Research Report

Liquidity Premium

Literature review of theoretical and empirical evidence

John Hibbert, Axel Kirchner, Gavin Kretzschmar, Alexander McNeil

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barrie+hibbert

Contents

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1 Overview

Introduction

The role of liquidity in determining asset prices is the subject of a vast research literature spanning a period of more than thirty years. The primary purpose of this report is to provide a summary of the main conclusions of researchers albeit with the objective of refining methods for ongoing estimation of the price of liquidity in specific asset markets. Given the volume of research which has been produced on this topic, it is not practical to review every reference in detail so we have concentrated our effort on recognised seminal work, papers that may have practical application or which provide useful insight into market dynamics and very recent research which analyses market behaviour over the past two years.

This price of liquidity – the liquidity premium – and its variability is currently the subject of enormous interest from accountants, actuaries, financial intermediaries and regulators given its role in determining prices, fair (i.e. market consistent) values for known liabilities and its impact on risk capital.

Structure of this paper

The main content of the paper is broken down into three sections. In section 2.1 we review definitions and sources of illiquidity. Section 2.2 summarises the theoretical evidence for liquidity premia and in section 2.3 the empirical evidence is summarised with a particular focus on corporate bond markets. An extensive (although not exhaustive) list of references is provided. The research studies are summarised in Table 2.1 and illustrated graphically in Figure 2.2.

Liquidity

Researchers identify two distinct types of liquidity. Trading liquidity refers to the ease with which an asset can be traded. Funding liquidity concerns the access of traders or firms to funding. We are concerned with the effect of trading liquidity on asset prices. In practice, market and funding liquidity will be linked - particularly during periods of market stress.

Market 'microstructure' theory is concerned with the trading mechanisms and processes of markets and how they affect transaction costs and other characteristics of markets. The quality of a market is judged by reference to three characteristics – tightness (measured by the size of spreads); depth (measured by trade impact); resilience (measured by the speed at which trade impact dissipates). These ideas are important for the purposes of understanding liquidity premia since, as we shall see, one of the primary drivers of liquidity premia are market transaction costs.

The literature identifies and tests the usefulness of various 'proxy' measures of trading costs including dealing spreads, measures of individual trade impact and activity, asset size and asset volatility. All of these turn out to be helpful in quantifying real-world liquidity premia.

Liquidity and asset prices - theory

Asset pricing theory tells us that, in a 'frictionless' market (i.e. where there are no trading costs) two assets with identical cash flows will have the same price. If this were not the case arbitrage profits could be realised. However, financial economists (see for example Amihud et al. [1986, 2005]) discuss pricing models of increasing sophistication in which investors face frictional costs where prices must be adjusted downwards and returns adjusted upwards to compensate investors for bearing illiquidity. They conclude that a liquidity premium may be observed in the pricing of any asset in a market subject to trading costs.

The literature also considers so-called 'clientele effects' whereby different groups of investors have different expected holding periods i.e. they face different probabilities of suffering a 'liquidity shock' which requires them to sell an asset. In the extreme, these investors are characterised as buy-and-hold (with no immediate needs for liquidity) and mark-to-market with a need to trade specified by a simple trading intensity or liquidity policy. The equilibrium that emerges in this class of models shows that investors with the shortest holding periods hold the assets with the lowest trading costs and investors with the longest holding periods hold assets with the highest trading costs. Correspondingly, they show that illiquid assets must offer higher returns relative to more liquid assets. The theoretical research tells us we should expect investors with long horizons to earn liquidity premia by holding relatively illiquid assets.

The (absolute) liquidity premium for a given security (or portfolio) can be thought of as being the price discount or excess return/yield offered by the security relative to some hypothetical, perfectly liquid security with otherwise equivalent characteristics. In practice these absolute liquidity premia are difficult to measure since all assets, with the exception of cash in the reference currency of the investor, are subject to illiquidity in varying degrees.

In practice, researchers choose to define relative liquidity premia as the difference in price between two otherwise identical securities with differing levels of liquidity. At any point in time, different assets and asset portfolios will contain different liquidity premia dependent on their fundamental liquidity characteristics and market conditions. We can think of a family of spreads (or price discounts) for different asset pools exhibiting varying degrees of illiquidity. In practical terms, this means that measures of liquidity premia will therefore be required to reference some benchmark asset pool. Portfolios of corporate bonds exhibit low levels of liquidity relative to government bonds and offer a liquidity premium as a result. However, corporate bonds do offer better liquidity than some financial assets so their associated liquidity premium should be viewed as one point on a wider spectrum of values.

Liquidity and asset prices - evidence

The theoretical literature of is strongly supported by empirical studies showing that illiquid securities are priced at discounts to identical liquid securities irrespective of the time period studied or the methodology used. In other words, hard-to-trade assets sell at a different price to more liquid assets with otherwise equivalent characteristics.

The price of liquidity changes through time. In times of market stress, both the level of illiquidity and the price of liquidity appear to rise. This is consistent with the microstructure theory.

As predicted by the theory on clientele effects (the demand from long-term 'buy-and-hold' investors to hold illiquid assets and earn the liquidity premia), the reward for illiquidity appears to be a decreasing function of transaction cost size.

Corporate bonds

The consensus from the academic literature seems clear: liquidity premia do exist in corporate bond markets. They can be substantial, but vary significantly through time. A number of different approaches have been adopted to quantify the impact of liquidity on corporate bond prices.

- Microstructure approaches provide worthwhile insights into why liquidity premia could and should exist in markets with trading frictions, although they tend not to lend themselves well to empirical estimation.

- 'Direct' approaches (including the CDS approach) involve choosing a pair of assets or asset portfolios which – other than liquidity – are assumed to be equivalent and then comparing prices, expected returns or yields.

- Structural model approaches using the Merton model. These are closely related to the direct method in that a corporate bond is compared to the cost of manufacturing an approximately equivalent synthetic position from a risk-free (liquid bond) and an option on the issuing firm's total assets.

- Regression-based approaches which typically regress one or more measures of asset liquidity and trading costs (whose choice is inspired by the microstructure literature) on observed asset prices or yields. Statistically significant regression coefficients are interpreted as providing an estimate for the 'pure' price of liquidity.

These studies are summarised in paragraph 2.3.1 and the accompanying table and figure.

Estimates for liquidity premia are made at different times and for different points on the illiquidity spectrum and vary between a few basis points in periods of stability for small liquidity differences to hundreds of basis points for highly illiquid assets in times of market distress. See for example Dick-Nielsen et al (2009) who estimate pre- and post- sub prime crisis results for bonds of various ratings.

The liquidity premium appears to rise across credit classes (although this is less clear when researchers control for asset volatility and the higher bid-ask spreads) i.e. lower credits may offer higher liquidity premia because they are simply less liquid.

Note that some analysts have estimated liquidity premia by deducting expected defaults from asset yields. Theory tells us that this does not provide an estimate for liquidity premia since it leaves behind the credit risk premium (compensation for unexpected defaults) so this method should be avoided by practitioners.

Equities

Much of the so-called 'small-cap' effect (the outperformance of small companies' equity over long horizons) is now attributed to their relative illiquidity compared to larger companies. These equity market liquidity premia have been estimated at 3-8% p.a. across different equity markets.

Government bonds & covered bonds

Government bond markets provide a rich information set because researchers are able to compare assets with virtually identical characteristics. The primary focus of researchers has been on US markets where they have estimated liquidity premia in a range of circa10-50 basis points.

Other studies examine the liquidity effect in Japanese treasury markets and Pfandbrief covered bond markets and identify comparable effects on pricing.

