JÖNKÖPING INTERNATIONAL BUSINESS SCHOOL
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Pricing Interest Rate Derivatives

The effects of the 2007 Credit Crisis

Paper within Business Administration, Accounting and Finance

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Jönköping May 2010

Acknowledgments

We would first of all like to thank our tutor Professor Andreas Stephan for his guidance and help throughout our work. We would also like to thank Dr. Marco Bianchetti and Rickard Jonsson at Handelsbanken for their involvement, as well as our fellow students and opponents for their feedback.

Jönköping May 24, 2010

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Abstract

Purpose The purpose of this paper is to investigate different methods for pricing interest rate derivatives before and after the credit crisis.

Method The study is an in depth study and is primarily concerned with collections of second hand data. The data has been primarily books and articles. From the articles more literature of importance has been found with help from the reference lists from other articles of importance.

The contact we had with a financial institute as well as with professors and market practitioners in the subject has been of great importance to the substance of our writings.

Frame of Reference An introduction to the problems with interest rate derivative pricing after the credit crisis and a presentation of how they are priced pre and post the credit crisis. This section also goes through the basic reasons behind the start of the credit crisis and how this has affected the overall financial markets. We will show how interest rate derivatives structure has changed and how they are priced due to differences in the underlying reference rates.

Analysis A comparison and the implementation of the two methods is presented.

Conclusion After comparing the methods this section presents the conclusion on why the multiple curve pricing method is more beneficial than the single curve pricing method.

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1 Introduction

This part introduces the thesis. A general background and motivation of the topic is followed by our purpose and research questions, ending with the delimitations. The last sectionof the thesis entitled "Glossary" gives explanations and definitions of terms that may be difficult to understand for the reader.

1.1 Background

The underlying cause of the credit crisis, which began in late 2007, was the burst of the US housing bubble. As subprime mortgages were increasing in the USA, new assets were developed based on the mortgages which in turn were sold to investors in the form of repackaged debt securities, and these mortgages were pooled together to create investment securities. Asset backed securities gives financial companies the opportunity to raise funds by borrowing against their assets and in turn create a new capital sourcing (Zweig, 2002). The new assets were given high credit ratings and were viewed as safe investments. However, they were not as safe as their ratings indicated, due to the fact that they were closely tied to the movement's in house prices (Mizen, 2008). This was a way for the banks to hedge against the risk of the mortgages that they were offering (Hull, 2009). As house prices in the US were increasing these securities were offering big returns compared to other investments, however, when house prices started to fall the losses on these investments were extreme because of the number of foreclosures on mortgages (Mizen, 2008).

The effects from the bubble bursting were that banks became unwilling to lend money to other banks due to the fact that the risk of another bank defaulting on a loan had increased drastically and banks were also unwilling to lend money due to the fact that they needed higher liquidity within the bank itself. This caused the LIBOR, which is the rate that banks use to borrow funds between each other, to increase drastically. In turn, this makes pricing interest rate derivatives hard due to the fact that the LIBOR has always been seen as a risk free rate. LIBOR is set by the 16 most credit worthy banks in London. When they have set their individual LIBOR rates these banks send their quotes to the British Bank Association which calculates an average by removing the top quartile and the bottom quartile and uses the quotes from the banks remaining to set the LIBOR. An interest rate derivative is a contract where the underlying asset is the right

to pay or receive a notional amount of money at a given interest rate; either fixed or floating. However, during the credit crisis banks were unwilling to lend money to each other due to counterparty risk.A new risk free rate had to be used as well as a new method of pricing interest rate derivatives. This had to be done in order to correct for the discrepancies that arose in the market because using the LIBOR as an underlying reference rate did not mirror a risk free rate that an investor could receive if instead putting his money where there is no risk at all, for example a bank account. Within the interest rate market there has always been a sort of segmentation, however, it has always been very small so there has been no need to attend to this problem. However, after the credit crisis the segmentation has increased and one can no longer only use one forward curve though it does not take into account the basis spreads. The forward curve is a graph of forward interest rate values of different periods of time, it is a way of valuing the time value of money (www.investorwords.com). One has to take into account several tenors in order to correct for the discrepancy.

What will be presented in the following sections are the problems with derivatives pricing as an effect of the credit crisis as well as the "old" or "pre- " credit crisis method of pricing interest rate derivatives as well as the "new" or "post-" credit crisis method, in the text called single and multiple curve framework. The single curve framework is the standardized method of pricing interest rate derivatives using one yield curve to calculate forward rates and discount factors. The multiple curve framework is an evolved framework that uses multiple unique forward curves and a separate discounting curve. We will also be looking at the differences between them and show how they can be implemented and also the increase in caution for risk after the credit crisis and how market practitioners are coping with this.

1.2 Purpose and Research Questions

The purpose of this paper is to investigate different methods for pricing interest rate swaps before and after the credit crisis. We want to look at the single and multiple curve pricing methods to see how institutions can benefit from a multiple curve pricing framework, not just during the crisis but as the new standard. Thus, the aim is to provide an understanding of the benefits from using a multiple curve pricing framework rather

than a single curve pricing framework. We will also examine the risks that have become more apparent after the credit crisis.

We developed two research questions that we used as guidance throughout our work and the outcomes are presented in the analysis.

How has the credit crunch affected the pre and post ways of pricing interest rate derivatives?

How and why is the multiple curve more beneficial than the single curve framework?

1.3 Delimitations

Due to time and limited academic level this paper will not deal with the calculations behind the pricing methods. To get an even deeper understanding in how this pricing process and the different methods for pricing really works first hand calculations were considered to be done. That showed to be too demanding since the relevant knowledge about the programs for calculating such complex instruments are beyond what is feasible for a bachelor thesis.

