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WORKING PAPERS

"Working Papers" provides a review of significant working papers in investment management. This section draws from recent research in order to highlight an area of topical interest. In selecting papers pertinent to a prominent topic, "Working Papers" acknowledges current trends in the investment management business, while simultaneously directing the reader to interesting and important recent work.

LIQUIDITY AND BOND MARKETS

Sanjiv R. Das[a,*], *Jan Ericsson*[b], *and Madhu Kalimipalli*[c]

1 Introduction

Liquidity is the ability of a market to absorb a large number of transactions without dramatically affecting price. The absence of liquidity for an asset implies difficulty in converting it into cash, and generally reduces incentives to hold the asset, unless a countervailing premium is offered. Liquidity is to markets as oxygen is to humans—only noticeable by its absence.

Defining liquidity is certainly one of its easiest aspects, though even this is not necessarily easy to do in all markets, or for all instruments. It is much harder to theorize and demonstrate what underlies liquidity, and just as hard to measure it.

In this brief review of extant working papers, we discuss the literature on liquidity in bond markets. Our exposition is broken down into three parts. We begin with a review of papers that provide theories of liquidity, i.e. what underlying mechanics and economics of the markets results in illiquidity, and how these mechanics determine the premiums for liquidity. We then move on to looking at the presence of liquidity in markets that are free of default risk, i.e. the Treasury markets. Finally, we review papers that cover liquidity in credit markets, i.e. the relationship of liquidity with default risk.

2 Theoretical models

Theoretical models of liquidity have been prevalent in the market microstructure literature for almost three decades. However, work aiming at incorporating the impact of market structure and illiquidity on the prices of financial instruments has a much briefer history. Recent papers have strived to

[a]Santa Clara University, Santa Clara, CA, USA.

[b]McGill University.

[c]Wilfred Laurier University.

*Corresponding author.

develop general equilibrium models where liquidity is a determinant of expected returns on assets. For example, Acharya and Pedersen (2003) derive a version of the CAPM where the uncertainty relating to both systematic and idiosyncratic changes in liquidity are incorporated. One result is that investors are prepared to pay more for securities whose returns are negatively correlated to market illiquidity, which is consistent with empirical evidence provided by Pastor and Stambaugh (2001). Although these approaches appear promising, we will now focus in more detail on recent work with a clearer bearing on fixed income markets.

A distinctive feature of most fixed income markets is that trading takes place over-the-counter in an environment dominated by a limited number of dealers. This means that finding a buyer for a given position can be time consuming and risky—often there will be no market maker who is committed to providing liquidity. One interesting approach to modeling this feature of OTC markets can be found in Duffie, Gârleanu, and Pedersen (DGP) (Duffie *et al.,* 2003). They structure the process of buyers meeting sellers as a search and bargaining game. In the simplest version of their model, agents in the economy differ along two dimensions. First, some may incur a cost of holding illiquid assets (low type), whereas others do not (high type).[1] The type of the investor is subject to uncertainty and DGP choose to model it as a two state Markov chain. In addition, only some are endowed with the illiquid asset to start with.[2] When two agents meet, they will trade, if doing so is mutually beneficial, which is the case when owners of the asset who bear holding costs meet high type agents who do not hold the asset.

The equilibrium price is shown to depend in an intuitive way on the parameters of the model. For example, the price will be lower if the probability of a low type agent switching to a high type agent decreases, if it becomes harder to meet buyers with which a profitable trade can be executed, the higher the bargaining power of the buyer, and finally, the more likely it is that the high type buyer becomes subjected to holding costs.

The model is then extended to accommodate risk aversion so that gains from trade derive from hedging benefits. In this more general setting, risk aversion and volatility both contribute to increased illiquidity discounts. By considering risk limits (modeled as a limit on the volatility of agents' holdings), DGP establish a link between volatility and liquidity. If the volatility of the illiquid asset's dividends increases, the market for the asset becomes thinner—more investors will be constrained not to purchase the asset as a result of the risk limits. Thus, volatile markets are characterized by longer expected search periods and thus lower liquidity. This implies that a shock to the volatility of the markets will be exacerbated by risk limits, such as Value-at-Risk, as these restrict the number of willing market participants.

Newman and Rierson (2003) have extended the DGP model to the case of corporate bonds and were able to show that large new issues can lead to decreases in prices across a whole market segment as providers of liquidity need time to search for suitable buyers and bear risk in the process. Empirically, they document substantial price impacts of large telecom issues on already floated issues by other companies (after controlling for credit risk and other factors). For example, the estimated impact of a Euro 16B issue by Deutsche Telekom on a \$2.8 billion British Telecom bond was estimated to exceed 1.5% or \$40 million.

