"Liquidity Risk and Correlation Risk:

Implications for Risk Management"

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1. Introduction

There has been a surge in the recent academic literature on issues concerning liquidity (starting with Amihud and Mendelson, 1986) and liquidity risk (Pastor and Stambaugh, 2003, and Acharya and Pedersen, 2005). While practitioners would perhaps question the relatively late arrival of these topics into academic focus, academics have traditionally preferred to look at the world through the lens of complete, or at least frictionless markets. The limitations of this traditional approach have however become glaringly transparent over the last decade or two in the wake of major financial events in which the ability to trade securities and access capital-market financing declined substantially. The most striking of these events include the stock market crash of 1987 in the United States, the Russian default in 1998, the Long Term Capital Management episode that followed, and, most recently, the aftermath of GM and Ford downgrade. It is thus timely and fitting to examine what we can learn from these events about sources of (il)liquidity and liquidity risk, and their implications for risk management at banks and financial institutions. As a part of this investigation, we will also look at the relation between the developing theory on liquidity risk and the apparently separate literature on correlation risk - the fluctuations over time in the correlation of returns across securities.

A central difficulty with discussing issues relating to liquidity is the lack of consensus on what it means. Liquidity is clearly multi-faceted and perhaps also a somewhat loosely employed economic concept. To capital market participants, liquidity generally refers to transaction costs arising from bid-ask spreads, price impacts, and (limited) market depth for trading in securities. By token, liquidity risk

for these participants generally refers to unpredictable variations in transaction costs. We shall henceforth refer to this notion of liquidity and liquidity risk as pertaining to "market liquidity." In contrast, and often times in addition, risk managers at banks and financial institutions are concerned about liquidity on the funding side, in other words, the ease with which cash shortfalls of the enterprise can be funded through various sources of internal or external financing. We shall refer to this as "funding liquidity" and its unpredictable fluctuations over time as funding liquidity risk.[4]

In this paper, we start by observing that capital and collateral requirements for trading of securities introduce an important linkage between market liquidity and funding liquidity of financial intermediaries. This first step enables us to focus on causes, effects and implications of market liquidity shocks, with the additional consideration that these are also related to funding liquidity shocks: Lack of trading capacity reduces profits of intermediaries, brings them closer to capital or collateral constraints, and further restricts their ability to provide liquidity to markets. Conversely, the collateral value of risky assets falls during periods of illiquidity and restricts the amount of secured funding that intermediaries can raise. While this linkage has been at the centre of some recent theoretical contributions (most notably, Gromb and Vayanos, 2002**,** and Brunnermeier and Pedersen, 2005), we focus on two important aspects that have hitherto received less direct attention in this literature.

First, that liquidity shocks are highly episodic and tend to be preceded by or associated with large and negative asset return shocks, whereby liquidity risk is rendered a particularly non-linear phenomenon. In particular, each of the striking events referred to in the opening paragraph of this Introduction was preceded by a

[4] Note that both these forms of liquidity risk pertain to uncertainty over prices, spreads, and the market depth for instruments in question. The key difference between market liquidity risk and funding liquidity risk can thus be understood as whether one is trying to trade some other entity's instruments or one's own.

significant shock to asset prices. Each of these shocks reduced the net worth of financial intermediaries, and, in turn, led to disproportionately large effects on market liquidity. An implication of this is that prices in capital markets effectively exhibit two "regimes". In the *normal* regime, intermediaries are well-capitalized and liquidity effects are minimal: prices of assets reflect fundamentals and there is no (or little) liquidity effect. In the *illiquidity* regime, intermediaries are close to their capital or collateral constraints and there is "cash-in-the-market" pricing (Allen and Gale, 1994, 1998). Under cash-in-the-market pricing, market price of a security exhibits an illiquidity discount that is declining in the total liquidity of market participants in that particular security market. Thus, prices indirectly reflect the "shadow" cost of capital to these intermediaries, that is, the cost they suffer from issuing an additional unit of funding capital to undertake a transaction, this effect being stronger in markets where financial intermediaries are more likely to be the marginal price-setters (for example, derivatives and complex structured products). .

Second, that this view of prices as consisting of two regimes, in terms of liquidity effects, helps in understanding the characteristics of a seemingly unrelated phenomenon, the risk that correlation of returns across different markets (within a country as well as across countries) fluctuates over time, the so-called "correlation risk". Two characteristics of correlation risk bear a striking relationship to liquidity risk – the fact that correlations in returns of primitive securities (such as stocks and bonds) appear to rise in bear markets relative to bull markets (Longin and Solnik, 2001 and Ang and Chen, 2002), and that implied correlation parameters produced by traditional derivative-pricing models also exhibit such substantial fluctuations.

Our main thesis is that an important component of these fluctuations in correlations is linked to liquidity risk and not to the correlation between cash flows

and discount rates of underlying securities. In the *normal* regime, correlations across asset prices are primarily driven by correlation in fundamentals of the underlying entities or risks. In contrast, in the *illiquidity* regime, prices are also affected by the liquidity position of market participants, and, in turn, by the shadow cost of capital constraints faced by intermediaries. Since this liquidity effect is related to intermediaries' capital rather than to a security's fundamentals, it affects prices of securities traded by these intermediaries across the board, inducing a correlation in securities' market prices that is over and above the one induced by fundamentals. Fluctuations in the capital of intermediaries and its issuance cost cause fluctuations in measured correlations. Since traditional covariance calculations and derivative-pricing models do not allow for such liquidity effects, they cannot isolate correlation risk due to fundamentals from that due to liquidity risk.

To summarize, market liquidity risk, funding liquidity risk, and correlation risk are all inter-twined and related in a non-linear fashion to the same underlying asset return uncertainty. These relationships between different dimensions of liquidity risk, and the seemingly unrelated correlation and asset return risks, have important implications for risk managers and the hedging strategies their institutions employ. We discuss different mechanisms to manage such risks and their relative merits, the main observation being that in the *normal* regime, hedging of correlation risk by model-implied hedging strategies is likely to be successful, whereas in the *illiquidity* regime, model-implied hedging based on underlying risks or securities is unlikely to be effective: in the *illiquidity* regime, hedging of liquidity risk and correlation risk requires holding of liquidity buffers and access to funding sources.

The remainder of the article is organized as follows. In Section 2, we discuss the types of financial intermediaries that play a role in the liquidity effects outlined

above and also describe the nature of funding liquidity risk they face. In Section 3, we establish the relationships between market liquidity risk, funding liquidity risk, and correlation risk, and their origins in negative asset return shocks. In Section 4, we document existing evidence on correlation risk and link it to liquidity-induced price regimes. We provide an illustration of these relationships in Section 5 based on the aftermath of GM and Ford downgrade in the bond market in May 2005. We present in Section 6 implications of this linkage for hedging and risk management at financial institutions. Section 7 concludes.