Further limitations might be the in-depth part of the paper. The subject is precise and does not leave time nor space to go into wider sections in the subject. The limitations lie in the challenging to sort out relevant data and to get a hold of the right data that is sufficient for the in-depth study. That is also why the search for information was focused at an early stage after evaluating the surroundings for appropriate material and then focusing on the most favorable writings on the subject.

2 Method

This section presents the method through which we fulfilled our purpose.

2.1 Qualitative and Quantitative

A distinction between qualitative and quantitative method ought to be clarified.

Qualitative method is the method where one is using smaller quantities of data and integrates this data into reality. The researcher is more interested in the real substance of the data.

Quantitative data is where one uses large samples of empirical data. The outcome is then the conclusion of all of these tests, interviews and other information gathered (www.ne.se).

The method for this paper is to gather appropriate data and to summarize our findings from already existing findings on the subject. It is therefore not of relevance to distinguish between qualitative and quantitative data. However, if one were to define a method for this paper, the first process of scooping for data would be quantitative method. The later part of the data collection with deeper investigation and interviews would be classified as quantitative data.

2.2 Primary and secondary data

The paper mainly relies on secondary data. The intent was to conduct primary data. This work was revised and reduced due to limitations in time and academic level required to conduct first hand studies. However, a strong believe is that this will not be to any disadvantage for the outcome of our purpose.

The primary data firstly planned to be gathered was the implementation of calculations of the multiple and single curve frameworks. In order to be successful with this and for the calculations to be of substantial worth we would be required to work in special statistical and finance programs such as Quantlib and R. It turned out that these programs required a higher level of knowledge than was suitable for a bachelor thesis. After careful consideration and discussion with statisticians and finance professors a decision to drop this idea of calculating the curves was taken.

The primary data is in-depth interview with a financial institute and also with a banker who is currently employed at Handelsbanken Capital Markets. Furthermore, primary data was collected through contact with a professor in Milan, Dr. Bianchetti. We did not conduct any interviews with him, but he provided us with suitable information and gave answer to our questions. This will be integrated in our work and will not be presented as appendix as the other interviews will.

2.3 Data collection

The initial task, to investigate the anomalies in interest rate derivative pricing after the credit crunch, required a lot of investigation in the subject to grasp the problem. This was done through information from the company both in the way they work and how the market is handling the situation and what was primary written about the new pricing techniques. The company provided a great deal of material and the primary article was "Two curves, one price" by Dr. Marco Bianchetti. The information from that article, the references Dr. Bianchetti presented and the information from the company made it possible to proceed with the databases at JIBS; mainly DIVA, a database of the schools publications. Use of reference lists led to more available publications of good quality on the subject. This initial process of data collection provided a solid foundation of knowledge to be able to select more carefully the relevant information needed for the basis of our paper.

Founding´s showed some of these authors had been writing several articles and also books about swaps and derivatives and the effects of the credit crisis and some of them also developed specific models for pricing these instruments. One of the professors we came across as particularly interesting was, as previous mentioned Dr. Marco Bianchetti. Dr. Bianchetti is a Senior Quant at Intesa San Paolo Bank in Italy and through email contact, we were able to acquire a lot of valuable information. The information was complementary articles that otherwise would have been hard to find. Bianchetti is one of the professors who has developed a model for pricing interest rate derivatives post the credit crisis. This model is the very core of the paper. To be able to have a personal connection with Dr. Bianchetti has been very beneficial and has increased the validity of our paper a great deal. Further articles found to be especially interesting and important for our researched are written by; F. Ametrano, M Fujii and others.

Furthermore, a lot of our research is based on John C. Hull's writings. Mainly from his book *Options, futures and other derivatives, 2003.*

2.4 Validity and Reliability

Validity is defined as the study of a phenomenon and making the study as precise and faithful as possible. In addition, validity is about conducting the study in a way so that it solely captures the subject and the phenomenon of interest. The validity is fulfilled when the researcher is conducting the study in such a way that the phenomenon is studied in a precise way to fulfill the purpose (McKinnon, 1988).

Reliability is concerned with the extensive collection of data. The researcher shall be able to collect data on which they can rely on.

According to McKinnon there are a number of threats to validity. Among these is data access limitations that might decrease the validity. Limitations to data access might be due to time constraints. There might also be restraints to what type of data one can access. One might not be able to get hold of specific data or people to fulfill the validity.

To increase the validity, using multiple strategies is of importance. Focus on using both second hand data as well as going into real life, as with the banks, are examples of this. This led us to see if there really was a real life connection to our findings. In doing this it meant increasing the validity and reliability. The reliability was strengthened, since conclusions could be drawn, that our secondary data was indeed in line with the empirical findings.

In field research there are many ways of going about, depending on the type of purpose you have. Therefore, there are many ways of avoiding the four typical threats that comes with researching. The threats that are of importance for us in this study would be observer bias, which is concerned with the researchers' perception in the study. You hear and see what you want to hear and see, especially in casual interviews, such as the ones we are conducting. Furthermore, the second threat is data limitations. The researcher is only at hand for a limited time and might therefore miss information prior or after the research time frame. Moreover, restrictions on access to certain data will be a

threat. Data of value might not be accessible for the researcher for numerous different reasons.

These threats can be overcome by the length of time in the field, using multiple methods and observations, and paying attention to what tactics are used during the study, to mention some of the tactics (McKinnon, 1988).

The information gathered from the financial institute contact, the contact with Dr. Bianchetti, the bank and the data from other sources and the fact that they have been consequently striving towards the same direction also increases the level of validity of our paper.

2.5 Criticism of the method

The criticism of our method would be the fact that since an in-depth study is conducted there is not much width. As discussed previously this is not an issue for the quality of our study, since a wider, quantitative study would not have yielded the in-depth qualitative analysis of the problem that we seek. Furthermore, it would have been useful to have more interviews and contact with the real world, such as more financial institutions and market practitioners. However, that would have been too time consuming and we have therefore only been in contact with Dr. Bianchetti, the financial institute and Handelsbanken in the matter. However, the discussion with Bianchetti will be incorporated in the paper and will not be presented as a full interview since the discussions were made on a more casual basis and not as an interview.