The DGP framework can be extended to study not just the impact of illiquidity on the valuation of securities but also on equilibrium market structure. Vayanos and Wang (VW) (2003) study the concentration of liquidity in some assets when there are apparent, very close substitutes available. Obvious example are on-the-run US Treasury bonds, for which there are many securities with similar exposures to term structure risk and essentially no credit risk available.

In their model, investors can trade two securities that are identical in terms of cash flows. As in DGP, buyers and sellers need to search for suitable counterparties, so there are no dealers and, in particular, no market makers who perform a centralized matching of potential trades. Investors differ in their valuation of the dividend stream that flows from the securities, which in turn is thought of as investors having different horizons. Their valuation is also subject to change over time. The securities trade in two markets which are segmented by assumption: investors only can perform a search in one market.

VW show the existence of an equilibrium market structure which allows different levels of liquidity in the two markets. As a result, the prices in the two markets differ in much the same way as we observe in Treasury markets for similar securities. Intuitively, the resulting equilibrium can be thought of as a clientele effect in the sense that traders with short horizons who require turnover speed will gravitate toward the liquid market and pay the higher price, whereas long-term investors will pay the lower price and accept the longer search times. Furthermore VW show that this outcome would be perfectly desirable. The asymmetric equilibrium with clientele effects is better from a social welfare perspective than a symmetric one where both markets end up being identical. Thus, observing a large discrepancy in price between on-the-run and off-the-run bonds may not be a symptom of an inefficient market and in fact, measures to "harmonize" the market segments could be socially costly.

In another recent paper, Ericsson and Renault (ER) (2003) develop a model for the valuation of illiquid corporate bonds. They construct a partial equilibrium model of a bondholder's decision to unload his holdings either directly as a result of a liquidity shock or in anticipation of future such shocks. In addition to the risk of financial distress, the probability of a forced sale through a liquidity shock is a separate source of risk. As these two factors can be correlated, the model can be thought of as allowing the overall state of the economy to impact both bond market liquidity and the risk of default for individual companies. When considering whether or not to sell, the bondholder faces a random number of offers from interested dealers, of which he retains the best.

Furthermore, the model allows for strategic interaction between the firm's shareholders and creditors in financial distress. After a default, the firm's distressed debt is still traded and bondholders are still subjected to the risk of liquidity shocks. As a result, the linkage between the price impact of default risk and liquidity risk will depend on the way that financial distress is resolved. In the absence of bond illiquidity, creditors and shareholders can renegotiate the terms of debt to avoid a costly liquidation. When illiquidity is added to this framework it can impact the relative bargaining strength of the two parties. If bondholders can press for immediate liquidation of the firm's assets and their bond is illiquid, their threat to do so becomes more credible. The reason is that when faced with the choice of liquidation or accepting a renegotiated debt contract, an illiquidity discount in the market for distressed debt will tilt them in favor of the former.

However, in a more realistic setting which reflects the mechanics of Chapter 11 procedures, the liquidation threat is no longer as strong. The firm will often remain under court supervision for periods of 2 years or more. By an analogous argument, this strengthens the position of shareholders if they can offer bondholders a way of avoiding a prolonged period of court proceedings and illiquid trading, say by an exchange offer. ER show that this generates a positive correlation between the default risk and illiquidity components of bond yield spreads.

In addition to this prediction, the ER model predicts that term structures of liquidity spreads should be downward sloping. This implication and the correlation effect between the two components of yield spreads in the model are tested on two datasets of corporate bonds prices covering the period 1996–2001.[3] Regression analysis uncovers a positive correlation as predicted and provides support for the slope of the term structure. An examination of the period surrounding the Russian default and LTCM crisis illustrates that the effect is stronger still during periods of market turbulence.

The various modeling approaches reviewed in this section offer interesting insights and empirical implications. Nevertheless, much work remains to be done if we want to develop models that can be used in practice to price and hedge liquidity risk. In the next two sections, we will discuss empirical work on liquidity in the fixed income markets. We begin by an overview of results for government securities and end with a discussion of results for securities subject to both default risk and illiquidity.