Other assets

In addition to stock and fixed income markets, other empirical studies have analysed the liquidity effect across a variety group of asset classes. The results demonstrate that the discount for illiquidity can be substantial, particularly for transitionally leveraged stock, derivatives, real-estate funds, hedge funds and closed-end funds. Further studies reveal illiquidity effects on the value of currency options, interest rate swap contracts and equity index-linked bonds.

Audience

This paper should be of interest to all those concerned with the valuation of assets and liabilities where market prices can be demonstrated, in part, to be determined by liquidity factors. Given the ongoing development of market-consistent, 'fair' valuations, the academic consensus will be of interest to accountants, actuaries, financial intermediaries and regulators.

2 Literature review

A truly vast literature has been generated by researchers over the past 30 years which is concerned with liquidity premia (LP) in asset markets. Given the volume of research which has been produced on this topic, it is not practical to review every reference in detail so we have concentrated our effort on recognised seminal work, papers that may have direct reference to our chosen definitions for LP and reference portfolios (corporate bonds) as well as very recent papers which analyse market behaviour over the past two exceptional years. An extensive list of references is provided, however, it should not be viewed as complete.

In Section 2.1 we summarise literature on liquidity and its sources, including key references from market microstructure theory. The theoretical literature supporting the rationale for liquidity premia in asset prices is the subject of Section 2.2 i.e. in asset markets where frictions (trading costs) exist, how would a financial economist expect asset prices to be affected? Section 2.3 reviews the empirical literature which aims to test these ideas using market data.

2.1 Liquidity

2.1.1 Trading and funding liquidity

Liquidity in finance is generally shorthand for either *trading (market) liquidity* or *funding liquidity*. Following Brunnermeier and Pedersen (2009), we understand these terms as follows:

Trading liquidity: the ease with which an asset can be traded

Funding liquidity: the ease with which a trader or firm can obtain funding.

Illiquidity is of course the opposite, referring to the various frictions and impediments that hamper the trading of assets or the procurement of funding.

Associated with both forms of liquidity is the idea of *liquidity risk*, the harmful consequences of illiquidity. The Bank of England Financial Stability Report (Bank of England (2007)) finds that trading (or market) liquidity risk is present when a trader or firm "cannot easily offset or eliminate a position without significantly affecting the market price." This presupposes that the firm needs to take these actions for some strategic or regulatory reason. If the firm can simply hold on to the position, the liquidity risk, which is a feature of the prevailing market, may not materialise. Funding liquidity risk occurs if "a firm is not able to meet its cash-flow needs."

The present report is concerned with the effect of trading (market) liquidity on asset prices. However, it is worth pointing out that market and funding liquidity are linked, particularly in crises where their interaction can be mutually reinforcing and lead to a liquidity spiral (Brunnermeier and Pedersen (2009); Bank of England (2007)). Firms that have difficulty obtaining funding may have to sell large asset holdings to satisfy cash-flow needs and this in turn can contribute to illiquidity in markets, forcing prices lower, distorting asset valuations on the balance sheet and in turn making funding even more difficult to obtain. Such liquidity spirals affect multiple market participants and contribute to systemic risk across multiple asset classes.

2.1.2 Market microstructure and sources of illiquidity

The discussion of sources of market liquidity enters the realm of *market microstructure theory*, which is concerned with how trading mechanisms affect the price formation process. There is a very extensive literature on this subject; see O'Hara (1995) and Madhavan (2000) for detailed overviews. The microstructure of a market is reflected in three main characteristics of market liquidity as identified by Kyle (1985):

Tightness: measured by the size of bid-ask-spreads;

Depth: measured by the volume of trades possible without affecting current prices;

Resilience: measured by the speed at which the price impact of trade dissipates.

These three dimensions of market liquidity and their relationship to price and to quantity bought or sold are shown diagrammatically in Figure 2.1 (Kerry 2008). This can be interpreted as a typical supply-demand curve with per-unit prices by volume that would have to be paid to acquire assets on the right-hand side and per-unit prices by volume that would be obtained when selling assets on the left-hand side.

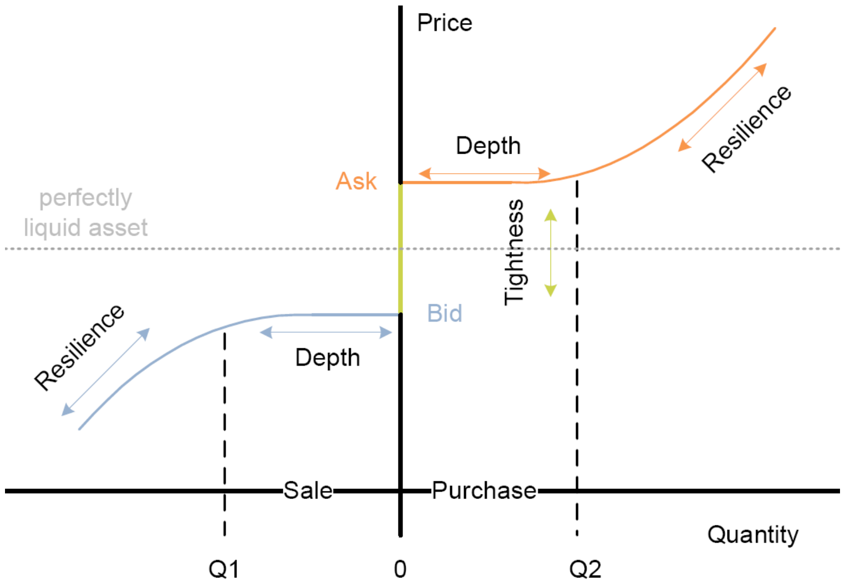


Figure 2.1: Dimensions of market liquidity (an adaptation of Kerry 2008)

Amihud et al. (2005) provide a useful overview of some of the main factors that affect the microstructure of the market and the liquidity of assets. They identify:

Exogenous transaction costs: these are costs incurred by the buyer and/or seller of a security each time it is traded, including brokerage fees, order processing costs and transaction taxes.

Inventory risk: sellers also incur costs when they are forced to sell to market makers because 'natural' buyers of the security are not present in the market at the time of sale; the market maker holds the security in inventory until such time as buyers appear but needs to be compensated for the risk of performing this role.

Private information: in a situation where either the buyer has private information that an investment is likely to appreciate in value or the seller has private information about anticipated asset writedowns, a trading loss will arise for the uninformed counterparty. Dealers must adjust their quoted spreads to protect (on average) against losses incurred on trades with these 'informed' counterparties.

Search friction: when an investor experiences difficulties in finding a counterparty who is willing to execute a trade this may result in him making price concessions he would not make in a perfectly competitive environment where buyers and sellers were immediately available; agents thus face opportunity costs between immediate execution of the deal at a discount and searching for a more attractive deal.

Many authors analyse the liquidity in markets using a microstructure approach. In Treasury markets Amihud and Mendelson (1986) provide evidence that average portfolio risk-adjusted returns increase with their bid-ask spread and that the slope of the return-spread relationship decreases with spread. Gourieroux et al. (1999) propose a microstructure model whose variables are spreads, trading volumes and volatilities to explain periodic fluctuations in market liquidity. Fleming (2003) examines various liquidity measures and argues that yield variation in the absence of public information is due to inventory effects. Brandt and Kavajecz (2004) analyse the Treasury market through the relationship between order-flow liquidity and yields. Their results suggest that 26% of the daily variation in yields can be explained by order-flow imbalances. Cohen and Shin (2003) apply a similar approach and find a significant impact of order-flow imbalance on the treasury security prices.

