

Modelling the Impact of Interest Rate Crisis

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Abstract

Financial crisis of 2007-2008 changed the assumptions underlying market models theoretically and in practice. Therefore, this paper focuses on modelling the impact of interest rate crisis. The aim is to describe pricing of financial derivatives mainly interest rate swap pricing method used under both pre-and post-crisis period. To model riskless rate/short rate and credit risk as well as to show various basis spreads that characterize post crisis fixed income markets. Riskless rate was modelled by use of a no arbitrage model CIR++ model and CIR model was used to model default intensity. Exact method of simulation was used by assuming that CIR++ model increments follow a non- central chi-square distribution and model parameters estimated by use of maximum likelihood method. Model parameters were estimated using both pre-and post-crisis 3 months US LIBOR daily market data and compared to analyze the impact of the crisis. For default intensity simulation Euler scheme method was used for the discretization.

Keywords: Interest rate; Single curve; Multi-curve; XIBOR model; Short rate; Credit risk; Exact simulation; Approximate simulation.

INTRODUCTION

The term fixed-income market describes a sector of the global financial market on which various interest rate-sensitive instruments, such as bonds, forward rate agreements, swaps, swaptions, caps /floors are traded. Zero coupon bonds are the simplest fixed-income products, which deliver a constant payment (often set to one unit of cash for simplicity) at a pre-specified future time referred to as maturity (Runggaldier, 2015). Nevertheless, their value at any time before maturity depends on the stochastic fluctuation of interest rates which is also true for other fixed-income

derivatives. Fixed-income instruments signify the largest portion of the global financial market larger than even equities. Therefore, developing realistic and analytically tractable models for the dynamics of the term structure of interest rates is of great benefit for the financial industry (Runggaldier, 2015). The value of the financial derivatives is dependent on the underlying interbank market rates hence a need for proper pricing in the interbank market.

According to the yearly statistics provided by the bank for International Settlements, the notional amounts outstanding each year for over-the-counter (OTC) interest rate derivatives add up to 80 % of the total trade volume in OTC derivatives that is (\$505 trillion out of the total volume of \$630 trillion corresponded to interest rate derivatives in 2014 (Runggaldier, 2015). The financial crisis affected all fixed-income markets hence prompting researchers to come up with better models that will be applicable in both pre-and post crisis times. The crisis triggered a profound evolution of classical frameworks that were adopted for trading derivative assets. Precisely the credit and liquidity issues were assumed to have minute impacts on the prices of financial instruments, both plain vanillas and exotics. Today, whether there is crisis or not, the market has learnt the lesson and persistently shows such effects. These are clearly visible in the market quotes of plain vanilla interest rate derivatives, such as Deposits, forward rate agreements (FRA), Swaps (IRS) and options (Caps, Floors and Swaptions) (Bianchetti, 2012). The standard no arbitrage frameworks adopted to price derivatives that were developed over forty years following the Copernican Revolution of the Black and Scholes (1973) and Merton (1973) have become obsolete after the market evolution. The ultimate idea of the construction of a single risk free yield curve, reflecting at the same time the present cost of funding of future cash flows and the level of forward rates, has been ruled out. Financial experts have therefore been forced to start the development of a new theoretical framework, and to review from scratch the no-arbitrage models used on the market for derivatives' pricing and risk analysis. This is because the initial approach did not take into account market information displayed by the basis swap spreads which became huge during the crisis period and could no longer be ignored. It also did not take into account that interest rate market had become segmented into sub areas according to different underlying tenors, that were characterized by different dynamics for example short rate process (Morini, 2009).

PRE-CRISIS PRICING APPROACH PROBLEM

The credit crisis of 2007–2008 and the Eurozone sovereign debt crisis in 2009– 2012 have had a great impact to all financial markets and have permanently changed the way in which the market functioned in practice. This has also changed the way in which their theoretical models were developed, therefore making it easier for one to distinguish between a pre-crisis and a post-crisis setting. There are some key features that were put forward by the crisis which include counterparty risk, which is the risk of a counterparty failing to fulfil its obligations in a financial contract, and liquidity or

funding risk, which is the risk of excessive costs of funding which occurs in a financial contract due to lack of liquidity in the market. These issues have raised a concern in the pricing practice in interbank market.

The reason being that, the underlying interest rates for most fixed-income instruments are the market rates such as Libor or Euribor rates and the manner in which the market quotes for these rates are constructed reflects both the counterparty and the liquidity risk of the interbank market. Review of the quoted prices for related instruments reveals that the relationships between Libor rates of different maturities that were previously considered standard, and held reasonably well before crisis, have broken down and presently each of the rates needs to be modelled as a separate thing. Consequently, major spreads are also observed between Libor/Euribor rates and the swap rates based on the overnight indexed swaps (OIS), which were following each other closely before crisis. The pre-crisis single curve pricing did not take into account information displayed by various basis spreads because the spreads were viewed as negligible.