3 Frame of Reference

This section presents problems of interest rate derivative pricing after the credit crisis and the different methods used, we also mention the risks involved in derivative pricing.

3.1 Problems with pricing Interest rate derivatives

After the beginning of the 2007 credit crisis there have been some anomalies arising in the interest rate markets. Before the credit crisis, the OIS and LIBOR were tracking each other closely, and FRA had a strong and precise relationship to the LIBOR that they were indexed to. An FRA, or forward rate agreement, is an agreement between two counterparties to lend or borrow at a future specified date with an interest rate agreed upon today (www.bloomberg.com). After the burst of the credit crisis there appeared a large basis spread between OIS and LIBOR and FRA could no longer be replicated using LIBOR spot rates, which means that we cannot construct an FRA using LIBOR though it is not seen as a good prediction of future interest rates. The increase in spread between the OIS and LIBOR and the problems to construct FRA´s have had a very strong impact on the financial markets around the world because they have made us question the interest rate markets during the credit crisis and distort our understanding of how all banks construct term structures of discount factors used to price all financial products (Morini, 2009). This means that we can question the way banks construct the yield curves for a given financial instrument which is then used to discount the cash flows of the contract that the parties have entered. Yield curve is a graphic representation of the yield of bonds with the same credit rating but with different maturities (www.bloomberg.com). To account for these anomalies a new framework for pricing interest rate derivatives has been developed, this framework, along with the standardized framework will be presented in the sections following (Ametrano, Bianchetti, 2009). We can see in Figure 1 below how OIS/LIBOR have diverged since the credit crisis began. An effect of this is that LIBOR can no longer be seen as a true risk free rate and therefore another interest rate should be used when pricing interest rate derivatives. The LIBOR cannot be seen as the best risk free rate anymore due to that it now contains risk that it didn´t before, such as credit and liquidity risk.

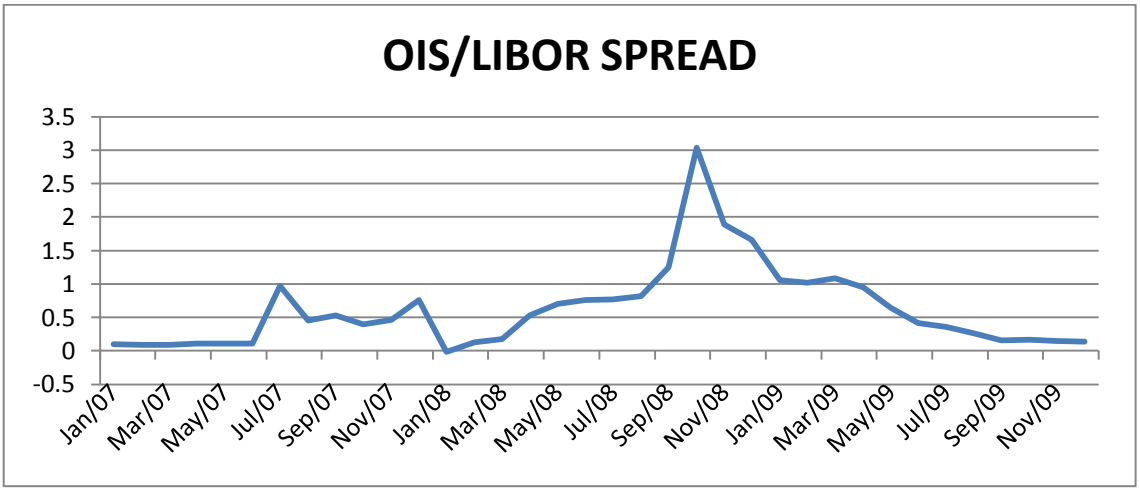


Figure 1: OIS/LIBOR Spread

The spread of the OIS/LIBOR was due to the fact that when the credit crisis began banks were unwilling to lend their money to other banks due to counterparty risk and so therefore LIBOR rates were set at a much higher level in order to keep lending to a minimum.

Mustafa Chowdhury, a U.S interest rate analyst at Deutsche Bank, says that the LIBOR has been used as the benchmark rate to price numerous financial products. However, with the credit crisis, market practitioners have realized that the LIBOR may not be the right rate to use. This is due to the fact that banks have several other rates to use for funding, such as the Federal Reserve where the cost has been more and more reflected in the OIS. The LIBOR has previously been used to reflect interbank credit, however, now it is more a reflection of transactions in the credit risk market. Mustafa Chowdhury believes that these issues will evolve into the use of a new index that is more connected to treasuries (Magidan, 2009). According to Bianchetti, the rate that is shown to be the most risk free is the EONIA rate since it includes negligible counterparty credit and liquidity risk (Bianchetti, 2010).

Market practioners argue that the OIS rate is a better indicator of a risk free rate (Morini, 2009). The OIS is a fixed-for-floating interest rate SWAP, where the floating rate of the SWAP is calculated using an overnight reference rate, for example the EONIA rate, in the Euro market (Morini, 2009). The fixed-for-floating interest rate SWAP means that one party pays fixed and receives floating and vice versa. The EONIA rate is based

on unsecure lending transactions of the panel banks in the Euro area. The EONIA includes information such as; monetary policy effects and the short-term liquidity expectations of these banks. The EONIA rate carries the shortest rate tenor (one day) and includes no counterparty credit or liquidity risk and is therefore the best representation of a risk free rate (Bianchetti, 2010). Since the OIS is based on an overnight rate, which means lending for an extremely short period of time, Morini argues that the OIS rate does not incorporate any credit or liquidity risk and therefore is a more appropriate risk free rate than LIBOR (Morini, 2009). Market operators use the OIS rate to make predictions of future overnight lending rates, therefore the OIS/LIBOR relationship is a good indication of credit and liquidity risks encountered by counterparties that come with lending for periods longer than one day (Morini, 2009). The OIS/LIBOR also provides a brief indication of the overall health of the financial sector, and if the spread widens, this is a signal that banks are more unwilling to lend money and if the spread decreases it indicates a higher liquidity in the market (McCormick, 2008).

