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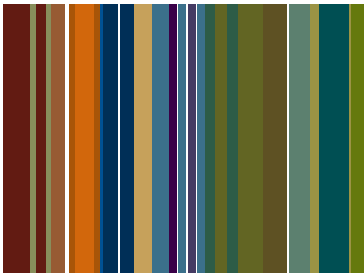

WHITE PAPER SERIES

Do you really know how to price an interest rate swap?

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The financial crisis has had a profound and pervasive effect on the pricing of interest rate derivatives. The accurate pricing of an interest rate swap is the foundation for running an interest rate business, making markets and managing risk. However, it's become much more difficult to correctly price and manage risk around this most vanilla of all derivatives instruments. Why is that the case? This article seeks to outline the evolution of swap pricing and understand the market problems that remain.

Pontus Eriksson, product manager, Front Arena, SunGard's capital markets business

IN THE GOOD OLD DAYS

The interest rate derivatives market began in the early 1970s and developed rapidly. Up until the credit crisis, pricing swaps followed the foundation of a single risk-free yield curve. This model assumed that the cost of funding future cash flows was the same as the inherent forward rates. More concretely, floating rate cash flows were assumed to be projected by the so-called swap curve, and cash flows on both sides of the leg were discounted with that same swap curve. This meant that a single curve was required to price a vanilla single currency swap.

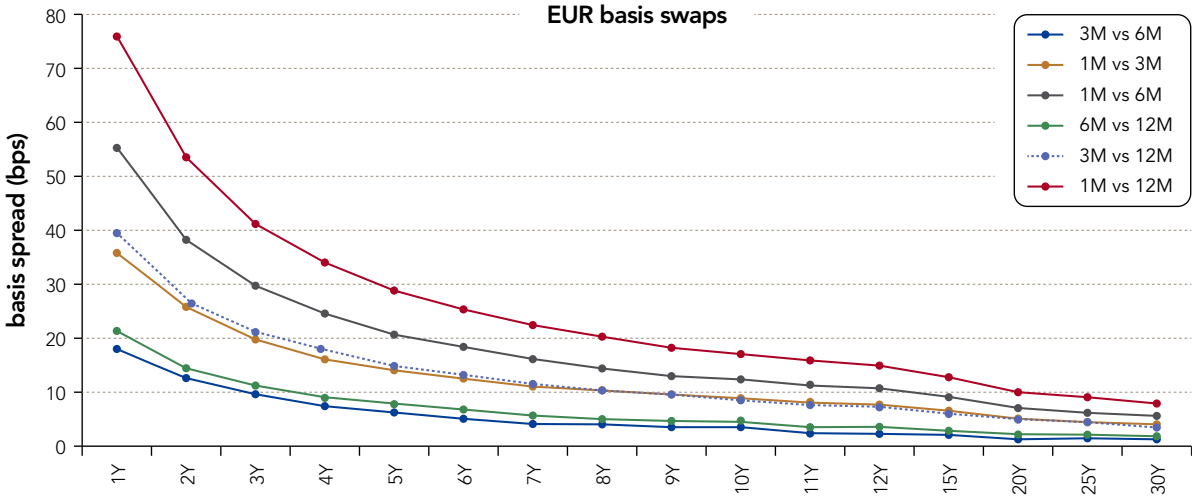
At the time, most of the discussions revolved around the issue of how to construct that single curve, and in particular what benchmark instruments to calibrate from and how to interpolate and extrapolate between the points. The main ambition in constructing the curve was to secure a smooth forward curve and make sure that benchmark instruments priced back to market price. In general, these questions and priorities are still important. However, as we will see later on, there are other intricacies that are now having significant importance when pricing swaps.

There is no typical swap curve, as different markets calibrate curves using different liquid instruments. For example, the EUR swap curve was typically constructed from deposits in the short term, futures in the mid-section and swaps in the longer end. Other markets were more driven by Forward Rate Agreements (FRAs) and naturally choose FRAs as benchmark instruments rather than futures.

Picking the best benchmark instrument could involve choosing to use deposits in the short end of the curve or Libor prices directly from the market. The latter has the benefit of reducing the fixing risk stemming from the difference between the rate fixing and the estimated value. By using the Libor fixing as a benchmark in the curve fixing, risk is removed. Often this was, and still is, the favored approach by many institutions.