Table i: Difference between pre-and post crisis market pricing

Pre -crisis	Post-crisis
Euribor/LIBOR was used as a risk-free rate	OIS rate used as a risk-free rate
Counterparty risk was assumed negligible	Collateralization of OTC derivatives due to perceived credit risk
Liquidity risk was assumed negligible	Liquidity risk priced in the interbank market
A single curve was used for both discounting and forwarding	Multiple curves are used depending on the tenor of the underlying instrument
Basis spreads were considered negligible	Information displayed by basis spread is useful when pricing derivatives

A single curve was constructed for various maturities and the rates were interpolated as shown.

Time	0.0	0.5	1.0	1.5	2.0
Rate	0.02	0.01	0.04	0.06	0.07

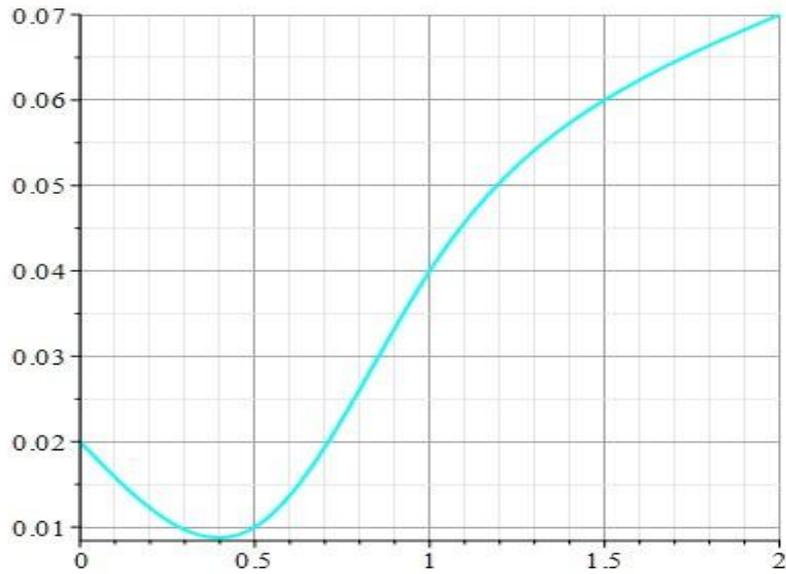


Figure i: shows an example of simulated forward curve under single

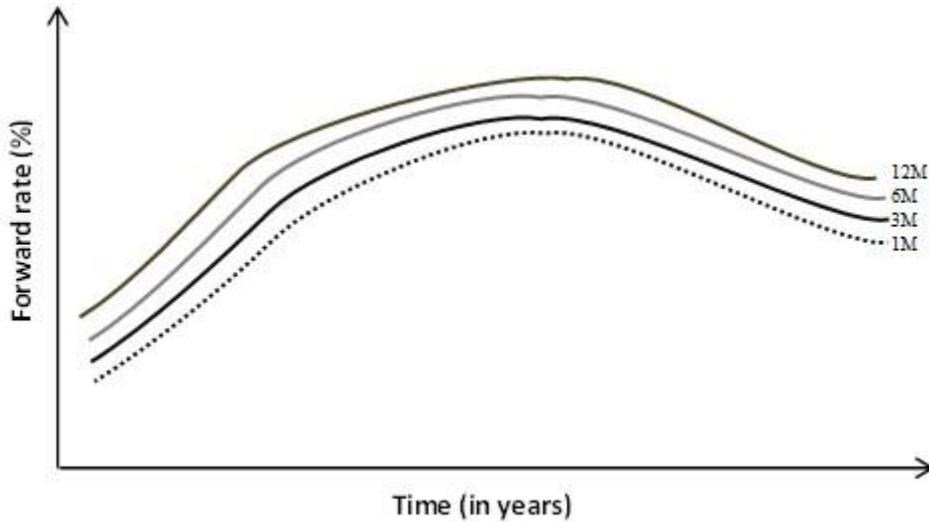


Figure ii: shows an example of a forward curve under multi-curve pricing framework

INTERBANK MARKET EVOLUTION AFTER CRISIS

Euribor/LIBOR - OIS Spread- This is as a result of different credit and liquidity risks reflected by Euribor/LIBOR and Eonia/Fed fund rates. Libor rates exploded and the rates became higher than the overnight rates hence Libor can no longer be used as a risk-free rate in valuation of financial derivatives and interbank lending.

FRA's Versus Forward Rates- There emerged a sudden divergence between implied forward rates and the quoted FRA's rates in August 2007.

Basis Swaps- A basis swap is defined as an interest rate swap which involves exchange of two floating interest payments. Basis risk is the risk that the normal relationship between two floating rates might change.

Collateralization and OIS discounting- The major driver of 2007 financial crisis is the counterparty credit risk, this prompted interbank market to introduce collateral agreements on all OTC derivatives to reduce the counterparty risk.

