Quantitative Portfolio Strategy
24 July 2015

Measuring Bond-Level Liquidity: Liquidity Cost Scores (LCS)

Vadim Konstantinovsky, CFA
+1 212 526 8290
vkonstan@barclays.com
BCI, US

Kwok Yuen Ng
+1 212 526 6685
kwok-yuen.ng@barclays.com
BCI, US

Bruce Phelps, CFA
+1 212 526 9205
bruce.phelps@barclays.com
BCI, US

www.barclays.com

- In 2009, Barclays introduced Liquidity Cost Scores (LCS) for USD credit bonds, a bond-level liquidity measure. LCS is defined as the cost of a standard, institutional-size, round-trip transaction and is expressed as a percentage of the bond's price. LCS can be aggregated across bonds in a portfolio, as well as compared over time and vs. a benchmark.
- Today, Barclays publishes monthly LCS for more than 18,300 global fixed-income securities with a total market value exceeding $44.5trn. This represents 91% of the total amount outstanding of the Barclays Global Aggregate Index.
- LCS has a variety of applications for bond portfolio management, including portfolio liquidity reporting; liquid portfolio and benchmark construction; monitoring trading desk inventory positions; quantifying the impact of transaction costs on alpha strategies; empirical market studies; etc.
- For some markets, along with LCS Barclays publishes Trade Efficiency Scores (TES), a relative bond-level measure representing an intra-market liquidity rank ranging from 1 (best) to 10 (worst). TES blends LCS and trading volume into a single rank. Unlike LCS, TES is a relative measure and is thus unaffected by overall market liquidity conditions.
- This report describes LCS-related developments and research since LCS was introduced in 2009. Readers can keep up-to-date on global liquidity conditions and LCS model developments by subscribing to the monthly *LCS Report* on *BarclaysLive*.

Introduction

Transaction cost considerations enter the decision-making process of all participants in fixed-income secondary markets – investors and broker/dealers alike. The timing and size of individual trades are influenced by the trade-off between the cost of trading and the opportunity cost of not trading. For example, the realized performance of potentially profitable alpha-generating strategies depends on how much their promised returns are eroded by trading costs, portfolio rebalancing may be difficult in illiquid markets, etc. Yet, although its importance is recognized, liquidity becomes an elusive concept when one tries to measure it.

Academics and policymakers are usually interested in aggregate market liquidity and use various variables to study or monitor it. Investors, however, care more about the liquidity of their portfolios, or even of a particular security. How to measure the liquidity of a single bond? In short, for all the attention paid to liquidity, there have been no reliable security-level measures. There has been some success in measuring liquidity in transparent and active equity markets, but in bond markets, the sheer number of instruments, and the infrequent trading in most of them, makes measuring bond-level liquidity a challenge. Besides, unlike largely exchange-based stock markets, bonds are still traded mostly over the counter. Even though in some markets (notably USD Credit) regulations require reporting of all trades, in many others, data on actual transactions is scarce.

In 2009, Barclays created a bond-level liquidity measure to fill a gap in the fixed income investor's toolbox.[1] Because of the dearth of actual transaction data, this measure relies on simultaneous two-way quotes issued by Barclays' traders to other market participants. Barclays is a large broker/dealer that also publishes broad and widely followed bond indices. Barclays traders make bid-ask spread indications for a significant number of bonds. These are automatically collated, parsed, and saved as part of Barclays index validation process. Clearly, on any given day, many more bonds are quoted than traded. Bid-ask spreads in themselves do not incorporate the potential market impact of large trades, which is often of interest, but many traders and investors find bid-ask spreads to be sufficiently positively correlated with market-impact costs.

The bond-level liquidity measure, Liquidity Cost Score (LCS), is defined as the cost of a standard, institutional-size, round-trip transaction. Hence, a lower LCS signifies better liquidity. LCS is expressed as a percentage of the bond's price and can be aggregated across bonds in a portfolio and compared over time. Portfolio managers can use this measure to quantify the liquidity of their holdings and compare them to a benchmark. A consistent, quantitative liquidity metric also facilitates more rigorous study of market liquidity and other market phenomena.

In June 2015, Barclays published LCS for more than 18,300 fixed-income securities with a total market value exceeding $44.5trn. This represents 91% of the total amount outstanding of Barclays' flagship Global Aggregate Index. The LCS asset class coverage currently includes the following markets:

- USD IG and HY Credit (including 144A no registration rights)
- USD Treasuries and TIPS
- USD Fixed Rate Agency MBS
- USD Emerging Markets
- Pan Euro IG and HY Credit (including GBP corporates with £100–200mn outstanding)

[1] Dastidar, S. and B. Phelps, "Introducing LCS – Liquidity Cost Scores for US Credit Bonds", October 2009, Barclays Research.

- Pan Euro Credit FRN
- Pan Euro Treasuries and Linkers
- Pan Euro Agencies and Local Authorities
- Global Covered Bonds
- Asia Pacific Treasuries

The first asset class in the LCS coverage universe was USD IG and HY credit, with an inception date of January 2007. The other markets have been added in subsequent years, with Asia Pacific Treasuries the latest (September 2013).

Monthly LCS is available for bonds which are constituents of one or another Barclays index. However, we have developed methodologies ("extended LCS models") to compute LCS for USD credit and emerging markets non-index and custom securities. We have also been able to approximate bond-level LCS for USD, EUR, and GBP credit bonds going back to 2001.

LCS Methodology

Traders post bid and ask quotes in two different ways: as yield spreads over Treasuries or as bid and ask prices. The former are "spread quotes" (typical for USD IG Credit), and the latter "price quotes" (most USD High Yield and non-USD bond markets). As a result, LCS is computed in one of two, conceptually identical, ways:

$$LCS = (Bid\ spread - Ask\ spread) \times \mathrm{OASD}$$ if bond is spread-quoted

$$LCS = \frac{Ask\ price - Bid\ price}{Bid\ \ price}$$ if bond is price-quoted

As an example, in June 2015, the ALCOA 5.4% of 4/5/2021, a Ba-rated bond issued in 2011, was quoted with a bid price of 107 and an ask price of 108. Its LCS is then (108 – 107) / 107 = 0.935, which means it would cost a manager just under one percent of the bond's value to execute an immediate round-trip transaction for a "normal-size" amount (around $3mn in the USD HY Credit market).

Major investment banks, including Barclays, are counterparties to the world's largest institutional investors. Barclays' bond-level bid-ask indications have a wide audience, which ensures quality of these quotes and, by extension, LCS values. Some bonds are quoted multiple times per day, while others only once or twice a month. Every month, thousands of simultaneous bid-ask quotes are collected and matched to CUSIPs. For every bond, LCS corresponding to each quote is computed and, at the end of the month, averaged into the bond's monthly LCS value.

Any particular bank's bid-ask spread is unlikely to be the "effective" market, ie, the highest bid and lowest offer across all broker/dealers. A trader's quotes for a particular bond are often influenced by his inventory or outlook. A trader temporarily long a bond may quote it with a tighter spread to entice a bid, and *vice versa* when short. Investors, however, can choose their counterparty and shop for best execution. As a result, LCS may overstate "best-execution" transaction costs. However, given Barclays' material presence in fixed-income markets, we think it is reasonable to suppose that its bid-ask quotes are not too far from market levels. Moreover, idiosyncratic circumstances are unlikely to persist throughout a whole month, and monthly averaging largely eliminates their influence. Nevertheless, LCS is a conservative measure of transaction costs.

Evidently, the quality of trader quotes is a key factor, and the LCS methodology recognizes that it may be uneven across bonds. It is safe to assume that very actively traded issues are likely to be quoted both at executable levels and uniformly among broker/dealers. The LCS methodology uses the term "benchmark" to describe such bonds. Benchmark bonds are high-profile securities that see good two-way flow and, importantly, are closely monitored by broker/dealers and investors. A trader is unlikely to quote such a bond carelessly because it would signal inattention to the market or weak market-making capability. A bond's benchmark status is determined by two criteria, "on-the-run" and "high volume". To be on-the-run, a bond has to meet several conditions – eg, to be a large and recent issue and have a maturity close to one of the main issuance points (2y, 5y, 10y, and 30y) on the yield curve. These conditions are waived if a bond has extremely high trading volume, in which case it also receives benchmark status.

Sometimes, trader quotes are bid-ask indications, as opposed to live, transactable, two-way markets. The LCS methodology tests each quote to decide whether it is a realistic bid-ask market or an indication. In the latter case, the model widens the bid-ask spread to ensure it is not too narrow compared with the "true" market. Bid-ask spreads are never made tighter, in the spirit of making LCS a conservative measure.

Last but not least, a bond may have no two-way trader quotes at all in a particular month. Its bid-ask market must therefore be estimated. However, such bonds are a minority in most markets. In the next section, we take a close look at how LCS is estimated for non-quoted bonds.

LCS Model for Non-Quoted Bonds

In the absence of a trader-quoted market for a bond, the model estimates what investors would likely have to pay to trade this bond. The model works as follows:

First, monthly cross-sectional regression analysis is used to estimate a statistical relationship between bonds' attributes and the observed LCS of quoted bonds. It is assumed that the same relationship holds for non-quoted bonds, and their LCS is calculated accordingly. Finally, LCS is adjusted upward, because a bond without a single trader quote in a month is likely to be less liquid than a quoted bond with similar attributes.[2] Cross-sectional models vary across markets. Some attributes important for, say, EUR covered bonds, do not matter, or indeed even exist, in the USD credit market. So, while the key set is usually the same, the econometric models are estimated to reflect specific properties of each market. In this paper, the large and diverse USD investment-grade corporate market will serve as an illustration of the LCS modeling approach.

Investors will find most attributes used in the LCS model quite intuitive. Recent and large issues are usually cheaper to trade than seasoned and small ones, so bond age and issue size are important. High-risk securities (ie, bonds with volatile spreads) tend to be costlier to trade than low-risk ones. A trader taking a position in a high-risk bond will quote wider bid-ask spreads, so some measure of credit risk must be included in the set of attributes.