On the other hand, when pricing with short term deposits, the same curve will not price that deposit back to its market price. This creates "internal arbitrage" and should be avoided.

Figure 1: Quotations (basis points) as of Feb. 16th, 2009 for the six EUR basis swap curves corresponding to the four Euribor swap curves 1M, 3M, 6M, 12M. Before the credit crunch of Aug. 2007 the basis spreads were just a few basis points (source: Reuters ICAPEURIBASIS).



Other choices included choosing the break point to use futures versus swaps. Swaps are generic instruments in the sense that they roll forward every day. A two-year swap benchmark is always a two-year swap. Futures are physical instruments with a fixed expiry date. Therefore, the expiry dates of the future will from time to time coincide with the expiry date of the swap. A critical choice has to be made: to remove the future, or let the future price have precedence? When there is a dislocation between the prices, a similar dilemma is created over the choice of using Libor fixing or deposits in the short term curve building.

So it's clear that even in the good old days, there was a balancing act to perform when choosing the best instruments to calibrate against. Yet the complexity was limited to these decisions.

THE MARKET ADOPTION OF FORWARD CURVES

As a result of the crisis, market participants have become much more aware of credit and liquidity risks. The credit crunch triggered an explosion of single-currency basis spreads. These are the spreads between receiving or paying interest based on different tenors, and they became very significant because of the increase in perceived credit risk.

This is because it is not the same thing to receive interest over a six-month period compared to receiving it over three months and reinvesting over the next three months if you know the interest payer may not exist in four months. So projecting cash flows over different tenors needs to be performed using different curves.

During the crisis, the preference towards receiving payments with higher frequency has become much more pronounced. The interest rate market has quickly transformed itself into a series of separate sub-markets representing each rate tenor. Participants have witnessed a "segmentation" of the interest rate market to reflect the inherent higher liquidity and credit risks.

This basis effect is not a new phenomenon but was deemed so small pre-crisis that it was practically excluded when pricing derivatives. During the crisis, market participants have been forced to develop a new set of governing rules to account for the much higher risk premia that evolved.

The effect of the basis widening becomes very clear when studying this graph in Fig 1. Similar effects were seen also in non-EUR currencies. One can no longer ignore the effect this has had on pricing an interest rate swap.

FORWARD CURVES TODAY

Forward curves are yield curves used to project forward cash flows. Each forward curve has its own constituent benchmark instruments. Only liquid benchmark instruments dependent on the specific tenor, similar to the forward curve tenor, are used. When calibrating the forward curve, the discounting curve has to be known (and fixed). Multiple curves need to be calibrated, and each uses its own set of vanilla instruments homogeneous in the underlying tenor. The base forward curve (Euribor 6M in EUR) is typically constructed from interest rate futures and swaps as benchmark instruments similar to how the EUR swap curve was created in the single-curve regime. However, today the other forward curves referencing for example the 1M tenor must be sourced from 1M-6M basis swaps.

LESSONS LEARNED

During this period, some market participants were quicker than others to adopt this new world order and priced the interest rate basis when trading swaps and other derivatives. Those who did not understand this transformation could lose significant sums of money. Moreover, many trading floors had difficulties in accounting for this because their trading systems could not support the new methodologies. Internal IT departments and software vendors had to respond quickly to bring this new functionality to traders. Time-to-market was key.

There is no evidence that the basis will gravitate towards being negligible again and market participants have learned a lesson. Market quotes of standard derivatives such as swaps, FRAs and deposits today price the tenor basis. The vast majority of market participants have now adopted this practice, although that so many participants were taken by surprise at the time is a lesson sorely learnt.

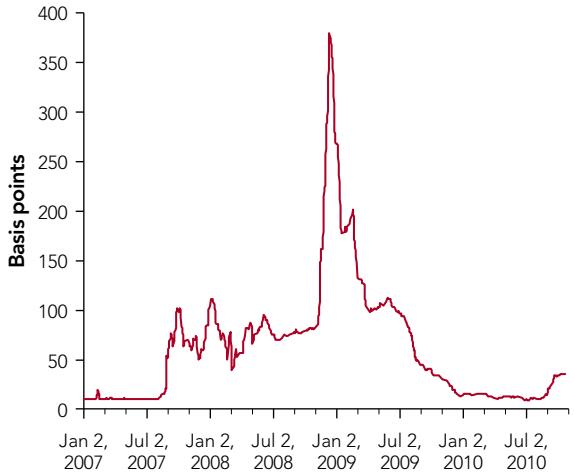
THE EMERGENCE OF OIS DISCOUNTING

Similarly during the crisis, the spread between the EUR deposit rate and the overnight indexed swap (OIS) rate exploded, peaking at roughly the time of Lehman's default. Since then the basis has shrunk, but it has not reached the levels seen before the crisis. This has led to the notion of OIS discounting.