Parts of this article are based on a paper on this topic by the authors for the Roundtable of the International Financial Risk Institute (IFRI) in September 2005. As a part of that preparation, we asked the Chief Risk Officers of several leading financial institutions, a number of questions concerning correlation risk, liquidity risk, their approach to hedging and the overall scope of risk management. The questions and their responses (an aggregated view) are presented in the Appendix. The themes that emerged from this survey are broadly consistent with the views expressed in this article, and, in turn, have shaped some of our thinking on the issues at hand.

2. Financial Institutions and Funding Liquidity Risk

"With market risk and credit risk, you could lose a fortune. With [funding] liquidity risk, you could lose the bank!" – Bruce McLean Forrest, UBS Group Treasury.

Put simply, funding liquidity risk is the risk that an institution will have to meet uncertain cash requirements in future arising from its day-to-day business activities. From the standpoint of this article, we are primarily interested in funding

liquidity risk faced by financial institutions that make markets in traded financial securities. Within this class, the focus is on those institutions where such trading constitutes a significant (possibly entire) portion of overall activity, for example, brokerage firms, specialist firms, trading desks of large banks, and also hedge funds.

Such institutions face net cash outflows during periods of systematic asset or liquidity shocks (recessions, e.g., the Great Depression, oil-price shocks, e.g., of mid 70's, stock-market crashes, e.g., in the United States in 1987, and real-estate crashes, e.g., in Japan in late 1980's), as well as during periods of idiosyncratic or institution-specific shocks (due to fraud, disclosure of accumulated losses or accounting irregularities, legal settlements, significant model risk, poor risk management and the resulting loss of reputation with capital providers). Some cases of such idiosyncratic shocks are Continental Illinois's collapse in 1989, the Metallegesellschaft meltdown in 1993/94, the Barings disaster in 1995, and to an extent the distress of Long Term Capital Management in 1998 in spite of its pre-existing complex web of borrowing relationships.

During systematic asset or liquidity shocks, there is a net inflow of funds into deposit-bearing institutions (commercial banks), *away* from institutions that rely on market sources of financing. A recent study by Gatev and Strahan (2005) shows that during times of systematic liquidity shocks, there is a "flight to quality" of deposits to commercial banks. The authors measure systematic liquidity shocks by a widening of the (non-financial) commercial-paper to treasury-bill spread; (the so-called "paper-bill spread"). The authors find that when the paper-bill spread widens, commercial banks in the United States experience an increase in deposit inflow.[5] The paper-bill spread is

[5] Furthermore, when the paper-bill spread widens, commercial banks experience a growth in assets, a growth in their commercial and industrial lending, and even a growth in their liquidity buffers: a 25 basis points (bps) increase in the paper-bill spread causes assets of commercial banks to grow at 0.4% weekly rate and their liquidity buffers to grow at 0.17%. Several additional aspects of this evidence are

considered a good proxy for periods when liquidity risk rises, making it difficult for non-deposit bearing institutions to raise financing from capital markets, as evidenced during the Penn Central default in 1970, the LTCM episode in 1998, and recently, the Enron bankruptcy in 2002.

In contrast, though idiosyncratic shocks are not accompanied by market-wide liquidity shocks, these typically result in questions about the affected institution's solvency: the lack of correlated shocks affecting other institutions (in other words, lack of other institutions to "share the blame with") makes it hard to distinguish institutional insolvency and illiquidity. The opaqueness of balance-sheets of financial institutions, for instance, due to the large amount of off-balance-sheet activities and difficult-to-value derivative transactions, aggravates the matter, calling into question the institution's overall management as well as specific risk-management practices. Furthermore, if the affected institution is large, a disorderly liquidation of assets could produce outcomes for the institution that could resemble those in times of market-wide shocks.[6] Finally, idiosyncratic liquidity needs often arise also on an intra-day basis (for example, due to collateral requirements or margin calls on traded securities).

When faced with such shocks (systematic or idiosyncratic), financial institutions can in principle rely on external forms of financing such as equity,

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noteworthy: (1) These effects are observed only for commercial banks and not for finance companies; (2) These effects do not depend on the safety, that is, default risk, of the commercial banks; and (3) Only the levels of deposit liabilities of commercial banks increase and not those of the non-deposit liabilities. These facts put together suggest that the flight of deposits to commercial banks arises due to their access to regulatory deposit insurance.

[6] The distinction between commercial banks and financial institutions is again of importance: While large commercial banks have a too-many-to-fail guarantee, such a guarantee has been witnessed for non-deposit-bearing financial institutions only in case of the LTCM (which also was a Fed-coordinated intervention rather than a government bailout).

subordinated debt, secured debt against collateral, and undrawn lines of credit, and on internal financing in the form of cash and retained earnings.

During times of systematic shocks, public markets such as equities and subordinated debt tend to dry up the first. There is a market-wide decline in the liquidity of securities that firms typically issue to raise capital. During times of idiosyncratic shocks, there is a firm-specific decline in liquidity of capital (for reasons discussed above). The increased risk premium and price impact in such times and the resulting dilution cost implies that public markets are generally not available to affected institutions as funding sources.[7] An important observation is that these funding sources – equity and subordinated debt – are *price-sensitive*.

Since price-sensitive funding sources are rendered too expensive, retained earnings and undrawn lines of credit which represent *price-insensitive* sources of funding (if they were arranged in advance) may constitute the first line of defence against illiquidity. Note however that retaining large quantities of cash (usually in the form of treasuries) entails significant opportunity costs for financial institutions and funding from lines of credit is subject to the material adversity clause (MAC) not being invoked by the lending institution. The affected institution would thus typically have to resort to the second line of defence and undertake at least some form of intermediate financing, such as secured borrowing against collateral.

The extent of collateralized borrowing that can be undertaken by the institution depends upon the market value of the collateral and the size of hair-cuts being charged by counterparties. Hair-cuts represent the percentage of value of an asset that cannot be borrowed against, and as such is another form of illiquidity in funding. Typically, hair-cuts are 2-5% for highly liquid assets such as OECD

[7] Several academic studies, e.g., Choe, Masulis and Nanda (1993), have shown that the price-impacts from equity issuances are greater in recessions than in expansions.

government bonds, 10-25% for highly-rated industrials, and 25-50% for illiquid assets like major-index equities, but are generally higher during liquidity crises. The variation in hair-cuts over time, and, in turn, in collateral values, creates a role for market liquidity in determining the institution's funding liquidity risk. Below, we explain how this effect of market liquidity on the funding liquidity of financial institutions feeds back and further reduces market liquidity, and what causes market liquidity to dry up in the first place.

3. Market Liquidity Risk, Funding Liquidity Risk and Correlation Risk

Recent evidence shows that asset shocks and liquidity shocks tend to be highly correlated, in the aggregate as well as at the level of individual securities. Figure 1 from Acharya and Pedersen (2005) plots the time-series of innovations in stock-market illiquidity computed using *ILLIQ*, the daily price-impact measure of Amihud (2002) over the period 1964-2000, a measure that has been shown by Amihud (2002) to be related to other measures of liquidity such as the bid-ask spread. The Amihud (2002) measure is computed for each stock on a monthly basis as the average of daily ratio of absolute return on the stock to total dollar volume traded. This monthly measure of illiquidity for stocks is equally weighted to obtain a measure of overall stock-market illiquidity. Finally, the time-series of stock-market illiquidity is analyzed using an AR(2) specification and the residuals or the innovations are divided by their standard deviation and plotted in the figure.