The decision on whether to include a certain attribute in the regression is based on its relationship with observed LCS. The "heat map" in Figure 1 segments the universe of trader-quoted corporates by age and issue size while controlling for maturity (hence four tables), with warmer backgrounds depicting higher LCS. Two clear gradients emerge: LCS is increases for higher age and lower issue size.[3]

[2] The LCS for a bond without quotes in a particular month may not immediately undergo the full adjustment. The model has a smoothing algorithm that takes into account whether the bond was quoted in preceding months.
[3] "A Case Study: Dependence of Liquidity on Bond Age", April 2012, LCS Report, Barclays Research.

FIGURE 1

Average LCS by Issue Size and Age. Trader-Quoted USD IG Corporates, June 2015

Maturity: 1-5				
Age, yr				
Size, mm	<1	1-5	5-7.5	7.5+
<300	0.62	0.68	0.88	0.70
300-500	0.59	0.60	0.74	0.68
500-750	0.38	0.51	0.61	0.65
750-1,500	0.35	0.41	0.55	0.55
1,500-2,000	0.23	0.35	0.46	0.48
2,000-3,000	0.25	0.26	0.42	0.42
>3,000	0.21	0.27	0.32	0.27

Maturity: 5-10			
Age, yr			
<1	1-5	5-7.5	7.5+
1.15	1.13		1.45
1.14	1.08	0.98	1.38
0.70	0.90	0.72	1.13
0.55	0.76		1.05
0.42	0.66		
0.34	0.54		
0.29	0.43		

Maturity: 10+				
Age, yr				
Size, mm	<1	1-5	5-7.5	7.5+
<300	1.64	1.88	1.64	2.18
300-500	1.62	1.86	1.86	2.04
500-750	1.08	1.74	1.85	1.98
750-1,500	0.86	1.49	1.75	1.81
1,500-2,000	0.59	1.22	1.61	1.46
2,000-3,000	0.61	0.98	1.21	1.31
>3,000	0.64	0.68		

Maturity: All			
Age, yr			
<1	1-5	5-7.5	7.5+
1.15	1.13		1.45
1.14	1.08	0.98	1.38
0.70	0.90	0.72	1.13
0.55	0.76		1.05
0.42	0.66		
0.34	0.54		
0.29	0.43		

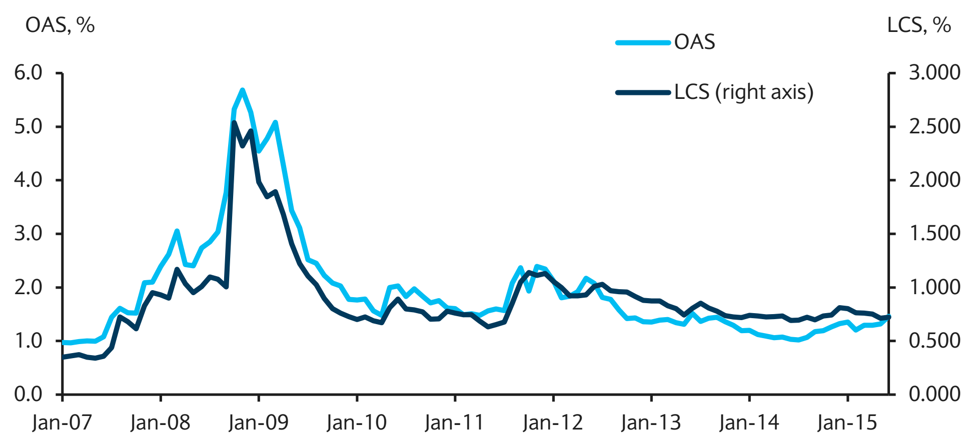
Buckets with fewer than 5 bonds are not shown.

Source: Barclays Research

Next, we look at the historical relationship between observed LCS and credit spread (OAS). The strength and stability of the relationship (Figure 2) is striking. Clearly, credit spread has to be one of the model variables.

FIGURE 2

LCS vs. OAS, Trader-Quoted USD IG Corporates, January 2007 – June 2015

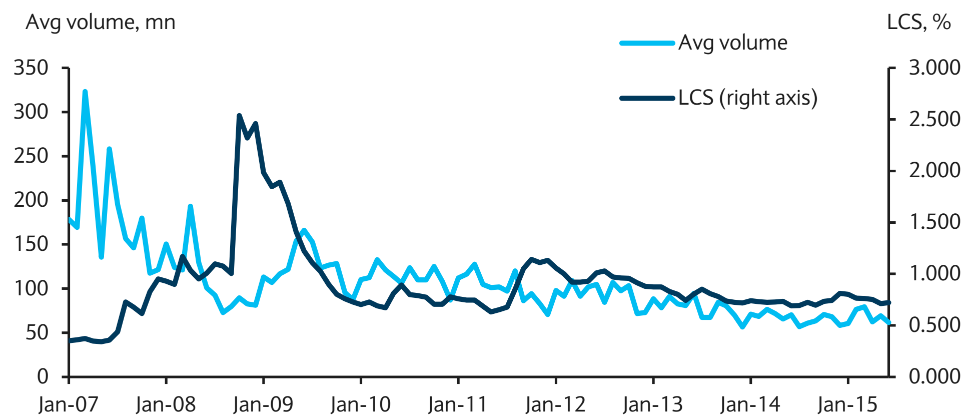


Source: Barclays Research

Another attribute to consider is a bond's trading volume. Many investors and academics use volume as a liquidity indicator in its own right. But when liquidity is defined as the cost of trading, one needs to examine carefully how trading volume affects it. Figure 3 shows the historical relationship between LCS and the average trading volume of trader-quoted corporates. Intuitively, one might assume a negative relationship between LCS and volume. Indeed, this was clearly the case during the credit crisis, when LCS and volume moved, or rather jumped, in opposite directions. However, in the more normal, post-crisis period, the relationship was muted at best. In fact, although not readily apparent in the plot, sometimes LCS and volume move in concert. In other words, markets, or at least market segments, can experience a liquidity crunch, ie, higher transaction costs, on very high volume. For example, bad news about an issuer may increase its perceived risk, leading to wider bid-ask spreads and high trading volume as investors react to the news and adjust their portfolios. In recent years, there has not been a meaningful relationship between volume and LCS. The scatter plot of LCS vs. volume for trader-quoted corporates in Figure 4 shows no discernible relationship between the two.[4] Still, the LCS model controls for trading volume. Although the volume variable may not be very important most of the time, it could become so during periods of market turbulence.

FIGURE 3

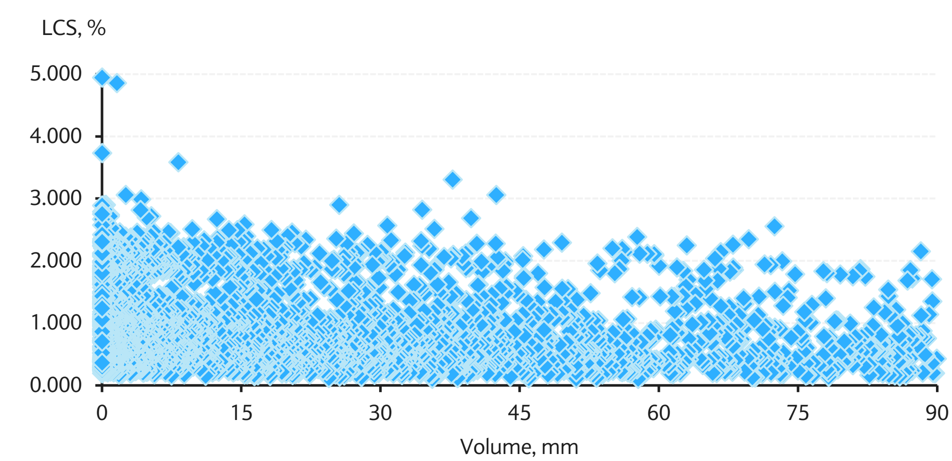
LCS vs. Trading Volume, Trader-Quoted USD IG Corporates, January 2007 – June 2015



Source: Barclays Research

FIGURE 4

LCS vs. TRACE Trading Volume, Trader-Quoted USD IG Corporates, Excludes the Top 10% by Volume, June 2015



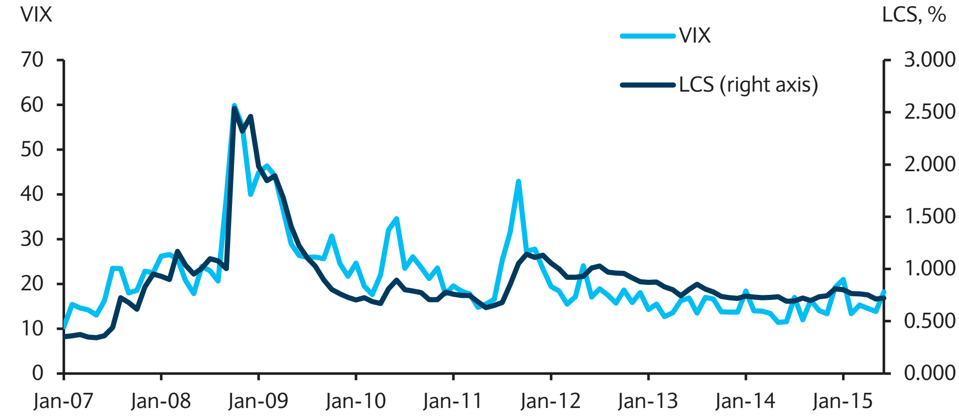
Source: Barclays Research

Two other market variables often used to judge the level of market risk are VIX and TED spread. Figures 5 and 6 plot the historical relationship between these and corporate LCS. As expected, both are highly correlated with LCS, particularly VIX. However, VIX and TED spread are also highly correlated with OAS, so including them in the model is redundant.

[4] Figure 4 excludes the top 10% volume bonds to make the graph more readable.