3 Liquidity and Treasury markets

The secondary market for US Treasury securities is a multiple-dealer OTC market. Trading takes place round the clock with most if it occurring during the New York trading hours. There are 30 primary government securities dealers who constitute the market makers in the Treasury bond market; the inter-dealer broker market accounts for more than 90% of the trading volume and constitutes the core of the US Treasury market. The primary dealers behave as informed investors and in addition to making markets, take positions on their own account. The dealers trade anonymously through six inter-dealer brokers. In contrast to the NYSE or AMEX, the inter-dealer broker market is not subject to market presence or price continuity rules that impose controls on bid–ask spreads and price changes. GovPX.Inc., a joint venture set up by the primary dealers and brokers in 1991, consolidates and provides the intra-day Treasury bond data, which is the source of most of the academic research in this field (for details see: Fleming and Remolona, 1999; Fleming, 2002).

One can think of three types of news shocks to the Treasury markets: intra-day calendar effects, public information effects and GARCH effects. However, unlike stock and corporate bond markets, the Treasury market is driven mainly by public information or macroeconomic news events. This implies that underlying price, liquidity, volume, and volatility dynamics can be primarily traced to inventory control motives of the dealers relative to their asymmetric information concerns.

Liquidity in Treasury markets is estimated in practice using alternative measures such as bid–ask spreads, quote size, trade size, number of trades, price impact coefficients(or Kyle lambda), yield spreads between on-the-run and off-the-run bonds, trading volume, trade, and quote frequency. Chakravarty and Sircar (1999), using bond trading data of insurance companies, show that bid–ask spreads for Treasury bonds are comparable to municipal and corporate bonds after adjusting for credit risk, interest rate risk, and trading activity. Similarly after controlling for bond differences, bid–ask spreads between large and small dealers is found to be not significantly different.

The bond issue size can affect the liquidity in Treasury markets. On the one hand, there is a liquidity effect implying that a larger issue size can lead to lower to higher prices (lower yields). On the other, there is supply effect implying that an increase in issue size can lead to higher yields if the demand curves for individual securities are downward sloping. Fleming (2002) looks at Treasury bond re-openings, where the Treasury sells additional quantities of existing securities, and finds that large issues have higher yields (lower prices) implying that liquidity effects are more than offset by the supply costs. Such liquidity effects are more pronounced when bills are off-the-run and insignificant than when bills are on-the-run. This implies that the borrowing costs for the Treasury can be high sometimes when it issues larger sized debt.

A related issue is the impact of liquidity on the relationship between volume and return volatility in bond markets. Downing and Zhang (2002) examine the OTC municipal bond markets which are less liquid and much less transparent in terms of information on trading activity and issuer specific information compared to equity and currency markets. The authors find a positive relation between number of trades and volatility. After conditioning for number of trades, however, they notice a strong negative relation between trade size and volatility; such a negative relation seems to be mainly evident in the largest quartile of trade size and is in contrast to the evidence of positive relation in more liquid markets. This implies that large size trades most often occur between informed institutional investors and have much less price impact in the markets.

Financial markets can sometimes be marked by flight-to-quality and flight-to-liquidity. An interesting issue is whether there exists a flight-to-liquidity premium in the Treasury bond prices. Previous research indicates that liquidity risk is priced in the Treasury markets; specifically, Treasury bills tend to be more liquid and hence have lower yields than notes of comparable maturity. Longstaff (2002) examines the price differences of zero coupon bonds issued by the US Treasury and the Resolution Funding Corporation (Refcorp). Refcorp bonds are effectively guaranteed by the US Treasury and have the same default-free status as Treasury bonds. Thus, the differences between Treasury and Refcorp bond prices can be attributed to underlying liquidity. The paper finds that yield spreads between Refcorp and Treasury bonds are statistically and economically significant and are directly related to a number of variables such as consumer confidence, equity and money market mutual fund flows, and bond purchases by the Treasury.

Another interesting issue is whether liquidity is correlated across financial markets. Chordia *et al.* (2003) study the common determinants of liquidity in stock and Treasury bond markets. They find that stock and bond market liquidities closely mimic each other in terms of their calendar effects. Volatility shocks seem to predict liquidity movements both within and across markets. Liquidity and volatility shocks are found to be positively and significantly correlated across stock and bond markets implying that the shocks are often systemic in nature. The authors provide evidence of linkages between microstructure liquidity and macro-level liquidity as captured by monetary policy changes and mutual fund flows. Any surprises in bond fund flows are informative in future liquidity for stock and bond markets.

Are the Treasury bond markets segmented based on liquidity? Babbel *et al.* (2003) document market segmentation between two seemingly close substitutes: on-the-run and off-the-run Treasury bonds. The authors construct matched observations of transaction prices in off-the-run securities and corresponding synthetic on-the-run prices. The synthetic securities prices are calculated by discounting the cash flows of the off-the-run bond using spot rates from the on-the-run market at the same instant as the transaction. The on-the-run market is significantly more liquid than the off-the-run market and, therefore, less susceptible to price movements due solely to transaction volume.