O'Hara (2003) presents an asymmetric information asset pricing model and argues that current asset pricing theory ignores the existence of information asymmetry in the market. She shows that assets which require access to private information for valuation also require higher equilibrium returns. Conversely, assets which can be valued based on publicly available information are shown to require lower equilibrium returns.

Chordia et al. (2001) analyse U.S. equity markets using daily data on trading activities (effective spreads, market depth and volume and number of daily transactions) over an extended period. They argue that liquidity has a direct link to corporate costs of capital. Analysing Treasury bond and equity markets simultaneously, Chordia et al. (2005) provide evidence of a theoretical linkage between the liquidity in these two markets.

Microstructure theory allows us to conclude that, where market frictions (i.e. trading costs) exist, assets which are more expensive to trade will sell at a discount. This discount, expressed as a liquidity premium, will depend on:

a. The anticipated size of dealing costs

b. The expected dealing intensity of the marginal trader

The demand for liquidity will be influenced by "clientele effects", i.e. the existence of investors with different needs for liquidity. Our expectation is that liquidity effects will manifest themselves in observable proxies. We will also discuss microstructure implications and clientele effects in more detail in the following sections.

2.1.3 Liquidity proxies

The aforementioned studies, and other empirical contributions that we summarise by asset class in Section 2.3, make extensive use of measurable microstructural variables which are associated with differing levels of market liquidity and which we refer to as liquidity proxies. This section contains a non-exhaustive list of variables that have been used as liquidity proxies:

Bid-ask spreads are a standard measure of aggregate liquidity but are not always directly observable in all asset markets. A prominent indirect measure is that of Roll (1984), which is computed to be twice the square root of the negative covariance between adjacent price changes (which tend to be negatively correlated).

Unique roundtrip costs (URC) are another way of measuring bid-ask spreads. The idea is to identify unique roundtrip trades by analysing sets of two or three trades of a given volume on a given day, which are likely to represent the sale and purchase of assets via a dealer, or via two dealers. The ratio $(P_{\max} - P_{\min})/P_{\max}$ is computed where $P_{\max}$ and $P_{\min}$ are the maximum and minimum prices within the unique roundtrip trade

Return-to-volume measures such as the so-called Amihud measure (Amihud and Mendelson 2002), are designed to measure the price impact of trades, i.e. aspects of the depth and resilience shown in Figure 2.1. The ILLIQ measure of Amihud is $|R_t \cdot 100|/v_t$ where R_t is the price return on an asset and v_t is the volume of trading.

Number of zero-return days counts quite literally the number of days on which there is no price change in an asset and thus measures trading intensity. Dick-Nielsen et al. (2009) point out that this measure is really a proxy for "number of zero-trade days". Note that there can be a very significant discrepancies between these counts depending on the choice of data sources.

Turnover which is total trading volume of an asset over some defined period divided by a measure of the amount of the asset in circulation in that period.

Volatility measured by a volatility index such as VIX, is identified to be strongly related to changes in liquidly measures (Bao et al. 2009)

In Kerry (2008) an indicator (or index) of liquidity is constructed by averaging nine measures, six of which are microstructural. They are: three different bid-ask spreads representing the gilt repo market, the US dollar foreign exchange market and average of individual stocks in the FTSE100; three different return-to-volume measures for the gilt market, the stocks of the FTSE and S&P equity options[1].

A comprehensive summary of liquidity proxies in the context of corporate bonds is found in Dick-Nielsen et al. (2009). These authors find the Amihud measure and unique roundtrip costs most useful in explaining bond spreads. The authors point out that these two measures are most consistent and significant. Results hold across multiple credit classes and for data pools capturing 2005-2007 observations (pre sub-prime crisis) and 2007-2008 observations (sub-prime crises) respectively. Furthermore, the variability of the above measures is also consistently significant and helps to capture the varying effects of liquidity with respect to prevailing market conditions. They also make the important point that data are critical to working with microstructural measures and promote the use of actual transaction data such as TRACE (Trade Reporting and Compliance Engine).

2.2 Liquidity and asset valuation

In this section we summarise theoretical literature which explores the link between liquidity, prices and values. The basic question is: what are the arguments to support the idea that liquidity is priced in financial assets? Or, in other words, why might we expect asset prices to offer investors a liquidity premium?

The concept of a liquidity premium is difficult to pin down in an absolute sense, since all assets, with the exception of cash in the reference currency of the investor, are subject to illiquidity in varying degrees. There is no single universal measure of the magnitude of the liquidity premium. At any point in time, different assets and asset portfolios will contain different liquidity premia dependent on their fundamental liquidity characteristics and market conditions. We can think of a family of spreads (or price discounts) for different

[1]The remaining three measures are price-related measures representing liquidity premia.

asset pools exhibiting varying degrees of illiquidity. It therefore seems natural to define ***relative*** liquidity premia.

Relative liquidity premium: the difference in price between two otherwise identical securities with differing levels of liquidity; this is interpreted as the additional compensation offered to the investor who is willing to invest in the less liquid of the two securities.

In practical terms, this means that measures of liquidity premia will therefore be required to reference some benchmark asset pool. In the context of fixed income securities it is much more common to express the relative liquidity premium in terms of the difference in yields between the bonds or, equivalently, the difference in yield spreads over a risk-free rate. Portfolios of corporate bonds exhibit low levels of liquidity relative to government bonds (especially when liquidity may be most needed) and offer a liquidity premium as a result. However, it is worth stressing that corporate bonds do offer better liquidity than some financial assets so their associated liquidity premium should be viewed as one point on a wider spectrum of values, albeit one which is arguably measurable and attainable.

So, any estimate of a liquidity premium should include a clear description of the asset portfolio to which it relates as well as the more liquid asset portfolio or notional perfectly-liquid asset against which it has been estimated.

The (absolute) liquidity premium for a given security could be thought of *abstractly* as being the price discount or excess return/yield offered by the security relative to some *hypothetical*, perfectly liquid security of the same type, although this seems, a priori, much more difficult to measure.

2.2.1 On the existence of a liquidity premium

Asset pricing theory postulates that in a frictionless market, two assets with identical cash flows should have the same price. If this were not the case arbitrage profits could be easily realised. But there is considerable evidence, across a variety of asset classes, that securities with the same cash flows can have different prices; we cite some of this evidence in Section 2.3.

Thus the assumption of frictionless markets is key to standard asset pricing and the empirical evidence forces us to reconsider the "absence of friction" in order to explain pricing anomalies. Amihud et al. (2005) discuss a number of pricing models of increasing sophistication in which the simple premise of frictional costs leads to the implication that prices must be adjusted downwards and returns adjusted upwards to compensate investors for bearing illiquidity. In other words they justify the existence of a liquidity premium in the pricing of any asset in a market subject to frictional costs.

The elaboration of this theory in a competitive equilibrium model with risk neutral agents and exogenous trading costs and trading horizons is found in Amihud and Mendelson (1986). The authors also consider the possibility of ***clientele effects*** whereby different groups of investors have different expected holding periods, modelled by different probabilities of selling up and leaving the market. The equilibrium that emerges in this model shows that the investors with the shortest holding periods hold the assets with the lowest trading costs and the investors with the longest holding periods hold the assets with the highest trading costs; correspondingly they show that the latter assets must offer the best returns and the former assets the lowest returns. In other words, they show how agents with long horizons can earn liquidity premia.

Acharya and Pedersen (2005) consider a model that admits stochastic variation in transaction costs and are able to derive a liquidity-adjusted version of the CAPM model that suggests that returns offer a premium for illiquidity as well as a "beta" that is subject to the uncertainties in transaction costs.

This body of theoretical work strongly supports the proposition that liquidity premia should exist in financial markets for most classes of asset.