Strikingly, liquidity shocks are highly episodic. That is, innovations in market illiquidity are generally small but occasionally quite large. The large innovations in fact coincide with the periods that anecdotally were characterized by liquidity crisis,

for instance, in 5/1970 (Penn Central commercial paper crisis), 11/1973 (oil crisis), 10/1987 (stock market crash), 8/1990 (Iraqi invasion of Kuwait), 4-12/1997 (Asian crisis), and 6–10/1998 (Russian default and Long-Term Capital Management crisis). Many of these episodes coincide with negative asset value shocks, highlighting the correlation of market-wide illiquidity with negative shocks to market-wide returns. The relative size of illiquidity peaks to also illustrates that when illiquidity does rise, it tends to do so suddenly, inducing a non-linear or regime-switching relationship between liquidity shocks and asset return shocks, an observation whose likely roots will be explored further in the discussion that follows.

In particular, Acharya and Pedersen (2005) derive theoretically that there are three covariances or betas that are relevant in asset-pricing from a liquidity risk standpoint: the covariance of security's illiquidity with market-wide illiquidity; the covariance of security's return or price changes with market-wide illiquidity; and, the covariance of security's illiquidity with market-wide return. They find empirically that the episodes associated with large negative return shocks or large illiquidity innovations are the most significant contributors to average values of these liquidity covariances. Furthermore, securities that do exhibit substantial liquidity covariances or betas in the above sense are also more illiquid on average. To emphasize, their evidence suggests that illiquid securities (such as equities) tend to become more illiquid during market-wide asset and liquidity shocks. This is also true for individual stocks within the broad class of equities.[8]

The importance of this result stems from three observations: First, asset shocks and liquidity shocks occur together potentially accentuating the overall impact of asset

[8] For other studies documenting the importance of some of these covariances, see, Chordia, Roll and Subrahmanyam (2000) for commonality in liquidity across securities, Pastor and Stambaugh (2003) for covariance of security returns with market liquidity, and Chordia, Sarkar and Subrahmanyam (2005) for commonality in liquidity across stocks and bonds.

shocks on funding liquidity of institutions – for example, because institutions hurt adversely by asset shocks would be forced to liquidate their positions in illiquid markets; second, when funding liquidity risk rises (due to risk of larger asset shocks), the market value of certain forms of collateral is expected to fall as well; and, third, when funding liquidity risk rises, hair-cuts (or illiquidity discount) on collateral may rise too since funding liquidity risk arises when there is market liquidity risk too. For instance, hair-cuts on AAA-rated commercial mortgages jump from 2% in normal times to 10% during stress times limiting their usefulness as collateral for secured funding.

To summarize, if funding liquidity risk coincides with market liquidity risk and asset return risk (and we argued above that it often will) then it may render an institution and its collateral illiquid. In episodes where asset return and market liquidity shocks are large, funding liquidity may become a concern even on an intra-day basis. If one institution suffers more adversely than others due to differential risk exposure or a compounding of asset shocks with managerial and risk-management issues, then the effect on funding liquidity can be particularly pernicious.

In order to understand the implications of this discussion further, it is useful to step back and ask the question: What causes market liquidity to fall dramatically during times of large negative asset shocks? The explanation has perhaps been best expounded in a recent paper by Brunnermeier and Pedersen (2005) who start from the premise that trading requires capital. Adverse asset shocks reduce the amount of capital available to financial intermediaries. This, in turn, lowers the ability of their trading desks to provide liquidity in the form of narrow bid-ask spreads, smaller price-impacts, and greater depth. As liquidity in the market worsens, trading falls and the short-term cash inflows of these institutions drop too since most of their profits arise

from market-making revenues. This worsening of short-term cash inflows of intermediaries, and, in turn, of their funding ability, limits their liquidity-provision role even further, giving rise to a downward spiral, and a sudden drop in both the funding liquidity of intermediaries and the market liquidity they provide. To summarize, if asset shock is large enough that the capital position of a sufficiently large number of intermediaries is rendered constrained (or close to being constrained), then there may be a *sudden* drying up of both funding and market liquidity.[9]

This link between funding and market liquidity risks implies that prices in capital markets effectively exhibit two "regimes". In the *normal* regime, intermediaries are well-capitalized and liquidity effects are minimal: prices of assets reflect fundamentals and no (or little) liquidity effect. Thus, the correlations across asset prices in these times are also driven primarily by correlation in fundamentals of the underlying entities or risks. In the *illiquidity* regime, intermediaries are close to their financing or capital constraints and prices now reflect the "shadow" cost of capital to these intermediaries, i.e., the cost they suffer from issuing an additional unit of funding capital to undertake a transaction. In economic parlance, there is "cash-in-the-market" pricing (Allen and Gale, 1994,1998) and the liquidity position of market participants in a particular security market affects the price of that security. Since this liquidity effect (the illiquidity discount) is related to intermediaries' capital rather than to fundamentals of the security, it affects prices of securities traded by these intermediaries across the board, inducing a correlation in securities' market prices that is over and above the one induced by fundamentals.

[9] Brunnermeier and Pedersen (2005) report the following instance highlighting the correlation of market and funding liquidity risks. As many as 12 NYSE specialist firms (out of a total of 50 specialist firms at the time) had no buying power whatsoever on October 19, 1987 during the stock-market crash due to lack of capital for posting margins on additional transactions.

In order to explore fully the implications of this view of prices as consisting of regimes differing in the extent of liquidity effects in prices, we document below the existing evidence on correlation risk. Next, we provide a way of understanding this evidence in the light of the regime-shifting view of prices.

4. Correlation Risk

Because it plays a central role in many aspects of financial theory – for example, portfolio theory, asset pricing and risk management – a good deal of attention has been devoted to changes in correlation both over time and under different economic conditions. In this section we document some known facts about how (measured) correlation behaves and suggest that at least some of aspects of this behaviour may be understood in terms of liquidity regimes in prices.

Much of the literature on correlation deals with one of four topics. First, many authors have looked at secular changes in the correlation between asset returns, e.g., between equities in different countries or between equities and bonds. Second, many authors have investigated the claim that the co-movement of prices in different sectors or markets often appears to become more pronounced in financial crises. Third, several studies examine the "fine structure" of correlation and, in particular, "asymmetry", i.e., whether correlation is different in, for example, bull versus bear markets and in periods of growth versus recessions. The fourth strand of this literature concerns measures of correlation that are related to derivative prices. The issue here is the extent to which the correlation parameter in a derivatives model (e.g., for the prices of CDO tranches) is connected with a conventional statistical measure..