Governments often issue securities to serve as benchmarks. Issuing benchmarks, such as sovereign bonds, can be very costly. Sovereign bond issuance can potentially crowd out the market, and hence dry up the liquidity of individual securities. It can increase the total indebtedness of a country, leading to higher default risk premium for all securities. What is the rationale behind using sovereign issues as benchmarks? Yuan (2002) shows that the government can stimulate liquidity by issuing securities to absorb the cost of acquiring systematic information and hence internalize all information externalities. After sovereign issuances, both primary and secondary corporate bond markets become more liquid and information-efficient. Therefore, the government has a role in facilitating the development of financial markets.

4 Liquidity and credit markets

Credit spreads in corporate bond markets are not pure—they reflect mixtures of default risk, liquidity risk, and tax effects, as well as clientele effects that cut across the other three. The recent growth of the credit derivatives market provides greater opportunities to tease out the liquidity effect from the other elements of the spread.

In a recent paper, Longstaff, Mithal, and Neis (LMN) (Longstaff *et al.,* 2002) compare spreads from the credit default swap market with spreads from corporate bonds, and identify tax and liquidity components. There are several useful findings from their work that bear highlighting. First, the premiums extracted from corporate bonds are on average, higher than that extracted from credit default swaps. Second, a regression of bond spreads on coupon rate (a proxy for tax effects) shows the presence of a tax effect.

Corporate bond liquidity effects may arise in different ways, and LMN explore these. First, there is a potential liquidity differential between Treasuries and corporate bonds. This occurs because torrid market conditions cause flights to safety away from corporates into Treasuries, resulting in lower liquidity for corporate bonds. Second, a particular corporate bond may trade at a discount versus comparable corporate bonds in the same class, because it is perceived as being a liquidity risk. The former premium may be extracted by a comparison of corporates to Treasuries, and the latter by comparing single issues with rating class averages. Since these are difficult to tease apart, LMN proceed to examine many different proxies for liquidity such as:

1. The bid–ask spread of comparable bonds from the same class.
2. The standard deviation of the spread. If the bond is illiquid and trades infrequently, then the standard deviation of the spread will be lower. This variable is extracted from all bonds in the same class.
3. The number of bonds in the same class.
4. A measure of Treasury liquidity, i.e. the difference in on- and off-the-run yields.
5. The difference in Treasury zeros and Refcorp bonds, i.e. a measure of the "flight to liquidity."

LMN find that all these proxies come in significantly, suggesting that liquidity effects are significant components of the spread, and may also be bifurcated into Treasury related effects and corporate market effects. In an important by-product of this study, LMN also find that changes in corporate spreads are reflected earlier in the equity and default swap markets. This may imply that illiquidity in the bond market interferes with the impounding of credit related information.

An examination of interest rate swap spreads also leads to extraction of liquidity effects. The paper by Liu, Longstaff, and Mandell (LLM) (Liu *et al.,* 2001) undertakes an empirical study of interest rate swap spreads, and examines their relation to Treasury yields. Swap spreads are especially useful in extracting liquidity components when the related Treasuries trade on special. LLM use a four-factor term structure model to extract credit risk premiums in swap spreads. The framework is rich enough to permit the extraction of default and liquidity components in swap spreads. They find that the four-factor model fits the Treasury and swap curves with very little error. In an affine setting, this enables the extraction of the implied short-term rate, which may then be compared to the actual rate, so as to assess liquidity.

Some useful comparisons are possible to determine liquidity effects, and are undertaken by LLM. First, the fact that, for on-the-run Treasuries, the implied riskless rate is much higher than the observed T-bill rate, implies the presence of a significant liquidity effect, in that short-term Treasuries embed substantial liquidity premiums, with higher prices, and resultant lower yields. Second, the implied riskless rate may be treated as the special repo rate for on-the-run bonds. This facilitates a comparison with repo rates on generic Treasuries. This offers another plausible measure of liquidity premiums, i.e. for the on- versus off-the-run liquidity effect. In both cases, significant liquidity effects are obtained.

Third, using the affine model, and investigating swap spreads, teases out the liquidity factor in spreads, along with the default risk component. LLM find that credit risk forms the major component of the swap spread, but the liquidity component is indeed more volatile. This provides the insight that changes in spreads may be driven primarily by liquidity effects, rather than changes in default risk. Swap spreads widening may thus be interpreted as revealing the changing liquidity of Treasury securities. Since data on these securities is widely available, this may be one simple way to derive an empirical time series of bond market liquidity.