2.2.2 Clientele effects and liquidity policies

As discussed by Amihud et al. (2005) clientele effects have a role in determining liquidity premia. Different investors have different investment horizons and differing needs when it comes to the ability to liquidate assets at any point in time. Acerbi and Scandolo (2007) talk of essentially the same thing when they describe investors as having different *liquidity policies*. It is common to stylise investors into two extreme classes: "buy-and-hold" investors and "mark-to-market" investors. Taking corporate bonds as the reference asset these two types can be described as follows.

Buy-and-hold investor: This investor has no need to sell the bond before it matures. Arguably the only risk the investor faces is pure credit risk, which is uncertainty that the bond issuer will default on the promised series of coupon payments or the final repayment of principal. This investor has no need for liquidity and can earn liquidity premia.

Mark-to-market investor: This investor has a shorter time horizon and is primarily interested in the return that could be made over a holding period less than the maturity of the bond. This investor needs the flexibility to liquidate his investment at any time and faces the additional risk (compared to the buy-and-hold investor) that market illiquidity will prevent him doing so on favourable terms.

In practice, the distinction between these two types of investor is less clear cut than described above – while holding the bond to maturity, buy-and-hold investors may still be concerned about mark-to-market volatility as this may effect asset valuations and their capital adequacy requirements.[2]

Nevertheless these distinctions are a useful simplification as they enable us to examine which of these two types of investor effectively sets prices within different asset markets. Here, asset pricing theory suggests that the price of an asset is determined by the "marginal investor". Suppose that the supply of the asset is fixed. Also suppose that all investors determine the price they would be prepared to pay for the asset and how much of the asset they would be prepared to buy at that price. Now arrange these theoretical 'buy orders' in decreasing order of price, and calculate the cumulative order quantity at each price. The marginal investor is then the investor whose order takes the cumulative order quantity up to the available supply of the asset, and the theoretical market price is the price that this investor would be prepared to pay.

Applying this concept to corporate bonds, we can see that the key question is whether or not there are sufficient buy-and-hold investors to take the full supply of assets. If the answer is yes, then the market price need only reflect compensation for credit risk (expected defaults and credit risk premium) and any liquidity premium should be small. If the answer is no, then the market price will be set by the marginal mark-to-market investor and a more significant liquidity premium will exist. Based on this market structure viewpoint it seems clear that liquidity premia should be market-state-dependent, since they are linked to the cost of immediate execution (Amihud and Mendelson 1986).

A novel and interesting approach to the issue of liquidity and value can be found in the work of Acerbi and Scandolo (2007). They establish a formal framework for asset portfolio valuation that seeks to make valuation compatible with two key observations:

1. In the presence of liquidity risk, portfolio valuation is not necessarily a linear operation. If we double the size of a portfolio, we do not necessarily double its value.

2. The concept of value for the portfolio is not fixed until we specify what we want to do with the portfolio, such as liquidate it in whole or in part, or hold all assets to maturity.

[2]It is also worth noting that high volatility in the market price of credit risk (the compensation investors require for taking on credit risk) increases uncertainty in sale price and will also affect the liquidity premium.

Acerbi and Scandolo (2007) distinguish carefully between assets and value; they argue that assets do not have value until they are placed in a portfolio and the intentions of the investor are articulated in terms of a "liquidity policy". The reality of prices in a market are represented by a set of given marginal supply-demand curves (essentially generalisations of Figure 2.1) which give a decreasing price per unit as we try to sell more of the asset. The value of a portfolio under a "liquidation policy" is obtained by integrating over these curves and summing up over different asset positions. Acerbi and Scandolo (2007) suggest that the value of a portfolio under a "buy-and-hold" policy should be obtained by marking long positions to best bid prices and short positions to best ask prices. The discrepancy between the two gives the "cost of liquidation" for the portfolio.[3] Other examples include liquidity policies between the two extremes of total liquidation and buy-and-hold lead to portfolio valuations between the two extremes.

The authors show that this set-up leads to intuitive properties of values, such as an increase in the value of a portfolio as we reduce its granularity and hence improve its liquidity. Also certain criticisms of the theory of coherent risk measures - for example, that coherent risk measures do not acknowledge that a doubling of portfolio positions can create more than a doubling of risk - are shown to be circumvented by allowing for liquidity in valuation.

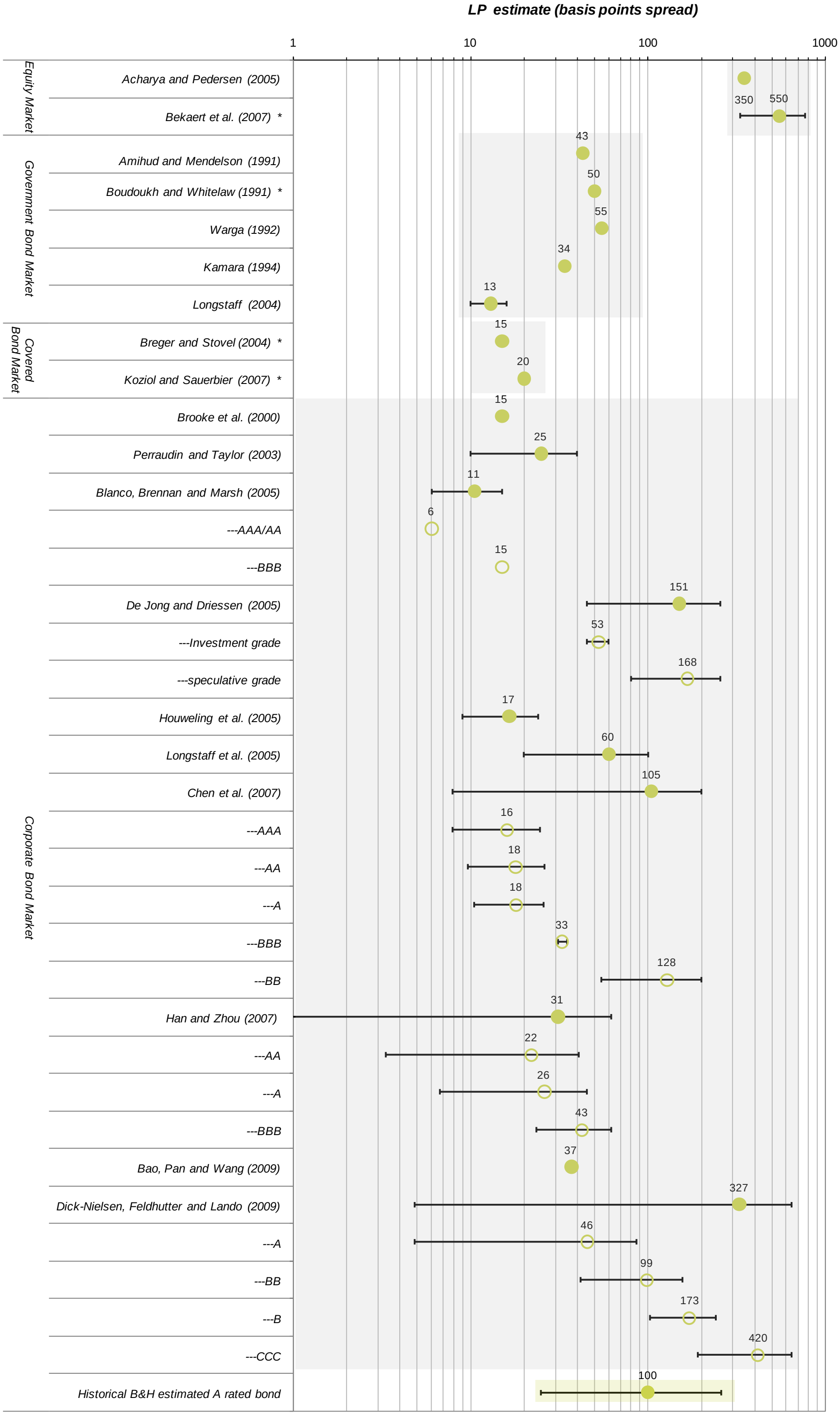
The theory is elegant but the main obstacle to implementing a practical valuation procedure based on it is the need to determine detailed marginal supply-demand curves (related to the curve shown in Figure 2.1) for every traded asset in the portfolio.

