Understanding OIS discounting

Amrut Nashikkar
+1 212 412 1848
amrut.nashikkar@barcap.com

www.barcap.com

The Dodd-Frank Act mandates central clearing for most swaps and the collateralization of uncleared swaps on dealer balance sheets. OIS discounting is the technically correct approach for pricing and valuing collateralized swaps, and it involves a thorough reconsideration of traditional pricing and valuation techniques. In this note we provide background and touch on some technical nuances involved.

- The traditional method of discounting using a Libor curve misstates the required collateral on a swap and its mark-to-market value. When collateral earns OIS, collateral and mark to market should be based on valuations that discount using a risk-free curve, such as the OIS curve.
- Investors need to rethink the relationship between forward rates and par rates. For the same par swap curve, if the curve is upward sloping and Libor-OIS spreads are positive, forward rates are lower under OIS discounting than they are under Libor discounting.
- The mark-to-market impact of a switch to OIS discounting from Libor discounting should materially affect only aged or off-market swaps, since the mark-to-market value of a par swap at initiation is zero under both discounting schemes.
- Possible market impact:
  - Impact on directional books: Given the rally in rates over the past few years, natural receivers of swaps should benefit and natural payers could lose in a switch to OIS discounting. This has implications for entities with large directional swap books, such as insurance companies and the GSEs.
  - Sensitivity to Libor-OIS spreads: Under Libor discounting, the mark-to-market value of a swap does not change as long as the Libor curve is unchanged. However, under OIS discounting, even if Libor swap rates are unchanged, mark-to-market values of a swap book would have exposure to Libor-OIS spread risk.
  - Valuation of asset swaps: Libor-swap legs of asset swap trades need to be revalued, especially considering that they trade away from the par swap curve.
  - Liquidity of the OIS curve: The OIS, or the FRA-OIS, market is likely to become more active, as market participants hedge both OIS and Libor-OIS risks.
  - Inconsistencies between related derivatives: Even if par swaps are traded consistently, differences could arise in forward-starting swaps and forward rate agreements, depending on the choice of discounting method.
  - Possible accounting implications: As the differences between valuations of collateralized and uncollateralized swaps become more apparent, additional questions regarding the use of Libor swaps as hedges during times of turmoil may arise.

Section 1: Introduction and motivation

OIS discounting means discounting the expected cash flows of a derivative using a nearly risk free curve such as an overnight index swap (OIS) curve. Under OIS discounting, the specific curve to which a particular swap is linked is irrelevant for discounting purposes – its only use is to generate forward cash flows. In contrast, when valuing a swap under traditional (3m Libor) discounting, forward 3m Libor cash flows are also discounted using discount factors from the 3m Libor swap curve. We outline the basics of OIS discounting while staying as non-technical as possible.

The report is divided into four sections. Section 1 describes introduces OIS discounting and discusses the motivation behind it. Section 2 looks at the mechanics through simple examples and formulae. Section 3 discusses the implications of OIS discounting for swap valuation, collateralization, and the pricing of forward-starting swaps. Section 4 looks at the possible market impact and challenges involved in migrating to the new framework.

Why has OIS discounting been introduced?

The financial crisis made the risks involved in OTC derivatives transactions very clear. An in-the-money OTC derivative carries significant counterparty risk, since the expected cash flows will not be realized if the counterparty defaults. Collateralization of OTC contracts using credit support annexes (CSAs) has long been a way of mitigating this risk.

In addition to the voluntary use of collateral in bilateral contracts, central clearing has increasingly become a feature of the swap market. In order to mitigate counterparty risk, clearing houses require initial and variation margins to be posted against swaps that they clear. Collateral posted in this form typically earns a rate linked to overnight interest rates.

Two regulatory factors are likely increasingly leading to essentially all swaps being collateralized. The first is the Dodd-Frank Act, which requires all eligible swaps to be centrally cleared. For uncleared swaps, it mandates collateralization requirements. Thus, in the future, participants in the swap market will take collateral needs into consideration when initiating trades. As this occurs, we expect OIS discounting to increasingly emerge as a market standard.