Credit and Liquidity Risk- Credit and liquidity risks were considered negligible in the interbank market before crisis, however liquidity needs had an effect on spreads of various rates for example Euribor - Eonia OIS spread. The other evidence of credit and liquidity risk is the difference in Euribor rates with different tenors. The difference between similar rates with different tenors has called for pricing of each tenor as different market but ensuring that there is no arbitrage opportunity.

METHODOLOGY XIBOR model

XIBOR model is a structural approach to post-crisis basis spreads in interbank market rates. Thus, the XIBOR model provides the first consistent framework that is able to endogenously generate all relevant post-crisis basis spreads from essential risk factors such as interest rate risk, credit risk, and liquidity risk. The model is based on three significant risk factors in the interbank market, that is; credit risk, interest rate risk and liquidity risk and the model supports and complements multi curve approach (Gallitschke et al., 2014).

Riskless Term Structure (Interest rate risk)

The riskless rate $r^{0/N}$ is associated with the relevant overnight rate, hence since the riskless term structure is based on an overnight rate, it is important to use a short rate model for $r^{0/N}$. It is therefore assumed that the risk-neutral dynamics of $r^{0/N} = \{r^{0/N}(t)\}$ are specified by a suitable market-consistent short rate model.

The associated discount curve (or OIS bond) is given by

$$\delta(t; T) = P^{OIS}(t, T) = E_t \left[e^{-\int_t^T r^{0/N}(s) ds} \right] \quad (1)$$

Interbank Market Default Risk

Credit risk is defined as the banks inability to meet its obligations or failure to repay payments owed to its counterparty in due time. Mathematically default can be modelled by means of default time τ^i . Default intensity can be modelled in various ways for example by use of structural models, incomplete models or reduced form

intensity models. Here default risk in the interbank market is modelled through banks' credit default intensities. We denote all the participants in the interbank cash market by $i = 1, \dots, I$. Therefore, each index $i = 1, \dots, I$ represent a fixed bank that is potentially relevant (now or in the future) for the determination of XIBOR rates, and τ^i denotes its default time. τ^1, \dots, τ^i can be modelled using doubly stochastic cox framework of

(Lando, 1998). Let $\xi = \{\xi(t)\}$ denote the full market filtration including jump events. For each bank i the risk-neutral default intensity or hazard rate is denote by $\lambda^i = \lambda^i(t)$, which is the arrival rate of default at t , conditioning on all information available at time t (Duffie and Singleton, 2003). The probability of default taking place in dt interval given that default has not occurred so far is $\lambda^i(t)dt$ and can be expressed as;

$$\mathbb{Q}_t(\tau^i > t + dt / \tau^i > t) = \lambda^i(t)dt \quad (2)$$

The risk neutral survival probability of bank i is given by

$$P_{00}^i(t, T) = \mathbb{Q}_t(\tau^i > T) = 1_{\{\tau^i > t\}} E_t \left[e^{-\int_t^T \lambda^i(s) ds} \right] \quad (3)$$

Then the price of a theoretical zero recovery interbank bond with no liquidity adjustment is given by

$$P_0^i(t, T) = E_t \left[e^{-\int_t^T r^{0/N}(s) + \lambda^i(s) ds} \right] \quad (4)$$

while the price of the interbank bond with recovery rate R can be given by

$$P^i(t, T) = \left(1 - \int_t^T f(t, s) P_0^i(t, s) ds \right) R + P_0^i(t, T)(1 - R), t \leq \tau^i \quad (5)$$

Interbank Cash market liquidity

For banks to meet their day to day liquidity needs, they depend on interbank cash markets, however for longer periods the interbank money market cannot necessarily be relied upon to constantly provide funding. Therefore, a liquidity shock is a significant risk in all cash transactions between financial institutions. Higher rates are charged by the refinancing bank in the event of a market freeze during the lifetime of an interbank market loan. The possibility of an interbank money market freeze at a random time σ is accounted for in the XIBOR model. Before the market freeze at σ , the unsecured overnight borrowing is available at the overnight rate $r^{0/N}$. In the event of a market freeze (that is at time $t > \sigma$) banks cannot access the interbank market at a risk-free rate anymore but can obtain funding at a higher rate (Gallitschke et al., 2014).

$$r^{0/N}(t) + q(t) > r^{0/N}(t). \quad (6)$$

We denote $\vartheta = \{\vartheta(s)\}$ the risk-neutral intensity of σ and define liquidity factor as:

$$q_0(t, T) = 1_{\sigma > t} E_t \left[e^{-\int_t^T \vartheta(s) ds} \right] \quad (7)$$

The three components that is, interest rate/riskless rate, credit and liquidity components highlighted above are combined to determine interbank money market lending rates (Gallitschke et al., 2014).

Remark: In modelling, short rate CIR++ model was used, while in modelling credit risk/default intensity CIR model was used. CIR++ model was simulated by use of the exact method of simulation and considering that the CIR increments follow a non-central chi-square distribution.