3.2 Single Curve Approach to Derivatives Pricing

Before the credit crisis broke out in 2007 there was a standard and traditional way for investment banks to price interest rate derivatives. The standard, before the credit crisis, method of pricing interest rate derivatives was to use one yield curve in order to calculate the forward rates and the discount factors. To make it clear for the reader we have broken it down into a few steps which are easily followed.

The first step is to select one limited set of the most liquid vanilla interest rate instruments which are traded in the market with increasing maturities. Some of the most common choices in the EUR market are a combination of short-term EUR Deposit (1m, 3m, 6m), medium-term futures on Euribor 3M (Ron, 2000) or FRAs (up to two years) and medium-long-term Swaps on Euribor 6M (up to ten years). In markets where the forward or futures market are illiquid, inefficient or doesn't exist for some specific tenors then it is better to use longer-term interbank deposit rates which in turn will lead to having to rely more heavily on bootstrapping (interpolation) (Ron, 2000). Bianchetti and Ametrano state that the procedure to select bootstrapping methods is not so much a science as it is an art. There is no financially sound choice of bootstrapping instruments and there is no one method or instrument better than the other (Bianchetti, Ametrano,

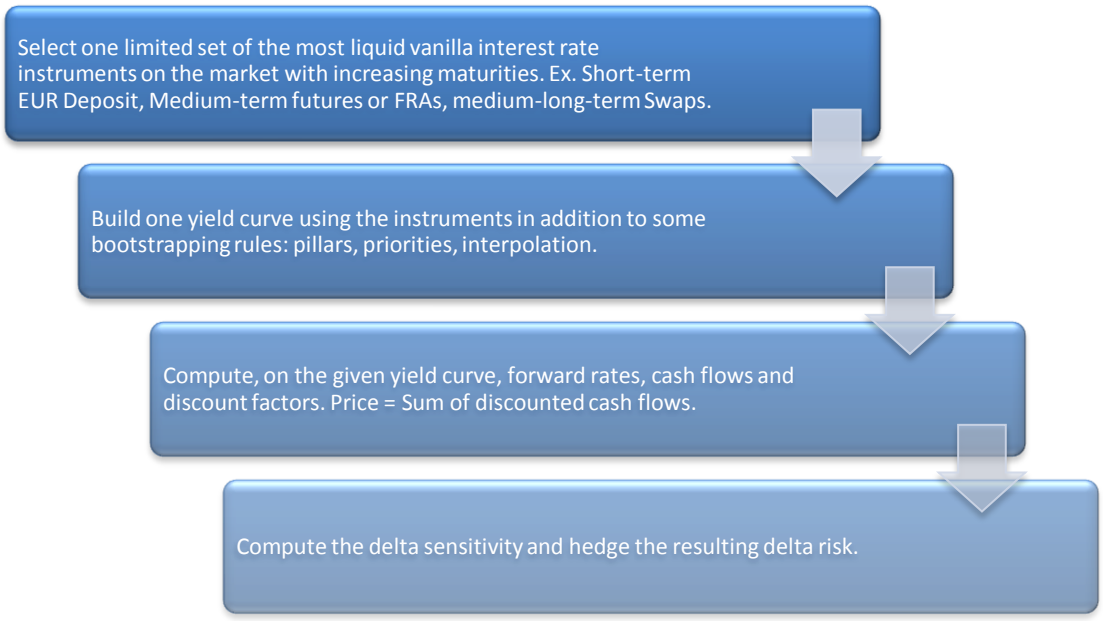
2009). The reason for the combination is to attain a low risk forward and discount rate because using more than one set of data with several different tenors gives us a spread of information that makes our end price much more precise than if just using one reference rate (Bianchetti & Ametrano, 2009).

The second step in the process is to build one yield curve using the instruments in addition to some bootstrapping rules (pillars, priorities, interpolation etc) (Bianchetti & Ametrano, 2009). Bootstrapping is a procedure in which to build a zero-coupon yield curve from these market instruments.

The third step involves computing, on the given yield curve, forward rates, cash flows and discount factors. To attain the price of the interest rate derivative we take the sum of the discounted cash flows (Bianchetti & Ametrano, 2009).

The fourth step, which we will only briefly mention, is that we will compute the delta sensitivity (www.mathworks.com) and hedge the resulting delta risk using suggested hedge ratios of the same market instruments that we used above (Bianchetti & Ametrano, 2009).

To give you a better overview of the different steps in the single curve framework, we present them below in a flow chart.



When developing the swap term structure we use the observed market interest rates combined with bootstrapping techniques such as interpolation, which is a method of approximating a price or yield that is unknown by using numbers that are known (www.bloomberg.com). Term structure is the relationship between yield to maturity and time to maturity (www.econmodel.com). In addition, dates are retrieved using the business-day convention. Swaps are most often constructed using a modified business-day convention, where the cash flow occurs on the following business day unless that day is in another month (Ron, 2000).

We have to keep in mind that this is a single-curve framework, where a unique curve is constructed and used to price interest rate derivatives in any given currency. This is also a relative pricing approach, because both the price and the hedge are calculated relatively to vanilla instruments quoted on the market. This method of pricing is also arbitrage prone due to that discount factors and forward rates obtained through bootstrapping are not always in line with the no arbitrage condition. The no arbitrage condition refers to the fact that in practice bid-ask spreads and transaction costs virtually hide any arbitrage possibilities (Bianchetti & Ametrano, 2009). Arbitrage is the simultaneous buying and selling of a security at two different prices in two different markets to make a riskless profit. A arbitrage opportunity arises when markets are not efficient, however, as mentioned above transaction costs usually hinders an arbitrage profit (www.bloomberg.com).