The second issue involves the capital adequacy guidelines under Basel III, which will be phased in between 2014 and 2018. Risk weights on collateralized versus uncollateralized swaps differ significantly – the former essentially get a zero risk weight, while the latter are weighted according to the risk weight of the counterparty. This means that banks and their swap desks will have incentives to undertake collateralized trades over uncollateralized trades.

What was the trigger for dealers to adopt OIS discounting?

Market participants have been long aware that discounting swap contracts using the Libor curve, as was traditional practice, is flawed in situations where the swap is collateralized and the collateral earns a rate that is lower than Libor. Before 2007, Libor-OIS spreads were in single digits. Therefore, for all practical purposes, the choice of a discounting curve was not crucial. However, the widening of Libor-OIS spreads during the crisis of 2007-08 brought the discrepancy caused by using the Libor curve for discounting risk-free cash flows to the forefront (more on this discrepancy later).

More recently, OIS discounting has become a hot topic because the LCH, the single largest clearinghouse for interest rates swaps, moved to OIS discounting to compute its margin requirements in June 2010. This means that the collateral that dealers have to post against cleared swap positions is computed using OIS discounting. This increases the incentive for dealers to adopt the same method with customers.

Why did the market traditionally discount swaps using the Libor curve?

Interest rate swaps were initially developed as a way for issuers of debt to take advantage of favorable funding costs by enabling them to change the profile of liability cash flows. Libor denoted the average funding cost for a typical financial institution. The assumption was that any swap-linked cash flows could be funded or reinvested at Libor. This made Libor the appropriate discounting rate.

However, when a swap is collateralized, there are two separate sources of cash flows – contractual flows (fixed v. floating payments) and flows related to the collateral that is posted or received in order to secure those cash flows. Since collateral typically earns the OIS rate rather than Libor, discounting swap cash flows using the Libor curve creates a problem.

What is the problem with valuing a collateralized swap using Libor discounting?

Suppose a dealer is paying fixed in a $100 notional 1y 2% swap to a customer against 3m Libor and the current swap rate is 2.5%. For the sake of simplicity, let us assume that the fixed cash flows are only exchanged annually. The question is, what is the fair value of the collateral that the dealer should make the customer pay?

If the dealer enters into an offsetting 2.5% receive-fixed swap, the two floating legs cancel out, and the only payment the dealer can expect is an annual payment of 0.5%. Furthermore, since the new swap was initiated at a value of zero, the discounted value of this annual payment is also the mark-to-market value of the original swap.

Suppose the mark-to-market value is determined by discounting using the Libor curve. Then, this value is: (0.5%*100)/(1+ 2.5%) = $0.4878

The whole point of marking to market and collateralization is that in case the counterparty defaults, the collateral, together with the interest it earns over the life of the swap, must cover the cash payment at the end of the swap.

Is $0.4878 in collateral enough in a world where collateral earns the OIS rate, say 1%? The answer is no. This is because $0.4878 invested over 1y at the OIS rate will generate: $0.4878*(1+1%) = $0.4926, which is not adequate enough for the $0.5 cash flow that the collateral is supposed to cover at the end of the year.

The correct amount of collateral that the dealer should require is 0.5%*100/(1+1%) or $0.49505. This is the final cash flow discounted at the OIS rate. When invested at the OIS rate, an amount of $0.49505 yields the final payout of $0.5 and, thus, covers the remaining payment in the swap. Therefore, the appropriate rate of discounting when marking the collateralized swap to market is the OIS rate, not the Libor rate.

What about valuation of uncollateralized swaps or bilateral swaps that are collateralized differently than the clearing house?

We take the same example as earlier, but leave the swap uncollateralized. Now, when the dealer enters into an offsetting swap with the same customer, he has effectively invested in zero-coupon debt with a notional of $0.5 issued by the customer. The appropriate valuation for this swap is $0.5 discounted at a rate that reflects the credit rating of the customer.

