econometric models, it is difficult to extrapolate when market conditions have structurally changed. For instance, to take an extreme example, if we thought that the post-crisis regulatory tightening was behind the evaporation of liquidity, undoing the regulations would probably not change anything for a long time, as business models have been adapted to a new environment and often show considerable inertia.

In the previous section we referred to the possible impact of the automation of market making on liquidity (in its breadth component). Greater post-trade transparency with broader and simplified access to data (MiFID 2 definitely did not go far enough in this direction, as the corporate bond universe for which reporting must take place within 15 minutes is extremely limited at the moment[32], and because access to data is not as simple as in the US) could accelerate this automation in Europe and increase liquidity by providing market participants with more reliable reference prices. The US data nevertheless show that, although transparency is a documented factor in liquidity (see [46] and [55]), it will not dramatically improve the situation.

To act upon the liquidity of the corporate bond market, we believe that changes need to be made to trading protocols, which means changing the roles of the various market participants (where possible switching from the current RFQ system to one more similar to an all-to-all CLOB system). Past failures show, however, that this will only be possible through an agreement/consortium between banks and/or asset managers.

A market-wide discussion about bond products themselves would also be advisable, as these products would benefit from being more standardised. This is a source of conflict between primary and secondary market participants regarding which a market-wide policy/communication might be wise.

CONCLUSION

This document about measuring the liquidity of the corporate bond market is a dense document that we hope will be a plentiful source of information about an issue that asset managers and regulators, in the broad sense, have found difficult to discuss.

After presenting the many changes currently taking place in the corporate bond market, we explained the importance of the market's structure when analysing the relevance of liquidity measures. Although many studies have been carried out on the corporate bond market, mainly in the US but also in Europe, these have often merely used traditional liquidity measures, initially designed to measure the liquidity of equity markets, and therefore suffer from a lack of perspective regarding the relevance of these measures.

We then conducted a critical review of the most commonly used liquidity measures and critically analysed most of the liquidity measures based on bid-ask spreads. We also showed that the breadth component of liquidity still needed to be considered. Next we demonstrated, by combining two measures, of the breadth and width components respectively, the fact that recent data send a worrying, but not necessarily alarming, signal for the AMF's supervisory scope, as to the liquidity of the corporate bond market.

We ended by proposing factors explaining the various components of the corporate bond market's liquidity and discussed ways of acting upon it. We hope that the various avenues suggested will provide the regulator with additional ideas and will contribute to positive market-wide action to promote the liquidity of corporate bonds.

[32] Since January 2018, information about transactions has had to be published within 15 minutes of execution, at least in theory. The regulations provide for exemptions, however, which take into account the degree of liquidity of a security, for instance, and permit deferred publication within two days of a transaction. For a bond to be viewed as liquid, it must meet three criteria assessed quarterly based on data declared to the ESMA: an average daily amount of transaction of at least €100,000, at least 80% of trading days, and an average daily number of transactions of at least 15. This last criterion will be gradually reduced to 2. In practice, the number of corporate bonds subject to post-trade transparency obligations was very low in May 2018, amounting to 227 for the whole of the EU, including only 11 for France.

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BIBLIOGRAPHY

[1] Viral V Acharya, Yakov Amihud, and Sreedhar T Bharath. Liquidity risk of corporate bond returns: A conditional approach. 2010.

[2] Viral V Acharya and Lasse Heje Pedersen. Asset pricing with liquidity risk. *Journal of Financial Economics*, 77(2): 375-410, 2005.

[3] Tobias Adrian, Nina Boyarchenko, and Or Shachar. Dealer balance sheets and bond liquidity provision. *Journal of Monetary Economics*, 2017.

[4] Tobias Adrian, Michael Fleming, Or Shachar, Daniel Stackman, and Erik Vogt. Has liquidity risk in the corporate bond market increased? 2015.

[5] Tobias Adrian, Michael Fleming, Or Shachar, and Erik Vogt. Has US corporate bond market liquidity deteriorated? *Liberty Street Economics, Federal Reserve Bank of New York*, 2015.

[6] Tobias Adrian, Michael Fleming, Daniel Stackman, and Erik Vogt. What's driving dealer balance sheet stagnation? 2015.

[7] Tobias Adrian, Michael Fleming, and Erik Vogt. Dealer positioning and expected returns. 2015.

[8] Tobias Adrian, Michael Fleming, Erik Vogt, and Zachary Wojtowicz. Did third avenue's liquidation reduce corporate bond market liquidity? *Liberty Street Economics, Federal Reserve Bank of New York*, 2015.

