Understanding Credit Risk Profiles of Over-the-Counter Derivative Transactions

By R. Sathis Kumar

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Abstract

There are two types of financial derivative transactions, namely exchange-traded and over-the- counter (OTC) derivative transactions. Exchange-traded transactions are executed on exchanges where an exchange will be one of the counterparties for every transaction and guarantees the payment as per the contract. OTC transactions are executed by two parties outside exchange.

Exchange-traded transactions are standardized contracts, whereas the OTC transactions can be customized as per convenience of the counterparties involved. As one of the counterparties in the exchange-traded derivative transactions is the exchange itself, credit risk involved in the transaction is almost nil, because the probability of default for these exchanges will be close to zero. However, there is huge amount of credit risk in the OTC derivative transactions, as the counterparties may not be sufficiently liquid or strong enough to honor the payments as per agreement.

The credit risk for such transactions can be calculated by various measures, such as current exposure and potential future exposure (PFE). While current exposure (which is calculated by the net replacement cost method) is a static measure, PFE is forward looking and is used by most of the investment banks in the calculation of both credit valuation adjustment (CVA) and economic capital. It is also used in setting the trading limit for counterparties.

With the increase in the range of application of PFE, it has become important to understand the potential future exposure involved in different types of instruments, like forwards, interest rate swaps and cross currency swaps. This paper tries to explain the PFE profiles for various major instruments and the sensitivity of the PFE profiles to changes in the trade parameters, such as time to maturity and notional and payment frequencies.

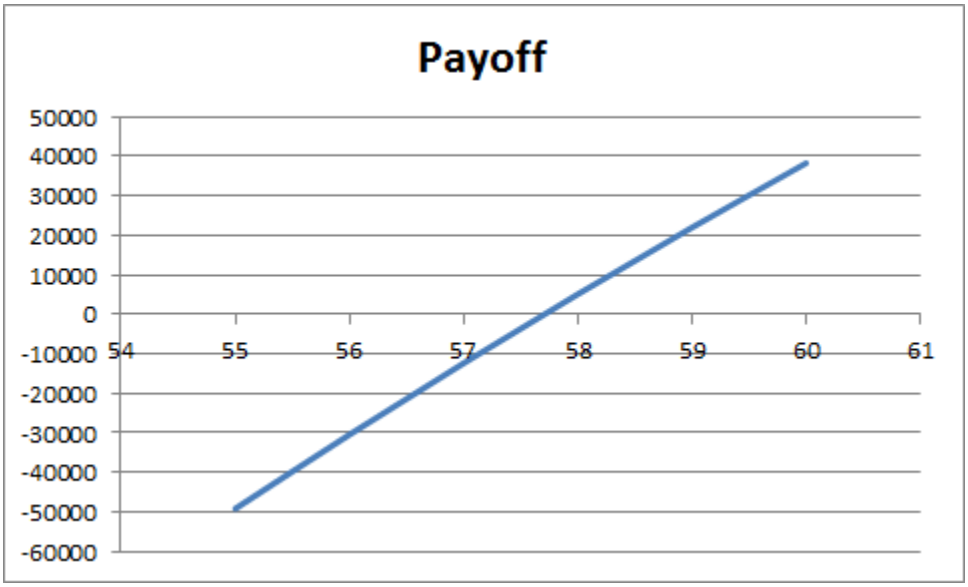
Introduction

Forwards

It is an agreement to buy or sell an asset at a certain future time for a certain price. An OTC forward is traded usually between two financial institutions. One of the parties in the contract assumes a long position who would be buying the underlying asset on a certain specified future date for a certain specified price. The other party will assume a Short position and agrees to sell the asset on the same date for same price.

Example of a forward contract: We will consider a forward contract where company X will receive 1 million USD in exchange to 57,703,925.17 INR (based on the spot FX and forward basis points on 06/14) on 21st Jun 2013. There are no cash flows on the date when this forward contract is entered. But there will be a cash inflow of 1 million USD whereas the cash outflow for the company X is 57,703,925.17 INR.

The payoff for the forward contracts can be represented in the diagram given below.

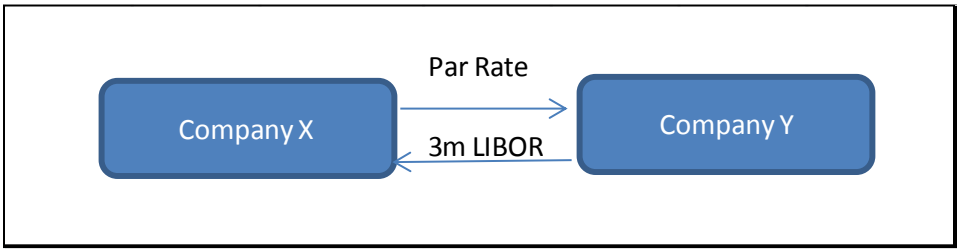


Interest Rate Swaps (IRS)

This is an example of derivative transactions which can be used to transform the nature of assets or liabilities. One party in this derivative agrees to pay cash flows equal to interest at a predetermined fixed rate on a notional principal for a number of years. In return, it receives interest at a floating rate on the same notional principal for the same period of time.

Example of an Interest Rate Swap:

Let us assume that company X enters into IRS such that it receives cash flows equal to interest based on 3month LIBOR rate on a notional of 1 million Euros every quarter. In return, company will pay interest rate based on fixed rate which makes the value of swap at the outset to be zero. The life of swap can be assumed as 5 years.



Payoff from IRS:

On any of the interest payment dates,

Cash outflow for Company X = (Par Rate/4) * Notional

Cash inflow for company X = (3m LIBOR on fixing date/4)* Notional

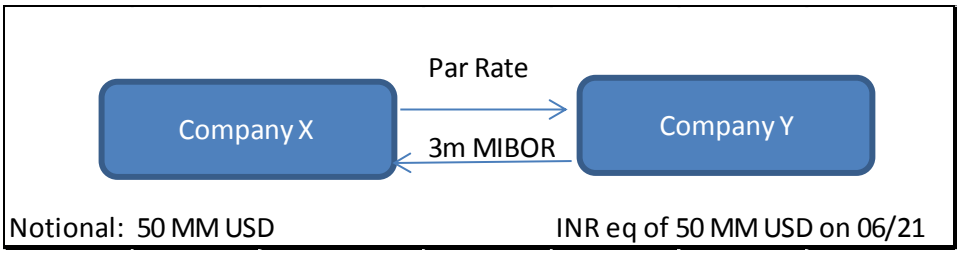
Net cash flow for company X = ((3m LIBOR – Par Rate)/4)* Notional

Cross Currency Swaps (CCS)

One party in this type of swap agrees to pay principal and interest payments in one currency in return to principal and interest payments in another currency.