2.3 Evidence for liquidity premia by asset class

The theoretical literature of previous sections is strongly supported by empirical studies showing that illiquid securities are priced at discounts to identical liquid securities; in other words, there is strong empirical support for the idea of *relative* liquidity premia. In Section 2.2 we summarised the literature on *theoretical arguments* for the existence of liquidity premia. In this section we summarise *empirical evidence* for their existence in a variety of asset classes. Broadly the literature has evolved from early stage studies that simply sought to identify the existence of liquidity measures. Early studies have more recently been refined by attempts to actually quantify and model liquidity premia. This has been undertaken using either direct (non-modelled), structural or reduced-form econometric approaches with varying degrees of success. The challenge seems to be that of capturing prevailing market conditions.

Our report provides a detailed summary of the vast literature generated over the past 30 years. Given the volume of research generated on this topic, it is not practical to review every reference in detail so we have concentrated our effort on recognised seminal work, papers that may have direct reference to our chosen definition of LP and reference portfolios (corporate bonds) and very topical papers which include coverage of recent market stress events. The majority of studies focus on regression-based tests of association between liquidity proxies and returns on assets or yields on bonds. The following sections summarise key findings in the literature and record pertinent quantitative results. An overview of important research contributions and an illustration of empirical results are presented in Figure 2.2 and Table 2.1. An extensive list of references is provided, however, it should not be viewed as complete.

[3] *This concept is, for example, applied to the calculation of the XETRA Liquidity Measure (XLM).*



*Bekaert et al. (2007) analyse emerging markets, Joudoukh and Whitelaw (1991) study Japanese market data, Breger and Stovel (2004) and Koziol and Sauerbier (2007) analyse the German covered bond market (Euro). All other studies investigate US market data.

Figure 2.2 : Estimates of liquidity premia across multiple asset classes – summary of empirical evidence

Table 2.1 Summary of empirical evidence

Asset class	Literature	Market	Time period	Liquidity measures / proxies	Estimation method	LP estimate	Remarks
Equity (Section 2.3.2)	Pastor and Stambaugh (2003)	US: daily returns of individual stocks on NYSE and AMEX	Jan 1966-Dec 1999	Weighted average of individual stock liquidity measure OLS estimated using market return, individual stock return and dollar volume.	regression analysis to test the liquidity beta	7.50%	The average returns on stocks with high liquidity sensitivities exceed returns for stocks with low sensitivities by 7.5%
	Acharya and Pedersen (2005)	US: daily stock returns from CRSP	Jul 1962-Dec 1999	Liquidity-adjusted version of CAPM model and Amihud (2002) measure of price impact (ratio of return to volume)	regression analysis	3.50%	relative liquidity premium as % of returns
	Bekaert et al. (2007)	Emerging markets: daily returns from 19 markets	Jan 1987-Dec 2003	Zero return and price pressure measures	vector-auto-regression of returns and liquidity	3.33%-7.70%	Geometric annual returns are calculated based on monthly estimations
Government bonds (Section 2.3.3)	Amihud and Mendelson (1991)	US: treasury securities, 6 months bills and notes	Apr 1987 - Nov 1987	Bid-ask spreads and commissions	regression analysis	43bp	
	Boudoukh and Whitelaw (1991)	Japan: Japanese government bonds	Jan 1986- Dec 1987	Yields difference of liquid benchmark bonds and a basket of side issues	direct approach	50bp	
	Warga (1992)	US: "on-the-run" vs. "off-the-run" treasury securities	Oct 1976-Jul 1984	Difference in the variable between "off the run" and "on the run" portfolio average values	regression analysis	55bp	
	Kamara (1994)	US: short-term treasury notes	Jan 1977- Jul 1984	Conditional variance of bill rates, turnover ratio and their product	regression analysis	34bp	
	Fleming (2002)	US: treasury bills bid-ask spreads	Jul 1996 - Dec 2000	Daily trading volume, number of trades and trading size for reopened and new bills	regression analysis		relative liquidity premium for reopened bills is 17% to 28% narrower
	Longstaff (2004)	US: treasury and Refcorp bonds	Apr 1991 - Mar 2001	Yields difference of Treasury and Refcorp bonds	regression analysis	10 to 16bp	10-15% of value of Treasury bond

Asset class	Literature	Market	Time period	Liquidity measures / proxies	Estimation method	LP estimate	Remarks
Corporate bonds (Section 2.3.1)	Brooke et al. (2000)	UK: Bank of England collateral repo rate	Jan 1998- Dec 2000	Turnover, market size and bid-offer spreads	direct approach	15bp	as average (-15 to 60bp)
	Perraudin and Taylor (2003)	US: US dollar-dominated bonds	Apr 1991- Mar 1998	Issue size, age of the issue and relative issue frequency	regression analysis	10-40bp	Portfolio estimate across all ratings
	Blanco, Brennan and Marsh (2005)	US: corporate bond and CDS market	Jan 2001-Jun 2002	Negative basis, difference between CDS and corporate bond spread	regression analysis	6bp 15bp	AAA/AA BBB
	De Jong and Driessen (2005)	US: dollar dominated corporate bonds	Jan 1993-Feb 2002	Amihud (2002) measure of price impact (ratio of return to volume)	regression analysis	45-60bp 80-256bp	Investment grade Speculative grade
	Houweling et al. (2005)	Euro: Euro corporate bonds	Jan 1999- May 2001	Nine indirect liquidity proxies are used (issue amount, listed, on-the run, age etc.)	regression analysis	9-24bp	Portfolio estimate across all ratings
	Longstaff et al. (2005)	US: 5 year corporate bond for 68 firms and CDS	Mar 2001- Oct 2002	Negative basis, difference between CDS and corporate bond spread	direct approach/ regression analysis	20-100bp	Portfolio estimate across all ratings
	Chen et al. (2007)	US: 4000 corporate bonds	Jan 1995-Dec 2003	Lesmond et al. (1999) measure of transaction costs, the occurrence of zero returns and bid-ask spread	regression analysis	8-25bp 10-26bp 11-26bp 31-35bp 54-201bp 59-459bp	AAA AA A BBB BB B
	Han and Zhou(2007)	US: corporate bond prices and CDS through TRACE	Jan 2001 - Apr 2007	Amihud (2002) measure of price impact, Roll (1984) measure, estimated bid-ask spread, roundtrip costs, zero trading days and turnover rate	regression analysis	0.3-32bp 3-41bp 7-45bp 24-62bp	AAA AA A BBB