In the early days, one of the most fundamental constants was the use of Libor as a discount rate to price derivatives trades. This assumption no longer holds and has been abandoned by banks and other financial institutions. It is now generally accepted that the OIS rate is the correct choice for discounting future cash flows on collateralized swaps. This is because the collateral would earn an interest rate based on the OIS rate, and the mark-to-market value of a collateralized swap's cash flows should be valued similarly.

Fig 2: The below picture shows the USD OIS-Libor spread during and after the crisis. At the peak of the crisis, spreads exploded, but even more interestingly, the spreads have not reverted to pre-crisis levels where they could be neglected. A spread of 10-40 basis points could not be dismissed as irrelevant by any market participant, particularly in a world of tightening margins.

US federal funds rate and US three-month Libor basis



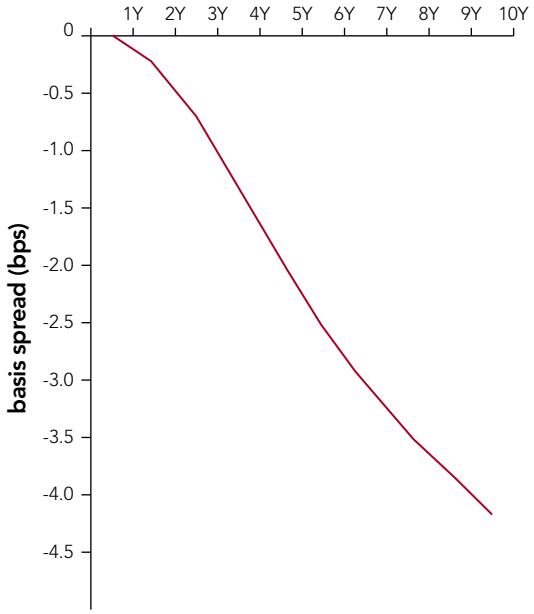
Source: Bloomberg

Fig 3: The picture below illustrates the pricing differential for a swap trade priced with Libor flat versus Libor plus 100 basis points, assuming no CSA agreement is in place. The case for pricing funding cost into a swap should be considered.

Pricing differentials on an uncollateralized interest rate swap

Maturity	Swap rate (Libor funding)	Swap rate (L+ 100 funding)	Difference -basis points
1Y	0.746%	0.746%	-0.046
2Y	1.148%	1.146%	-0.267
3Y	1.615%	1.608%	-0.725
4Y	2.068%	2.054%	-1.332
5Y	2.467%	2.447%	-1.960
6Y	2.786%	2.761%	-2.536
7Y	3.035%	3.005%	-3.035
8Y	3.232%	3.197%	-3.468
9Y	3.389%	3.350%	-3.847
10Y	3.519%	3.477%	-4.196

Note: difference in prices for US dollar 10-year interest rate swap priced by bank funding at Libor and one bank funding at Libor+100 basis points. The client receives fixed payments from the banks, and pays US three-month Libor



Source: Barclays Capital

Similarly, non-collateralized trades should be discounted using their own cost of funding for the bank. Individual banks typically fund at different levels, so the same swap will not have the same value from one bank to the other.

There have always been discussions about where the true "risk-free" rate is. Until recently, the Libor curve has been used. This rate represents the average counterparty risk (and liquidity risk) among the contributing banks. Although these banks are the major tier-one, this rate still comes with risk (e.g. Lehman). Banks have recognized this and no longer use the Libor curve as a proxy for the risk-free rate. The OIS curve has usurped the throne.

ACCOUNTING FOR COLLATERALIZATION AND DISCOUNTING IS THE NEW NORM

The main brokers today quote the common type of interest rate derivatives using OIS rates for discounting. The main clearing houses also use OIS discounting to calculate margin. This is a significant step. But many banks still are not using this approach. Today, the mid-price on a standard interest swap will be based on the assumptions the deal is collateralized. This affects the curve construction of the forward curves as they depend on standard swap market quotes. More specifically, the OIS curve will be used to discount the swap benchmark instrument in the construction of the forward curve. Uncollateralized trades look different from a pricing perspective because of assumptions about credit value adjustment (CVA) and funding costs.