Example of a Cross Currency Swap:

Let us assume that company X enters into a Cross Currency swap where it receives quarterly interest based on 3 month MIBOR on INR notional equivalent to 50 million USD on 21st June 2013. In return, it pays a fixed interest which makes the swap value at the outset to be zero. Kindly note that there will be exchange of principal on the maturity date which is 5 years from the start date (06/21/2013)



Payoff from CCS:

Payoff for the CCS will be similar to IRS with the only difference being the notional used to calculate the Interest. Also, principals will be exchanged on the maturity date.

Potential Future Exposure

PFE is defined as the maximum credit exposure over a specified period of time calculated at a specified confidence interval. This can also defined as sensitivity of risk with respect to market prices.

Maximum value of PFE over any given time horizon is called Maximum Peak Exposure (MPE).

Calculation of PFE

There are broadly three methods to calculate PFE which are

a) Current Exposure + Add on factor method
b) Semi-analytical method
c) Monte-Carlo simulation method

Let us look at each method below

Current Exposure + Add-on Factor Method

The simplest method is to take the Current Exposure and add a component which represents the uncertainty in exposure in the future. The add-on factor should account

i) Time horizon of the instrument
ii) Volatility of the instrument

Hence longer maturity instruments or higher volatile instruments will get higher add-ons when we calculate PFE under this method.

Semi-Analytical Method

The advantage of this method is less time consumption as compared to Monte-Carlo simulation. But they are more sophisticated than the previous method in this section

The Semi-Analytical Method comprises the following steps:

a) Make the assumptions regarding the risk factors driving the exposure of the instrument
b) Find the distribution of exposure defined by these risk factors
c) Calculate Semi-analytical approximation to a risk metric for that exposure distribution

This method is heavily reliant on the assumptions we make with respect to risk factors.

Monte Carlo Simulation Method

This method is the most complex and time consuming method of all to calculate the exposure in the future. This method can deal with complexities ignored by previous two methods such as Path dependency, Netting and Collateralization etc.

A general Monte Carlo simulation method comprises the following steps:

a) Choose the risk factors influencing the exposure of the instrument
b) Choose the models to calculate the values of risk factors in the future
c) Construct the scenarios
d) Value the instrument under each scenario
e) Apply any credit risk mitigation such as Collateralization and Netting etc.

In this study, we have chosen Monte Carlo simulation to calculate Potential future exposure.

The steps we followed to calculate PFE, using Monte Carlo simulation, are as follows:

a) Identify Risk factors: We have to identify the risk factors which will influence the value of the instrument for which we intend to calculate Potential Future Exposure. We assumed the risk factors affecting the value of the derivative transactions are FX and IR rates
b) Simulate the Risk factors: We have to simulate the Risk factors using appropriate models. These FX and IR rates have been simulated using Geometric Brownian Motion model and Hull-White model respectively. Number of simulations used is 20,000.
c) Value the derivative: valued the derivative under examination using these simulated IR and FX rates. Hence we will have 20,000 values for a trade on any simulated date
d) Calculate PFE: Calculated PFE which is the maximum credit exposure at a specified confidence interval. Hence we will get PFE for each date we simulate
e) Calculate MPE: calculated Maximum Peak exposure is the maximum of all PFEs till the maturity date for the trade

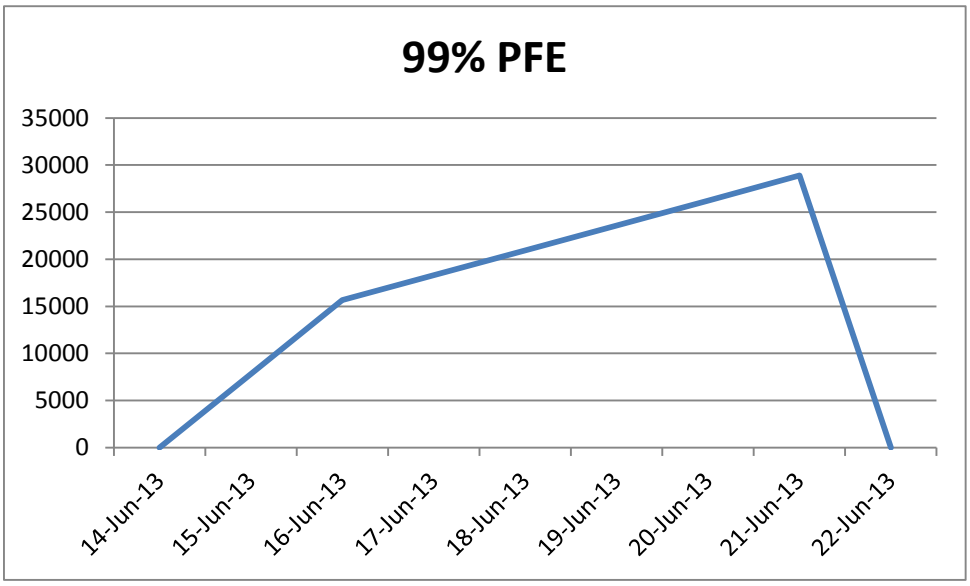
PFE Profiles

PFE Profiles for Forward Contracts

Let us consider the Forward contracts as given below

Receive	1 MM USD
Pay	57,703,925 INR
Trade Date	6/14/2013
Maturity Date	6/21/2013

PFE profile obtained for this forward contract is given in the diagram below.