[9] Tobias Adrian, Michael Fleming, Erik Vogt, and Zachary Wojtowicz. Corporate bond market liquidity redux: More price-based evidence. 2016.

[10] Tobias Adrian, Michael J Fleming, Jonathan E Goldberg, Morgan Lewis, Fabio M Natalucci, and Jason J Wu. Dealer balance sheet capacity and market liquidity during the 2013 sello in xed income markets. 2013.

[11] Tobias Adrian, Michael J Fleming, Or Shachar, and Erik Vogt. Market liquidity after the financial crisis. 2016.

[12] AMF. Le marché obligataire secondaire. 2009.

[13] AMF. Etude sur la liquidité des marchés obligataires français. 2015.

[14] AMF. Les ETF : caractéristiques, état des lieux et analyse des risques - le cas du marché français. 2017.

[15] Yakov Amihud. Illiquidity and stock returns: cross-section and time-series effects. *Journal of Financial markets*,

5(1): 31-56, 2002.

[16] Mike Anderson and René M Stulz. Is post-crisis bond liquidity lower? 2017.

[17] Matteo Aquilina and Felix Suntheim. Liquidity in the UK corporate bond market: evidence from trade data. *The Journal of Fixed Income*, 26(3): 49-62, 2016.

[18] Jack Bao, Maureen O'Hara, and Xing Alex Zhou. The Volcker rule and market-making in times of stress. 2016.

[19] Jack Bao, Jun Pan, and Jiang Wang. The illiquidity of corporate bonds. *The Journal of Finance*, 66(3) :911-946, 2011.

[20] Hendrik Bessembinder, Stacey E Jacobsen, William F Maxwell, and Kumar Venka-taraman. Capital commitment and illiquidity in corporate bonds. 2016.

[21] Bruno Biais and Richard C Green. The microstructure of the bond market in the 20th century. *Tepper School of Business*, 2007.

[22] BIS. Market-making and proprietary trading: Industry trends, drivers and policy implications. 2014.

[23] BIS. Electronic trading in fixed income markets. 2016.

[24] BIS. Fixed income market liquidity. 2016.

[25] BlackRock. Corporate bond market structure: the time for reform is now. 2014.

[26] BlackRock. Addressing market liquidity. 2015.

[27] BlackRock. Bond ETFs: benefits, challenges, opportunities. 2015.

[28] Antoine Bouveret, Peter Breuer, Yingyuan Chen, David Jones, and Tsuyoshi Sasaki. Fragilities in the US treasury market: Lessons from the ash rally of October 15, 2014. 2015.

[29] Markus K Brunnermeier and Lasse Heje Pedersen. Market liquidity and funding liquidity. *The review of Financial studies*, 22(6) :2201-2238, 2008.

[30] Robert Bushman, Anh Le, and Florin Vasvari. Implied bond liquidity. The University of North Carolina at Chapel Hill Working paper, 2010.

[31] George Chacko. Liquidity risk in the corporate bond markets. 2005.

[32] Long Chen, David A Lesmond, and Jason Wei. Corporate yield spreads and bond liquidity. *The Journal of Finance*, 62(1) :119-149, 2007.

[33] Jaewon Choi and Yesol Huh. Customer liquidity provision: Implications for corporate bond transaction costs. 2016.

[34] Tarun Chordia, Richard Roll, and Avanidhar Subrahmanyam. Commonality in liqui-dity. *Journal of Financial economics*, 56(1): 3-28, 2000.

[35] Tarun Chordia, Richard Roll, and Avanidhar Subrahmanyam. Market liquidity and trading activity. *The Journal of Finance*, 56(2) :501-530, 2001.

[36] Carole Comerton-Forde, Terrence Hendershott, Charles M Jones, Pamela C Moulton, and Mark S Seasholes. Time variation in liquidity: The role of market-maker inventories and revenues. *The Journal of Finance*, 65(1): 295-331, 2010.

[37] Shane A Corwin and Paul Schultz. A simple way to estimate bid-ask spreads from daily high and low prices. *The Journal of Finance*, 67(2): 719-760, 2012.

[38] Caitlin Dannhauser. The impact of innovation: Evidence from corporate bond ETFs. 2016.

[39] Frank De Jong and Joost Driessen. Liquidity risk premia in corporate bond markets. 2006.

[40] Jens Dick-Nielsen. Liquidity biases in trace. 2009.

[41] Jens Dick-Nielsen. How to clean enhanced trace data. 2014.

[42] Jens Dick-Nielsen, Peter Feldhütter, and David Lando. Corporate bond liquidity before and after the onset of the subprime crisis. *Journal of Financial Economics*, 103(3): 471-492, 2012.