FIGURE 5

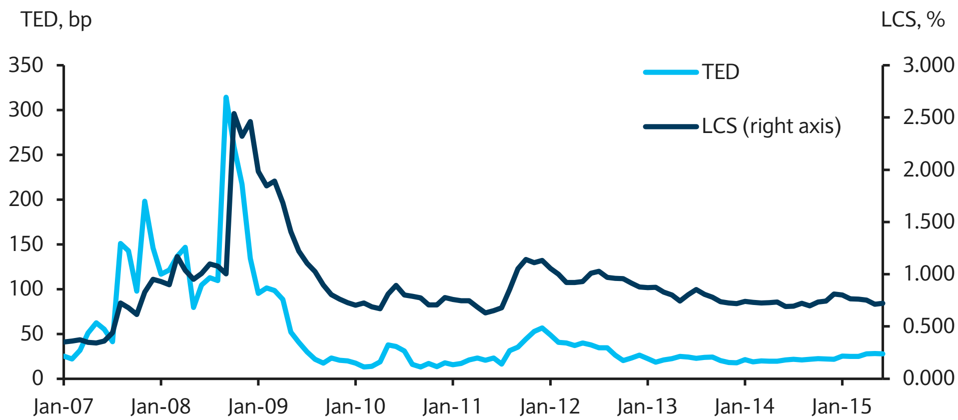
LCS vs. VIX, Trader-Quoted USD IG Corporates, January 2007 – June 2015



Source: Barclays Research

FIGURE 6

LCS vs. TED Spread, Trader-Quoted USD IG Corporates, January 2007 – June 2015



Source: Barclays Research

In the end, a set of bond attributes is finalized that forms the regression-based model for non-quoted USD corporate bonds. Some of the more important factors are:

- DTS (= OASD × OAS);
- LCS benchmark status;
- Bond's industry sector and quality;
- Age;
- Amount outstanding;
- Trading volume; and
- Price distance from par

The coefficients of these factors are almost always statistically significant. The R^2 of the regression usually ranges between 60% and 80%.

Liquidity in different markets is often driven by factors specific to that market. For example, the country of issuer does not really matter in the USD corporate market but is of paramount importance for Pan-Euro corporates, etc. LCS models for different asset classes are developed and implemented individually.

Properties of LCS

Investors are concerned not only with a bond's current LCS level but with its variability. Portfolio managers need to have some idea how the LCS of their portfolio is likely to behave in the near future, when they may have to transact. "Current liquidity conditions" should reflect not only the aggregate LCS level of, say, the USD Corporate Index, but also intra-market dispersion. The stability of relative LCS rankings within a market is also important: How likely is a bond in a particular LCS quintile to be there next month? Finally, does LCS make it possible/easy to compare the liquidity of different markets?

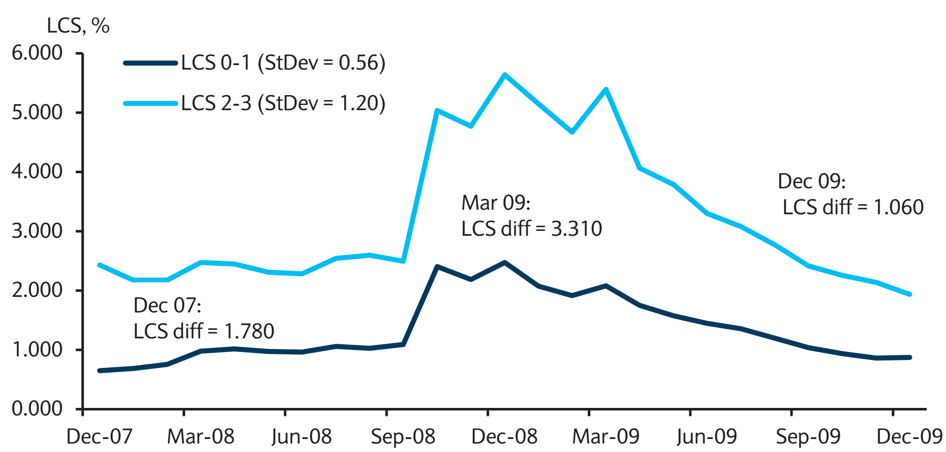
Relationship between LCS Level and LCS Volatility

It is well known that high spread levels are usually accompanied by high absolute short-term spread volatility. Spread is also a major driver of transaction costs. When credit market conditions deteriorate, traders demand more compensation for taking the risk of holding inventory. Putting the two relationships together, one might reasonably expect the short-term volatility of LCS to be proportional to its level.[5]

If true, such a relationship means that, in difficult liquidity conditions (high aggregate LCS levels), investors also face increased short-term liquidity uncertainty. To investigate this, we look at the behavior of two hypothetical IG corporate portfolios in the 2007-09 crisis period. The first, "liquid", portfolio contains bonds with LCS below 1.000 as of January 2007. The other, "illiquid", portfolio consists of bonds with LCS of 2.000-3.000. At the outset, the difference in average LCS of the two portfolios is 1.780 (Figure 7). In the absence of an LCS level-volatility relationship, this LCS gap should remain relatively stable, with both portfolios becoming less liquid as the crisis unfolds. Yet this is not the case. The gap widens markedly, almost doubling to 3.313 in March 2009. As the crisis subsides, it narrows beyond its pre-crisis level, to 1.063 in December 2009.

FIGURE 7

LCS Level and Liquidity Risk in Turbulent Markets, a Portfolio Example, USD IG Credit, December 2007 – December 2009



Source: Barclays Research

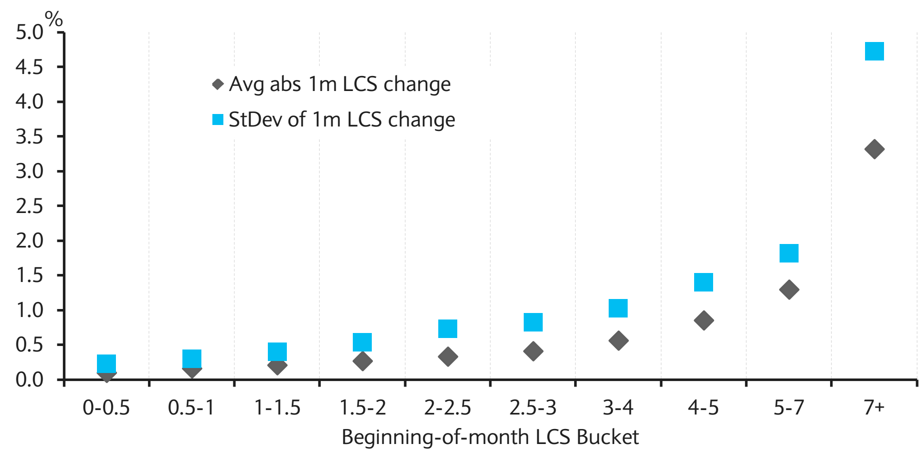
[5] "A Case Study: The Relationship between LCS Level and LCS Volatility", June 2013, LCS Report, Barclays Research.

This relationship is investigated using a large (about 450,000 observations) sample of trader-quoted LCS values for bonds in the USD IG Credit and HY indices. Separately for IG and HY, each bond's one-month ΔLCS is measured, forming a sample of LCS – ΔLCS pairs. Bonds are then sorted into 10 buckets, based on their beginning-of-the-month LCS. Finally, for every such bucket, average absolute value, standard deviation, and distribution of one-month ΔLCS are computed.

Figure 8 shows that, during the same stressful period, the relationship is both strong and linear, except for the sparsely populated high-LCS buckets. A regression testing the statistical significance of this relationship yields highly significant coefficients for both IG and HY.

FIGURE 8

LCS Level and Liquidity Risk in Turbulent Markets, USD IG Credit, December 2007 – December 2009



Source: Barclays Research

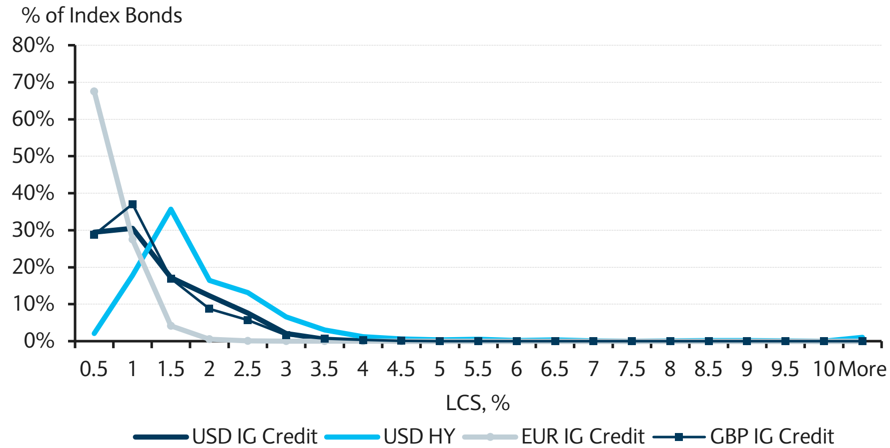
Besides the systemic relationship between current liquidity conditions and short-term liquidity uncertainty, portfolio managers are concerned about liquidity tail risk, ie, being stuck with bonds that are very costly to trade. To study this, we look at the distribution of LCS changes, calculating, for each LCS bucket, the absolute range of one-month ΔLCS, and generating 100 equally spaced buckets. For both IG and HY, high-LCS buckets show markedly increased liquidity tail risk.

Cross-Sectional Distribution and Persistence of LCS

In broad markets, such as USD credit, there is a wide dispersion of LCS values, which parallels equally wide distributions of factors that influence LCS, eg, issue size, age, and spread. The LCS distribution contains valuable information about market conditions, beyond simple statistics like a market-value-weighted average or median LCS. Figure 9 shows June 2015 cross-sectional distributions of LCS for four major credit markets, USD IG and HY, EUR IG, and GBP IG. EUR IG credit, for example, is not only the most liquid of the four but heavily concentrated, with 93% of bonds with an LCS below 1.000. On the other hand, USD HY is not only the least liquid market but also the one with the fattest tail. The standard deviation of USD HY LCS is almost six times that of EUR IG.