RESULTS AND ANALYSIS

Analyzing pre-and post-crisis market data

Pre-and post-crisis LIBOR rate plot

Before Financial crisis of 2007 similar rates for different tenors moved together, for example there was no big difference between 3Month and 6Month LIBOR rates. As a result of the crisis rates began to vary/ show a huge difference depending on the tenors hence calling for pricing of different tenors differently. Figure (iii) shows a plot of 3M vs 6M LIBOR market data for the period between January 2005 to December 2015.

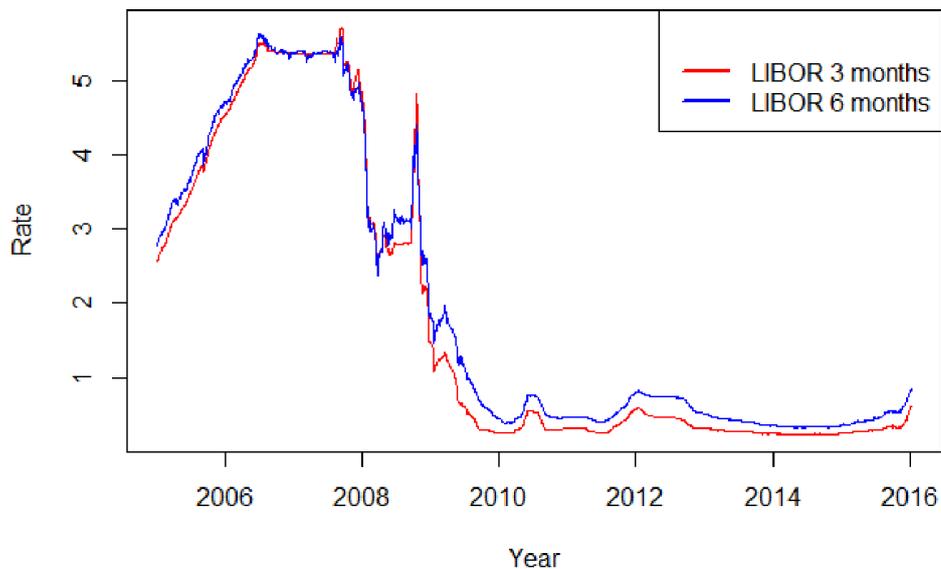


Figure iii; US 3M vs 6M LIBOR daily rate market data

Figure (iii) shows the break point that is, 3 months and 6 month LIBOR rates moved closely in 2005 and 2006 but went up between 2007 and 2008. From 2009 the rates reduced and began to differ as can be seen from the plot, the 6 month LIBOR rate is greater than the 3 month LIBOR rate and the difference cannot be assumed negligible as before. This shows that there is a high perceived credit risk as the tenor increases and therefore it supports pricing of financial securities depending on the underlying tenor.

Pre and post crisis swap rate market data

Financial derivative rates also went up and began to differ depending on the underlying tenor, the spread between the rates indicates the level of credit and liquidity in the market. Figure (iv) shows a plot of 5 vs 10-year maturity swap market data.

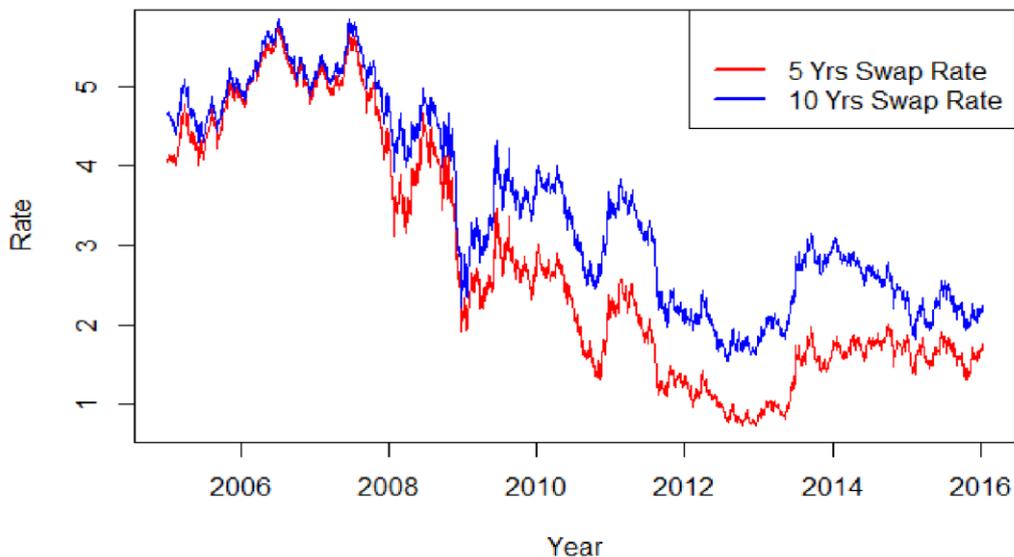


Figure iv: 5-year vs 10-year swap market data plot

The difference between swap rates for different tenors was assumed negligible before Crisis, for example, 3 months and 6-month swap market rate also moved together before crisis but after crisis there is a huge spread between them. Since the financial crisis the spread has no longer been negligible which signifies a major change in pricing of interest rate derivatives rendering the single curve pricing methods obsolete. Figure (iv) shows the assumption of negligible spread was valid since the rates were almost the same. The spread signifies credit risk for long maturities as opposed to short maturities.