The level of collateralization on interest rates derivatives has increased in the last few years due to better awareness of counterparty risk. It will further increase with upcoming regulatory changes because the regulatory capital requirements for uncollateralized trades will make it more conducive for banks to embed this into transactions. Certainly interbank trading is mostly associated with mutual Collateral Support Annexes (CSA's). According to the ISDA Margin Review 2010, around 70% of the global interest rate and credit derivative market is collateralized. However, many commercial banks trade with clients, and here the level of collateralization is still relatively low. Therefore it is important to understand the pricing aspects that come into play regarding uncollateralized trades.

OWN COST OF FUNDING

Using one's own cost of funding priced into non-collateralized trades has also created some havoc in the markets because higher-quality banks with a lower cost of funding have been able to offer a better rate to clients that receive fixed through a swap. Despite what is theoretically correct, several participants still use the Libor rate for pricing non-collateralized deals. This is a pragmatic approach because it can be difficult to construct the funding curve and competitiveness can be negatively impacted when offering quotes to customers. There is a balancing act between pricing the deal correctly and being competitive and swallowing the effect internally. Passing costs on to clients by incorporating the bank's cost of funding into a plain vanilla swap can make banks uncompetitive.

Of course, banks are in the business of lending or borrowing money when transacting an uncollateralized swap deal. The outstanding market value represents whether they are long or short. Qualitatively, there is not much difference between charging for a loan under a swap deal as opposed to making an outright loan and so counterparty risk should be considered when pricing loans. Like the change of price of Interest Rate Swaps, this phenomenon is completely new because counterparty risk had previously been priced in using a simple spread or an upfront payment.

THE INCREASED IMPORTANCE OF FUNDING DESKS

Several of the medium to large banks have set up specific desks to manage the funding risk of their derivatives business. This is similar to how Credit Value Adjustment (CVA) desks emerged as separate entities to take care of counterparty pricing driven by increased counterparty risks and new regulations. The funding desk charges the trading desks for non-collateralized deals with the spread between the funding and the OIS rate. Managing funding risk and hedging it is not straightforward because few instruments isolate this risk. Centralized desk aggregation is crucial to optimize the use of funds and ensure fair value for clients. Clients are either paying or receiving funding and it is in both counterparts' interest that they should receive a fair level for the funding aspect of the deal.

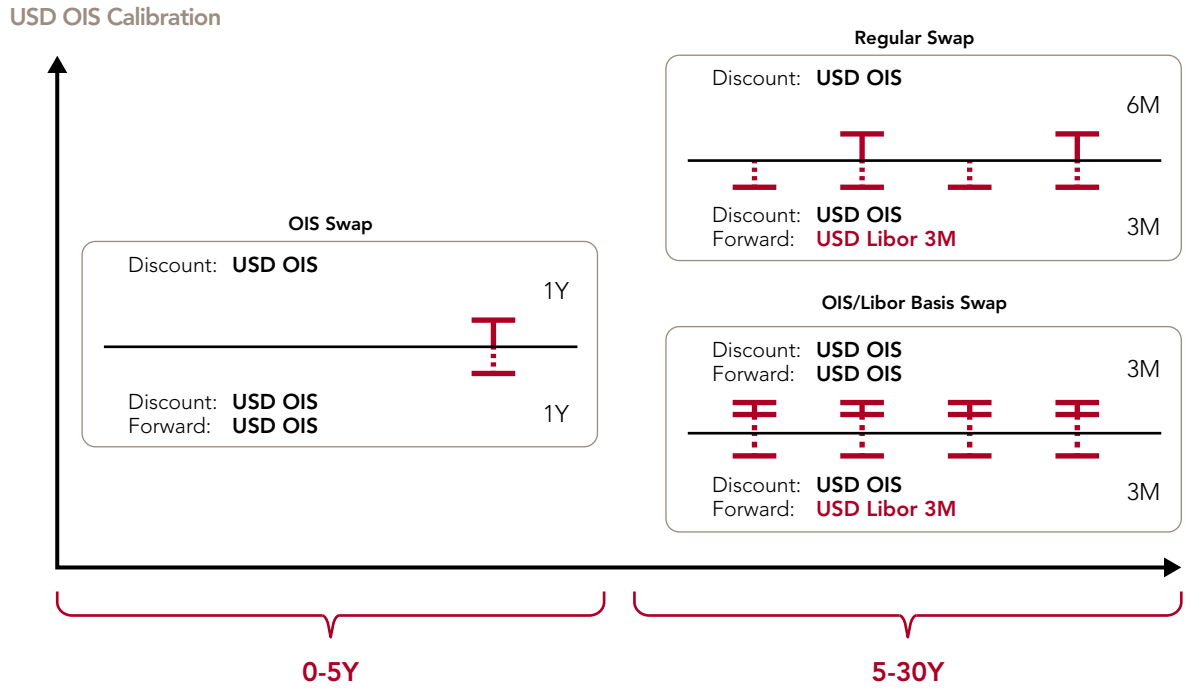
ARE OIS RATES A GIVEN?