FIGURE 9

Cross-Sectional Frequency Distribution of LCS, Various Markets, June 2015

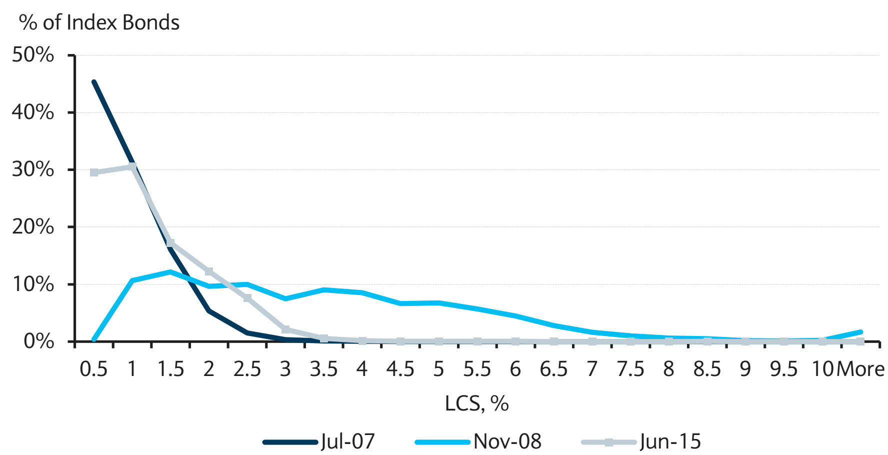


Source: Barclays Research

LCS dispersion can change significantly. Figure 10 shows cross-sectional distributions for two very different market environments: the pre-crisis month of July 2007, widely considered a time of very good market liquidity, and the turbulent November 2008. The properties of the two distributions could not be more different. The June 2015, distribution lies between the two extremes.

FIGURE 10

Historical Cross-Sectional Frequency Distribution of LCS, USD IG Credit



Source: Barclays Research

Another important question concerns the stability of LCS for groups of similar securities. For any particular bond, LCS may change significantly for a number of reasons, but, on average, one would expect bonds that were in a particular place on the liquidity spectrum last month to remain there in the current month. In other words, how persistent is LCS? How quickly do bonds migrate along the liquidity scale? This question is answered by dividing the Barclays USD IG Credit Index into LCS quintiles and measuring transition rates among different quintiles. Figure 11 shows the transition rates for June 2015 and, for comparison, for October 2008. Overall, in normal liquidity regimes, the majority of bonds tend to stay in the last-month quintile. Perhaps not surprisingly, it is particularly true for the most- and least-liquid quintiles (85% and 91%, respectively). At the peak of the credit and liquidity crisis of 2008, the corresponding rates were 63% and 71%.

FIGURE 11

LCS Quintiles: Transition Rates and Average LCS, %, USD IG Credit, June 2015

1 mo prior	Current (Jun-15)				
May-15	**Q1 (0.262)**	**Q2 (0.507)**	**Q3 (0.814)**	**Q4 (1.251)**	**Q5 (2.110)**
Q1 (0.260)	84.9%	13.9%	1.1%	0.0%	0.0%
Q2 (0.507)	6.7%	76.7%	15.6%	1.0%	0.0%
Q3 (0.819)	1.3%	9.2%	76.8%	12.1%	0.6%
Q4 (1.287)	0.2%	0.8%	7.3%	80.5%	11.2%
Q5 (2.175)	0.0%	0.1%	0.2%	8.9%	90.9%

LCS Quintiles: Transition Rates and Average LCS, %, USD IG Credit, October 2008

1 mo prior	Current (Oct-08)				
Sep-08	**Q1 (1.196)**	**Q2 (2.049)**	**Q3 (3.196)**	**Q4 (4.374)**	**Q5 (7.127)**
Q1 (0.551)	63.0%	29.7%	4.4%	2.8%	0.1%
Q2 (1.053)	18.9%	46.9%	24.0%	6.9%	3.2%
Q3 (1.521)	4.2%	24.3%	41.8%	23.2%	6.5%
Q4 (2.090)	0.9%	7.7%	23.4%	48.4%	19.6%
Q5 (3.175)	0.6%	3.1%	6.4%	18.7%	71.2%

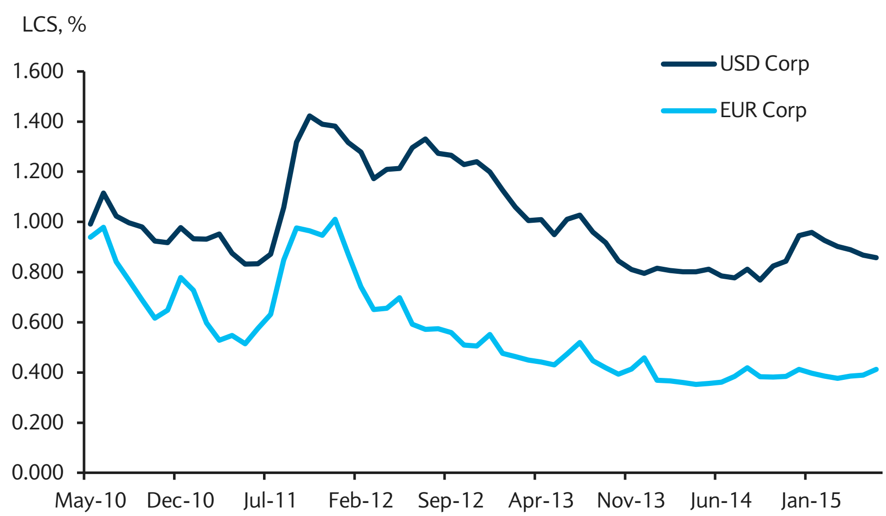
Source: Barclays Research

Cross-Market Liquidity Comparisons

Portfolio managers are also interested in comparing liquidity across different markets. Figure 12 shows historical time series for USD and EUR corporates. Most of the time, USD LCS has been significantly higher than EUR LCS. Is the EUR corporate market really more liquid? While true in an absolute sense, this is not how portfolio managers look at it. They want to know in which market it would be cheaper to trade the same bond. Comparing market-level LCS says little about relative liquidity, as potentially large differences in bond characteristics between these markets could invalidate the comparison. For example, when one market largely comprises short-duration, newly issued, low-spread bonds, while the other consists mainly of long-duration, seasoned, high-spread bonds, a lower aggregate LCS of the first market would be expected.[6]

FIGURE 12

Historical LCS of USD and EUR Credit, %, May 2010 – June 2015



Source: Barclays Research

[6] Konstantinovsky, V. and B. Phelps, "Corporate Liquidity across Markets", September 2014, Barclays Research.

The USD and EUR corporate markets are indeed different in several attributes important to LCS. As Figure 13 shows, the USD corporates have longer spread duration and higher spread levels. Both contribute to higher LCS. Their product, used in the LCS model, is twice that of EUR corporates. Besides, bonds in the USD market tend to be older and have a smaller issue size. Every one of these attributes is an important determinant of LCS.

FIGURE 13

Market Attributes Driving Corporate LCS: USD vs. EUR, June 2015

	USD Corp	EUR Corp
LCS, %	0.858	0.412
OASD	6.99	5.19
OAS, bp	144	122
OASD x OAS	11.88	5.67
Avg age, yr	4.4	2.9
Avg issue size, $mn	731	919
Avg volume, $mn	47	39

Source: Barclays Research

To evaluate the relative liquidity of these markets correctly, one needs to account for differences in bond attributes. This is achieved by regressing LCS of the most liquid, trader-quoted USD and EUR corporates on their age, issue size, DTS, and trading volume. To enable a direct comparison, there is also a dummy variable that indicates whether the bond is USD or EUR. If the coefficient on this variable is statistically significant, its sign will show whether the USD market has worse (a positive coefficient) or better (negative) liquidity. Figure 14 shows the regression results for June 2015. The USD dummy coefficient is positive and significant, indicating relatively less liquidity in the USD corporate market, all other things equal. However, the difference is small. So, the 0.446 difference between USD and EUR LCS (Figure 13) is explained almost entirely by market attributes. The true measure of relative liquidity, ie, LCS difference between identical bonds in the two markets, is only 0.060.

FIGURE 14

USD and EUR Corporates: Cross-Sectional Regression Results, June 2015

	Constant	Age	Issue size	OASD × OAS	Volume	USD dummy
coefficient	0.316	0.003	-5.6E-05	0.019	-2.4E-04	0.060
t-stat	(33.59)	(1.65)	(-8.92)	(45.38)	(-8.17)	(6.66)

Source: Barclays Research

Applications of LCS for Portfolio Management

Measuring Bonds' Relative Liquidity

LCS is an absolute measure that fluctuates with overall market liquidity, so a time series of LCS for a particular bond would not tell us how the bond has measured up against its peers over time.

Another liquidity measure, derived from LCS, is Trade Efficiency Score (TES). TES is a relative bond-level liquidity rank ranging from 1 (best) to 10 (worst). It helps to quickly judge a bond's liquidity relative to similar bonds, both currently and over time.

In addition, while LCS captures the cost of trading, it does not directly measure a bond's actual trading flow. Many corporate bonds, for example, trade very infrequently, so LCS may not adequately reflect the difficulty of implementing large or numerous trades. Traders interested in immediate execution may prefer a bond with a higher current trading volume to a similar bond with the same LCS but lower volume. TES blends LCS and trading volume into a single relative score that reflects both the cost and flow. Within one market, bond-level TES are comparable over time and among bonds, and come close to the way many traders think about liquidity, ie, in terms of both transaction costs and market impact. As a relative measure, TES can serve as a liquidity filter in portfolio construction. It is also a valuable tool for back-testing investment strategies. Using only low-TES bonds in a back-test shows how realistic the strategy is in practice, and how achievable its promised returns are.[7]

To compute TES, each bond in a particular market is first assigned to an OASD-adjusted LCS quintile, and to a monthly trading volume decile. (LCS is a product of the bid-ask spread and OASD, so the duration adjustment is necessary for relative-liquidity comparison of bonds with different durations.) Then, these two quantiles are added, and the sum (which ranges from 2 to 15) is mapped to a TES ranking from 1 to 10. Figure 15 provides the details.