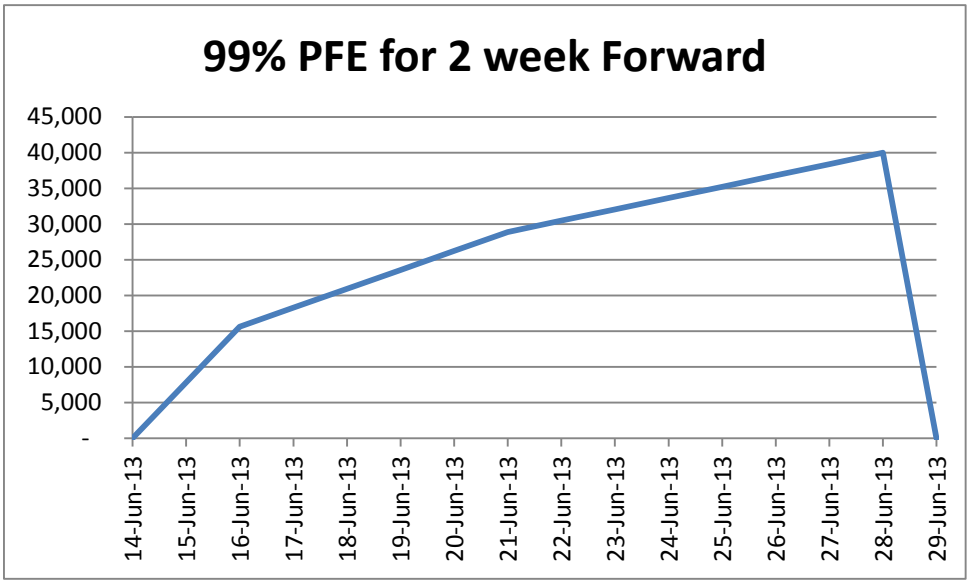


There are two obvious observations from the PFE profile above which are; more or less linear increase in the exposure and steeper increase in PFE for first two days than the remaining period. Linear increase in the exposure can be attributed to the use of linear forecasting model like GBM model to simulate FX rates. Higher rate of increase in PFE can be attributed to the uncertainty involved because of settlement risk on over and above Credit Risk. After this trade is settled, PFE profile is increasing at a constant rate till maturity where it reaches the maximum. MPE (Maximum Peak Exposure) is obtained on the maturity for any Forward contract. After maturity, the PFE for the trade falls to zero as the trade ceases to exist.

Sensitivity against Trade Parameters for Forwards

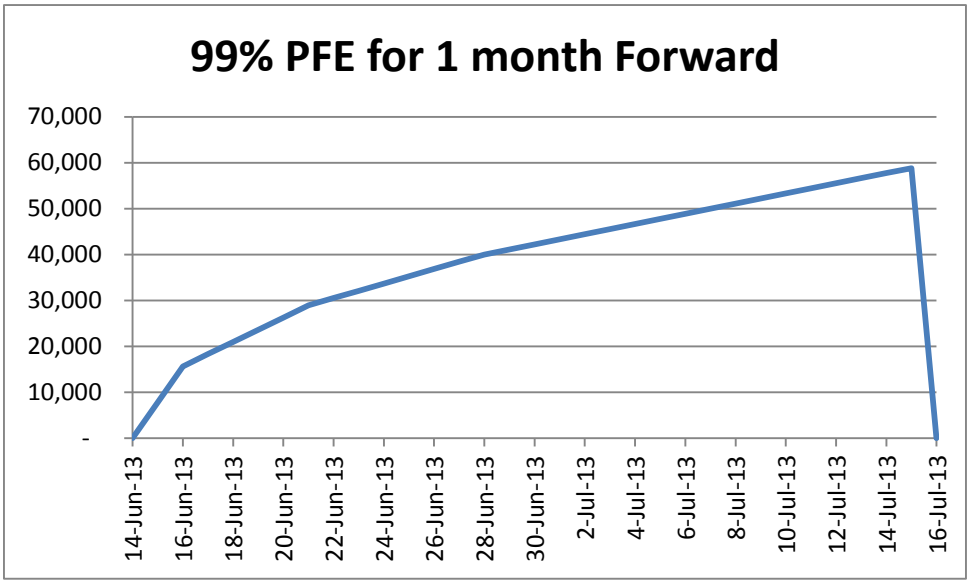
Sensitivity to Term

Let us see the impact of increase in term of the forward contract from 1 week to 2 weeks, keeping other terms intact.



As we can see from the profile above, Settlement risk is present for first two days which has increased PFE more after which it is increasing at more or less constant rate.

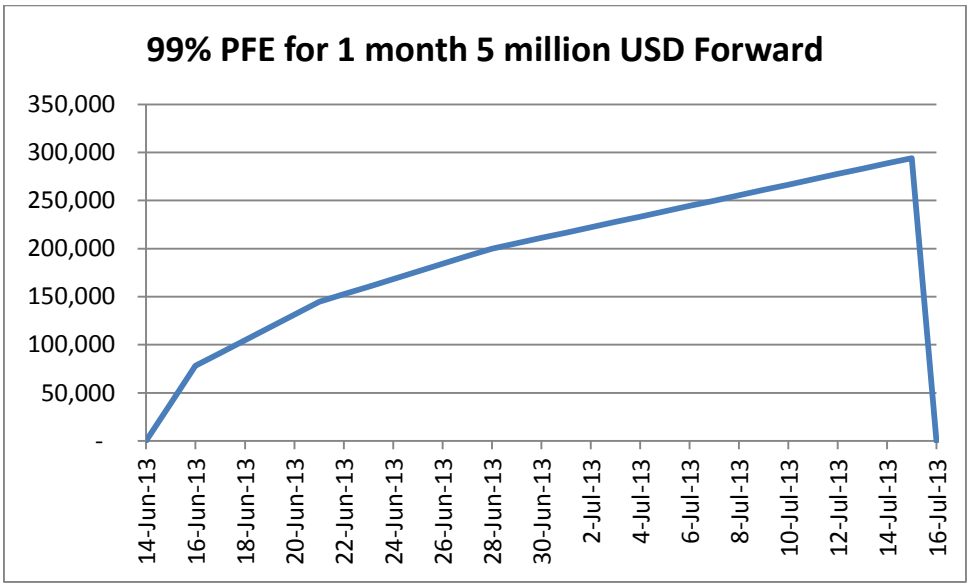
Now let's increase the term of the contract to 1 month, keeping other terms intact.



Same behavior is observed when we increase the term to 1 month which is steeper increase for first two days post which increase at more or less constant rate

Sensitivity to Notional

Now let's try to increase the notional from 1 million USD to 5 million USD.