The most liquid OIS markets are in US dollar, Euro, Sterling, Swiss franc and Yen. The EUR OIS market is liquid up to 30 years and an OIS curve can be easily calibrated using conventional calibration tools and OIS benchmark instruments. Note the EUR forward curve for regular swaps must be calibrated separately due to OIS discounting. For very long swaps, assumptions have to be made about how to extrapolate the OIS curve beyond the last benchmark instrument. What about markets where OIS benchmarks are not liquid or do not even exist?

In USD, the OIS (or Fed Funds) market is only liquid for up to two to five years. Therefore, calibration becomes an issue. How do you construct an OIS curve in USD when there are no benchmark instruments beyond five years? A market convention is developing where OIS vs. Fixed and OIS vs. Libor basis swaps are being used simultaneously. For each tenor beyond the five-year point, there are two benchmark instruments that make up the OIS rate together. The challenge here is that both these benchmark instruments depend on the curve they try to calibrate – the OIS curve. It seems like a circular dependency, but this can be solved by adjusting the Libor rates with the OIS versus Libor basis.

On the very short end of the curve, typically up to a few months, standard practice is to account for a flat extrapolation in forward rates using the Monetary Policy Committee (MPC) rate, because participants want to include their expectation of the MPC rates in the price. If the OIS benchmark expiry dates do not coincide with MPC dates, care should be taken in the interpolation because new MPC rates typically come as a step-wise increase or decrease.

Fig 4: The picture below illustrates how the USD OIS curve can be constructed by sourcing different benchmark instruments in different regimes of the curve. Note the complicated step whereby the OIS curve calibration (assuming forward curve fixed) will be dependent on the forward curve calibration (assuming OIS fixed).