FIGURE 15

Trade Efficiency Scores, the Barclays USD IG Corporate Index (ex. 144-A), June 2015

Vol Decile + LCS Quintile	TES	# bonds	# bonds %	MV %	Age, yr	Issue size mn	OAS, bp	OASD	LCS, %	Vol, mn
2 and 3	1	727	13.36	26.10	2.1	1,480	145.1	7.82	0.453	266
4 and 5	2	645	11.86	16.46	3.5	1,022	131.4	6.45	0.653	71
6	3	373	6.86	7.92	3.7	851	130.7	6.03	0.786	59
7	4	407	7.48	7.95	4.2	774	135.0	6.23	0.899	39
8	5	439	8.07	7.26	4.6	652	140.9	6.68	1.039	27
9	6	469	8.62	6.83	4.6	576	144.4	6.29	1.020	18
10	7	472	8.68	6.54	4.9	541	147.5	6.99	1.118	10
11	8	497	9.14	6.03	5.8	468	151.8	7.13	1.166	6
12	9	518	9.52	5.83	5.7	437	155.5	7.04	1.223	3
13-15	10	892	16.40	9.07	8.2	375	174.3	7.31	1.560	1

Source: Barclays Research

The TES buckets differ in the number of bonds and market value. For example, the TES1 bucket comprises approximately 13% of the corporate market by number of bonds and 26% by market value, while the TES3 bucket accounts for 7% of bonds and 8% of market value.

The attributes of bonds in different TES buckets vary substantially and predictably. By construction, low-TES buckets have bonds with low LCS and high trading volume. As Figure 15 shows, the average LCS for TES1 is less than a third of that for TES10. Its average monthly trading volume is $266mn per bond compared with $1mn for TES10. Low-TES buckets tend to be populated by large, recent issues. Average issue size decreases dramatically in higher-TES buckets, while average age increases.

Liquidity and Market Efficiency

Market efficiency is an important topic for both academics and investors. The main characteristic of efficiency is how quickly asset prices reflect available information. Insufficient liquidity is among the reasons they may not.

Portfolio managers know that in a liquid market, prices adjust rapidly to news and changes in portfolio preferences. With many potential buyers and sellers constantly inquiring, quoting and trading, prices (and, hence, excess returns[8]) quickly reflect an equilibrium of

[7] "A Case Study: Constructing and Testing an Alpha Strategy Using LCS", June 2011, LCS Report, Barclays Research.
[8] Corporate excess return is total return less the return of a duration-matched Treasury portfolio.

many viewpoints. In contrast, limited quoting and trading activity slows the propagation and evaluation of news. Hence, one way to assess efficiency is to check for "price inertia" when past returns help explain current-period returns.

To investigate informational efficiency of the USD IG corporate market, the index is partitioned into liquidity strata based on TES. One would expect more liquid segments to display less price inertia. The comparison of price inertia in various TES buckets can reveal whether low-TES buckets are indeed more efficient than high-TES ones.[9]

Price inertia is measured by regressing current-month excess returns (ER) on prior month's excess returns:[10]

$$ER_t = \alpha + \beta_1 \times ER_{t-1} + \varepsilon_t$$

For a market with no price inertia, the estimated regression coefficient on the lagged return term would be statistically indistinguishable from zero. Figure 16 presents the estimated OLS coefficients and adjusted R^2 for the Barclays USD IG Corporate Index and, for comparison, for the Barclays Treasury Index and S&P 500 (SPX).[11]

FIGURE 16

Estimated Autoregression Coefficients, Monthly Returns, February 2007 – April 2015

	Intercept	Lag(-1)	Adj R^2
Corp ER	0.04	**0.34**	0.11
	(0.24)	(2.63)	
Tsy TR	**0.36**	0.05	0.00
	(2.92)	(0.57)	
SPX TR	0.57	0.18	0.02
	(1.05)	(1.38)	

Based on the AIC, we estimate the model using one lag. Standard errors are Newey-West with a truncation parameter of 3. t-statistics are in parentheses. Coefficients in bold are statistically significant at the 5% confidence level.
Source: Barclays Research

As Figure 16 shows, the one-month lag coefficient is not significant for the Treasury Index and SPX. This means that their previous-month returns do not help explain the current-month returns, which is consistent with the common view that these are very liquid markets. In other words, prices (and returns) quickly adjust to new equilibrium levels. Not so for the Corporate Index. The lag coefficient (0.34) is statistically significant, meaning that current-month excess returns have a 0.34 autocorrelation with previous-month returns; 11% of the variation in the current-month returns is explained by the previous-month excess returns.

What could explain this pattern in the Corporate Index? Unlike Treasury bonds and stocks, many corporate bonds trade rarely or not at all in a particular month. Hence, while changes in investors' views quickly affect bid and ask prices of actively traded bonds, their effect on infrequently-traded bonds is probably more gradual. Eventually, the news does become fully reflected in their prices, but the delayed adjustment causes lagged returns to be positively correlated with the current period's returns.

How uniform is price inertia within the corporate market? The same analysis is repeated for each of the 10 TES buckets. In low-TES buckets, lagged excess returns should have little explanatory power, ie, statistically insignificant coefficients and low R^2, while in high-TES buckets, one would expect significant coefficients that explain a meaningful percentage of the bucket's excess return volatility.

[9] Konstantinovsky, V. and B. Phelps, "Liquidity and Market Efficiency: Cash Corporates, ETFs, and CDX", March 2015, Barclays Research.
[10] All corporate bonds are trader-priced at the end of each month.
[11] The regression for the Treasury and SPX uses total returns.

FIGURE 17

Estimated Autoregression Coefficients by TES Bucket, Monthly Returns, February 2007 – April 2015

	Intercept	Lag(-1)	Adj R^2
TES1 ER	0.02	0.17	0.02
	(0.08)	(1.31)	
TES2 ER	0.06	**0.28**	0.07
	(0.34)	(2.16)	
TES3 ER	0.07	**0.34**	0.10
	(0.40)	(2.83)	
TES4 ER	0.06	**0.37**	0.13
	(0.33)	(3.03)	
TES5 ER	0.06	**0.39**	0.14
	(0.38)	(3.17)	
TES6 ER	0.05	**0.43**	0.17
	(0.28)	(3.43)	
TES7 ER	0.04	**0.43**	0.17
	(0.25)	(3.38)	
TES8 ER	0.02	**0.44**	0.19
	(0.15)	(3.53)	
TES9 ER	0.02	**0.50**	0.24
	(0.13)	(4.01)	
TES10 ER	0.06	**0.48**	0.22
	(0.37)	(3.90)	
Corp ER	0.04	**0.34**	0.11
	(0.24)	(2.63)	

Note: Based on the AIC, we estimate the model using one lag. Standard errors are Newey-West with a truncation parameter of 3. T-statistics are in parentheses. Coefficients in bold are statistically significant at the 5% confidence level. Source: Barclays Research

Figure 17 presents the autoregressive model output by TES bucket, which shows large variation in price inertia within the corporate market.

For the most liquid bucket, TES1, the lagged ER coefficient is statistically zero, and the regression R^2 is close to zero. TES1 bonds are relatively cheap to trade and have relatively high trading volumes, so it is not surprising that new information is quickly and fully reflected in their prices and, hence, excess returns.

Beyond TES1, the picture quickly changes. For TES2, the coefficient for the lagged ER term is positive (0.28) and statistically significant. The R^2 is 7%. Moving from TES1 to TES2 produces a noticeable increase in price inertia, suggesting a reduction in liquidity, as confirmed by the LCS and trading volume levels for the two buckets (Figure 15).

As TES increases, both the coefficient of the lagged ER term and the regression R^2 rise almost monotonically. For TES9 and TES10, the first lag coefficient reaches 0.50, and the R^2 is high at 24%.

To summarize, market efficiency varies significantly within the corporate market and is determined largely, if not entirely, by liquidity. Also, the results suggest that TES, and hence, LCS, does a good job partitioning the market by liquidity.

Credit Spread Decomposition

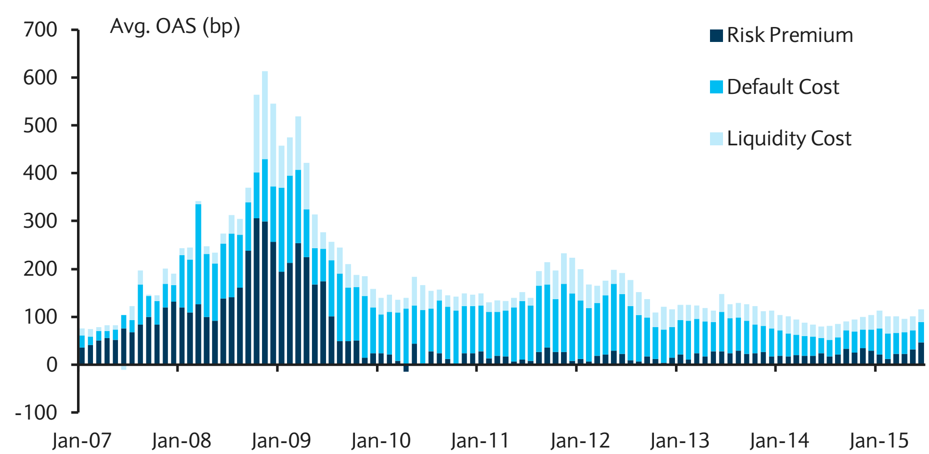
Credit spreads compensate credit investors for the possibility that a bond may default with a recovery value less than par. However, many studies have shown that spreads of credit bonds are generally much wider than is justified by their subsequent default and recovery experience. One of the explanations of this “excess” spread is expected liquidity cost. LCS, a quantitative measure of liquidity, helps illustrate this, by allowing the decomposition of a bond's spread into expected default loss, expected liquidity cost, and "risk premium" components.

The approach is to regress bond-level credit spreads (OAS) on liquidity cost (LCS) and expected default cost (issuer's market-quoted 5y CDS). The intercept term represents a market-level risk premium common to all bonds. Figure 18 shows the results of this decomposition from January 2007 through June 2015.[12]

Portfolio managers have looked at this spread decomposition to gain certain insights. For example, although the OAS levels in September 2007 and April 2010 were similar, Figure 18 shows that the components of OAS were very different. The OAS in September 2007 consisted mainly of a market-wide risk premium unrelated to default or liquidity costs, whereas default cost was the main contributor to OAS in April 2010. During the crisis period (2008 to early 2009), the market-wide risk premium and liquidity cost, and not default risk, were the largest components of average OAS. For buy-and-hold investors, who do not need to sell in the foreseeable future, the unusually high risk premium and liquidity components of OAS may have presented an opportunity to add credit exposure.