Secular Changes in Correlation

Many authors have studied secular changes in financial asset correlations. For example, Kaplanis (1988), Longin and Solnik (1995) and others have studied the evolution of the international correlation between equity returns. Many studies of betas in the early CAPM literature provided evidence on the correlation pattern of individual equities. However, although it is quite possible that some of the observed changes in correlation may be related to changes in liquidity, the time scale of these changes is quite different (and much longer than) the time scale of regime changes caused by asset shocks of concern in this article.

Higher Correlation in Crises

A common feature of many of the financial crises of the last few decades is that problems that appear in one market appear frequently to spread, or least to manifest themselves in other markets. Examples here would include the stock market crash of October 1987 and the 1997 Asian crisis. Indeed, these events are also often described in terms of correlation and it is claimed that the correlation between markets and between assets is 'higher in a crisis'. In contrast to the long-run behaviour of correlation discussed above, it is natural to consider the impact on correlation of changes in liquidity induced by crises.

There are main two explanations of "crisis related" changes in correlation. The first is "contagion" – that captures the idea that the *structure* of the relation between markets is different in a crisis. The alternative view is "interdependence": here the structure of the relation between markets does not change but the world is considered to become, perhaps briefly, riskier.

There is no universally accepted precise definition but a well known paper by Forbes and Rigobon (2002) defines contagion as

> … a significant increase in cross-market linkages after a shock to one country (or group of countries). (Forbes and Rigobon (2002, p2223)).

The term "cross-market linkages" refers to the idea that, after a "crisis" shock to one country (or group of countries), other countries acquire *sensitivity to this shock* that is *not present in non-crisis periods*. In other words, under this definition, the *structure* of dependence is different in a crisis.

It turns out that there are statistical biases that arise in measuring changes in the correlation of returns when the crisis itself is identified by the characteristics of these same returns. For example, if a crisis is identified by the size of returns that are negative and *large*, then estimates of correlation are biased upwards and an adjusted measure must be used. As Forbes and Rigobon (2001) say in a review article that discusses, inter alia, their well-know earlier (1999) paper:

> Results [in Forbes and Rigobon (1999)] are striking. Tests based on the unadjusted correlation coefficients find evidence of contagion in a significant number of countries – about 50 percent of the sample during the Asian crisis and U.S. crash and in about 20 percent of the sample after the Mexican collapse. When the same tests are based on the adjusted correlation coefficients, however, the incidence of contagion falls dramatically – to zero in most cases. An extensive sensitivity analysis evaluates the impact of: adjusting the frequency of returns and lag structure; modifying period definitions; altering the source of contagion; varying the interest rate controls; and utilizing returns denominated in local currency instead of dollars. In each case, the central result does not change (although the exact number of cases of contagion is dependent on the specification estimated.) Forbes and Rigobon conclude that when contagion is defined as a significant increase in cross-market relationships and correlation coefficients are adjusted for heteroscedasticity, there was virtually no contagion during the East Asian crisis, Mexican peso collapse, and U.S. stock market crash.

Thus Forbes and Rigobon reject the hypothesis of contagion in favour of "co-movement", i.e., unusually large changes in a common factor. From the perspective of international economics this distinction is important since policy responses would be

potentially quite different in these two cases. However, for our purposes the distinction is less critical since the correlation is higher in both cases. The hypothesis proposed in this paper is that the increase in co-movement observed in markets around crises is attributable in substantial part to unusually large changes in the *liquidity* factor – the cost of capital faced by financial intermediaries. We support this hypothesis in Section 5 by examining the case of GM and Ford downgrade in May 2005 and the associated increase in co-movement across different asset markets.

Asymmetry in Correlation

The third strand of research on correlation changes asks whether financial risks are the same in downturns and upturns, a question that has attracted attention over many years. For example, there is substantial evidence that equity volatility is higher in downturns (Bekaert and Wu, 2000). More recently, interest in the asymmetry of risk has extended from volatility to correlation where, for a wide range of assets, there is a well-documented tendency for correlation to be larger on the downside than the upside. The possible existence of asymmetric correlation is important and would have implications for, not only risk measurement, but also the effectiveness of hedging and the benefits of diversification.

Ang and Chen (2002), for example, find strong asymmetry in the correlations between the aggregate US market and US stock portfolios sorted by industry classification, size, value and momentum. Longin and Solnik (2001), in an important study of *international* equity returns, calculate the correlation between pairs of national equity markets. In both cases the correlations are computed for return outcomes that lie within given regions, that is, for returns that exceed a given threshold level in *both markets* (“exceedances”).

The results they obtain are striking and their estimates of correlation highly asymmetric, with the correlation for negative exceedances much larger than for positive exceedances.

The central idea advanced in this paper is that large *negative* asset shocks create binding capital or collateral constraints on capital intermediaries – the illiquidity regime – that, in turn, give rise to depressed prices for instruments in which these institutions make markets. Also, factors that affect the extent to which these constraints bind induce excess co-movement of prices in the illiquidity regime relative to the normal regime. A key feature of this mechanism is precisely its asymmetry and so the phenomenon documented by Longin and Solnik (2001) and Ang and Chen (2002) is consistent with our view of liquidity-induced price regimes.

Correlation and Derivatives

Our argument to this point has been that price changes in the illiquidity regime are subject to a common factor - the cost of capital for financially constrained intermediaries. This common factor increases the observed – measurable – correlation between returns. However, another, related feature of the illiquidity regime is that no-arbitrage relations between derivative instruments and the underlying assets, reasonably perfect under normal conditions, become much less precisely met. Because derivatives pricing models are often calibrated to actual prices in terms of a volatility or correlation parameter it means that, even if the model is "correct" in absence of arbitrage, deviations from no-arbitrage pricing will emerge as deviations between actual and implied volatility or correlation.

Not all derivatives depend on correlation but many do. One example is the well-known "quanto" contract where, for example, a quanto forward contract on the

DAX pays a number of US dollars equal to the difference between the level of the DAX (a Euro-denominated price) and the (Euro-denominated) strike price. The value of this contract will depend on the correlation between the DAX (in Euros) and the Euro-US$ FX rate.

A second example is the relation between the implied volatility on options on individual stocks and the implied volatility on a stock index. As the average correlation between individual stocks changes, the relation between the index ISD and individual stock ISDs will also change. Driessen, Maenhout and Vilkov (2005) show that the average implied correlation derived from options on the S&P 100 index and on its individual component stocks (0.47) is systematically higher than observed correlation (0.29). Driessen et. al. account for these differences in terms of a "correlation risk premium".

A third and very important example is the default correlation parameter in the valuation of certain credit derivatives. For example, as the correlation between the default of the different credits underlying a CDO changes, so does the relative pricing of the different CDO tranches. Once again, however, changes in implied correlation in CDOs may reflect not only changes in the perceived correlation of actual default but deviations in the relative pricing of different tranches, as occurred in the case of GM and Ford downgrade.