Uncollateralized in-the-money swaps with a customer who has a poor credit rating should be worth less than those with a customer who has a high credit rating. There are more nuances to this general assertion because credit considerations need to be taken into account when initiating the swap itself.

More generally, the curve used for discounting a swap should be consistent with how the swap is collateralized or funded. There is an extensive literature on these valuation adjustments, which can be quite involved depending on the type of collateral, the credit rating of the counterparty and the nature of collateralization (one-way or two-way). The details, however, are beyond the scope of this primer.

Section 2: The mechanics of OIS discounting

What is an overnight index swap (OIS)?

In an overnight index swap, two parties agree to exchange the difference between interest accrued at the fixed rate and interest accrued at a compounded floating rate on the notional of the swap. The floating leg is computed using the effective fed funds rate. The fixed versus compounded floating payments are exchanged at maturity date + 2, as long as the maturity of the swap is less than 1y. For OIS of more than 1y, payments are exchanged annually.

How does one build an OIS curve?

There are several ways to build an OIS curve. The simplest is to use market OIS rates (available on Bloomberg) starting with a maturity of 1wk and extending out to 5y. These swap rates denote zero-coupon rates to maturity, using the Actual/360 convention, for maturities less than 1y, and annually payable par rates for maturities greater than 1y. Beyond the 5y maturity point, 3m Libor swap rates may be adjusted by the Libor-OIS basis (both of which extend out to the 30y point) to arrive at par OIS rates.

The second possibility is to use OIS rates implied by the fed funds futures market. The additional complication of using fed funds futures is that they represent arithmetic averages of the overnight fed funds rate, as opposed to the compounded average represented by the OIS rate. This can make a substantial difference. Furthermore, there are only a fixed number of meetings when the fed funds rate can be changed by the Fed. These meeting dates need to be accounted for while constructing the front end of the curve, by introducing appropriate “steps” at meeting dates.

For maturities greater than 2y, an OIS curve is needed, which may again be “backed out” of the OIS curve using the 3m Libor swap curve and the Libor-OIS basis curve, which is available out to a 30y maturity. Figure 2 is a schedule of discount factors bootstrapped from the OIS curve, compared with those bootstrapped from a Libor curve.

Does bootstrapping the par swap curve to generate forwards still work?

The short answer is no. In traditional Libor discounting, all we need is the Libor swap curve to derive forward Libor rates. Under OIS discounting, we need both the Libor swap curve and the OIS curve. With a given Libor swap par curve, it is no longer possible to get Libor forward rates, since discount factors from the OIS curve need to be used to construct the forwards. The traditional bootstrapping approach to generate forward Libor rates is:

Formula 1

$$DF_n = \frac{1 - R_n \sum_{j=1}^{n-1} A_j DF_j}{1 + R_n A_n}$$

Followed by:

Formula 2

$$L_{n-1,n} = \frac{DF_{n-1} - DF_n}{DF_n A_n}$$

Here n denotes the maturity in terms of the number of resets, R denotes the fixed swap rate, and DF_j denotes the zero-coupon discount factor for reset date j, $L_{n-1,n}$ denotes the forward Libor rate from the $(n-1)^{th}$ reset date to the n^{th} reset date, and A_n is the accrual factor from n-1 to n according to the ACT/360 convention.

However, the implicit assumption in these formulae is that the fixed leg of the swap for every maturity is at par at initiation and that the floating leg of the swap resets to par on every Libor reset date. Under OIS discounting, the fixed and floating legs of the swap will trade at a premium at initiation, since the curve being used to discount the cash flows is lower than the Libor curve. This means that the bootstrapping formula needs to be modified. For one, the discount factors need to be bootstrapped from the OIS curve using a process we described earlier (since the fixed leg of an OIS swap under OIS discounting should still be at par).

However, for constructing forward Libor rates, the traditional bootstrapping formula changes. If DF denotes OIS discount factors, then forward Libor rates can be computed recursively.