The two papers discussed so far highlight our increasing awareness of liquidity effects in Treasury and corporate bond markets. There is a simple lesson to be learned here—liquidity is not a single effect. Indeed, there are different types of liquidity, depending on what aspect of spreads is looked at. Also, liquidity is a relative effect, derived from a comparison of markets, bonds, or maturities.

The paper by Chen, Lesmond, and Wei (CLW) (Chen *et al.,* 2002) undertakes an empirical study aimed at assessing two important aspects of credit market liquidity: (a) extracting the liquidity component in credit spreads and (b) examining the relationship between liquidity and default risk (the primary remaining component of yields). The liquidity component is found to be mildly correlated with bid–ask spreads on corporate bonds, and liquidity premiums in investment grade bond prices is on the order of $0.15 per $100 (median value, averages are closer to $0.37), which conforms to other estimates in earlier work.

CLW undertake liquidity extraction through the use of a limited dependent variable (LDV) approach, which does not need bid–ask spreads (used in earlier work, which leaves out too many bonds, given a paucity of trades on both sides each day). The approach uses daily close prices only, which reflect liquidity (or the lack thereof) from the incidence of zero returns (recall that the LMN paper also contained a version of this proxy for liquidity). The LDV method is based on the premise that a trade occurs when its information component is sufficient to outweigh liquidity costs, and hence, the absence of trades, reflected in zero returns, provides a measure of liquidity. CLW also extract the maturity related component of liquidity, which is found to be an increase of $0.02 for every additional year of maturity. Liquidity is also a function of bond age, and the amount of the issue outstanding.

It is found counter-intuitively, that lower grade bonds are more liquid than high grade ones, *after* controlling for firm size. However, this need not be that surprising, because a smaller firm would only issue paper conditional on it being sure it would attain a liquidity threshold. Hence, with the appropriate conditioning, this result is a valid depiction of liquidity effects. The paper also confirms that liquidity comprises a secondary, but significant component of spreads, ranging from 20–35% of the total.

While it is intuitive to believe that a positive correlation exists between credit and liquidity risk, this may not always be true. Ye (2001) provides an interesting theoretical model in which the correlation is negative. He proposes a simple valuation model for swaps when bankruptcy risk exists, and shows that even small illiquidity in the resale market for bankrupt swaps can lead to an inverse relationship of credit and liquidity premiums.

Casual inspection of the literature on bond market liquidity shows that there are myriad ways in which the phenomenon has been investigated. The paper by Houweling, Mentink, and Vorst (HMV) (Houweling *et al.*, 2003) provides an excellent collection of measures of liquidity in bond markets. They consider eight different measures in all, and find some to be superior to others. They also show how to control correctly for non-liquidity effects while measuring liquidity. They find liquidity to be 10–24 basis points of total spreads.

HMV applied their technique to a unique set of corporate Euro-bonds. The eight liquidity measures are: (i) issued amount, (ii) coupon, (iii) the fact of listing, (iv) age, (v) missing prices, (vi) price volatility, (vii) number of contributors, and (viii) price dispersion. HMV used five controls for maturity, credit, and currency differences across the bonds. There is strong evidence that liquidity risk is priced in these markets, which offers confirmation of similar results in the US markets. Since the paper uses bond portfolio formation to extract the effects, liquidity is clearly systematically priced. HMV find that price volatility and number of contributors are the most significant explanatory variables for liquidity premiums.

There is an impressive and growing body of research on credit market liquidity. The literature here offers three promising avenues of future research. First, the examination of the flight-to-liquidity as a form of the flight-to-quality is finding acceptance. Second, a better understanding of the correlation between liquidity premiums and default premiums will lead, eventually, to better design of derivative products on liquidity risk, as well as credit risk. Third, the growing evidence of liquidity risk embedded in spreads implies that great care is required in the design of reduced-form models for extracting probabilities of default—to insure that default probabilities do not reflect the often high levels of liquidity risk.

Notes

[1] These costs can arise because the agent needs to hold liquid cash to protect himself against shortages, high financing costs, an undesirable correlation between the asset's returns and his overall portfolio or perhaps for tax reasons.

[2] They also have a portion of their holdings in a liquid risk-free asset.

[3] For 1986–1996, ER rely on monthly dealer quotes and between 1996–2001 the analysis is carried out using transaction data on bond trades by US insurance companies.

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