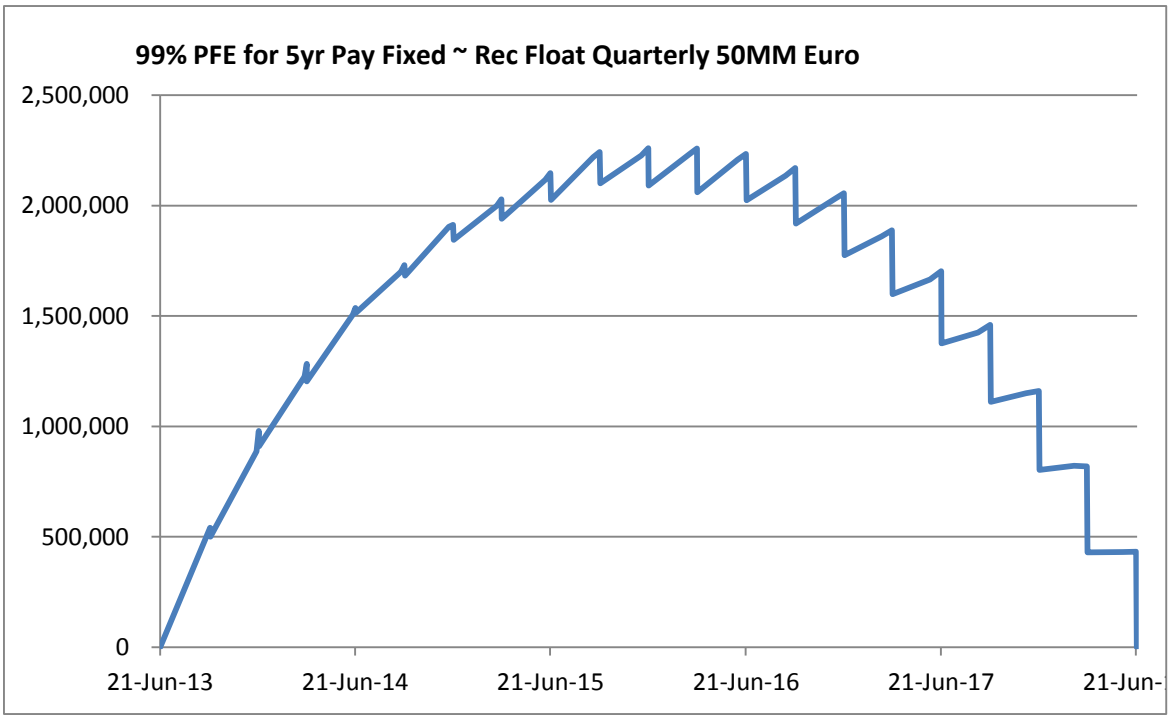
As we can see from above profile, the shape of the PFE profile remains the same while the exposure is getting magnified as compared to first example in this section.

PFE Profiles for Interest Rate Swaps

Let us consider the IRS as given below in the table

Currency	EUR
Term	5 years
Notional	50 MM Euros
Pay	Par Fixed Rate
Receive	3m LIBOR
Payment Frequencies	Quarterly
Start Date	21-Jun-13

We will get the PFE profile as shown in the diagram next page.



There are two effects when PFE is calculated for an Interest Rate Swaps which are

a) Fractional time Effect*[1]
b) No of future Payments effect*[2]

Fractional time effect: Time between the Trade start date and the date for which PFE is calculated. This effect is continuously changing effect. As time passes by, there is a diffusion effect (for all instruments) increasing exposure due the risk factor values moving away from current rates. Hence this effect will increase the exposure continuously as we step deeper in the future.

No of future Payment effect: At the start of trade, no of future payments will be 100% and it is a discrete effect which changes only on Payment dates. For example, after 1st payment in a 5 year swap where there are quarterly payments, 95% of the cash flows will be remaining. PFE will decrease on all payment dates in the swap though the magnitude of the decrease depends on the rate of change of no of future payments.

As the trade is Pay Fixed ~ Rec Float, the company X will be in the money when the simulated 3m LIBOR rates are higher than the par fixed rate they have to pay . As the range of simulated rates is higher as fractional time increases, PFE for the trade because of the Fractional effect continuously keeps on increasing till there is change in the discrete effect which is no of future payments. PFE will dip on the payment date because of the change in No of future payment effect. As the magnitude of dip depends directly on the rate of change of the effect, the magnitude of the dip is very small on the first payment

[1] Term coined by Author, not present in Literature
[2] Term coined by Author, not present in Literature

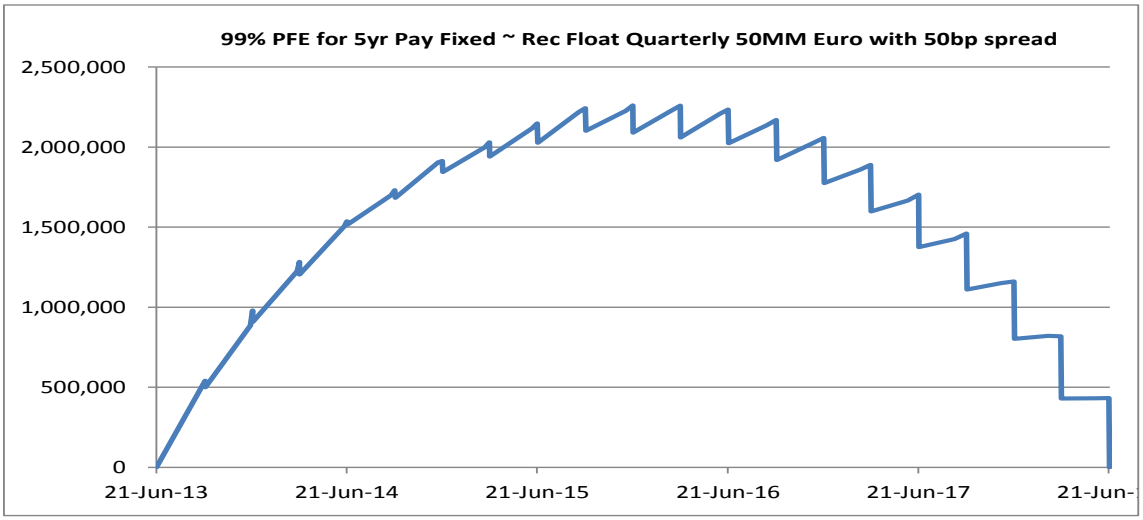
date as it dips from 100% to 95% whereas it is the maximum on the last payment date which is the maturity date from 5% to 0%. [2]

On the first payment date, increase in PFE from Trade start date to first payment date due to Fractional time effect is more than the decrease in PFE due to change in the no of future payments effect on that day. Hence net effect of PFE from last payment date (in this case, the Trade start date) is positive. As we proceed, net effect of PFE from last payment date starts decreasing and goes into negative territory at some point in the life of swap (usually happens when % of no of future payments are between 40% to 50%).