Swap price cash flow analysis

This helps one understand how an interest rate swap works. Consider the following swap with a notional amount of \$3000.

Table ii: shows two interest rate schedules

Schedule	Start date	End date	Frequency	Rate
Schedule1	05/01/2006	05/01/2010	Monthly	3%
Schedule2	05/01/2007	05/01/2009	Quarterly	Benchmark rate 1%

Paying leg1

Cash flow := [*7.643835616 on 'February 5, 2006'*, *6.904109589 on 'March 5, 2006'*, *7.643835616 on 'April 5, 2006'*, *7.397260274 on 'May 5, 2006'*, *7.643835616 on 'June 5, 2006'*, *7.397260274 on 'July 5, 2006'*, *7.643835616 on 'August 5, 2006'*, *7.643835616 on 'September 5, 2006'*, *7.397260274 on 'October 5, 2006'*, *7.643835616 on 'November 5, 2006'*, *7.397260274 on 'December 5, 2006'*, *7.643835616 on 'January 5, 2007'*, *7.643835616 on 'February 5, 2007'*, *6.904109589 on 'March 5, 2007'*, *7.643835616 on 'April 5, 2007'*, *7.397260274 on 'May 5, 2007'*, *7.643835616 on 'June 5, 2007'*, *7.397260274 on 'July 5, 2007'*, *7.643835616 on 'August 5, 2007'*, *7.643835616 on 'September 5, 2007'*, *7.397260274 on 'October 5, 2007'*, *7.643835616 on 'November 5, 2007'*, *7.397260274 on 'December 5, 2007'*, *7.641140804 on 'January 5, 2008'*, *7.622950820 on 'February 5, 2008'*, *7.131147541 on 'March 5, 2008'*, *7.622950820 on 'April 5, 2008'*, *7.377049180 on 'May 5, 2008'*, *7.622950820 on 'June 5, 2008'*, *7.377049180 on 'July 5, 2008'*, *7.622950820 on 'August 5, 2008'*, *7.622950820 on 'September 5, 2008'*, *7.377049180 on 'October 5, 2008'*, *7.622950820 on 'November 5, 2008'*, *7.377049180 on 'December 5, 2008'*, *7.625645632 on 'January 5, 2009'*, *7.643835616 on 'February 5, 2009'*, *6.904109589 on 'March 5, 2009'*, *7.643835616 on 'April 5, 2009'*, *7.397260274 on 'May 5, 2009'*, *7.643835616 on 'June 5, 2009'*, *7.397260274 on 'July 5, 2009'*, *7.643835616 on 'August 5, 2009'*, *7.643835616 on 'September 5, 2009'*, *7.397260274 on 'October 5, 2009'*, *7.643835616 on 'November 5, 2009'*, *7.397260274 on 'December 5, 2009'*, *7.643835616 on 'January 5, 2010'*]

Paying Leg2

Cash flow: = [*14.80364796 on 'April 5, 2007'*, *14.96823556 on 'July 5, 2007'*, *15.13282543 on 'October 5, 2007'*, *15.13125175 on 'January 5, 2008'*, *14.92731330 on 'April 5, 2008'*, *14.92731330 on 'July 5, 2008'*, *15.09145290 on 'October 5, 2008'*, *15.09302657 on 'January 5, 2009'*]

Receiving Leg1

Cash flow: = [*`14.80364796 on 'April 5, 2007'`, `14.96823556 on 'July 5, 2007'`, `15.13282543 on 'October 5, 2007'`, `15.13125175 on 'January 5, 2008'`, `14.92731330 on 'April 5, 2008'`, `14.92731330 on 'July 5, 2008'`, `15.09145290 on 'October 5, 2008'`, `15.09302657 on 'January 5, 2009'`]*