[43] Jens Dick-Nielsen and Marco Rossi. The cost of immediacy for corporate bonds. 2016.

[44] Chris Downing, Shane Underwood, and Yuhang Xing. Is liquidity risk priced in the corporate bond market. 2005.

[45] Darrell Duffie. Market making under the proposed Volcker rule. 2012.

[46] Amy K Edwards, Lawrence E Harris, and Michael S Piwowar. Corporate bond market transaction costs and transparency. *The Journal of Finance*, 62(3): 1421-1451, 2007.

[47] Zoltan Eisler and Jean-Philippe Bouchaud. Price impact without order book: A study of the OTC credit index market. 2016.

[48] FCA. New evidence on liquidity in UK corporate bond markets. 2017.

[49] Peter Feldhütter. The same bond at different prices : identifying search frictions and selling pressures. *The Review of Financial Studies*, 25(4) :1155-1206, 2011.

[50] Ingo Fender and Ulf Lewrick. Shifting tides-market liquidity and market-making in fixed income instruments. 2015.

[51] Kingsley YL Fong, Craig W Holden, and Charles A Trzcinka. What are the best liquidity proxies for global research? *Review of Finance*, 2017.

[52] Thierry Foucault, Marco Pagano, and Ailsa Röell. Market liquidity: theory, evidence, and policy. *Oxford University Press*, 2013.

[53] Nils Friewald, Rainer Jankowitsch, and Marti G Subrahmanyam. Illiquidity or credit deterioration: A study of liquidity in the US corporate bond market during financial crises. *Journal of Financial Economics*, 105(1): 18-36, 2012.

[54] Itay Goldstein, Hao Jiang, and David T Ng. Investor flows and fragility in corporate bond funds. *Journal of Financial Economics*, 2017.

[55] Michael A Goldstein, Edith S Hotchkiss, and Erik R Sirri. Transparency and liquidity: A controlled experiment on corporate bonds. *The review of financial studies*, 20(2):235-273, 2006.

[56] Ruslan Y Goyenko, Craig W Holden, and Charles A Trzcinka. Do liquidity measures measure liquidity? *Journal of Financial Economics*, 92(2): 153-181, 2009.

[57] TABB Group. Bond liquidity metrics: Reading between the lines. 2017.

[58] Olivier Guéant. The financial mathematics of market liquidity: From optimal execution to market making. *CRC Press*, 2016.

[59] Olivier Guéant. Optimal market making. Applied Mathematical Finance, pages 1-43, 2017.

[60] Olivier Guéant, Charles-Albert Lehalle, and Joaquin Fernandez-Tapia. Dealing with the inventory risk: a solution to the market making problem. *Mathematics and financial economics*, pages 1-31, 2013.

[61] Olivier Guéant and Jiang Pu. Mid-price estimation for European corporate bonds: a particle filtering approach, 2018.

[62] Lawrence Harris. Transaction costs, trade throughs, and riskless principal trading in corporate bond markets. 2015.

[63] Lawrence E Harris and Michael S Piwowar. Secondary trading costs in the municipal bond market. *The Journal of Finance*, 61(3):1361-1397, 2006.

[64] Joel Hasbrouck. Trading costs and returns for us equities: Estimating effective costs from daily data. *The Journal of Finance*, 64(3):1445-1477, 2009.

[65] Stephanie Heck, Dimitri Margaritis, and Aline Muller. Liquidity patterns in the US corporate bond market. 2016.

[66] Marius Loe Heggen and Terje Simarud. A study of corporate bond liquidity. Master's thesis, BI Norwegian Business School, 2016.

[67] Jean Helwege, Jing-Zhi Huang, and Yuan Wang. Liquidity effects in corporate bond spreads. *Journal of Banking & Finance*, 45: 105-116, 2014.

[68] Terrence Hendershott, Dan Li, Dmitry Livdan, and Norman Schürho. Relationship trading in OTC markets. *Swiss Finance Institute, Working Paper*, 2016.

[69] Gwangheon Hong and Arthur Warga. An empirical study of bond market transactions. *Financial Analysts Journal*, 56(2): 32-46, 2000.

[70] Guillaume Horny, Simone Manganelli, and Benoît Mojon. Measuring financial fragmentation in the euro area corporate bond market. 2016.

[71] Patrick Houweling, Albert Mentink, and Ton Vorst. Comparing possible proxies of corporate bond liquidity. *Journal of Banking & Finance*, 29(6): 1331-1358, 2005.

[72] ICMA. The current state and future evolution of the european investment grade corporate bond secondary market: perspectives from the market. 2014.