Sensitivity against Trade Parameters for IRS:

Sensitivity to Spread

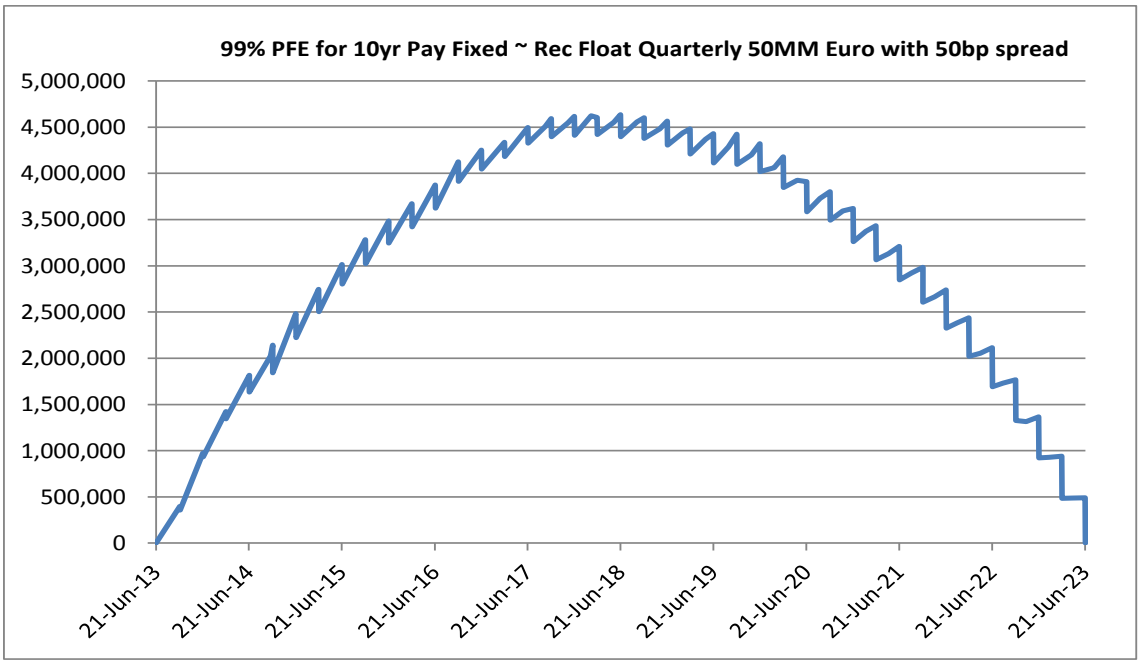
Let us add a spread of 50bps to the floating leg in the swap and adjust the fixed rate of the swap such a way that initial value of swap is zero. Other terms are not changed.



As we can see from above profile, there is **NO**change in the PFE profile when we add the spread on the floating leg for a swap and adjust the fixed rate so that value of swap at the outset is zero.

Sensitivity to Term

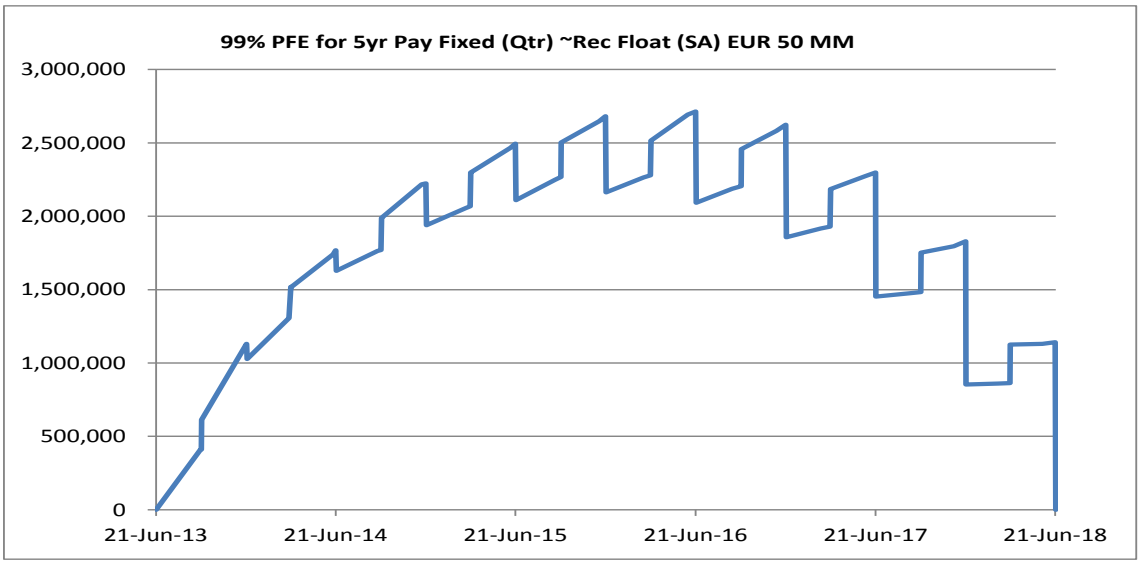
Let us now increase the time to maturity of the swap in the above example to 10 years, keeping other terms intact.



As we can see from the profile above, the PFE profile behaves in the same pattern which is steady increase in PFE due to fractional time effect and decrease in PFE on the payment date depending on the rate of change in number of future payments. Maximum peak exposure obtained here is almost double of what we got in the first example in this section before.