Asset class	Literature	Market	Time period	Liquidity measures / proxies	Estimation method	LP estimate	Remarks
	Webber (2007)	Euro, US, UK: Corporate bond spreads - Merrill Lynch indices	end 1997/1998 - end 2007	Extended structural Merton-style model to estimate fair credit spread. Liquidity premium is interpreted as the residual spread between fair credit spread and market spread	structural Merton-style model		multiple charts with time series for Euro, UK, US investment grade and high-yield corporate bond spreads
	Bao, Pan and Wang (2009)	US: corporate bonds	Apr 2003-Dec 2008	The negative of auto covariance of prices changes	regression analysis	37bp	Portfolio estimate across all ratings
	Dick-Nielsen, Feldhutter and Lando (2009)	US: corporate bonds through TRACE (Trade Reporting and Compliance Engine)	Jan 2001-Mar 2008	Amihud (2002) measure of price impact, Roll (1984) measure, estimated bid-ask spread and turnover rate	regression analysis / liquidity score	5-87bp 42-157bp 103-243bp 191-649bp	A BB B CCC
Covered bonds (Section 2.3.4)	Breger and Stovel (2004)	Euro: German Pfandbriefe	May 1999 - Aug 2003	Comparisons of illiquid traditional Pfandbriefe to liquid Jumbo Pfandbriefe Effects, analysis of credit and liquidity risk effects on spreads	regression analysis	15bp	for AA rated bonds with low duration
	Koziol and Sauerbier (2007)	Euro: German Pfandbriefe	Jan 2000 - Dec 2001	Estimate term structure of liquidity spread using a ratio of Lookback options on liquid and illiquid instruments	Option theoretical approach	20bp	Sample median, averaged
Other (2.3.5)	Brenner et al.(2001)	Israel: currency options	Apr 1994- Jun 1997	Price differences between options issued in Tel Aviv Stock Exchange and Bank of Israel	regression analysis		price differences 21% lower for liquid options
	Dimson and Hanke (2002)	US: equity index-linked bonds	1980s - 2001	Transaction cost, effective bid-ask spread	regression analysis	2.71%	LP discount factor

2.3.1 Corporate bonds

In recent years many academic studies have explored the evidence for liquidity premia in corporate bond markets and suggested explanations for their observed magnitude. It is worth emphasising that the overwhelming majority of these find evidence for significant liquidity premia in corporate bond markets. As always care must be taken in interpreting the research as the term ***liquidity premium*** is used differently by different authors.

We now focus our attention on the main approaches that have been used in attempts to quantify liquidity premia in corporate bond prices and spreads. A number of approaches to estimation of liquidity premia have been adopted by researchers. They do not fall into neat classifications but we choose to group them as follows:

1. Microstructure approach
2. Direct approach (including CDS approach)
3. Structural model approach
4. Regression-based approach.

Microstructure approach

Microstructure models provide a valuable framework for understanding how the demand to trade (trading intensity) and the market costs of transacting will translate into differences in expected asset returns and yields. The basic idea is that, in the valuation of any security, the marginal investor will take into account the dealing costs expected when the security is sold. The price discount (relative to some notional perfectly liquid security) due to illiquidity is then the discounted value of future expected costs. This discount will depend on the risk-neutral trading intensity of the investor and the cost of trading. Both the demand to trade and the cost of trading will be sensitive to market conditions.

This is an extensive literature which has been developed over more than 30 years. However, the microstructure models do not lend themselves to straightforward empirical tests so they are mainly used to inspire and choose liquidity proxies which are included as explanatory variables for liquidity premia in regression-based estimation studies. Nevertheless, they provide worthwhile insights into why liquidity premia could and should exist in markets with trading frictions.

An example of a microstructure model implementation is described by Koziol and Sauerbier (2007). The authors propose an option theoretical approach which addresses the dimensions of price and time to estimate a liquidity spread. The liquidity spread is explained as the relation between the value of an option for the liquid case and the value of an option for the illiquid case.

Direct approach (including CDS approach)

Several papers have focussed on the difference between the yields on two financial instruments which are considered identical in every respect apart from liquidity i.e. ease and/or cost of purchase or sale.

Direct methods involve choosing a pair of assets or asset portfolios which – other than liquidity – are assumed to be equivalent and then comparing prices, expected returns or yields to infer an LP for the relatively illiquid asset or portfolio. As an example, Dignan (2003) quotes the spread and liquidity variability in credit-risk-free issuers such as the Overseas Private Investment Corporation which is guaranteed by the full faith and credit of the US government.

Duffie (1999) shows by no arbitrage that the spread of the corporate floating rate note (FRN) over the default free FRN should be equal to the CDS premium. In practice, the empirical results show a meaningful negative difference between the CDS premium and the floating spread. This difference is called the negative basis. In their seminal paper, Longstaff et al. (2005) use the negative basis argument to develop a method which isolates the liquidity risk priced into the corporate spreads.

From a general market point of view, CDS contracts are considered to be relatively liquid assets as the outstanding amount written on CDS contracts is not fixed and can flexibly increase accordingly to demand, unlike in the bond market. In principle, this makes CDS contracts ideal for constructing synthetic instruments with exposure to credit risk. For example, CDS contracts are attractive to investors who wish to take short positions in credit risk. Borrowing corporate bonds is considered to be difficult and expensive and CDS contracts offer a liquid alternative. Investors simply need to enter into a new CDS contract on the corresponding reference entity (bond issuer) to receive default protection and effectively be short credit risk.

Longstaff et al. (2005) effectively propose to create a synthetic credit-risk-free corporate bond by buying a CDS on the reference entity. The residual spread is interpreted as a measure of corporate bond liquidity. The authors use two approaches to estimate the size of the default component of corporate bond spreads (and hence the non-default component or liquidity premium). Firstly, they use the credit default swap premium directly as a measure of the (risk-neutral) default component. Secondly, they use a reduced-form model discounting corporate bond cash flows at an adjusted rate that includes a liquidity (or convenience yield) process.

Direct CDS spread based approaches are attractive because of their simplicity. However, this direct measure of the default component is biased as indicated by Duffie and Liou (2001) who illustrate three reasons for this bias.

1. The default probability is obtained in the risk neutral world and investors are risk averse. As a result this tends to overestimate the default component of the bond, especially during a financial turmoil.

2. CDS spread also prices the counterparty risk that the protection seller will default. The protection buyer expects to pay a smaller premium because of this added risk.

3. CDS may also have embedded liquidity risk. This results in a biased measure of the default component and then a bias in the measure of the liquidity premium itself.

To remove these biases from the estimation, Longstaff et al. (2005) propose a model-implied approach. This method tends to average out the bias by using the work of Duffie and Singleton (2003) to price credit default swaps and corporate bonds. In their sample of 68 firms between March 2001 and October 2002 Longstaff et al. (2005) find that on average the default component accounts for 51% of spread relative to treasuries for AAA/AA-rated bonds, 56% for A-rated bonds, 71% for BBB-rated bonds, and 83% for BB-rated bonds. Simultaneously, there is evidence of a significant non-default component for every firm in their sample (of 5 year bonds), of 20-100bp. This non-default component is strongly mean reverting and is strongly related to measures of individual corporate bond illiquidity such as the size of the bid-offer spread and the outstanding principal amount.

Elton et al. (2001) concluded that expected losses are only a small component of spreads, but that the remainder could largely be accounted for by risk premia and differential tax treatment. However, this latter conclusion has been doubted by subsequent researchers who reason that the tax argument would only apply in the US where government bonds, but not corporate bonds, are exempt from state taxes. Berndt et al. (2005) estimate default risk premia from credit default swap rates and Moody's KMV estimated default frequency data. They find a significant (50%) variation in default risk premia over the period 2000-2004.

Structural model approach

A number of authors advocate the use of structural models to extract the liquidity component from corporate bond yields. The development of these theoretical models originates from the Merton (1974) model with the idea that it is possible to derive an estimate of a fair credit spread and to compare this estimate to actual market spreads to infer the liquidity component. Structural approaches using the Merton model are closely related to the direct method in that a corporate bond yield is compared to the cost of manufacturing an approximately equivalent synthetic position from a risk-free (liquid bond) and an option on the issuing firm's total assets. The fair spread on the synthetic bond is obtained by viewing companies' equity as a call option on its total assets where the strike is the value of the debt. As such, it exclusively describes credit risk and excludes liquidity costs. The liquidity premium is then defined as the residual between fair spread and market spread. Many earlier papers simply looked at the expected level of defaults as a credit risk component of the total spread. However, more recent papers also allow for the credit risk premium to account for unexpected losses.