This formula attempts to explicitly equate the present values of the fixed and floating legs of a swap when both are discounted using the OIS curve. Here $L_{n-1,n}$ denotes the forward 3m Libor rate from the $(n-1)^{th}$ reset date to the n^{th} reset date.

Formula 3

$$L_{n-1,n} = \frac{R_n \sum_{j=1}^{n} A_j DF_j - \sum_{j=1}^{n-1} A_j DF_j L_{j-1,j}}{DF_j A_j}$$

Section 3: Valuation issues

How do you value a swap at initiation?

Although neither the floating nor the fixed leg is at par at initiation, the mark-to-market value of a par swap should still be zero for the fixed leg to denote an at-market swap rate.

How does the relationship between par and forward rates change under OIS discounting?

If we take the par swap curve as given, then for that curve to be the same under OIS discounting or Libor discounting, the implied forward rates would need to be slightly

different. Alternately, if we take 3m Libor forwards as given, then the implied par rates would need to be slightly different between OIS discounting and Libor discounting.

We can show this through a simple numerical example. Consider a fixed-rate swap payable annually against 1y Libor. Say 1y Libor = 1% and the 2y par swap rate = 2%.

Assume that Libor-OIS basis is 1%. This means that the par 1y OIS rate is 0% and the par 2y OIS rate is 1%.

"Traditional" bootstrapping using a Libor curve:

First compute discount factors from the par rates using Formula 1.

DF_1 (1y discount factor) = (1 + 1/100) = 0.9909

DF_2 (2y discount factor) = (1 – 2/100*0.9909)/(1+2/100) = 0.960978

Next, compute the forward Libor rate using Formula 2:

1y1y rate = 0.9909/0.962507 – 1= 3.03%

"Modified" bootstrapping using both the Libor and OIS curves

First compute OIS discount factors from the par *OIS* rates by applying Formula 1 to the OIS curve.

DF_1 = 1/(1+0/100) = 1

DF_2 = (1 – 1/100*1)/(1+1/100) = 0.980198

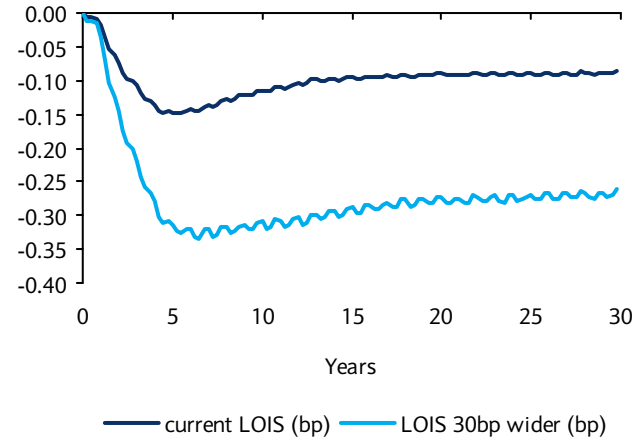
Using these discount factors, compute what the 1y1y rate would need to be for the 2y swap that pays 2% against 1y Libor to be "fair".

Using formula 3 above, this can be calculated as

$(2\%*(DF_1 + DF_2) – 1\%*DF_1)/ DF_2 = 3.02\%$

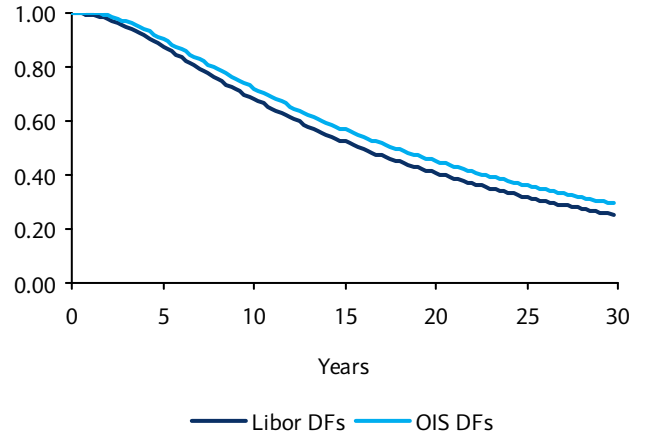
This rate is 1bp lower than the forward rate calculated under Libor discounting. An investor