3.3 Multiple Curve Approach to Derivatives Pricing

The single curve framework or pre credit crisis method that we presented above is no longer efficient under the current market conditions. There are three reasons for this: the first is that it does not account for the market information of the basis swap spreads, which is now much larger than before the credit crisis and can no longer be ignored (Bianchetti, 2010). The basis spread is the difference between lending and borrowing rates and leads to interest rate risk (Hull, 2003). Second, it does not take into consideration that the interest rate market is divided into sub-areas corresponding to instruments with distinct tenors and different dynamics, for example short rate processes. Short rate is the interest rate at which an entity can borrow money for a short period of time (www.math.uu.se). Because of this, pricing and hedging interest rate derivatives using

one single yield curve by combining different tenors can lead to faulty or "dirty" results. Thirdly, according to no arbitrage, two identical cash flows must show the same present value hence we need a separate or unique discounting curve (Bianchetti, 2010). This is explained in more depth below.

Market practitioners have agreed on that for each given contract a specific discount curve should be selected, which they use to calculate the net present value (NPV) of the contract´s future cash flows, which is consistent with its characteristics and the counterparty in question. They will then build as many forward curves as market tenors (e.g. 1m, 3m, 6m, and 1y). Using this approach the future cash flows will be generated by the curves underlying rate tenors and their NPV is calculated through the selected discount curve. These assumptions of separate discount and forward curves, for a single currency, and given that there is no risk of default, goes against the classic standardized pre credit crisis pricing methods (presented in previous section), which were based on unique and consistent zero-coupon curves, which contain all relevant information regarding the risk neutral projection of future rates and the NPV of the cash flows (Mercurio, 2010). The big difference here is adapting to the new way of pricing; to use one zero-coupon curve for future rate calculations and another for discounting the cash flows (Mercurio, 2010).

To present the multiple curve framework in a clear way we have used the following steps to show how this is done.

The first step is to construct one discounting curve using the preferred vanilla interest rate instruments and bootstrapping procedures (Bianchetti, 2010).

The second step is to select multiple separate forwarding curves using the preferred separate set of vanilla interest rate instruments traded on the market with increasing maturities, each of which are compatible in the underlying rate (1m, 3m, 6m, 12m) (Ametrano & Bianchetti, 2010).

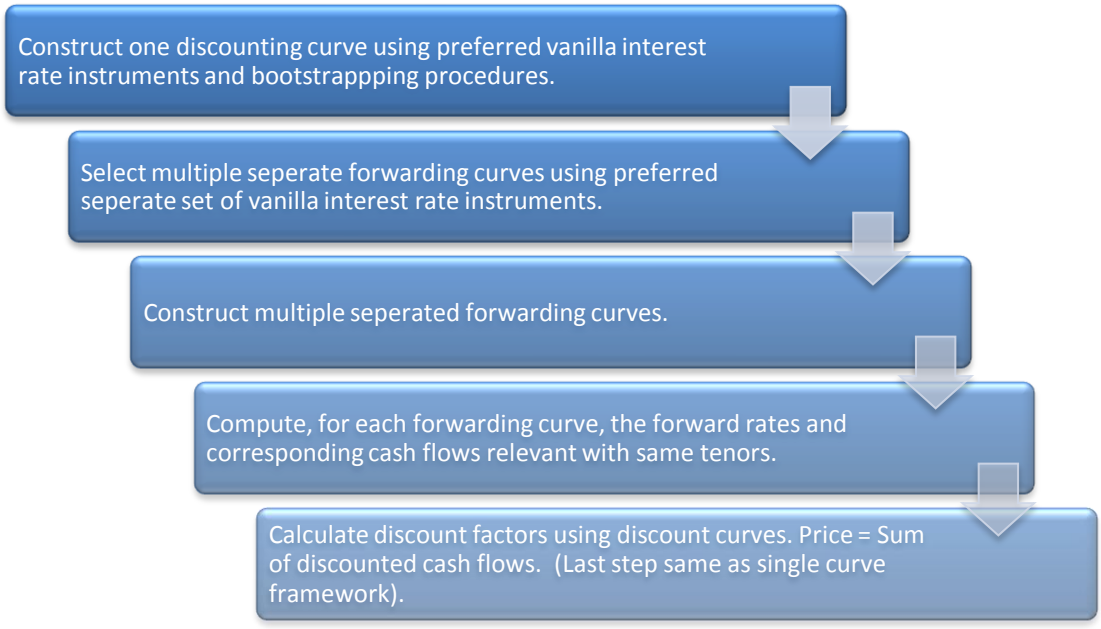
Thirdly, we will construct multiple separated forwarding curves using our preferred vanilla interest rate instruments and their given bootstrapping rules (Ametrano & Bianchetti, 2010).

The fourth step is the process of computing for each forwarding curve the forward rates and the corresponding cash flows relevant for pricing derivatives on the same underlying tenors (Amterano & Bianchetti, 2010).

The next and fifth step we calculate the discount factors using the discounting curves and we attain the price by summing up the discounted cash flows (Ametrano & Bianchetti, 2010).

The last step is the same as for the single curve method; we compute the delta sensitivity and hedge the resulting delta risk using suggested hedge ratios of the same market instruments that we used above (Ametrano & Bianchetti, 2010).

To give you an overview of the steps involved in the multiple curve framework, we present them below in a flow chart.