Researchers seek to apply more sophisticated (structural) models, i.e. variants of the Merton (1974) model, in an effort to explain a greater proportion of observed credit spreads.

Most of the literature on structural models considers models in which default barriers are given exogenously. Merton (1974), Black and Cox (1976) and Geske (1977) assume that default is triggered by a positive net worth condition or by a cash flow constraint. The Leland and Toft (1996) model, an extension of the Leland (1994) model, shows an alternate way to derive default. In both models, endogenous conditions are derived under which a company will declare bankruptcy. That is, the default barrier is derived and calculated dependent on several variables with the authors focusing on the optimal capital structure of the firm and corporate bond prices for varying debt maturity. While Leland (1994) assumes debt of infinite maturity, the Leland and Toft (1996) model allows us to choose not only the amount but also the maturity of debt. The authors construct a setting such that the debt structure is consistent with a constant bankruptcy asset level. It is worth noting that, while credit spreads are analysed for arbitrary maturities, liquidity premia are not explicitly mentioned in either paper. The proposed model extensions, however, form an important foundation.

Collin-Dufresne and Goldstein (2001) allow for firms adjusting outstanding debt levels in response to changes in firm value, thus generating some mean reversion in leverage ratios. Their model generates credit spreads that are larger than standard models for low-leverage firms and less sensitive to changes in firm value, both of which are more consistent with empirical findings. Cremers et al. (2004) show the importance of using equity option implied volatilities, including the implied volatility skew, as these implicitly allow for the effects of stochastic volatility and jumps in firm value (relative to the basic Black-Scholes option model).

Webber (2007) proposes a structural model based on Leland and Toft (1996) and demonstrates that credit and illiquidity risk premia both appear to have increased abruptly during the recent financial market turmoil. The model suggests that the compensation corporate bond investors require for bearing expected default losses has increased substantially since mid-2007 - consistent with expectations among market participants of higher corporate default rates.

Ericsson et al. (2005) conclude that the underestimation of bond spreads from structural models may not stem from an inability to properly account for default risk but rather from other factors such as illiquidity, taxes and changing risk premia. Willemann (2004) finds that on average credit risk accounts for 40% of 5 year investment grade bond spreads.

Regression based approach

Many of the empirical studies use regression-based techniques to identify the liquidity proxies that were most strongly associated with higher asset returns or, more particularly in the case of fixed income instruments, with higher yield spreads.

Brooke et al. (2000) discuss differences in liquidity and resulting yields between various short-term money market instruments. They suggest that turnover, market size and bid-offer spreads may provide some indication of differing liquidity conditions. However, these variables are state dependent and may change rapidly. For the period from 1998-2000, Brooke et al. (2000) show that the average spread between the Bank of England two-week repo rate and the two-week general collateral repo rate was 15bp but it was highly volatile (ranging from around 60bp to -15bp).

Perraudin and Taylor (2003) examine the difference in spreads between liquid and illiquid corporate bonds and estimate that relative illiquidity accounts for between 10bp and 40bp of spread. They conclude that for high credit quality debt liquidity spreads are as large (or larger) than risk premiums and much larger than expected losses. De Jong and Driessen (2005) find that lower-rated and longer-maturity corporate bonds have greater exposure to liquidity with an estimated liquidity premium for long-maturity investment grade bonds is around 45 bps. Houweling et al. (2005) look at various possible proxies for assessing the liquidity of corporate bonds and reject the hypothesis that liquidity risk is not priced in a sample set of Euro corporate bonds. Their estimates for the pure liquidity premium vary from 9 to 24bp. Chen et al. (2007) examine the liquidity cost in the US corporate bonds market and find that liquidity has a positive effect on the corporate yield spread for both investment grade and speculative grade bonds. They find that the yield spread increased by 37 bps for investment-grade bonds and 128 bps for speculative bonds when moving from one liquidity cost to a lower liquidity cost group.

Regression analyses can also form the basis of an approach to the quantification of liquidity premia, which might be called reduced-form in that it simply posits a relationship between the liquidity proxies and the size of the liquidity premium. The basic idea is to construct a scorecard from the significant liquidity proxies and to use the predictor of the spread as a measure of the liquidity premium.

A good example of this kind of analysis is Dick-Nielsen et al. (2009) who set up a regression model for panels of quarterly spread data for different bond issues. As well as investigating eight liquidity proxies they control their analyses for factors representing credit risk (operating income to sales, ratio of long term debt to assets, leverage ratio, equity volatility and pre-tax interest coverage) and other important determinants of bond yields, such as bond age, time-to-maturity and size of coupon. A time series of liquidity scores is derived by computing the linear predictor associated with the liquidity proxies. Bonds are then classified by rating, time period (before and after the onset of the sub prime crisis) and maturity. This gives a distribution of liquidity scores within each classification bucket and an average liquidity component is then computed by taking the 50th sample percentile (representing a bond with average liquidity) minus the 5th sample percentile (representing a bond with very high liquidity). This average liquidity component can be thought of as a measure of the typical liquidity premium in each category.

Most studies use simple linear regression in their analyses. It is worth noting that linear models are unable to sufficiently capture non-linear tail dependencies as typically encountered in times of market stress. Dick-Nielsen et al. (2009) also include measures of variability for the explanatory variables of *unique roundtrip costs* and the *Amihud measure* to arrive at a model which robustly captures the prevailing state of the market.

Whilst there is some mixed evidence, the consensus from the academic literature seems clear: liquidity premia do exist in corporate bond markets, can be substantial, but vary significantly through time. Perhaps the most telling evidence for the existence of liquidity premia in corporate bond markets comes from the markets themselves. It is hard to find a market practitioner, whether asset manager, broker or financier, who does not believe that markets price liquidity risk. If this is the case, then almost of necessity liquidity premia will exist. Outside corporate bond markets, investment bankers are able to construct financial instruments which are essentially credit-risk free (being marked-to-market and fully collateralised) but give up liquidity for a positive spread even after all costs. The result seems clear: liquidity is important and those who need it must pay for it.

2.3.2 Equities

Although Black (1971) established four conditions which need to hold for the market in a stock to be considered liquid, systematic empirical studies of liquidity effects in equity markets appear to begin with Amihud and Mendelson (1986). In that paper and in Amihud and Mendelson (1989) it was shown that liquidity is an important factor in asset pricing because expected returns on stocks increase with illiquidity as measured by the bid-ask spread proxy. The estimated liquidity effect was strong, significant and persisted after controlling for systematic risk, size and unsystematic risks. In a separate study of liquidity premia, Amihud and Mendelson (2002) provided further cross-sectional and time-series evidence that excess equity returns at least partly represented an illiquidity premium.