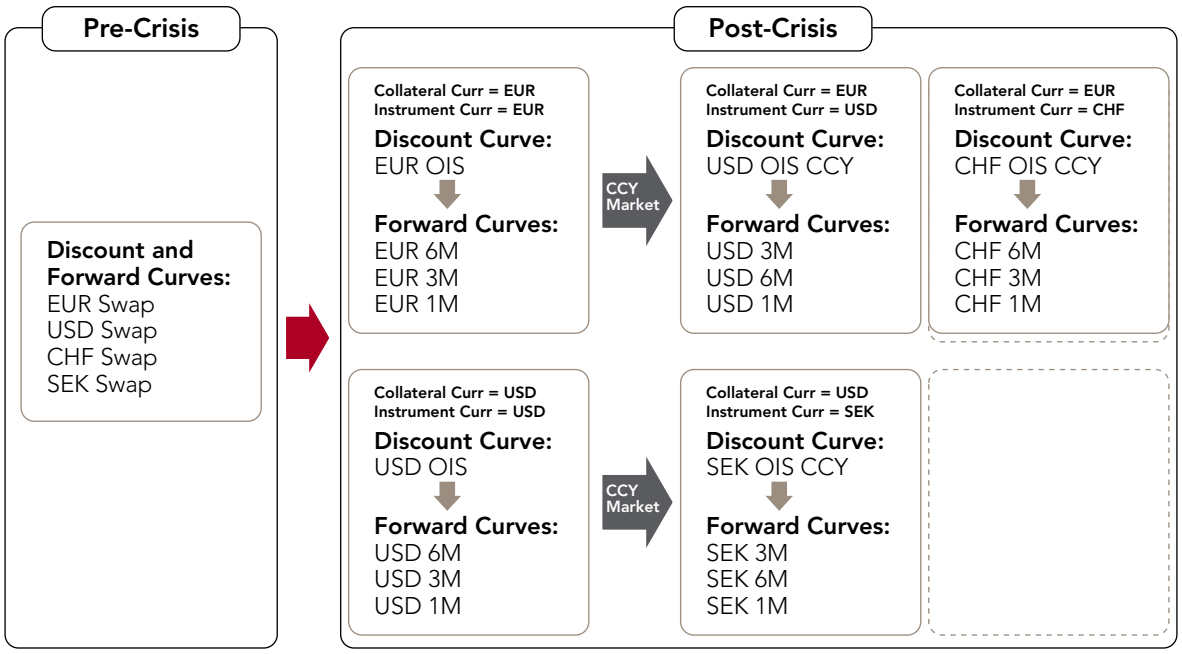


In many markets (such as ZAR, SEK, DKK, AUD) either no OIS market exists or it may exist for only a few years. How to construct an OIS curve in those currencies also involves some complex questions.

How do you calibrate a curve where no benchmark instrument exists? Well, many market participants use the USD OIS curve and then cross currency convert this curve into a foreign currency OIS curve.
The conversion can be achieved using FX forwards in the short end of the curve, typically up to one year, and cross currency swaps in the longer end. By using this approach, a foreign OIS curve can be "synthesized" by using USD as the base and imposing FX consistency from the FX and rates markets.

The synthesized curve could be modified - let's say up two years - by using liquid OIS instruments if they are available.
This introduces, of course, an inconsistency. A number of banks are using these curves for different purposes – the synthesized curve is used for discounting derivatives with CSA agreements and the domestically generated OIS is only used to price the domestic OIS instruments. Hence they separate their usage and avoid being too exposed to the issue.

Fig 5: The picture below illustrates how OIS and forward curves have emerged during the crisis. Due to dependencies between the curves a specific sequential order is needed when calibrating them. Depending on collateral currency, OIS curves can either be constructed from their benchmark instruments or induced via the CCY market.



Irrespective of how the OIS curve is constructed, this curve is completely separated from the forward curves used in derivatives pricing, as explained earlier.

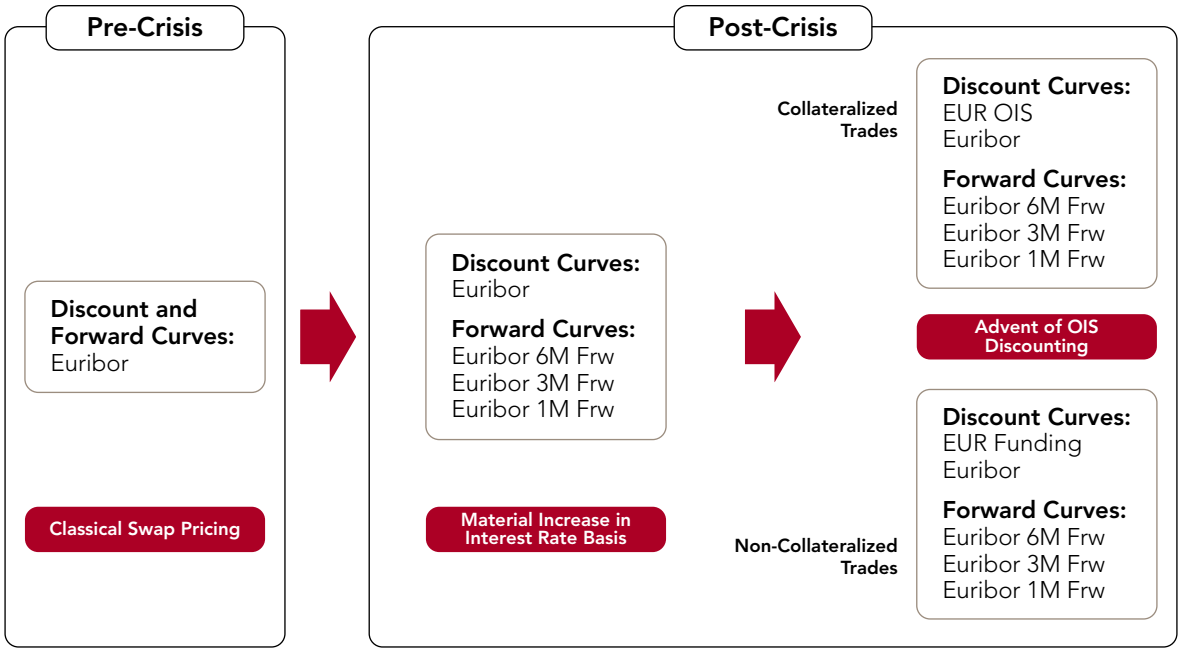
CSA AGREEMENTS RISKS: A POTENTIAL REMEDY