FIGURE 18

Risk Premium, Default, and Liquidity Components of the USD IG Credit OAS, January 2007 – June 2015



Source: Barclays Research

Liquidity-Adjusted Tail Risk

In times of market upheavals that often trigger massive portfolio liquidations, portfolio managers find it difficult or impossible to realize the mark-to-market value of their holdings. As a result, actual losses may far exceed the estimates of traditional VaR models based on published bid prices. To correct this shortcoming of regular VaR models, one needs to recognize that losses in tail events are exacerbated by significant transaction costs. A quantitative measure of liquidity allows investors to modify their tail-risk models accordingly. One possible method of adjusting VaR models is to model a bond's mid-price, rather than its bid price, and then lower it according to the bond's LCS during a tail event to arrive at a bid price more realistic in adverse market conditions.[13]

[12] Dastidar, S. and B. Phelps, "Decomposing Bond-Level Credit OAS into Default and Liquidity Components", July 2010, Barclays Research.
[13] "LCS Application: LCS-Adjusted Tail Risk", August 2011, LCS Report, Barclays Research.

To illustrate, both a traditional VaR model and the "LCS VaR" model are applied to three structurally similar test portfolios of USD corporate bonds – in the stressful environment of November 2008, and in March 2011, when markets returned to normal. The first two portfolios differ in risk (OAS) and liquidity (LCS). The spread of the "Illiquid High-OAS" portfolio is about twice as high as that of the "Liquid Low-OAS" portfolio. Its LCS is much higher as well. To control for spread, a third, "Illiquid Low-OAS", portfolio is created, with an OAS similar to that of the "Liquid Low-OAS" portfolio but with higher LCS, and its tail risk is also modeled for November 2008. This experiment asks two questions:

- In extreme scenarios, how much more does it cost to liquidate illiquid bonds compared with equally risky (same OAS) but more liquid bonds?
- Do transaction costs affect tail risk in difficult times more than in calm periods?

FIGURE 19

Traditional vs. Transaction-Costs Adjusted 99% VaR, Test Portfolio Losses, %MV

	November 2008			March 2011			Nov 2008 vs. Mar 2011	
Portfolio	VaR	LCS VaR	Difference	VaR	LCS VaR	Difference	VaR	LCS VaR
Liquid Low-OAS	-7.2	-8.1	-0.9	-4.3	-4.5	-0.2	-2.9	-3.6
Illiquid High-OAS	-10.6	-12.7	-2.1	-5.1	-5.4	-0.3	-5.5	-7.3
Illiquid Low-OAS	-7.2	-8.7	-1.5					

Source: Barclays Research

Figure 19 shows the results. In the stressful month of November 2008, both models predictably estimate bigger loss for the Illiquid High-OAS portfolio than for the Liquid Low-OAS portfolio. However, in the LCS VaR model, the difference is 1.2 percentage points bigger (-0.9% vs. -2.1%). In the calm month of March 2011, the two models' tail risk estimates are closer to each other. The difference in tail losses between the stressful and the calm months is also bigger for the LCS VaR model.

The results for the third, control portfolio show clearly that the higher tail loss predicted by the LCS VaR model indeed owes to higher transaction costs. In November 2008, the traditional model, based on spreads only, calculates identical losses for the Liquid Low-OAS and the Illiquid Low-OAS portfolios. The LCS VaR model, however, predicts 0.6 percentage points bigger loss for the Illiquid Low-OAS portfolio. The increase represents the additional loss because of poorer liquidity. LCS for USD credit are available back to 2007, so investors have liquidity data for the 2008-2009 crisis experience to adjust their tail-risk models.

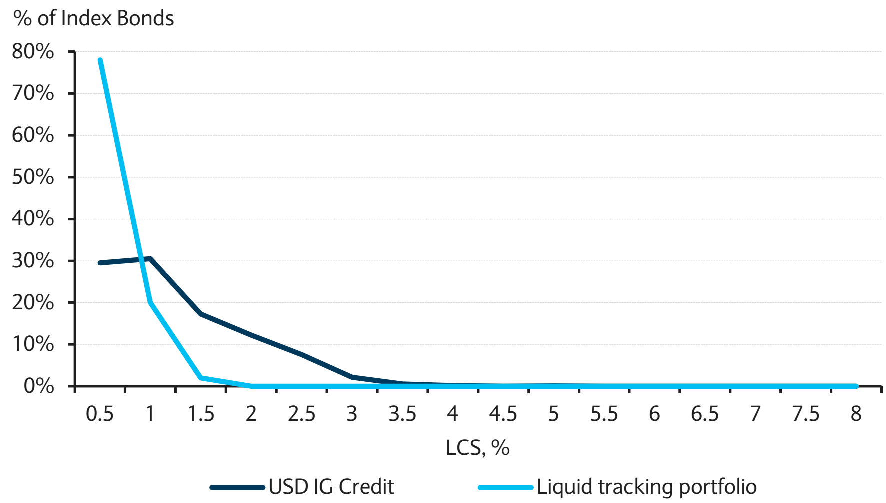
Benchmark Replication

Portfolio managers often look for ways to obtain exposure to short-term beta, for reasons that range from passive index replication to hedging out market exposure in alpha strategies. In broad markets such as USD corporates, which comprise thousands of securities, this is not a trivial task. While good tracking is the main objective, realistic implementation at a reasonable cost is critical. Total return swaps on broad credit indices are often unavailable, or quite expensive. Credit derivatives tend to track cash indices poorly. At the same time, index replication using cash bonds may be difficult because it is sometimes hard to decide which bonds are liquid enough. By its very nature, a tracking portfolio needs to be rebalanced on a regular basis, so liquidity is important.

A quantitative measure of bond liquidity allows a portfolio manager to objectively select a universe of liquid bonds from which to construct tracking portfolios, or proxies, for various benchmarks. With the liquid bond universe in place, the manager can apply a transparent, rules-based proxy construction methodology that relies on stratified sampling. An example of such a liquid proxy used by some portfolio managers is a 50-bond portfolio that tracks the Barclays USD Credit Index (6,334 bonds as of June 2015). To construct it, the index is divided into five sectors (basic, consumer, financial, technology, and other), and five duration categories (0-3, 3-5, 5-7, 7-10, and 10+). The "eligible universe" is formed by selecting for each of the resulting 25 buckets the top 20% most liquid index bonds according to their LCS rank, and adding to this set the top LCS quintile of bonds by duration category. 50 bonds are then selected by stratified sampling to match the contribution to DTS, as well as the market value percentage, of the Credit Index within each of the 25 sector-duration buckets.[14]

FIGURE 20

Cross-Sectional Distribution of LCS, Liquid Tracking Portfolio vs. the USD IG Credit Index, June 2015



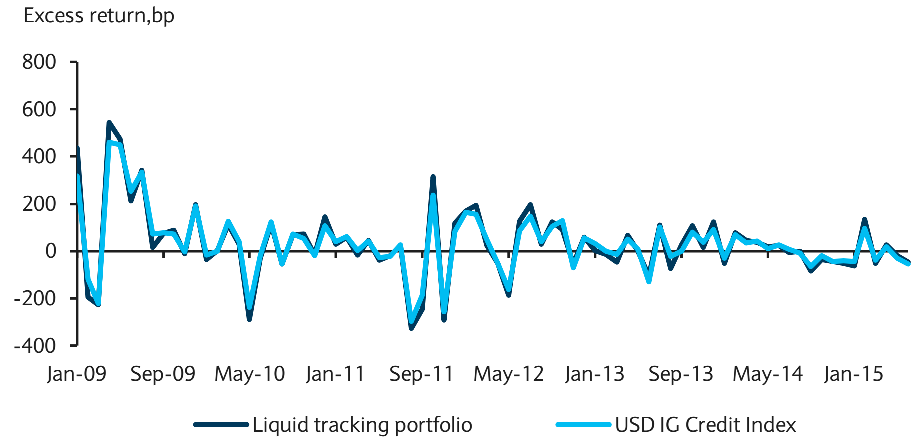
Source: Barclays Research

The cross-sectional LCS distribution in Figure 20 shows a heavy concentration in low-LCS bonds in the tracking portfolio, and a much wider distribution in the index. In June 2015, the LCS of the tracking portfolio was 0.410 vs. 0.813 for the Credit Index. Figure 21 shows that, since January 2009, the liquid proxy has tracked the index very closely, with the average monthly tracking error of just -0.1bp and the monthly tracking error volatility of less than a quarter of the index's excess return volatility over the same period (31bp vs. 131bp). The top ten holdings of the tracking portfolio are in Figure 22.

[14] Edelstein, A., S. Dastidar and B. Phelps, "Tradable Credit Portfolio (TCX) to Track the USD IG Credit Index", April 2010, Barclays Research.