Receiving Leg2

Cash flow := [*`7.643835616 on 'February 5, 2006'`, `6.904109589 on 'March 5, 2006'`, `7.643835616 on 'April 5, 2006'`, `7.397260274 on 'May 5, 2006'`, `7.643835616 on 'June 5, 2006'`, `7.397260274 on 'July 5, 2006'`, `7.643835616 on 'August 5, 2006'`, `7.643835616 on 'September 5, 2006'`, `7.397260274 on 'October 5, 2006'`, `7.643835616 on 'November 5, 2006'`, `7.397260274 on 'December 5, 2006'`, `7.643835616 on 'January 5, 2007'`, `7.643835616 on 'February 5, 2007'`, `6.904109589 on 'March 5, 2007'`, `7.643835616 on 'April 5, 2007'`, `7.397260274 on 'May 5, 2007'`, `7.643835616 on 'June 5, 2007'`, `7.397260274 on 'July 5, 2007'`, `7.643835616 on 'August 5, 2007'`, `7.643835616 on 'September 5, 2007'`, `7.397260274 on 'October 5, 2007'`, `7.643835616 on 'November 5, 2007'`, `7.397260274 on 'December 5, 2007'`, `7.641140804 on 'January 5, 2008'`, `7.622950820 on 'February 5, 2008'`, `7.131147541 on 'March 5, 2008'`, `7.622950820 on 'April 5, 2008'`, `7.377049180 on 'May 5, 2008'`, `7.622950820 on 'June 5, 2008'`, `7.377049180 on 'July 5, 2008'`, `7.622950820 on 'August 5, 2008'`, `7.622950820 on 'September 5, 2008'`, `7.377049180 on 'October 5, 2008'`, `7.622950820 on 'November 5, 2008'`, `7.377049180 on 'December 5, 2008'`, `7.625645632 on 'January 5, 2009'`, `7.643835616 on 'February 5, 2009'`, `6.904109589 on 'March 5, 2009'`, `7.643835616 on 'April 5, 2009'`, `7.397260274 on 'May 5, 2009'`, `7.643835616 on 'June 5, 2009'`, `7.397260274 on 'July 5, 2009'`, `7.643835616 on 'August 5, 2009'`, `7.643835616 on 'September 5, 2009'`, `7.397260274 on 'October 5, 2009'`, `7.643835616 on 'November 5, 2009'`, `7.397260274 on 'December 5, 2009'`, `7.643835616 on 'January 5, 2010'`]*

The net present value of swap1 is equal to -219.4012102 and that of the swap 2 is equal to 219.4012102 meaning that the value of the interest rate at inception is equal to zero. This explains how an interest rate swap works as a financial instrument.

Modelling short rate

The risk-free rate $r^{0/N}$ was modelled by use of CIR ++ model under the assumption of Brigo and Mercurio (2001a) that the instantaneous short rate changes under the risk neutral measure given by the dynamics

$$r^{0/N}(t) = x^0(t) + \psi(t; \alpha) \quad (8)$$

Where

$$dx^0(t) = k^0[\theta^0 - x^0(t)]dt + \sigma^0 \sqrt{x^0(t)}dW^0(t), X(0) = X_0 \quad (9)$$

In simulating the short rate path, we set the parameters $k=0.1$, $\theta=0.06$, $\sigma=0.06$. Figure 3 shows the plot of the exact simulation of CIR++ process for 5000 time steps. The short rate is stochastic that is it changes over time. The process approaches its long term mean slowly because of a small value of the mean reversion coefficient. It also has low fluctuation because the value of the volatility is small. The process starts at the initial value of 0.1 but it is pulled towards its long term mean of 0.06 which is the value of θ . Also, the main advantage of this process is that the rates can never drop below 0%. This represents the real-world situation where interest rates are not negative.

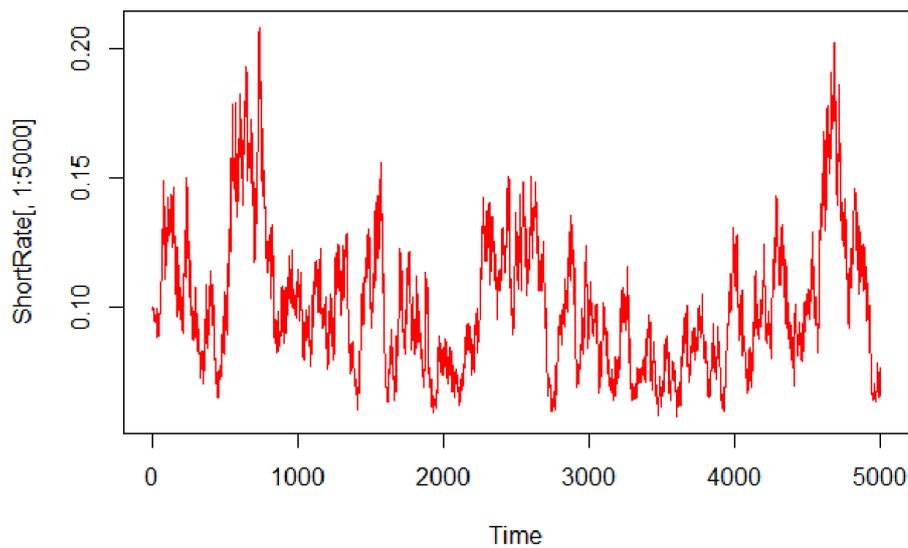


Figure v: Simulated path of short rate by CIR++ process

We also simulate the short rate path using parameters $k=0.128$, $\theta=0.052$ and $\sigma=0.066$ to have a view of how the process behaves with variation in parameters as shown in figure (vi). below.