Sensitivity to Payment Frequencies

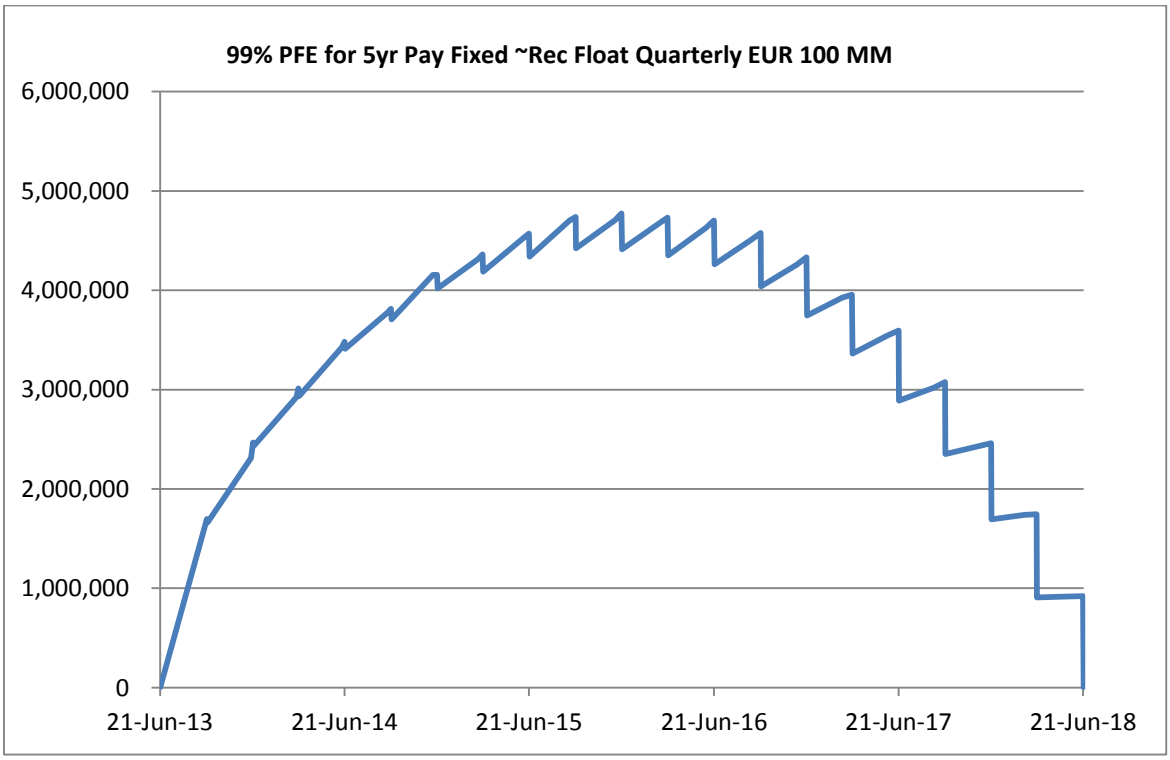
Let us now change in the payment frequencies on the floating leg of the swap to Half yearly, keeping other terms of the first IRS discussed intact.



As mentioned, there are two effects for the PFE profile namely, fractional time effect and no of future payments. Fractional time effect for this swap will be same as that of the first swap we discussed. But as this is a swap where company X pay fixed rate once every 3 months, PFE on these dates where there is a cash outflow only for Company X, PFE will increase. As the company has higher cash inflow compared to cash outflow once every 6 months, PFE on these dates when there are cash inflows for the company X will decrease. These discrete changes in the PFE will depend on rate of change in number of future payments.

Sensitivity to Notional

Let us study the impact of change in notional for the first swap example in this section to 100 MM Euro, keeping other terms intact.



As we can see from the diagram above, the PFE is magnified profile (doubled) of first swap example we discussed in this section.

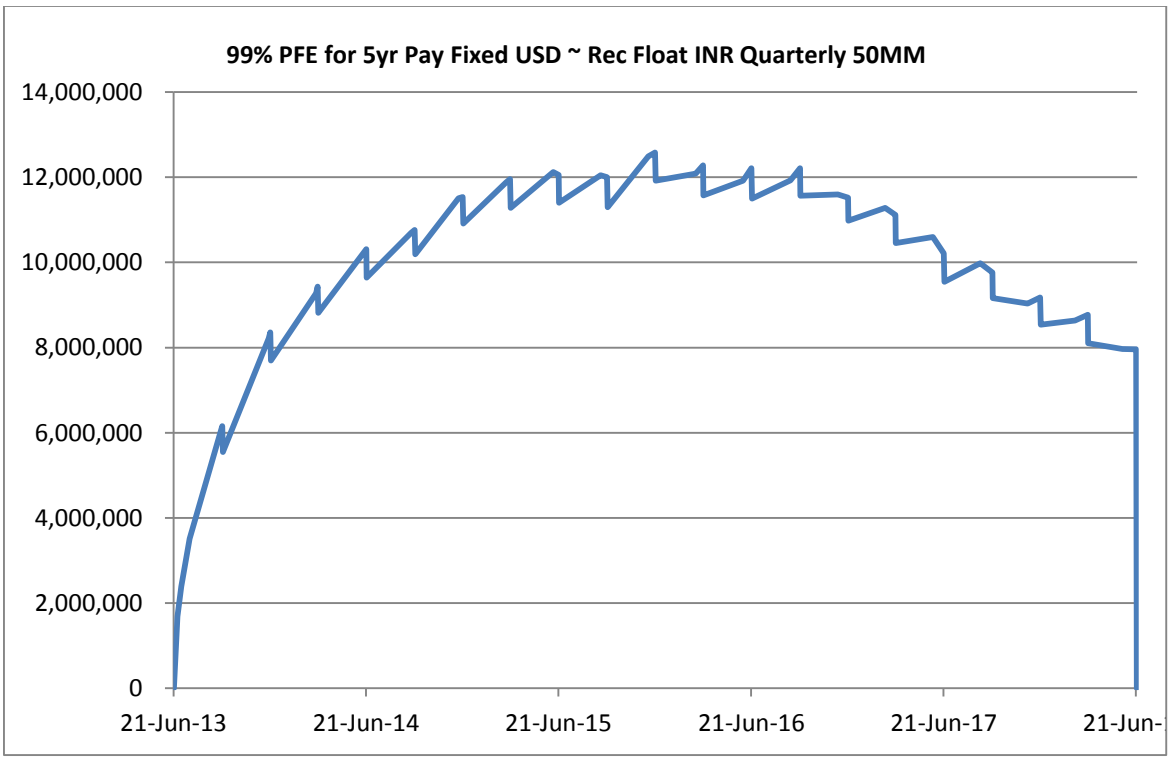
PFE Profiles for Cross Currency Swaps

Let us consider the Cross Currency Swap as given below

Currency	USD~INR
Term	5 years
Notional	50 MM USD ~ Equi. INR on 06/21/2013

Pay	Par Fixed Rate
Receive	3m MIBOR
Payment Frequencies	Quarterly
Start Date	21-Jun-13