Figure 1: Differences in 1y forward rates under OIS discounting and Libor discounting at different levels of Libor-OIS spreads



Source: Barclays Capital

Figure 2: Discount factors computed from the OIS curve are higher than those from the Libor curve



Source: Barclays Capital

using Libor discounting would estimate a 1y1y rate of 3.03%, while another investor using OIS discounting would estimate the 1y1y rate to be 3.02%.

Figure 1 shows the difference between implied 1y forward rates for the market par-swap curve under Libor discounting and OIS discounting. Implied forward rates under OIS discounting are lower than those under Libor discounting. This would be the expected situation when the OIS curve is below the Libor curve (as would be normally expected) and when the curve is upward sloping.

The intuition behind this result is somewhat subtle. A par rate is a weighted average of forward rates, where the weights are discount factors for the dates when the forward cash flows are realized. When you lower the discounting curve from Libor to OIS, discount factors at the back end are lowered more than those at the front end because of the compounding effect. To offset this, if the par rate is to remain the same, forward rates at the back end need to be lowered to offset the effect of higher discount factors. The difference between forwards arrived at using OIS discounting and those arrived at using Libor discounting would itself be directly depend on the Libor-OIS spread curve.

How does the valuation of swaps change under Libor and OIS discounting?

Changing the discounting rate obviously implies that swap valuations must change. OIS discounting makes the largest difference to the valuation of off-market swaps. As we move away from par, the differences become bigger.

Take a $100 notional 10y receive 5% fixed against 3m Libor swap when the market 10y par swap rate is 2.5%. How does its value change under Libor and OIS discounting? If we assume that we enter into an offsetting par swap for $100 notional, that trade cancels all the floating payments and leaves a fixed stream of $1.25 every six months for the next 10 years, an annuity that is payable semiannually. Again, because the offsetting par swap is initiated at zero, the value of this annuity is the mark-to-market value of the 5% swap.

If the Libor curve is 30bp higher than the OIS curve, then switching from Libor to OIS discounting means moving down the discount rate for this annuity by 30bp. Therefore, the impact of switching to OIS discounting from Libor discounting for a swap with a fixed rate of R when the par swap rate is r is approximately given by:

MTM impact = (Libor-OIS)* DV01 of annuity with per-period payments of (R-r)*Notional

This means that in-the-money swaps gain under OIS discounting as long as Libor-OIS spreads are positive. For the same reason, out-of-the-money swaps lose under OIS discounting. Furthermore, not only does the above formula give an approximate mark-to-market adjustment for switching from Libor to OIS discounting, it also describes how the mark-to-market value of any swap changes because of changes in Libor-OIS spreads, even if the par swap rate itself remains constant. The sensitivity of the swap to Libor-OIS spreads is approximately equal to the DV01 of an annuity that pays the difference between the fixed rate of the swap and the par rate prevailing in the market.

Under stressed market conditions when Libor-OIS spreads widen, the differences between Libor discounting and OIS discounting can be particularly stark, especially for swaps that are significantly out of the money.

Figure 3 shows how the difference created by moving from Libor discounting to OIS discounting varies for swaps with different fixed rates, while keeping the Libor and OIS curves constant. Here we have valued the swaps assuming that the forward 3m Libor curve

is the same between Libor and OIS discounting. As the formula suggests, the effect of switching from Libor to OIS discounting is the greatest for swaps that are far in the money or out of the money relative to the at-market par rate.

Why are collateralized swaps exposed to Libor-OIS spread risk?