FIGURE 21

Excess Returns of the Liquid Tracking Portfolio vs. the USD IG Credit Index, January 2009 – June 2015



Source: Barclays Research

FIGURE 22

Top Ten Holdings by Market Value in the Liquid Tracking Portfolio, USD IG Credit, June 2015

Cusip	Ticker	Issuer	Coupon	Maturity	Price	Age	OAS, bp	OASD	LCS, %	Avg Vol, $mn
38141GFM	GS	GOLDMAN SACHS GROUP	6.150	4/1/2018	110.72	7.34	116.3	2.51	0.231	199.1
715638BM	PERU	PERU REPUBLIC OF	5.625	11/18/2050	111.00	4.70	186.8	15.70	0.883	132.7
298785GU	EIB	EUROPEAN INVESTMENT BANK	1.250	5/15/2018	100.37	0.39	17.3	2.78	0.187	-
02687QDG	AIG	AMERICAN INTL GROUP	5.850	1/16/2018	110.22	7.64	83.6	2.37	0.236	116.4
91913YAT	VLO	VALERO ENERGY	4.900	3/15/2045	92.69	0.39	233.2	14.52	0.725	86.5
06738EAD	BACR	BARCLAYS PLC	2.750	11/8/2019	99.50	0.72	140.6	4.08	0.206	228.6
500769DP	KFW	KREDIT FUER WIEDERAUFBAU-GLOBA	4.000	1/27/2020	110.00	5.51	19.0	4.14	0.281	-
61747YDY	MS	MORGAN STANLEY DEAN WITTER	4.300	1/27/2045	92.50	0.51	168.3	15.52	1.162	445.7
86960BAG	SHBASS	SVENSKA HANDELSBANKEN	2.250	6/17/2019	100.29	1.12	84.0	3.77	0.191	46.5
9151153X	UNIHGR	UNIVERSITY TEX PERM UNIV FD	5.262	7/1/2039	121.54	5.87	87.9	13.86	0.281	0.3

Source: Barclays Research

Dealer Inventories and Market Liquidity

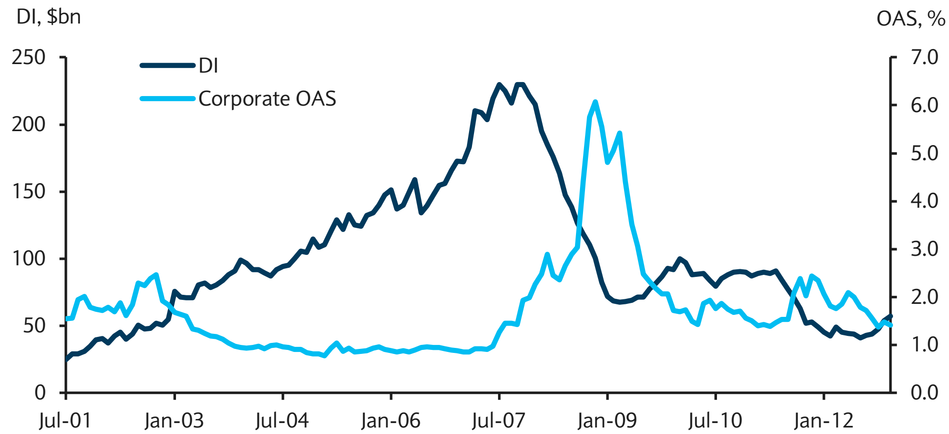
Beginning in early 2008, corporate bond dealer inventories collapsed after a steady, multi-year build-up. Higher capital requirements, diminished risk appetite, and new legislation have kept inventories low. Figure 23 shows the dramatic inventories decline concurrent with an equally dramatic spread widening.

This precipitous decline in bond inventories held by primary market makers gave rise to all kinds of speculation about liquidity consequences. The discussions continue to this day, usually on a qualitative level. The prevailing opinion is that constrained inventories cause a material reduction in liquidity. Indeed, just like with spreads, Figure 24 shows a concurrent jump in LCS. However, most views have lacked empirical support. LCS helps bring some hard evidence to the discussion.[15]

[15] Konstantinovsky, V. and B. Phelps, "Implications of Constrained Broker/Dealer Inventories for Corporate Market Liquidity", May 2012, Barclays Research.

FIGURE 23

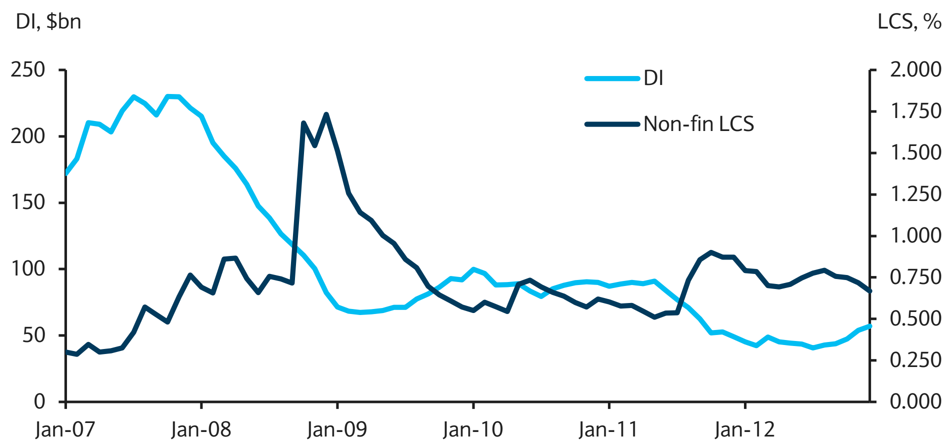
US Dealer Corporate Bond Inventories vs. OAS of the Barclays USD IG Corporate Index, July 2001 – December 2012



Source: Federal Reserve Bank of New York, Barclays Research

FIGURE 24

US Dealer Corporate Bond Inventories vs. the Non-Financial USD IG Corporate LCS, January 2007 – December 2012



Source: Federal Reserve Bank of New York, Barclays Research

A regression analysis controlling for changes in market risk (OAS), trading volume, and dealer distress (TED Spread) reveals a significant relationship between LCS (of quoted bonds only, to eliminate model dependency) and dealer inventories in the immediate post-crisis period, thus confirming and quantifying the negative effect of the reduced inventories on transaction costs. Figure 25 shows the regression output.

FIGURE 25

LCS vs. Dealer Inventories, Regression Results, July 2009 – April 2012

ΔLCS

Constant	ΔOAS	ΔVolume	ΔDI	ΔTED Spread	R^2
-0.0039	0.1361	0.0001	**-0.0052**	**0.3046**	
(-0.63)	(3.58)	(0.50)	(-3.77)	(2.81)	62%

Source: Barclays Research

These results mean that, even after accounting for changes in OAS and dealer distress, decreases in dealer inventories are associated with increases in LCS. More precisely, a $10bn decline in dealer inventories is associated with a 5.2bp increase in LCS. Assuming 100% annual credit portfolio turnover, this deterioration in liquidity would correspond to performance drag of approximately 5.2bp a year in additional transaction costs.

Conclusion

Liquidity is important for all financial market participants. At the same time, attention has been paid mainly to its aggregate metrics, leaving investors and portfolio managers with no reliable measures of bond-level liquidity, particularly in mostly over-the-counter bond markets with thousands of outstanding securities and little publicly-available transaction data.

Liquidity Cost Scores (LCS), a bond-level liquidity measure, provides an objective and quantitative way to measure individual bonds' liquidity. LCS can be aggregated to the portfolio and benchmark level, as well as compared over time. A few LCS applications described in this paper illustrate how fixed-income portfolio managers use this measure. Finally, LCS provides valuable and relevant data for academics and policy makers studying and monitoring liquidity in bond markets.

Analyst Certification

We, Vadim Konstantinovsky, CFA, Kwok Yuen Ng and Bruce Phelps, CFA, hereby certify (1) that the views expressed in this research report accurately reflect our personal views about any or all of the subject securities or issuers referred to in this research report and (2) no part of our compensation was, is or will be directly or indirectly related to the specific recommendations or views expressed in this research report.

Important Disclosures:

Barclays Research is a part of the Investment Bank of Barclays Bank PLC and its affiliates (collectively and each individually, "Barclays"). For current important disclosures regarding companies that are the subject of this research report, please send a written request to: Barclays Research Compliance, 745 Seventh Avenue, 14th Floor, New York, NY 10019 or refer to http://publicresearch.barclays.com or call 212-526-1072.

Barclays Capital Inc. and/or one of its affiliates does and seeks to do business with companies covered in its research reports. As a result, investors should be aware that Barclays may have a conflict of interest that could affect the objectivity of this report. Barclays Capital Inc. and/or one of its affiliates regularly trades, generally deals as principal and generally provides liquidity (as market maker or otherwise) in the debt securities that are the subject of this research report (and related derivatives thereof). Barclays trading desks may have either a long and / or short position in such securities, other financial instruments and / or derivatives, which may pose a conflict with the interests of investing customers. Where permitted and subject to appropriate information barrier restrictions, Barclays fixed income research analysts regularly interact with its trading desk personnel regarding current market conditions and prices. Barclays fixed income research analysts receive compensation based on various factors including, but not limited to, the quality of their work, the overall performance of the firm (including the profitability of the Investment Banking Department), the profitability and revenues of the Markets business and the potential interest of the firm's investing clients in research with respect to the asset class covered by the analyst. To the extent that any historical pricing information was obtained from Barclays trading desks, the firm makes no representation that it is accurate or complete. All levels, prices and spreads are historical and do not represent current market levels, prices or spreads, some or all of which may have changed since the publication of this document. The Investment Bank's Research Department produces various types of research including, but not limited to, fundamental analysis, equity-linked analysis, quantitative analysis, and trade ideas. Recommendations contained in one type of research may differ from recommendations contained in other types of research, whether as a result of differing time horizons, methodologies, or otherwise. Unless otherwise indicated, trade ideas contained herein are provided as of the date of this report and are subject to change without notice due to changes in prices. In order to access Barclays Statement regarding Research Dissemination Policies and Procedures, please refer to https://live.barcap.com/publiccp/RSR/nyfipubs/disclaimer/disclaimer-research-dissemination.html. In order to access Barclays Research Conflict Management Policy Statement, please refer to: https://live.barcap.com/publiccp/RSR/nyfipubs/disclaimer/disclaimer-conflict-management.html.

Barclays legal entities involved in publishing research:

Barclays Bank PLC (Barclays, UK)
Barclays Capital Inc. (BCI, US)
Barclays Securities Japan Limited (BSJL, Japan)
Barclays Bank PLC, Tokyo branch (Barclays Bank, Japan)
Barclays Bank PLC, Hong Kong branch (Barclays Bank, Hong Kong)
Barclays Capital Canada Inc. (BCCI, Canada)
Absa Bank Limited (Absa, South Africa)
Barclays Bank Mexico, S.A. (BBMX, Mexico)
Barclays Capital Securities Taiwan Limited (BCSTW, Taiwan)
Barclays Capital Securities Limited (BCSL, South Korea)
Barclays Securities (India) Private Limited (BSIPL, India)
Barclays Bank PLC, India branch (Barclays Bank, India)
Barclays Bank PLC, Singapore branch (Barclays Bank, Singapore)
Barclays Bank PLC, Australia branch (Barclays Bank, Australia)

Disclaimer:

This publication has been produced by the Investment Bank of Barclays Bank PLC and/or one or more of its affiliates (collectively and each individually, "Barclays"). It has been distributed by one or more Barclays legal entities that are a part of the Investment Bank as provided below. It is provided to our clients for information purposes only, and Barclays makes no express or implied warranties, and expressly disclaims all warranties of merchantability or fitness for a particular purpose or use with respect to any data included in this publication. Barclays will not treat unauthorized recipients of this report as its clients. Prices shown are indicative and Barclays is not offering to buy or sell or soliciting offers to buy or sell any financial instrument.