The methods and procedures presented above is a better and more consistent way of pricing interest rate derivatives given the new market conditions that have arisen as an effect of the credit crisis. However, this new method is more demanding than the single curve framework presented earlier. It has become more demanding due to the fact that the discounting curve plays an important role, more so in the multiple curve framework than in the single curve framework and therefore must be built with special care. Also, when building multiple curves it requires us to focus on multiple quotations and lastly,

hedging becomes more complicated because we are using multiple bootstrapping instruments (Ametrano & Bianchetti, 2009). The use of multiple bootstrapping instruments such as deposits, futures, swaps and FRAs is important because it gives us a better spread of information in our valuation (Ametrano & Bianchetti, 2009). This is not done in the single curve framework because as the name suggests we are only using one curve to calculate the price.

3.1 Risk Management as an effect of the Credit Crisis

3.1.1 Liquidity and Credit Risk

Liquidity problems for LIBOR banks are among the main reasons used to explain the gap opened between the LIBOR and OIS during the crisis. When this occurred the FRA forward gap and the Basis swap spread, presented in Figure 3, also widened. This was of great importance to explain liquidity risk. However, to understand this better we need to define liquidity risk and the different scenarios a bank may face.

1. Funding Liquidity Risk: the risk of running short of available funds.
2. Market Liquidity Risk: the risk of having large exposures to illiquid markets, where it may be difficult to sell a certain security.
3. Systematic Liquidity Risk: the risk of a global crisis where it becomes difficult to borrow.

Morini argues, in his paper *Solving the puzzle in the interest rate market*, that a bank is not affected by these three elements unless all three occur at the same time. Morini states that if for example a bank faces problem 1, but not 2, it will be able to liquidate its assets to get funding liquidity. And we can also see that even if problems 1 and 2 occur, a bank should be able to borrow funds to overcome these problems.

Furthermore, we can see that it is hard to separate liquidity risk from credit risk and that they often are connected. If for example Bank A is funding liquidity risk for Bank B, then it is strongly correlated with the default of Bank B since funding liquidity risk is measured by the cost of financing on a bank, then an increase in the cost is usually a cause and a consequence of an increase in default risk (Morini, 2009). Market liquidity risk refers to the difficulties of transferring a specific deposit for a counterparty and because of this is also strongly correlated to the risk of default of the counterparty (Morini,

2009). The systematic risk is also strongly correlated to the risk of default of a LIBOR counterparty (Morini, 2009). Systematic risk is the risk of a whole financial market or system collapsing (macroblog.typepad.com). While market risk means the risk of a certain investment decreasing in value because some underlying factors such as interest rate risk, currency risk, equity risk or commodity risk (www.mas.gov.sg). Therefore, banks need to attend to both liquidity risks and credit risks as they are intertwined.

3.1.2 CSA Agreements

The risks in the derivative market have increased and market practitioners have become more aware and cautious of the risks involved with derivative products. Banks and market players have started, in a wider sense than before the credit crisis, to use for example collateral to limit the risks of their counterparties.

Companies that deal with derivatives have started to implement a more frequent use of CSA agreements when entering into a Swap for example. To give you a better idea of a CSA agreement here is an example:

If Bank A and Bank B have numerous derivative transactions between them and the net positions measured in market value are as such that Bank B is in "debt" to Bank A. Bank B must in this case send money or government bonds to Bank A equivalent to the value of the debt. This debt is valued daily and entails that counterparty risk has decreased. If Bank B would go bankrupt the next day, Bank A would keep the collateral that they received from Bank B, hence, theoretically only carrying the risk of transactions for one day. However, all existing transactions between Bank A and Bank B will be worthless so Bank A could still make a loss due to Bank B´s bankruptcy, but it will be lower than if there had not been a CSA agreement (R. Jonsson, personal communication, 2010-05-04).

CSA agreements are all constructed differently, aspects that are considered between the counterparties are; value of the debt and credit rating of the counterparty. So there will always be a negotiation between the two parties with these aspects in mind. This in turn has led to a discussion of whether dealers should price derivatives differently of whether there exists a CSA agreement or not. CSA agreements is not something that has

emerged recently, however, it has become widely more used since the credit crisis began in 2007 (R. Jonsson, personal communication, 2010-05-04).

While CSA agreements have aided banks to reduce counterparty risk, there are also some negative aspects of the agreements. In figure 2 we can see the pros and cons of using collateral to reduce counterparty risk.