We get PFE profile as given in the diagram below

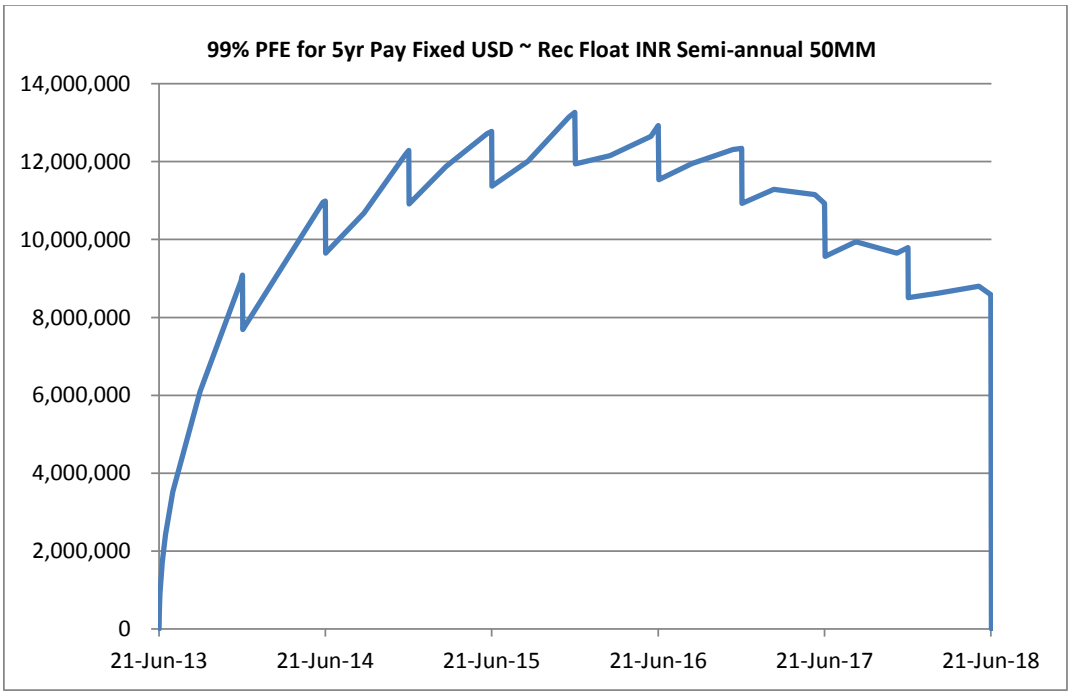


PFE profile for a Cross Currency Swap will behave similar to an IRS, i.e. with Fractional time effect and No of future payments effect. Dip in the PFE happens on all the payment dates while till the payment date from the previous one, PFE keeps on increasing because of Fractional time effect. As there is a terminal payment on the maturity date, PFE profile will not be semi-circled one as was with IRS.

Sensitivity against Trade Parameters for CCS

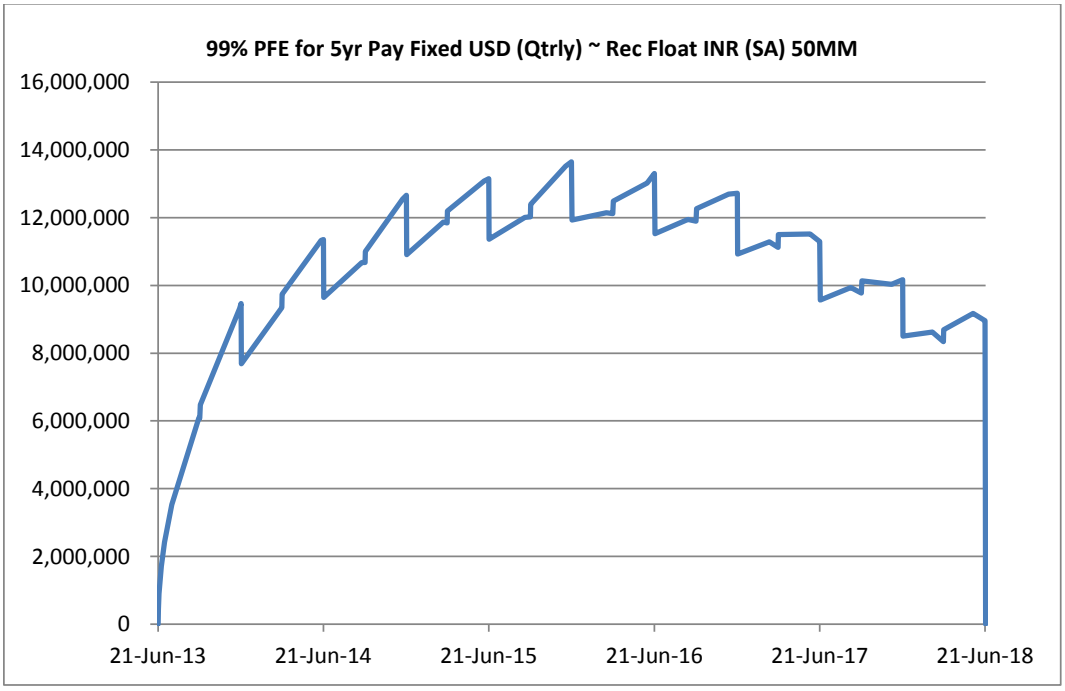
Sensitivity to Payment Frequencies

Let us see the impact of changing the payment frequencies on both legs to Semi-Annual keeping other terms intact.



As expected, number of dips in the profile halved with maximum peak exposure remains almost same.