To sum up, illiquidity shocks may have two distinct but complementary effects on the correlation parameters in derivative pricing. First, the presence of illiquidity shocks may increase the actual, i.e., observed correlation of the underlying instruments. Ignoring such correlation risk (and potentially the associated risk premium) can lead to systematic errors in pricing and hedging based on traditional models. At the same time, in the illiquidity regime deviations from "frictionless" no-

arbitrage conditions may emerge and give rise to deviations between actual and implied correlation.

5. Example: Effect of GM and Ford downgrades on credit markets[10]

Events surrounding the recent GM and Ford downgrades provide a good example of price correlation induced by liquidity effects. On May 5 2005, Standard and Poors downgraded General Motors (GM and GMAC) and Ford (and FMC) to "junk" category and maintained a negative outlook. While the downgrades were to a large extent anticipated by the market, the precise timing was uncertain. What was striking about the downgrade was that it triggered significant changes, not only in the prices of the securities of GM and Ford (Figure 2, Chart 1), and more broadly of the automobile sector, but also in other markets and sectors, for example, the credit-default swaps (CDS) for financial institutions and the mezzanine and equity tranches of collateralized debt obligations (CDOs). These prices moved considerably in the short-run and exhibited at least a partial reversal within a few weeks (Figure 2, Chart 7).

The widening of the CDS premia for financial institutions was particularly striking and illustrates very well induced price correlation between this sector and the auto-sector during this episode. One possible explanation for this surprising outcome is that the downgrades resulted in huge losses to some of the hedge funds (especially through their correlation exposures, as explained below), and the markets were uncertain about the size of exposure that financial institutions, as prime brokers, had

[10] Parts of this section on the effects of GM and Ford downgrade on CDS and CDO markets have been prepared with the help of Ronald Johannes of Bank of England. All errors and attribution of facts represented remain our responsibility, and not of Ronald Johannes.

to these funds. A plausible alternative mechanism focuses on the inventory risk that intermediaries faced in the period following the downgrade announcement. Many institutional investors and funds holding GM and Ford bonds, a very small fraction of global financial securities but not of dollar-denominated and Eurozone corporate debt, [11] were forced to liquidate these securities to comply with regulatory or charter restrictions that prevented them from investing in junk-rated securities. Other investors following index tracking policies, even if permitted to continue to hold Ford and GM bonds, will have sold Ford and GM bonds when these were removed from leading investment grade indices. Even high-yield investors often face restrictions on the maximum exposure to an individual name.

It is likely that the market found it difficult to absorb the large supply of GM and Ford debt and that, at least in the short run, there was a significant increase in the quantity held by financial intermediaries. Since default risk is greater and, perhaps of even more significance, the collateral value (especially when adjusted for hair-cuts) smaller for junk-rated securities, financial intermediaries ended up with significantly risky inventory. Even marking these positions to market was rendered difficult due to the illiquidity resulting from unreliable or out-of-date quotes posted on otherwise reliable price feeds such as those from MarkIt Partners.

On this occasion it appears that, as prices moved from the *normal* regime to the *illiquidity* regime, the inventory risk of these intermediaries, the increased counterparty risk in their prime brokerage operations from exposure to hedge funds and the consequent funding pressure caused CDS spreads on investment banks to increase along with spreads in much of the rest of the credit market. As Figure 2, Chart 7 illustrates, the rise in CDS prices of financial institutions at least partly

[11] One estimate of total US domestic corporate debt in June 2006 was around $5 trillion, so Ford/GM debt would have been 10% of dollar-denominated corporate debt.

reversed in the next few weeks, reflecting the temporary nature of the liquidity impact of the GM and Ford downgrades. This pattern is consistent with the academic literature (e.g., Pastor and Stambaugh, 2003) that in fact uses price reversals to measure market illiquidity.

Next let us consider the effect on the CDO market, specifically on the mezzanine and equity tranches of CDS indexes. A large number of hedge funds and leveraged short-term traders had a *positive correlation* exposure due to being short mezzanine tranches of CDOs (long mezzanine protection) and long the junior or equity tranches (short junior protection). This trade benefits from an increase in the correlation of default exposure of the constituent names of the CDO, but leaves exposure to idiosyncratic default risk of individual names. The GM and Ford downgrades generated losses on these positions and a large number of these players moved out of equity tranches into mezzanine tranches. The liquidity effects and the relative pricing of equity to mezzanine (both spreads widened in absolute terms) implied that the unwinding of positive correlation trades occurred at significant price impacts or fire-sale discounts. This price pressure pushed further down the mark-to-market valuation of positive correlation trades producing a significant swing in relative prices of different CDO tranches. Once again, as seen in Figure 2, Chart 5, this effect was temporary and largely reversed itself within a few weeks. In effect, a part of the swing in implied correlations from CDO pricing models occurred due to illiquidity in the market for CDO tranches affecting prices of these tranches.

This discussion points to a rather important implication of the regime-switching liquidity view of prices. Measuring and interpreting correlation risk through implied correlations from models that do not capture such regime switches can be highly misleading. Although the losses in the correlation trades were described in

terms of changes in correlation, it seems more accurate to recognise that, in the illiquidity regime at least, relative prices deviated from those predicted by standard models. Using such models to parameterise the shift in terms of a change in correlation seems arbitrary. More fundamentally, designing hedging strategies using models that do not reflect the actual reasons for fluctuations in implied correlation can pose a significant "model risk" for banks and financial institutions.

While it is difficult as of yet to build simple models that capture liquidity effects and perhaps even more difficult to calibrate the small body of such models that exist, it is in order to point out that managing the funding liquidity risk (and, in turn, hedging against market liquidity risk) may be necessary and effective in managing liquidity related correlation risk across securities. In contrast, hedges based on traditional models employing underlying securities may not work well during times of market-wide shocks: Indeed, as Tucker (2005) points out, this is a general point that is observed in markets in different guises. During the stock market crash of 1987 many US pension funds were pursing portfolio insurance strategies (footnote: Many of these funds were advised by Leland, O'Brien and Rubinstein) based on delta calculations from the Black-Scholes model. The Black-Scholes model is a model of the *normal* regime when markets are close to being frictionless. In the *illiquidity* regime, delta hedging based on the Black-Scholes model is incorrect since it ignores the price-impact of the dynamic delta hedge on the underlying stock market. The same criticism applies to many similar hedging strategies in the illiquidity regime and, in particular to delta hedging a long position in the equity tranche of a CDO by shorting the mezzanine tranche.[12]

[12] Some of these ideas are reminiscent of those in Grossman (1988) and Grossman and Zhou (1996) who considered the implications of employing Black-Scholes model for an option in a world with frictions wherein the traded option is not exactly identical to its Black-Scholes replicating strategy.