Without limiting any of the foregoing and to the extent permitted by law, in no event shall Barclays, nor any affiliate, nor any of their respective officers, directors, partners, or employees have any liability for (a) any special, punitive, indirect, or consequential damages; or (b) any lost profits, lost revenue, loss of anticipated savings or loss of opportunity or other financial loss, even if notified of the possibility of such damages, arising from any use of this publication or its contents.

Other than disclosures relating to Barclays, the information contained in this publication has been obtained from sources that Barclays Research believes to be reliable, but Barclays does not represent or warrant that it is accurate or complete. Barclays is not responsible for, and makes no warranties whatsoever as to, the content of any third-party web site accessed via a hyperlink in this publication and such information is not incorporated by reference.

The views in this publication are those of the author(s) and are subject to change, and Barclays has no obligation to update its opinions or the information in this publication. The analyst recommendations in this publication reflect solely and exclusively those of the author(s), and such opinions were prepared independently of any other interests, including those of Barclays and/or its affiliates. This publication does not constitute personal investment advice or take into account the individual financial circumstances or objectives of the clients who receive it. The securities discussed herein may not be suitable for all investors. Barclays recommends that investors independently evaluate each issuer, security or instrument discussed herein and consult any independent advisors they believe necessary. The value of and income from any investment may fluctuate from day to day as a result of changes in relevant economic markets (including changes in market liquidity). The information herein is not intended to predict actual results, which may differ substantially from those reflected. Past performance is not necessarily indicative of future results.

This material has been issued and approved for distribution in the UK and European Economic Area by Barclays Bank PLC. It is being made available primarily to persons who are investment professionals as that term is defined in Article 19 of the Financial Services and Markets Act 2000 (Financial Promotion) Order 2005. It is directed at, and therefore should only be relied upon by, persons who have professional experience in matters relating to investments. The investments to which it relates are available only to such persons and will be entered into only with such persons. Barclays Bank PLC is authorised by the Prudential Regulation Authority and regulated by the Financial Conduct Authority and the Prudential Regulation Authority and is a member of the London Stock Exchange.

The Investment Bank of Barclays Bank PLC undertakes U.S. securities business in the name of its wholly owned subsidiary Barclays Capital Inc., a FINRA and SIPC member. Barclays Capital Inc., a U.S. registered broker/dealer, is distributing this material in the United States and, in connection therewith accepts responsibility for its contents. Any U.S. person wishing to effect a transaction in any security discussed herein should do so only by contacting a representative of Barclays Capital Inc. in the U.S. at 745 Seventh Avenue, New York, New York 10019.

Non-U.S. persons should contact and execute transactions through a Barclays Bank PLC branch or affiliate in their home jurisdiction unless local regulations permit otherwise.

Barclays Bank PLC, Paris Branch (registered in France under Paris RCS number 381 066 281) is regulated by the Autorité des marchés financiers and the Autorité de contrôle prudentiel. Registered office 34/36 Avenue de Friedland 75008 Paris.

This material is distributed in Canada by Barclays Capital Canada Inc., a registered investment dealer, a Dealer Member of IIROC (www.iiroc.ca), and a Member of the Canadian Investor Protection Fund (CIPF).

Subject to the conditions of this publication as set out above, the Corporate & Investment Banking Division of Absa Bank Limited, an authorised financial services provider (Registration No.: 1986/004794/06. Registered Credit Provider Reg No NCRCP7), is distributing this material in South Africa. Absa Bank Limited is regulated by the South African Reserve Bank. This publication is not, nor is it intended to be, advice as defined and/or contemplated in the (South African) Financial Advisory and Intermediary Services Act, 37 of 2002, or any other financial, investment, trading, tax, legal, accounting, retirement, actuarial or other professional advice or service whatsoever. Any South African person or entity wishing to effect a transaction in any security discussed herein should do so only by contacting a representative of the Corporate & Investment Banking Division of Absa Bank Limited in South Africa, 15 Alice Lane, Sandton, Johannesburg, Gauteng 2196. Absa Bank Limited is a member of the Barclays group.

In Japan, foreign exchange research reports are prepared and distributed by Barclays Bank PLC Tokyo Branch. Other research reports are distributed to institutional investors in Japan by Barclays Securities Japan Limited. Barclays Securities Japan Limited is a joint-stock company incorporated in Japan with registered office of 6-10-1 Roppongi, Minato-ku, Tokyo 106-6131, Japan. It is a subsidiary of Barclays Bank PLC and a registered financial instruments firm regulated by the Financial Services Agency of Japan. Registered Number: Kanto Zaimukyokucho (kinsho) No. 143.

Barclays Bank PLC, Hong Kong Branch is distributing this material in Hong Kong as an authorised institution regulated by the Hong Kong Monetary Authority. Registered Office: 41/F, Cheung Kong Center, 2 Queen's Road Central, Hong Kong.

Information on securities/instruments that trade in Taiwan or written by a Taiwan-based research analyst is distributed by Barclays Capital Securities Taiwan Limited to its clients. The material on securities/instruments not traded in Taiwan is not to be construed as 'recommendation' in Taiwan. Barclays Capital Securities Taiwan Limited does not accept orders from clients to trade in such securities. This material may not be distributed to the public media or used by the public media without prior written consent of Barclays.

This material is distributed in South Korea by Barclays Capital Securities Limited, Seoul Branch.

All Indian securities related research and other equity research are distributed in India by Barclays Securities (India) Private Limited (BSIPL). BSIPL is a company incorporated under the Companies Act, 1956 having CIN U67120MH2006PTC161063. BSIPL is registered and regulated by the Securities and Exchange Board of India (SEBI) as a Portfolio Manager INP000002585; Stock Broker/Trading and Clearing Member: National Stock Exchange of India Limited (NSE) Capital Market INB231292732, NSE Futures & Options INF231292732, NSE Currency derivatives INE231450334, Bombay Stock Exchange Limited (BSE) Capital Market INB011292738, BSE Futures & Options INF011292738; Merchant Banker: INM000011195; Depository Participant (DP) with the National Securities & Depositories Limited (NSDL): DP ID: IN-DP-NSDL-299-2008; Investment Adviser: INA000000391. The registered office of BSIPL is at 208, Ceejay House, Shivsagar Estate, Dr. A. Besant Road, Worli, Mumbai – 400 018, India. Telephone No: +91 22 67196000. Fax number: +91 22 67196100. Any other reports are distributed in India by Barclays Bank PLC, India Branch.

Barclays Bank PLC Frankfurt Branch distributes this material in Germany under the supervision of Bundesanstalt für Finanzdienstleistungsaufsicht (BaFin).

This material is distributed in Malaysia by Barclays Capital Markets Malaysia Sdn Bhd.

This material is distributed in Brazil by Banco Barclays S.A.

This material is distributed in Mexico by Barclays Bank Mexico, S.A.

Barclays Bank PLC in the Dubai International Financial Centre (Registered No. 0060) is regulated by the Dubai Financial Services Authority (DFSA). Principal place of business in the Dubai International Financial Centre: The Gate Village, Building 4, Level 4, PO Box 506504, Dubai, United Arab Emirates. Barclays Bank PLC-DIFC Branch, may only undertake the financial services activities that fall within the scope of its existing DFSA licence. Related financial products or services are only available to Professional Clients, as defined by the Dubai Financial Services Authority.

Barclays Bank PLC in the UAE is regulated by the Central Bank of the UAE and is licensed to conduct business activities as a branch of a commercial bank incorporated outside the UAE in Dubai (Licence No.: 13/1844/2008, Registered Office: Building No. 6, Burj Dubai Business Hub, Sheikh Zayed Road, Dubai City) and Abu Dhabi (Licence No.: 13/952/2008, Registered Office: Al Jazira Towers, Hamdan Street, PO Box 2734, Abu Dhabi).

Barclays Bank PLC in the Qatar Financial Centre (Registered No. 00018) is authorised by the Qatar Financial Centre Regulatory Authority (QFCRA). Barclays Bank PLC-QFC Branch may only undertake the regulated activities that fall within the scope of its existing QFCRA licence. Principal place of business in Qatar: Qatar Financial Centre, Office 1002, 10th Floor, QFC Tower, Diplomatic Area, West Bay, PO Box 15891, Doha, Qatar. Related financial products or services are only available to Business Customers as defined by the Qatar Financial Centre Regulatory Authority.

This material is distributed in the UAE (including the Dubai International Financial Centre) and Qatar by Barclays Bank PLC.

This material is distributed in Russia by OOO Barclays Capital, affiliated company of Barclays Bank PLC, registered and regulated in Russia by the FSFM. Broker License #177-11850-100000; Dealer License #177-11855-010000. Registered address in Russia: 125047 Moscow, 1st Tverskaya-Yamskaya str. 21.

This material is distributed in Singapore by the Singapore branch of Barclays Bank PLC, a bank licensed in Singapore by the Monetary Authority of Singapore. For matters in connection with this report, recipients in Singapore may contact the Singapore branch of Barclays Bank PLC, whose registered address is One Raffles Quay Level 28, South Tower, Singapore 048583.

Barclays Bank PLC, Australia Branch (ARBN 062 449 585, AFSL 246617) is distributing this material in Australia. It is directed at 'wholesale clients' as defined by Australian Corporations Act 2001.

IRS Circular 230 Prepared Materials Disclaimer: Barclays does not provide tax advice and nothing contained herein should be construed to be tax advice. Please be advised that any discussion of U.S. tax matters contained herein (including any attachments) (i) is not intended or written to be used, and cannot be used, by you for the purpose of avoiding U.S. tax-related penalties; and (ii) was written to support the promotion or marketing of the transactions or other matters addressed herein. Accordingly, you should seek advice based on your particular circumstances from an independent tax advisor.