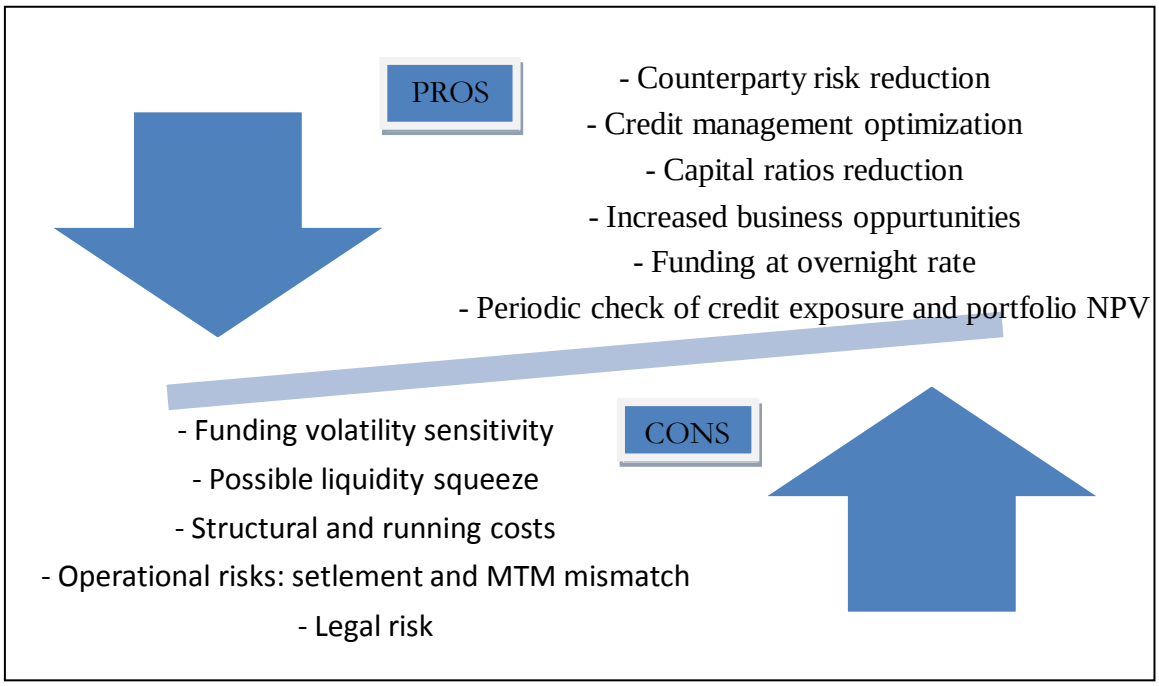


Figure 2: Pros and Cons of using Collateral (Bianchetti, 2010).

4 Analysis

In this part with use our theoretical framework to empirically implement it and we also present interest rate characteristics and risk management.

4.1 Empirical Implementation

Pricing interest rate derivatives has, due to the credit crisis, changed from 2007 until today. The main reason for this is that spreads between different interest rates as well as forward rates have become larger and can no longer be neglected. This has called for market practioners to expand and develop their methods of pricing these financial instruments.

In Figure 3 we can see the basis points as of February 16, 2009 for the six EUR basis swap curves corresponding to the four Euribor swap curves 1M, 3M, 6M and 12M. Before the credit crisis started in 2007 the spread were only a few basis points, however, now we can see a greater divergence between them. We can see in Figure 3 that in the time interval 1 year – 30 years the spread is decreasing from almost 80 basis points to around two basis points. This spread is in large due to liquidity risk banks suffered under the credit crisis and due to this banks started to demand payments more frequently; quarterly instead of semi-annually. To minimize the time that they are vulnerable against counterparties and also to keep their required liquidity levels (Bianchetti, 2010). These basis spreads that we can see in Figure 3, although present before the credit crisis, became more apparent and larger after the credit crisis and could no longer be avoided.

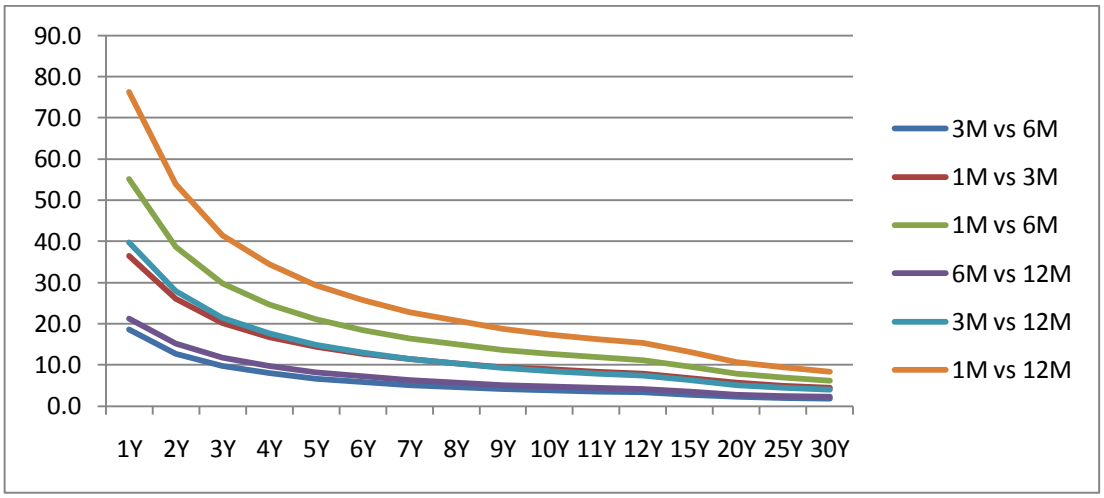


Figure 3: EUR Basis Swaps (data from Dr. Marco Bianchetti, 2010)

4.2 Implementing the Single Curve Framework

In our example in Appendix 1 we show a basic "pre credit crisis" approach to pricing a interest rate swap. In our example the notional amount is 100 million dollars and the agreement runs for a two year period. The information that we have used in this example is the 3M Libor (www.bankrate.com) and the CME Eurodollar CD Futures Price, our interval is a three-month period from March to December. At the beginning of the contract we can see that the present values of both the floating and the fixed cash flows are the same. We have discounted the floating cash flows using the forward discount factors calculated from the Eurodollar prices, and the fixed cash flows have been calculated using our Swap rate and then discounted using the forward discount factors. The discount factors are calculated using the period forward rates. We can see a clear relationship in Figure 4 that the forward rates are increasing with longer maturity which is normal due to the fact that there is more risk involved when lending money for a longer period of time.