Tucker (2005) expresses the risk management implications of this analysis in a rather succinct manner: “Is the Street and/or the fund community short volatility or gamma or vega in a big way in any particular market (where they are the primary players)?” Knowing the positions of peers in markets where institutional investors are dynamically managing short options positions is the key in many such other settings: In 1994 and 2003, the dynamic hedging of the negative convexity of US mortgage-backed securities amplified the rise in dollar bond yields (in this case the financial sector is structurally short prepayment options), and another case in point is the Constant Proportion Portfolio Insurance (CPPI) strategy sold by hedge funds, where to preserve the nominal principal, the “guarantor” sells units, in say, a fund of funds as its value falls.

To summarize, delta hedges based on *normal* regime models entail significant “model risk” in *illiquidity* times, and, in fact, may amplify price fluctuations. In such times, liquid or “quality” instruments (that is, instruments such as treasuries whose collateral value and tradeability are not adversely affected in illiquid times) may be better than dynamic underlying hedges to weather illiquidity-induced price shocks. Next, we discuss this and the management of liquidity risk more broadly.

6. Management of Funding Liquidity Risk

Since many banks and financial intermediaries regard funding liquidity risk as one of the most critical, its management is often termed as arranging for “life insurance.” The key question in times of funding shortfalls is whether the institution’s funding sources are available or not: What arrangements has the institution made for funding in times of shortfalls? Are there standby lines of credit, and, if yes, will the

counterparty on which lines of credit are drawn be healthy in such times? Are there adequate cash buffers (treasuries and good quality OECD government bonds)? Will the other security holdings of the institution have the required value and liquidity for collateral-based borrowing?

Unfortunately, not much academic literature exists on how financial intermediaries manage liquidity.[13] Nevertheless, it is possible to provide some robust conclusions based on the ideas presented in this paper. The first important dimension we discuss is the role played by bank capital and how it should be employed in liquidity risk management

Is capital a buffer against liquidity risk? The answer to this is yes to some extent, but largely no. On average, capital does increase the ability of large banks and financial institutions to create liquidity. In an important recent contribution, Berger and Bouwman (2005) document that for large banks, a unit of capital enables the bank to hold 2.5 units of net illiquidity.[14] They suggest that capital reduces the risk of failure for the institution by creating a buffer against liquidity risk, and, this in turn, enables the bank to invest more in illiquid assets. However, it is unclear whether capital by itself can serve as a buffer in times of a substantial liquidity shock: Capital sources such as equity and subordinated debt may be rendered illiquid, either because

[13] There is however evidence on liquidity management at commercial banks. Aspachs, Nier and Tiesset (2005) examine the holdings of liquid assets – cash, reverse repos, bills, and commercial paper – for 57 UK-resident banks. They find that liquidity holdings of banks are countercyclical. During economic upturns, measured by high GDP growth rates, bank liquidity buffers are low, whereas during downturns, these buffers grow: all else being equal, a reduction in GDP growth rate by 1% raises the liquidity holdings by around 8%. These effects are stronger for smaller banks that may face greater liquidity risk than larger banks due to limited access to capital markets, and, hence, find it optimal to hold greater precautionary buffers during downturns.

[14] Berger and Bouwman (2005) classify the balance sheet and off-balance sheet activities of banks into Illiquid, Semi-liquid, and Liquid assets and liabilities. Next, they define measures of liquidity creation of the bank by taking a weighted difference between assets and liabilities. They also take account of undrawn lines of credit extended by banks to borrowers and also those arranged by banks for their own use. Next, they relate the extent of bank capital (bank's lagged equity capital ratio) to the bank's measures of liquidity creation in a year. In essence, they ask the question of how much illiquidity does a unit of bank capital enable the bank to hold in its portfolio

the liquidity shock is a systematic one or because the shock is idiosyncratic and raises questions also about the solvency of the institution.

As discussed before, the relevant funding sources in such a situation are bilateral funds (such as lines of credit) and easy-to-collateralize securities. Essentially, capital cannot necessarily perform the *state-contingent liquidity* role that lines of credit can perform and the *unconditional liquidity* role performed by high quality instruments such as Treasuries. This distinction between capital and liquidity in times of liquidity crisis is important, and implies that liquidity risk may in fact represent a distinctive aspect of risk management, over and above other risks to banks (which are typically managed through the provision of economic capital).

This distinction between capital and liquidity is particularly striking for large banks and financial institutions: they are typically well-capitalized, far above the regulatory minimum requirements, and yet are not always sure if this capital will translate into liquidity when needed. One attractive use of capital is thus to employ it to arrange lines of credit and liquidity buffers (holdings of treasuries). If central bank support in the form of lender of last resort is anticipated (implicitly or explicitly) for commercial banks and large financial institutions, or if deposit insurance coverage is substantial, then capital can be parked in the form of standby lines of credit from such banks and financial institutions. The advantage of lines of credit over cash and treasuries is that a unit of capital invested in purchasing lines of credit can create far more liquidity in stress time than a unit of cash and treasuries. Their disadvantage relative to treasuries is that first, there is the risk of the Material Adversity Clause (MAC) being invoked, and second, there is always some counterparty risk when a line of credit is issued by a financial institution rather than by the central bank.

With these suggestions for better employment of capital to manage liquidity risk, we examine some of the operational issues of liquidity-risk management. It is interesting that many banks and financial institutions do consider liquidity risk as a separate source of risk in their risk management. Furthermore, liquidity risk is typically managed by projections of cash flows and funding sources based on stress tests and scenarios (for example, going concern scenario, liquidity squeeze, bank-specific crisis, general market crisis, with additional qualifications based on currency-specific, market-specific, sector-specific, and country-specific risks). Horizons for making these projections seem to vary across institutions: some adopt a one-year horizon recognizing the limitation that positions evolve dynamically, whereas others adopt a one-month or one-week horizon, partly to match the period by which assets may get sold without engaging in disorderly or fire-sale liquidations, and partly to match central bank requirements such as the five-day worth liquidity reserve requirement by Bank of England. Finally, there are contingency plans put in place that detail the specific aspects of coordination across desks, locations, and possibly currencies.

While the specifics of liquidity risk-management process do warrant careful attention, especially for institutions and their risk-management desks, we focus here on a final set of broad observations.

What are the merits of treating liquidity risk as a separate source of risk? As has been central to the themes of this article, liquidity issues are generally preceeded by large negative asset shocks of some sort. This covariance between liquidity risk and asset return risk must thus be taken into account while managing liquidity risk. The difficulty however is that liquidity risk arises only in times of large negative asset shocks, that is, it is highly non-linear in asset return risk. The feedback between

funding and market liquidity risks makes this problem particularly severe from the standpoint of capturing liquidity risk adequately by merely appealing to asset return risk, and recognizing that liquidity risk may be correlated with it.

On the one hand, this discussion implies that liquidity risk *can* be partly hedged by better management of asset return risk. Nevertheless, complete hedging of liquidity risk may be economically infeasible and most likely too expensive. On the other hand, the discussion also implies that liquidity risk does have a "sudden" or a "jump" component to it, which can be managed by some kind of stress or scenario analysis, similar to the current practice at banks and financial institutions.