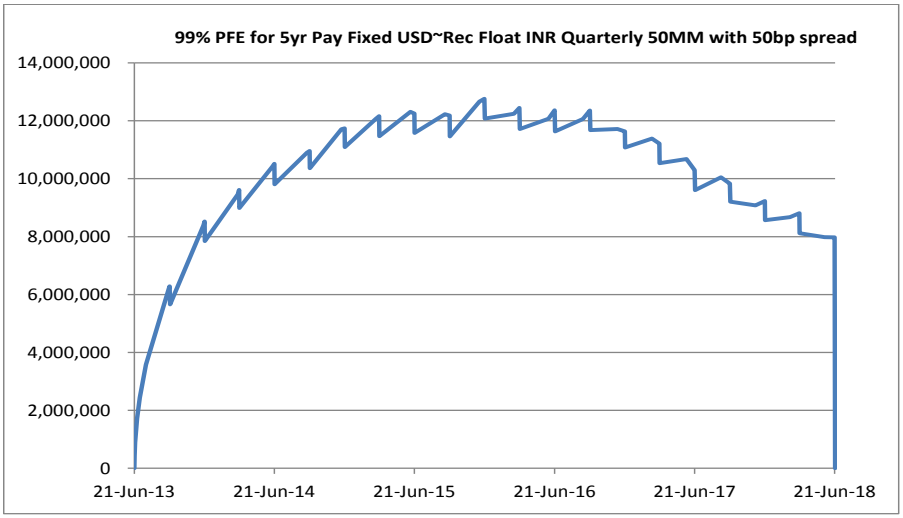
Let us now change the payment frequencies on the fixed side of the swap in the above example to Quarterly keeping other terms intact



The fractional time effect remains the same as was in the previous examples. As we pay in this swap, PFE on every cash outflow date increases proportional to rate of change of future cash outflows and PFE on every cash inflow date decreases proportional to rate of change of future cash inflows.

Sensitivity to Spread

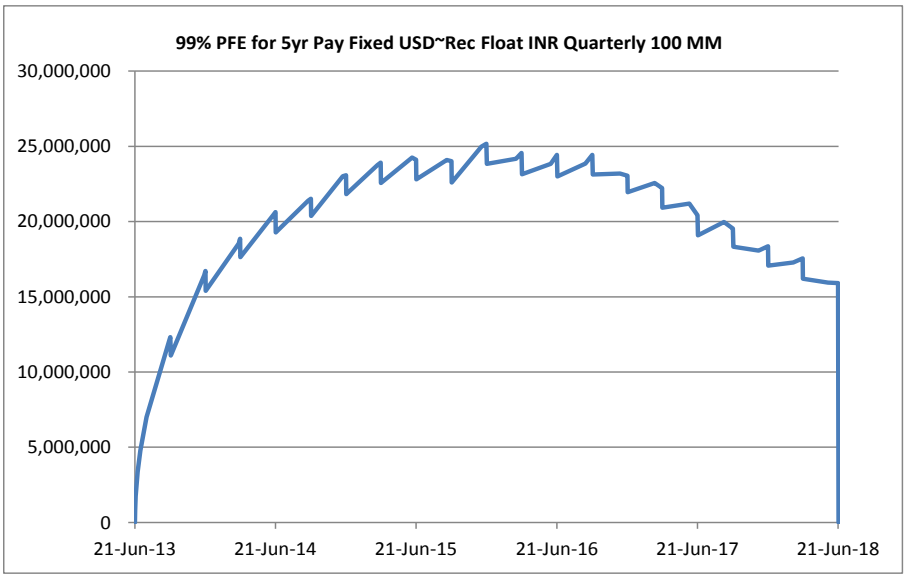
Let us now add a spread of 50basis points to the float leg of the first CCS example we analyzed



The PFE profile and maximum peak exposure remains exactly same as compared to that of first cross currency swap we discussed. Hence increase in spread on a par swap does not alter the PFE profile.

Sensitivity to Notional

Let us increase the notional of the first cross currency swap example to 100 million USD and corresponding increase in INR notional as per the FX rate on 06/21/2013 which is the start date.



PFE profile has doubled as compared to that of first swap in this section. Hence PFE profile is linearly dependent on notional.

PFE Calculation for Illiquid OTC Transactions

All the above discussions assume that the transaction under observation is liquid, i.e. there is neither asset liquidity risk nor funding liquidity risk while dealing with the transactions. Asset liquidity risk is defined as the risk due to inability to execute the transaction at the current market prices while Funding liquidity risk is defined as the risk due to inability to fund payments which will force a firm to liquidate the assets. Not all the OTC transactions are liquid enough to hold the same assumption. Also high liquid transaction can become illiquid during the course of time. Hence we need to tweak the method discussed above to calculate PFE of illiquid transactions as well.

One method which could be used in such cases is adjusting the parameters used to simulate risk factors based on forecast of illiquidity of the instrument under observation. For example, if the instrument for which we need to calculate PFE is illiquid, the parameters such as drift and volatility etc which are used by models such as Hull-White model or GBM model to simulate FX and IR in the above examples can be adjusted so that it will take care of the liquidity risk which might arise from the instrument under observation.

Second method to adapt for the illiquidity is adjusting the PFE based on the forecast of illiquidity of the instrument. Once PFE is calculated using the normal method above, it can be scaled up or down by a factor to reflect the liquidity of the instrument.

Conclusion

As we have seen in the recent Credit Crisis, counterparty credit risk has gained significant importance and institutions are taking considerable efforts to measure and mitigate it. While trying to mitigate the CCR, Potential Future Exposure is one of the important parameters a firm should consider. In this paper, we have tried to explain the PFE profiles for various OTC transactions and sensitivity of the profile against the trade terms. To certain extent, PFE and MPE for OTC derivative transactions depend on the models used to simulate the underlying risk factors. But the profile for the different transactions will not see much difference in the shape irrespective of the models used.

About the Author

Sathis Kumar R (FRM) is an assistant manager in the Financial Services Analytics unit at Genpact. He has four years of experience in the field of financial risk management. He has analyzed various risk parameters, such as Current Exposure, CVA, VaR and PFE, for the derivative book of a global conglomerate. He has also experience in the area of securitization backed by micro-finance loans.

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