The process starts at the initial value of 0.1 but it is pulled towards its long term mean of 0.052 which is the value of θ and the rates remain positive a major advantage of using CIR++ as a short rate model. As noted the process is mean reverting and the speed at which the mean reverts depends on the parameter k of the CIR++ model.

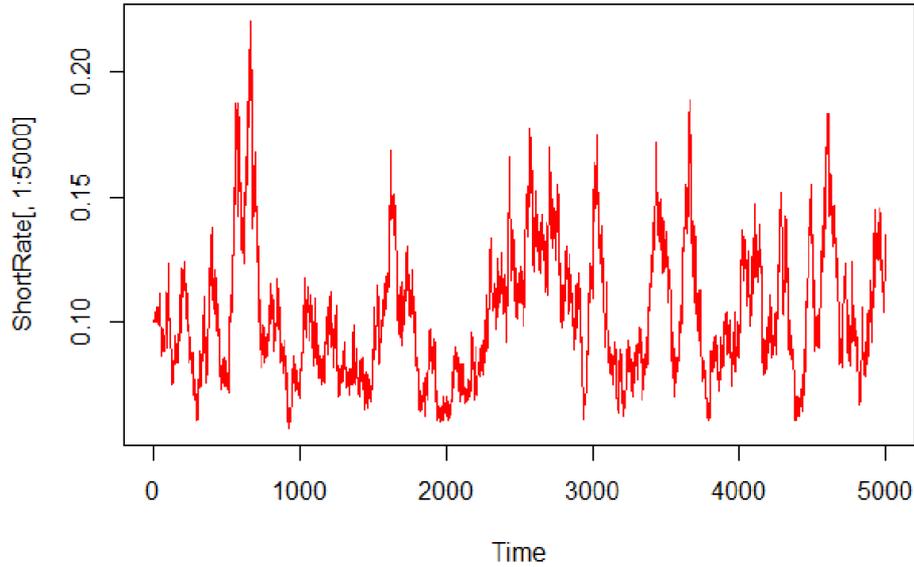


Figure vi; Simulated path of short rate by CIR++ process

We estimated the values of θ , k and σ using the historic 3-month period US daily LIBOR rate for the period between January 2005 to July 2008 and September 2009 to December 2013. We use 3 month USLIBOR rate because it is the shortest unsecured lending rate and we are modelling the short rate. The maximum likelihood estimates of the three parameters are as shown in table (iii)

Table iii; MLE of the US 3 month LIBOR rate for pre and post crisis period

Parameters	Pre-crisis period value	Post-crisis period value
θ	1.00000000	0.22725025
k	0.01000000	0.01000000
σ	1.00000000	0.01736931

Default intensity

The individual bank's default intensity λ^i follow the dynamics

$$\lambda(t) = x^i(t) \tag{10}$$

Where

$$dx^i(t) = k^i[\theta^i - x^i(t)]dt + \sigma^i\sqrt{x^i(t)}dW^i(t) \tag{11}$$

is a Feller diffusion model named after Cox et al. (1985) and $W^1 \dots \dots W^1$. We assume that default intensity is not constant but it is a function of other stochastic variables hence default time can be generated by Poisson process referred to as doubly

stochastic process or cox process. Here the intensity can be assumed to evolve as a square root diffusion process.

$$\text{CIR process } dx^i(t) = k^i[\theta^i - x^i(t)]dt + \sigma^i\sqrt{x^i(t)}dW^i(t)$$

$$\text{Survival probability } P(s/t) = e^{-\int_t^T \lambda^i(u)du}$$

Expected values of survival probability given past information

$$P(s/t) = E_t \left[e^{-\int_t^T \lambda^i(u)du} / F_t \right]$$

In simulating default intensity $\lambda^i(t)$ we test several values of the model parameters so as to appreciate the reaction of the default process $\lambda^i(t)$.

Default Model Simulation

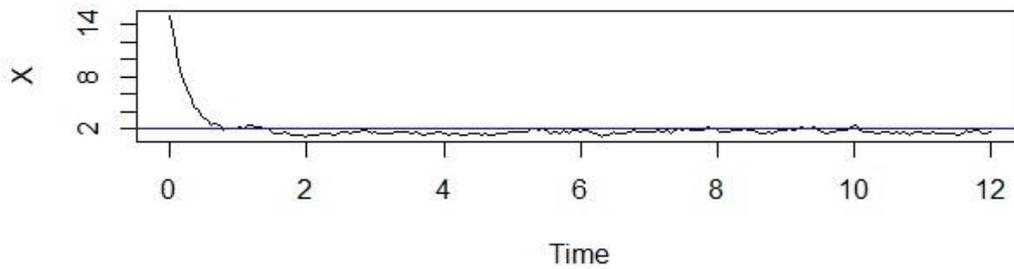


Figure vii; One simulation of CIR process $d(t) = k^i[\theta^i - x^i(t)]dt + \sigma^i\sqrt{x^i(t)}dW^i(t)$