We believe however that tying the modelling of stress scenarios for liquidity risk to an institution's asset return risk would be fruitful for risk-management desks. A good example is based on correlation risk. As discussed in Sections 4 and 5, correlation risk can arise from illiquidity affecting the prices of a spectrum of securities during stress times. Correlation risk is typically considered a risk at the level of a trading desk. However, when correlations are induced by market illiquidity, correlation risk is most likely to be associated with funding risk at the overall firm level. If funding risk and correlation risk are positively correlated (depending on whether the institution is long or short correlation), stress scenarios may be more adverse than anticipated based on funding risk alone. By the same token, if funding risk and correlation risk are negatively correlated, not modelling this association would lead to over-hedging in the form of excessively large cash or buffers of quality collateral.

A final observation regarding liquidity risk management is in order. The recent literature, specifically, Caballero and Krishnamurthy (Working Paper, 2005) has attributed "Knightian uncertainty", put simply economic behaviour that takes

decisions to minimize the worst-case scenario for an objective function, as being at the root of flights of capital and liquidity observed in the markets. Their premise is that institutions and fund-managers exhibit the usual risk-averse behaviour in markets they understand well, but have “ambiguity aversion” towards investments in markets they do not regularly participate in. During crisis times, this leads to restricted flows of capital across markets. This also leads to flight to quality in crisis times as uncertainty about underlying fundamentals of some markets increases. Scenario-based stress tests and resulting liquidity risk management resemble to some degree behaviour that would be observed under Knightian uncertainty preferences. One wonders whether there is a feedback at a general equilibrium level of how institutions manage liquidity risk to how liquidity flows in times of stress, but that is a much deeper question beyond the scope of this article.

7. Concluding Remarks

In this article, we have attempted to provide a conceptual link between liquidity risk and correlation risk, and the implications of this link for risk management at financial institutions. At the heart of our ideas has been the notion that large negative asset shocks lower the net worth of financial intermediaries and bring them closer to capital or collateral constraints they face. These constraints arise in equilibrium as a market response to more fundamental adverse selection and moral hazard problems, or simply due to regulatory requirements. Understanding the micro-foundations of liquidity risk and correlation risk thus necessarily requires a closer scrutiny of the specific institutions that give rise to these constraints.

Another important consideration is what prevents “outside” capital (e.g., pension funds, insurance funds, etc.) from entering a market when there is an illiquidity discount in this market. One possibility is that the same underlying friction that renders a financial intermediary illiquid also prevents this capital from investing in the market: imperfect information about insolvency and about illiquidity of the intermediary may ultimately stem from opaqueness of its balance-sheet. A second possibility is that there may be limited expertise in outside capital providers at owning the assets being sold at discounts. And third, there may simply be reasons relating to regulatory frictions and marketing styles that entrench the heterogeneity in investment patterns of different institutions. Interestingly, under either of these three possibilities, one would expect liquidity effects central to this article to be of greater relevance and magnitude for markets such as derivatives and structured products where sophisticated financial intermediaries are the marginal price-setters. In contrast, markets such as equities that enjoy substantial retail investments and flows may be less vulnerable to such effects.

These observations lead to the counterintuitive conclusion that with the increase in degree of financial intermediation and its sophistication, liquidity risk in capital markets may have in fact increased, and episodic liquidity crises increased in frequency, a conclusion that many would find consistent with observed outcomes over the past decade.

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Appendix: Results of CRO Survey

This Appendix contains the results of a survey of Chief Risk Officers (CROs) conducted as part of the preparation of an earlier paper on this topic by the authors, "Understanding and Managing Correlation Risk and Liquidity Risk", commissioned by the International Financial Risk Institute (IFRI) and presented at the IFRI Roundtable on September 29-30 2005. Part A of this Appendix contains the questions we circulated to member CROs and Part B their (summarised) responses. Since this article focuses on correlation risk, liquidity risk, and their management, we have restricted our summary of the survey to these topics.

A. Questions

The questions asked of the risk officers and members of IFRI were as follows.

1. *Correlation*: Do you consider changes in the degree of correlation between markets as a major risk management issue? If so, (i) do you consider this to be a problem only in times of market stress or do you think that there is a trend towards higher correlation as markets become more integrated? Has your firm carried out formal analysis in this area? If so, with what results? What changes to its risk management procedures has your firm adopted (or is planning to adopt) to address this problem?

2. *Liquidity Risk*.

   Does your firm consider changes in funding liquidity to be a major risk factor? If so, how would you characterise the most important aspects of funding liquidity risk? Do you have a view on the mechanism that creates liquidity

crises? Do you think that financial regulation, in particular, capital adequacy regulation, makes liquidity crises more or less likely?

3. *Liquidity Management*. Does your firm's risk assessment system take liquidity risk into account explicitly and, if so, how? In particular, is liquidity risk accounted for at the level of individual contracts, a trading desk or at the level of the enterprise? Does your firm have a policy for the management of liquidity risk? If so, please describe both the policy and how the management of liquidity is co-ordinated across the firm?

4. *Static versus Dynamic Hedges*. In those cases where managing the risk of a position requires dynamic adjustment over time (probably the majority of cases), how important are the problems created by: (i) hedging costs, (ii) model risk, and (iii) changes in liquidity? If your answer depends on the context, please give examples.

B. Responses

We received around twelve sets of answers to these questions and summarize below what we considered as the most salient responses.

1. **Correlation:** There is overall consensus that changes in correlation are a matter of concern for risk management. Several features of correlation risk were mentioned:
    - Increasing globalisation of markets has produced a trend in correlation (increasing over time across markets and products), creating a challenge for risk management of newer products such as Collateralized Debt Obligations (CDOs).
    - Increases in correlation reduce the benefits of diversification.

- Correlations seem to be higher in times of market stress. At least some responses mention the cause for this as the significant withdrawal of capital and liquidity from specific capital markets.

2. **Correlation risk management:** There is mixed feedback on whether there is institutional response to correlation changes:
    - Most responses mentioned the use of correlations (high as well as low) from stress periods (market crash, flight to quality events) in stress tests, and some mentioned deploying this for economic capital calculations as well. The stress tests are primarily employed for the trading book correlations, but some also mention the banking (credit) book correlations.
    - There is mention in some cases of the risk of "over-modelling" correlation, especially the fact that statistical correlations may be intrinsically different from implied model-based correlations: the latter may simply reflect a model's calibration bias when it does not account for shifts in statistical correlations. The lack of clarity on what is the real correlation risk was cited by some as the reason for not engaging in an elaborate institutional response to it.
    - It is recognized that an important problem in managing correlation risk is one of deciding the relevant time horizon for assessing the impact of a change in correlation. Though one year is typically the risk horizon, this is problematic for positions that evolve dynamically and at different pace (e.g., new and growing credit portfolios).
    - There were also some banks and institutions which said that correlation changes were not a major risk-management issue because they relate

mainly to market risks and the latter form only small part of overall risk (in particular, market risk is small relative to the total size of credit risk).