Three market liquidity proxies dominate the literature: bid-ask spread, trading volume and stock turnover. Brennan and Subrahmanyam (1996) estimate liquidity costs from intraday trade and quote data. Their results are consistent with Amihud and Mendelson (1986) and they conclude that liquidity costs have significant positive (and concave) effect on expected stock returns (as predicted by the theoretical work on clientele effects, see Section 2.2.2). Eleswarapu (1997) studies daily data from NASDAQ stocks and tests for the effect of bid-ask spreads, stock betas and logarithm of size on stock returns. Regression results suggest that the relative bid-ask spread is the only significant effect. Loderer and Roth (2005) use relative bid-ask spreads as a measure of liquidity and obtain consistent results. Brennan et al. (1998) use stock trading volume (in USD) as a measure of liquidity and find that volume has a negative and significant effect on risk-adjusted stock returns. Using the same measure of liquidity, Pástor and Stambaugh (2003) find that liquidity appears to be a state variable that is priced in common stocks. Expected stock returns have higher sensitivity to aggregate liquidity; results also suggest that smaller stocks are less liquid in terms of volume. Datar et al. (1998) and Nguyen and Mishra (2005) use stock turnover as a measure of liquidity. The results suggest that stock returns are significantly negatively related to stock turnover. Chordia et al. (2005) investigate liquidity across equity and Treasury bond markets and suggest that strong volatility linkages between stock and bond returns would affect the liquidity in both markets.

There are also a few studies that attempt to quantify the size of the liquidity effect in stocks. Acharya and Pedersen (2005) use a broad model to assess the liquidity premium as required to hold the most illiquid stocks at the level of 3.5%. Bekaert et al. (2007) study the liquidity risk in 19 emerging markets and estimated a local liquidity premium around 85 basis points per month.

2.3.3 Government Bonds

Government bond markets provide a rich information set for studying the existence and resulting quantitative effects of liquidity premia because researchers are able to compare assets with virtually identical characteristics. Amihud and Mendelson (1991) provide evidence of liquidity difference in US treasury securities by analysing the yields between 6 months U.S Treasury bills and notes. The average yield difference between the two securities is 43bps. Kamara (1994) finds an average spread of short-term treasury notes and bills is 34bps. He posits this reflects differences in liquidity, tax treatment and dealer inventories. Warga (1992) finds that recently issued, "on-the-run" Treasury securities have on average 55bps lower returns than "off-the-run" issues, a result suggesting that the greater liquidity of on-the-run issues is positively priced. Similar results are also obtained by Fleming (2002). Krishnamurthi (2002) studies the yield difference between on-the-run and off-the run 30 year bond yields and concludes that the yield difference results from a demand for liquid assets. These findings are consistent with the theory mooted by Duffie et al. (2002) and Vayanos and Weill (2005). Longstaff (2004) finds that the yield differential between zero-coupon Treasury and Resolution Funding Corporation (a government agency) bond yields range from 10 to 16bps. The liquidity premium is larger for long-term bonds, representing around 10%-15% the value of Treasury bond.

Other studies examine the liquidity effect in Japanese treasury market. Boudoukh and Whitelaw (1993) find that the yield difference between the designated benchmark Japanese government bond and similar but less liquid Japanese government bonds averages more than 50bps. Elton and Green (1998) examine the liquidity on Japanese Treasury securities. They find that there is a significant negative difference between low-volume and high-volume bond with similar maturity.

2.3.4 Covered bonds

Covered bonds are often regarded as a good source for the analysis of relative liquidity effects. For covered bonds which are backed with high quality collateral, the expected price effect of credit risk will naturally be very low.

German Pfandbriefe are one of the oldest class of covered bonds and are backed with prime mortgages or loans to the public sector. Pfandbriefe are issued in accordance to the Pfandbrief Act which aims to provide a high level of investor protection: "Financial institutions must satisfy stringent requirements in order to receive a license to issue Pfandbriefe. The Mortgage, Ship and Public Pfandbriefe outstanding must be covered by mortgage, ship mortgage or public-sector loans of at least an equal amount. These cover assets are entered into separate cover registers. In the event of an issuer's insolvency, the claims of the Pfandbrief creditors are privileged by a preferential right in respect of the cover assets in the registers. Pfandbrief business is subject to special supervision by the Federal Financial Supervisory Authority (BaFin). In addition to the ongoing supervision on the basis of the German Banking Act, a Pfandbrief department monitors fulfilment of the provisions set down in the Pfandbrief Act. The obligation to disclose key data concerning the cover pools on a quarterly basis makes the composition of the cover pools transparent and comparable over time. The standardization as a result of the Pfandbrief Act gives the Pfandbrief market, which weighed in at approx. EUR 890 bn as at end December 2007, a depth that is exceeded only by the market for public-sector bonds."[4]

Koziol and Sauerbier (2007) give a comprehensive view on underlying legislation and regulation and highlight the comparability to German government bonds: Following changes in rules and market regulation back in 1995, the *Jumbo Pfandbrief* has since emerged as a standardised and highly liquid covered bond instrument with top notch credit rating and transparent pricing. Compared to traditional Pfandbriefe which comprise of a large number of specialised small and relatively illiquid issues, Jumbo Pfandbriefe are standardised (straight bond format – no embedded options, no prepayment risk) with a minimum issue size of 500million EUR to ensure a high level of liquidity. Jumbo Pfandbriefe continue to attract increasing numbers of investors in global markets, although market participants still regard them to be less liquid than comparable government bonds (Koziol and Sauerbier 2007).

Breger and Stovel (2004) examine the effect of liquidity and credit risk for the German Pfandbrief market. Testing for the effects of liquidity and credit risk between traditional and Jumbo Pfandbriefe, Breger and Stovel (2004) conclude that a liquidity premium of 15bp is observable whereas credit risk effects remain insignificant due to the perceived high levels of credit quality even for AA rated Pfandbriefe.

Koziol and Sauerbier (2007) use examples from the German Jumbo Pfandbrief market and propose an option theoretical approach and use Monte Carlo simulation to estimate a liquidity spread for fixed income assets. In particular, Koziol and Sauerbier (2007) highlight the time dependent nature of a liquidity premium for fixed income assets and find that the simulated *liquidity spread* resembles a humped-shaped function of maturity which increases with interest rate volatility.

Combining cross section and time series analysis, Koziol and Sauerbier (2007) conclude that liquidity explains a large part of the observed spreads while credit risk has little or no explanatory power. Their estimate of a median liquidity spread for AAA rated Jumbo Pfandbriefe, averaged over the sample period from January 2000 to December 2001, is 20pb (with a standard deviation of 11bp).

[4] *Cited freely from "The Pfandbrief – a reliable funding source and a sought-after investment", http://www.pfandbrief.org/d/internet.nsf/tindex/en_basics.htm*

2.3.5 Other asset classes

In addition to stock and fixed income markets, other empirical studies have analysed the liquidity effect across a variety group of asset classes. Longstaff (2001) argues that in reality, investors face liquidity constraints in virtually all financial markets. The results demonstrate that the discount for illiquidity can be substantial, particularly for transitionally leveraged stock, derivatives, real estate and hedge-fund holdings.

Browne et al. (2003) argue that holders of an illiquid annuity demand a liquidity premium, which compensates the inability to continuously rebalance an investment portfolio due to institutionalized constraints. The liquidity is dependent on investors' attitudes toward financial risk, current portfolio holdings and subjective expectations about future investment returns. Manzler (2004) demonstrates that the liquidity of closed-end funds is driven by underlying portfolio liquidity. In option markets, Brenner et al. (2001) examine the illiquidity effect on the value of currency options. The results show that options issued by central banks which are not traded until maturity are priced approximately 21% lower than comparable exchange-traded options on average. Liu et al. (2006) examine how the market prices the default and liquidity risk in interest rate swap contracts using a five-factor affine framework. Results show that the interest rate swap spread is driven by a persistent liquidity process. Dimson and Hanke (2002) analyse the liquidity in equity index-linked bonds by comparing them against the reference equity index. They find that, compared to their underlying value, the prices of these bonds is discounted by around 3%. Chordia et al. (2005) suggest that the strong volatility linkages between stock and bond returns would affect the liquidity in both markets.

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