survival probability with deterministic intensity

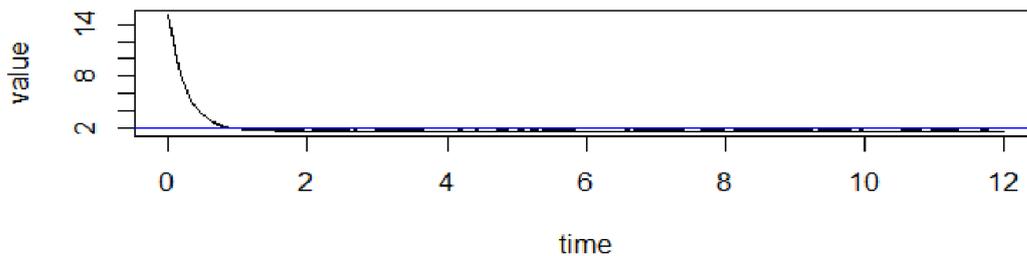


Figure viii; Survival probability to time s given survival to time t

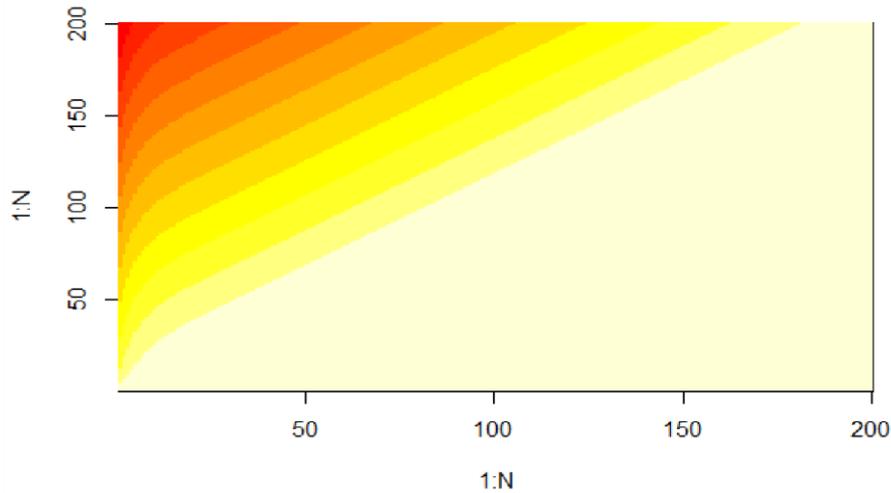


Figure ix; Log Matrix of the expected values of survival probability, $P(s/t) = E_t \left[e^{-\int_t^T \lambda^i(u) du} / F_t \right]$

From figure (vii), the process behaves as expected because it begins at the initial value of 15 and at time 2 it reaches its long term mean of 2. We used the mean reversion coefficient ($k=4$) hence since it is a high value then the process converges to its long term mean quickly. The volatility $\sigma=0.4$ is low hence limiting the fluctuation of the process. From figure (viii) the behavior of the survival probability with deterministic intensity (t) is similar to that of a single realization of square root diffusion process. We simulated the survival probability with deterministic intensity (t) and 1000 CIR process realizations. The survival probability curve is smooth and downward sloping reaching its long term mean at time 2. Figure (ix) displays a level curve the log matrix of the doubly stochastic survival probability with a random/stochastic intensity (t). Due to the fact that the effect of exponential has been removed the function decreases so fast to its final state. The function quickly decreases to its long run mean that it is not easy to notice the transition states. Therefore, even with the logarithm the survival probability function decreases rapidly to its final state. As the process approaches its final state there is an increase in various states and the dots of various states increase displaying the convexity of the doubly stochastic function (inequality of Jensen preserved).

The process was repeated with different values of the CIR parameters to see how the model behaves with change in parameters.

CONCLUSION

Pricing of fixed income market securities changed tremendously as a result of 2007-2008 financial crisis and this has resulted to adopting a new pricing framework (multi-curve) as the best pricing method as compared to single curve pricing. It is of

great benefit to correctly price these instruments because derivative markets specifically interest rate swap market has grown tremendously and these instruments are used by financial institutions for risk management that is to hedge against fall or rise in interest rates. Borrowing and lending was considered to be done at a risk-free rate LIBOR but as a result of the crisis overnight rate(OIS) is used as risk free interest rates. Pricing is also done depending on the tenor of the underlying instrument because of different credit and liquidity risk associated to various tenors, for example the longer the maturity the higher the credit and liquidity risk is because financial markets keep on changing. Credit risk is no longer considered negligible; therefore, it is priced in the interbank market rates.

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