Collateralized swaps, when discounted using the OIS curve, have an explicit exposure to Libor-OIS spreads, not just to the Libor term structure. If swap rates are unchanged but Libor-OIS spreads tighten, the two discounting curves move closer. In this case, in-the-money receive-fixed swaps lose, but they gain when Libor-OIS spreads widen. This introduces volatility to Libor-swap hedges when Libor-OIS spreads are volatile, as was the case in late 2008. Hedging a receive-fixed Libor position would require entering a Libor-OIS spread tightener.

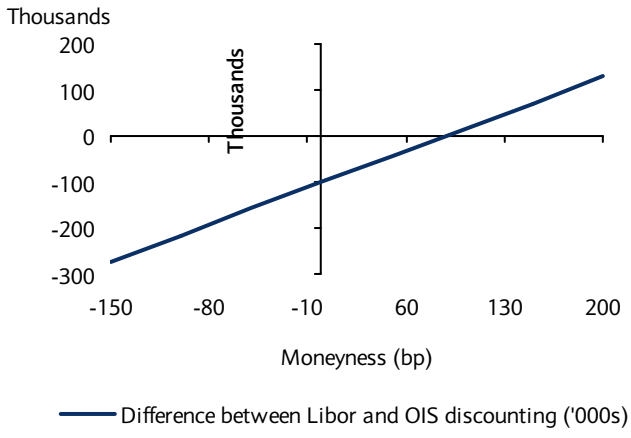
Figure 4 shows the impact of changes in the Libor-OIS spread on the valuation of a $100mn notional 10y receive 6% fixed against 3m Libor. Notice that the differences in valuation are nearly linear in the change in the Libor-OIS spread.

Is there need for a convexity adjustment?

Ideally there is a need for a convexity adjustment. This is because of the margin cash flows associated with the swap. Consider an investor who is receiving 1y1y rates. Let us assume that 1y1y rates are perfectly correlated with overnight rates. When rates rally, the investor receives collateral equal to the change in the market value of the swap. However, this collateral will earn the lower overnight rate. When rates sell off, the investor has to post collateral. However, this collateral will need to be borrowed at a higher overnight rate. Thus, convexity hurts the investor, who will demand a slightly higher swap rate than would have been the case without collateralization.

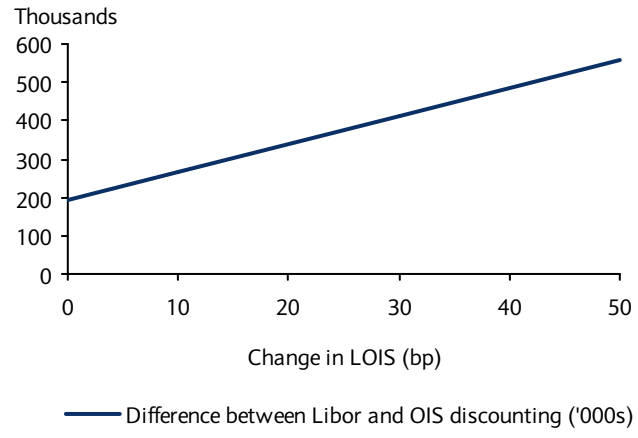
In principle, this adjustment is similar to the convexity adjustment for Eurodollar futures. The only difference is that in a futures contract, the variation margin is on the basis of the final futures cashflow, while in this case, the variation margin is on the basis of the *discounted* value of the final cashflow.

Figure 3: Difference in mark-to-market value between Libor and OIS discounting for $100mn of 10y-3m Libor swaps with different fixed rates



Source: Barclays Capital

Figure 4: Impact of changes in Libor-OIS spreads on the difference between Libor and OIS discounting for a $100mn 10y 6% 3m Libor swap



Source: Barclays Capital

Section 4: Market implications

Move could affect directional books substantially

Given the drift lower in rates over the past few years, most receive-fixed swaps initiated in the past are likely to be in the money and most pay-fixed swaps are likely to be out of the money. The mark-to-market impact of moving from Libor to OIS discounting is likely to be limited for market participants that run hedged swap books with a large number of offsetting positions. However, there is likely to be a greater impact on directional books, such as those of investors who use swaps primarily to hedge asset or liability duration. For example, insurance companies generally receive fixed at the long end of the curve. On the other hand the GSEs are generally payers of swaps.