New and more standardized CSA agreements are needed to eliminate problems with the existing documentation. The problem boils down to the number of options in existing CSA agreements. Counterparties can agree to a list of collateral that is eligible to be posted, and this can differ significantly from contract to contract. The ability to post collateral in different currencies can lead to a delivery option that can be quite valuable if there are large FX movements.

The theoretically correct OIS curve should be determined by the currency of the collateral. If there is optionality, the cheapest-to-deliver collateral should be used. A trade collateralized with dollar cash would be discounted using the Federal Funds rate. A trade collateralized with a CSA agreement that allows delivery in a choice of several currencies should be discounted with the OIS in the cheapest to deliver currency. Hence discounting depends on the collateral currency.

The current approach for most participants does not price in this effect because it is simply too complicated in relation to its financial gains. A standardized CSA agreement such as that recently promoted by ISDA can remove this uncertainty and make pricing more streamlined. However many legacy CSA's will not be able to be retired for a long time to come.

Fig 6: The below schematic illustrates the yield curves involved in pricing a swap pre- versus post-crisis. In reality, a one-month, three-month and six-month Libor curve will be needed for every currency.



HOW DO WE PRICE A SWAP TODAY?

The level of complexity described above brings with it a whole new set of risk factors and yield curves – and therefore new risk management needs. Managing this set of curves, the basis risks stemming from differences in forward rates, and differences in OIS/funding rates and the curve calibrations all clearly indicate a need for trading and risk management systems that can handle all of these complexities in an efficient and transparent manner.

THE WORLD HAS CHANGED FOREVER

The world has changed, with significant consequences for trading. Vanilla quotes are encapsulating OIS discounting. Liquidity and counterparty credit risk are now being priced in, and basis risk has emerged as a key risk factor.

Trading desks now need to sit closer to the funding, CVA and collateral management desks. The asset and liability management function must take hedge accounting into consideration as swaps are no longer perfect hedges to bonds if they are priced with different discounting assumptions.

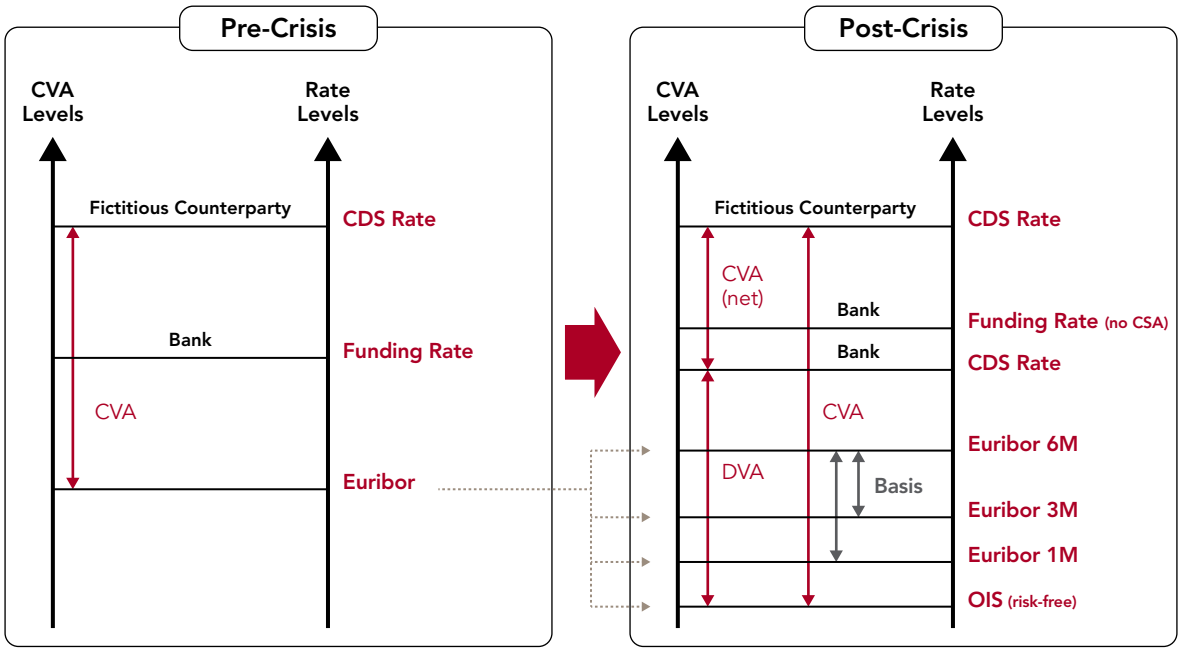
In contradiction to what regulators are looking for, pricing transparency has decreased.