[73] ICMA. The european credit repo market: The cornerstone of corporate bond market liquidity. 2017.

[74] IMF. Market liquidity - resilient or fleeting. 2015.

[75] IOSCO. Corporate bond markets: A global perspective. 2014.

[76] IOSCO. Examination of liquidity of the secondary corporate bond markets. 2017.

[77] Rainer Jankowitsch, Amrut Nashikkar, and Marti G Subrahmanyam. Price dispersion in OTC markets: A new measure of liquidity. *Journal of Banking & Finance*, 35(2):343-357, 2011.

[78] Madhu Kalimipalli and Subhankar Nayak. Idiosyncratic volatility vs. liquidity? Evidence from the us corporate bond market. *Journal of Financial Intermediation*, 21(2): 217-242, 2012.

[79] Madhu Kalimipalli, Subhankar Nayak, and M Fabricio Perez. Dynamic effects of idiosyncratic volatility and liquidity on corporate bond spreads. *Journal of Banking & Finance*, 37(8): 2969-2990, 2013.

[80] David A Lesmond, Joseph P Ogden, and Charles A Trzcinka. A new estimate of transaction costs. *The Review of Financial Studies*, 12(5) :1113-1141, 1999.

[81] H. Lin, J. Wang, and C. Wu. Liquidity risk and the cross-section of expected corporate bond returns. *Journal of Financial Economics*, 99: 628-650, 2011.

[82] Francis A Longsta, Sanjay Mithal, and Eric Neis. Corporate yield spreads: Default risk or liquidity? New evidence from the credit default swap market. *The Journal of Finance*, 60(5): 2213-2253, 2005.

[83] Sriketan Mahanti, Amrut Nashikkar, Marti Subrahmanyam, George Chacko, and Gaurav Mallik. Latent liquidity: A new measure of liquidity, with an application to corporate bonds. *Journal of Financial Economics*, 88(2):272-298, 2008.

[84] Ben R Marshall, Nhut H Nguyen, and Nuttawat Visaltanachoti. Commodity liquidity measurement and transaction costs. *The Review of Financial Studies*, 25(2) :599-638, 2011.

[85] Massimo Massa and Lei Zhang. Cds and the liquidity provision in the bond market. 2012.

[86] McKinsey & Company. Corporate bond e-trading: Same game, new playing field. 2013.

[87] Bruce Mizrach. Analysis of corporate bond liquidity. *FINRA Research Notes*, 2015.

[88] Alain Monfort and Jean-Paul Renne. Decomposing euro-area sovereign spreads: credit and liquidity risks. Review of Finance, 18(6):2103-2151, 2013.

[89] Maureen O'Hara, Yihui Wang, and Xing Alex Zhou. The execution quality of corporate bonds. 2016.

[90] Lubos Pastor and Robert F Stambaugh. Liquidity risk and expected stock returns. *Journal of Political economy*, 111(3): 642-685, 2003.

[91] Mitchell A Petersen and David Fialkowski. Posted versus effective spreads : Good prices or bad quotes ? *Journal of Financial Economics*, 35(3):269-292, 1994.

[92] PwC. Global Financial markets liquidity study. 2015.

[93] Oliver Randall. Pricing and liquidity in the US corporate bond market. Unpublished working paper. *New York University, New York, NY*, 2013.

[94] RBS. The credit liquidity trap. 2014.

[95] Joint Staff Report. The US treasury market on October 15, 2014. 2015.

[96] Goldman Sachs Global Macro Research. A look at liquidity. *Top of Mind, 37*, 2015.

[97] Richard Roll. A simple implicit measure of the effective bid-ask spread in an e-client market. *The Journal of Finance , 39(4)*: 1127-1139, 1984.

[98] Raphael Schestag, Philipp Schuster, and Marliese Uhrig-Homburg. Measuring liquidity in bond markets. *The Review of Financial Studies, 29(5)*: 1170-1219, 2016.

[99] Paul Schultz. Corporate bond trading costs: A peek behind the curtain. *The Journal of Finance, 56(2)*: 677-698, 2001.

[100] Brian Scott-Quinn and Deyber Cano. European corporate bond trading-the role of the buy-side in pricing and liquidity provision. 2013.

[101] Jonathan S. Sokobin. Remarks at the north american electronic bond trading forum. 2016.

[102] Philip Sommer and Stefano Pasquali. Liquidity - how to capture a multidimensional beast. *The Journal of Trading*, *11(2)*: 21-39, 2016.

[103] Galib Sultan. ETFs and corporate bond liquidity. 2015.

[104] Francesco Trebbi and Kairong Xiao. Regulation and market liquidity. 2015.