Given the rally in rates over the past few years, most aged swaps are likely to be significantly in the money. Therefore, natural receivers of long-dated swaps could be net beneficiaries of a switch to OIS discounting, but swap payers could see the value of their swap books decline.

Changes in hedging strategies

We believe dealers are likely to hedge swap book exposures using the FRA-OIS market to a greater extent. This could make the OIS market more liquid, even beyond 5y maturities.

The change in discounting methodology affects swaps that are farthest away from par; a good example is asset swaps. Although most vanilla swaps are par swaps at initiation, one leg of an asset swap is typically tied to the coupon or the return on a particular security. This means that asset swaps could be substantially away from par. Introducing OIS discounting means introducing explicit Libor-OIS risk to positions that previously had exposure to only Libor risk. As a result, it is possible that the OIS curve will become a benchmark for asset swaps to avoid this risk altogether. If this occurs, there could be receiving in Libor swaps and paying in OIS, thereby leading to Libor-OIS compression.

Inconsistent forwards

As we discussed, forward rates bootstrapped from the same par curve under Libor discounting and OIS discounting are different. As a result, there may be differences between estimates of forward rates among market participants, based on which discounting method is used. Over time, as the market gravitates toward a standard OIS discounting curve, these differences should disappear. In some products, it may be a while before this convergence occurs. For example, at-the-money forward rates for swaptions could differ across dealers depending on the discounting method used. Until it is standard practice among dealers to discount swaptions using OIS, the differences may persist.

Accounting concerns

At this stage it is unclear whether the accounting treatment for Libor swaps designated as rate hedges for other financial instruments could be affected by changing the discount curve. Depending on how accounting rules play out, there could be a number of possible alternatives. Of particular concern is the fact that the valuation of identical collateralized and uncollateralized swaps can be considerably different, which brings into question their hedging effectiveness against each other.

References

1. "Pricing collateralized swaps," Johannes, M. and S. Sundaresan, Columbia Business School Working Paper, 2003.

2. "Funding beyond discounting: collateral agreements and derivatives pricing," Piterbarg, V., *Risk Magazine*, 2010.

Analyst Certification(s)

I, Amrut Nashikkar, hereby certify (1) that the views expressed in this research report accurately reflect my personal views about any or all of the subject securities or issuers referred to in this research report and (2) no part of my compensation was, is or will be directly or indirectly related to the specific recommendations or views expressed in this research report.

Important Disclosures

For current important disclosures regarding companies that are the subject of this research report, please send a written request to: Barclays Capital Research Compliance, 745 Seventh Avenue, 17th Floor, New York, NY 10019 or refer to https://ecommerce.barcap.com/research/cgi-bin/all/disclosuresSearch.pl or call 212-526-1072.

Barclays Capital does and seeks to do business with companies covered in its research reports. As a result, investors should be aware that Barclays Capital may have a conflict of interest that could affect the objectivity of this report. Any reference to Barclays Capital includes its affiliates. Barclays Capital and/or an affiliate thereof (the "firm") 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). The firm's proprietary trading accounts may have either a long and / or short position in such securities and / or derivative instruments, which may pose a conflict with the interests of investing customers. Where permitted and subject to appropriate information barrier restrictions, the firm's fixed income research analysts regularly interact with its trading desk personnel to determine current prices of fixed income securities. The firm's fixed income research analyst(s) 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 Fixed Income Division and the outstanding principal amount and trading value of, the profitability of, and the potential interest of the firms 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 Capital 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. Barclays Capital produces a variety of research products including, but not limited to, fundamental analysis, equity-linked analysis, quantitative analysis, and trade ideas. Recommendations contained in one type of research product may differ from recommendations contained in other types of research products, whether as a result of differing time horizons, methodologies, or otherwise.