In addition, what will happen to legacy trades? Will they have to be re-marked? One fact is clear: default risk should be modeled explicitly and relative to the risk-free curve (and not the funding curve).

Traders need to rethink how forward rates and par rates relate to each other. Forward rates will be lower under OIS discounting given positive OIS versus Libor spreads. Switching to OIS discounting will have consequences for mark-to-market prices and in particular aged off-par swaps and asset swaps. Of course, trading books with a balance between receiver and payer swaps will see fewer effects as the deviance in mark-to-market will cancel out but more directional trading books could take a much more substantial hits. Asset swaps mimic the fixed rate cash flows of the underlying bond. Assuming the asset swap spread is positive, which is usually the case, the asset swap under OIS discounting will be significantly affected.

Libor versus OIS spreads has emerged as a new risk factor, and this exposure must be managed. Several market participants have already adopted the OIS curve as the risk-free curve, but it will take a while until the market as a whole gravitates toward a standard OIS discounting curve.

Fig 7: The below picture illustrates the increased number of rates to track when factoring in liquidity and counterparty credit risk. Note the bifurcation of the Euribor rate into different rate tenors and the CVA cost of counterparty risk.



THE RIGHT TECHNOLOGY CAN HELP MANAGE THIS CHANGE

Trading systems must be re-engineered to cater for multiple curves and their calibration. Interfaces to downstream systems must be considered – there are larger implications than for the trading desks alone. The risk management department needs to embrace funding, liquidity and credit risk to a larger degree. Suddenly the value of a trade will be dependent upon your trading partner, and no two trades will have the exact same price. Many trading systems simply do not have the capacity to separate the valuation between trades, and these changes in pricing libraries, trading systems, risk management processes and pricing culture are not easily done. And what consequences does this have on other asset classes, such as credit, equity and structured derivatives, which are also dependent on the "correct" risk-free discounting curve?

Most banks have a menagerie of interconnected trading and risk management systems. Making the adaptation to some of these systems without considering the entire chain of new valuation requirements will create internal inconsistencies.

Several banks are using the most suited system to act as a 'curve engine' which they use centrally across the bank and push out curves to other less sophisticated systems.

New regulations such as the Dodd-Frank Act will further accelerate the need for more precise valuation methods by mandating central clearing for standardized OTC derivatives. As central clearing increases, voluntary collateralization under bilateral agreements will also increase due to incentives for banks to reduce capital adequacy. More instruments will be collateralized and hence more instruments will need to be valued with OIS discounting.

All of a sudden, pricing interest rate derivatives is not so simple anymore. The reign of the single risk-free curve is a chapter that belongs to the past. When the book is reopened tomorrow, will your trading system be ready to cater for the changes?

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ABOUT THE AUTHOR

Pontus Eriksson has more than 12 years of experience in the capital markets and has been a senior product manager for SunGard's Front Arena trading and risk management solution for the last six years. He is in charge of managing the fixed income, interest rates and credit side of Front Arena. He is driving the direction of the product by working closely with Front Arena customers and prospects, and is monitoring evolving demands by following market trends and speaking at global industry events around the world. In the past, Pontus held several positions within SunGard from development to project management. Pontus holds a Masters in Engineering Physics from the Royal Institute of Technology in Stockholm and studied Economics at the University of Stockholm. Pontus would appreciate any feedback at pontus.eriksson@sungard.com.

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ABOUT FRONT ARENA

SunGard's Front Arena is a global capital markets solution that delivers electronic trading and position control across multiple asset classes and business lines. Integrating sales and distribution, trading and risk management, and settlement and accounting, Front Arena helps capital markets businesses around the world improve performance, transparency and automation.

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