3. **Liquidity risk:** There is consensus that **funding liquidity-risk** is important but there are opposite views on when it matters:
    - View # 1: only in times of **market-wide** (country or global) crisis of confidence
    - View # 2: only at times of crisis affecting **own institution**
    - View #3: both market-wide as well as idiosyncratic crisis, especially if the institution is in a banking sector with very few players.

Most institutions seem to consider that in times of crisis, capital and liquidity are not the same in the sense of ability to access short-term funding. Also, liquidity risk was seen to be a bigger concern for institutions relying more on short-term and capital-market funding.

4. **Management of liquidity risk:** A distinction was pointed out between the management of:
    - Impact of changes in market liquidity in traded instruments ("market liquidity"), and
    - Access to short-term funding ("funding liquidity")
    - The management of market liquidity is generally performed at the level of individual trading desks, whereas the management of funding liquidity risk is performed at the firm level.
    - As with correlation risk, the management of funding liquidity risk also employs stress scenarios and contingency plans.
    - The approach to managing funding liquidity appears in almost all cases to be carried out using projections of inflows / outflows and net liquidity

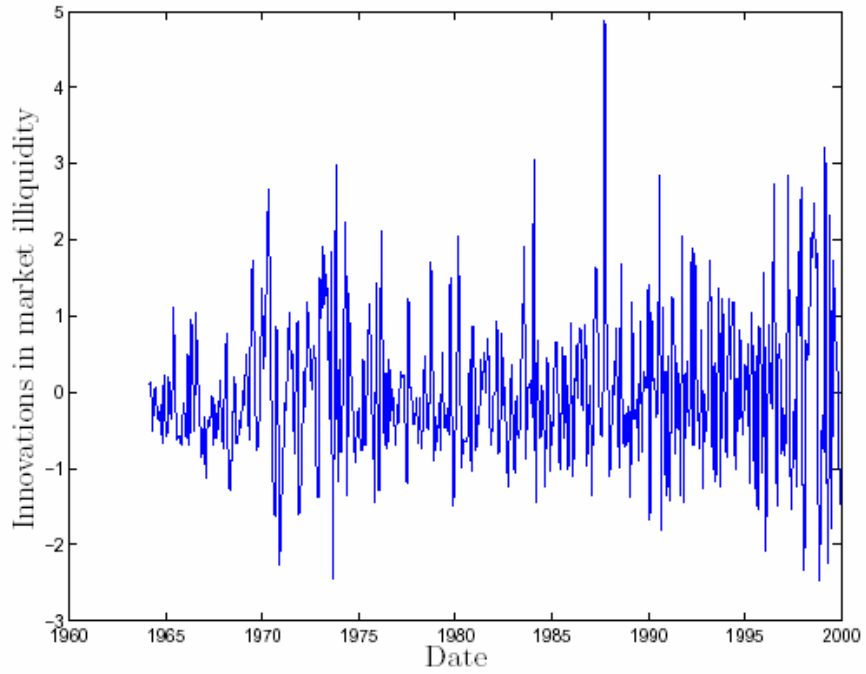
needs. These methods – as we understand them – do not seem to address in a modelled or statistical fashion the uncertainty in future liquidity needs / access.

Finally, both internal and external funding of liquidity needs is considered important, with the following important differences:

- The issue about the source of funding is not just about availability but also about price. In particular, cash and bilateral commitments for secured borrowing are generally price insensitive, and thus, preferred to unsecured wholesale funding at time of liquidity needs.

Figure 1

Source: Acharya and Pedersen (2005)

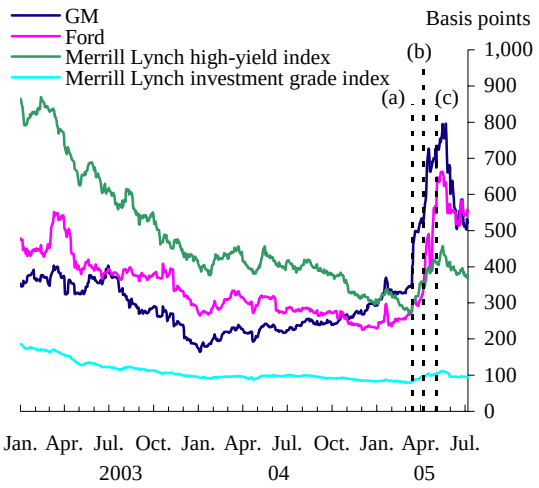


Standardized innovations in market illiquidity from 1964–1999.

Figure 2

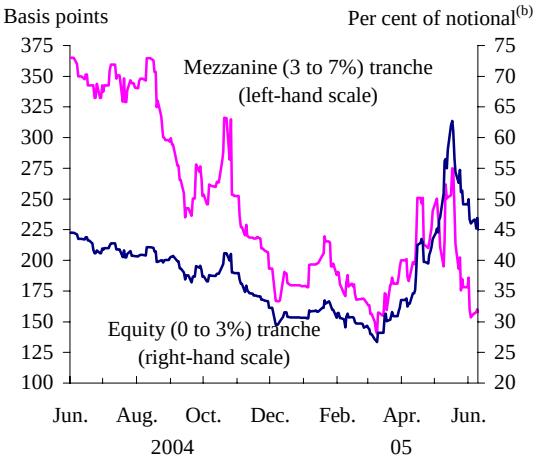
(Prepared with the help of Ronald Johannes of Bank of England)

Chart 1: GM/Ford bond spreads



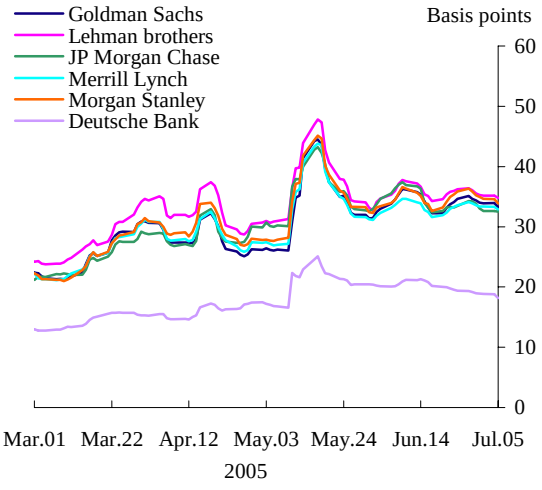
Source: Merrill Lynch. Spreads option adjusted.
(a) GM profit warning, 16th March.
(b) Ford profit wanting, 8th April.
(c) Ford and GM downgrade to junk by S&P, 5th May.

Chart 5: Equity and mezzanine tranche spreads of US CDS index[(a)]



Source: JP Morgan Chase and Co.
(a) Five-year on-the-run Dow Jones CDX North America investment grade index (DJ.CDX.NA.IG).
(b) Equity tranches are quoted as an upfront price (a per cent of the notional transaction size). A higher price for credit protection indicates an increase in tranche risk, so the upfront price acts like a spread.

Chart 7: Selected bank CDS premia[(a)]



Source: MarkIt.
(a) 5-year senior debt CDS contracts.