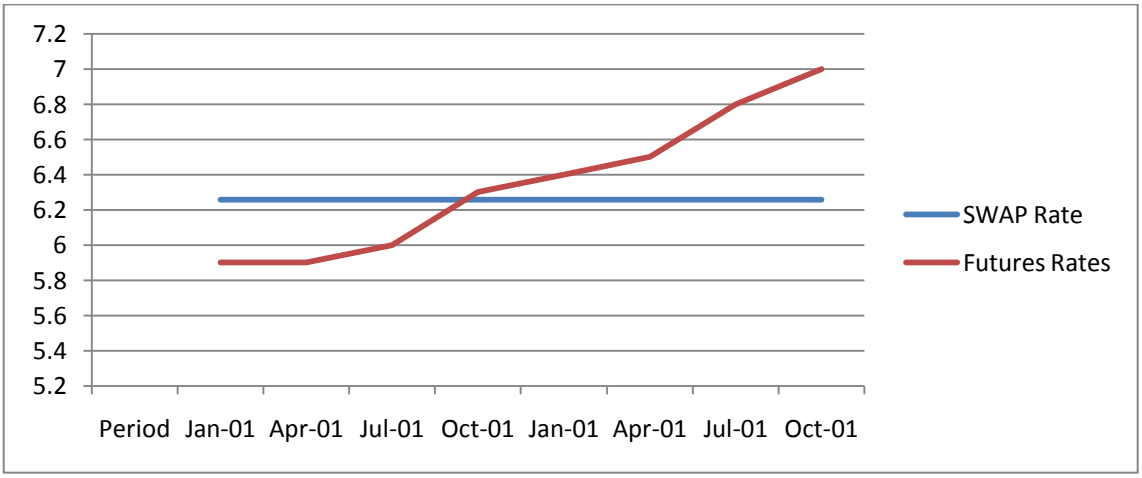


Figure 4: Swap Rate and Futures Rates (Appendix 1)

The Swap rate is calculated by discounting the floating cash flows and the notional amount. The Swap rate is the rate to which the fixed rate counterparty is willing to pay for borrowing and in return receive 3M Libor. The Swap rate according to our calculations is 6.25706% and the 3M Libor was 5.9%[1]. So at the beginning of the contract

[1] The calculations were made based on Fabozzi, 2005. So the 3M Libor does not reflect the current 3M Libor which is 0.47%.

there is not one party that has benefited from the agreement and this is important to be sure that there are no arbitrage opportunities (Hagan, West, 2007). And whether or not the fixed rate payer or the floating rate payer benefits or makes a profit from the agreement is a result of what happens to the floating interest rate (LIBOR). Below we can see an illustration that explains who benefits from any given scenario following by a section explaining the characteristics of interest rates and how they move.

	Rates Rise	Rates Fall
Issuer Pays Fixed	+	-
Issuer Receives Fixed	-	+

Table 1: Relationship between interest rates and fixed payer and receiver

The party that pays fixed will benefit from the swap if rates rise and will face a loss if rates fall, this is because when the rate is locked in at the fixed rate the party would have been better off in borrowing at a floating rate if rates fall and vice versa. The party that receives fixed rate payments will benefit if rates fall and face a loss if rates rise, this is because if rates rise so will the floating rate payments and vice versa.

4.1 Characteristics of Interest Rates

A small or negligible difference between short and long term interest rates occurs in the later part of an economic cycle when interest rates increase due to higher inflation expectations and tighter monetary policy. This is called a "shallow" or "flat" yield curve and higher short term rates reflect less available money, as monetary policy is tightened, and higher inflation is a result in the later part of the economic cycle (Umut Irturk, 2006).

When the difference between long and short term interest rates is large, the yield curve is said to be "steep". This is thought to reflect a "loose" monetary policy which means credit and money is readily available in an economy. This situation usually develops early in the economic cycle when a country's monetary authorities are trying to stimulate the economy after a recession or slowdown in economic growth. The low short term

interest rates reflect the easy availability of money and low or declining inflation. Higher longer term interest rates reflect investors' fears of future inflation, recognizing that future monetary policy and economic conditions could be much different (Umut Irturk, 2006).

Tight monetary policy results in short term interest rates being higher than longer term rates. This occurs as a shortage of money and credit drives up the cost of short term capital. Longer term rates stay lower, as investors see an eventual loosening of monetary policy and declining inflation. This increases the demand for long term bonds which lock in the higher long term rates (Umut Irturk, 2006).

4.2 Implementing the Multiple Curve Framework

This following section will present method to construct an Interest Rate Swap using separate forwarding curve and discount curve. In the previous example we derive the forward rates and the discount factors both from the LIBOR and Eurodollar CD Futures price. In the multiple framework we will instead use separate information when calculating the forward rates and the discount factors. In Figures 5, 6 and 7, we can see 3M Forward curve, 6M Forward curve and the Discounting curve. The unique discounting curve shown in Figure 7 is important in the multiple curve framework because the future cash flows, of both parties in the contract, need to show the same present values at inception. The cash flows refer to the fixed interest rate payer and the floating interest rate payer.

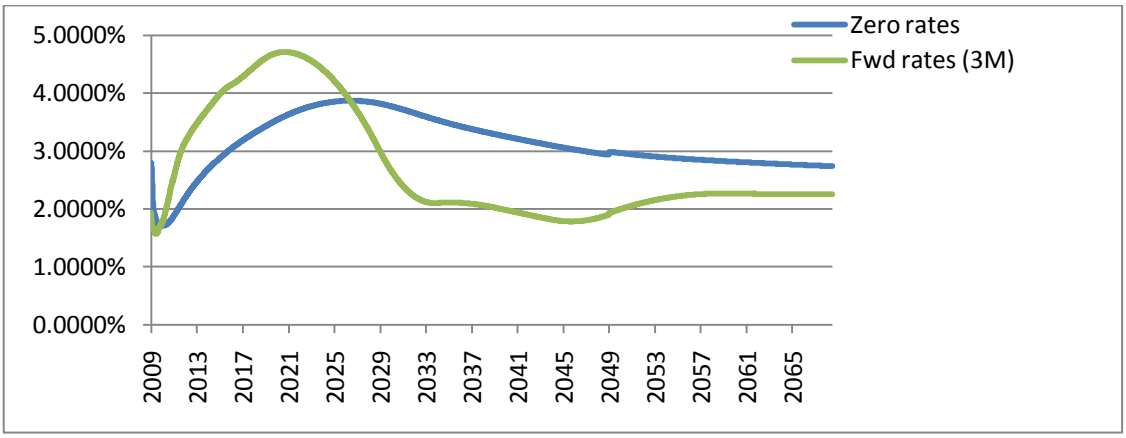


Figure 5: EUR Forwarding Curve 3M (Data from Dr. Marco Bianchetti, 2010)

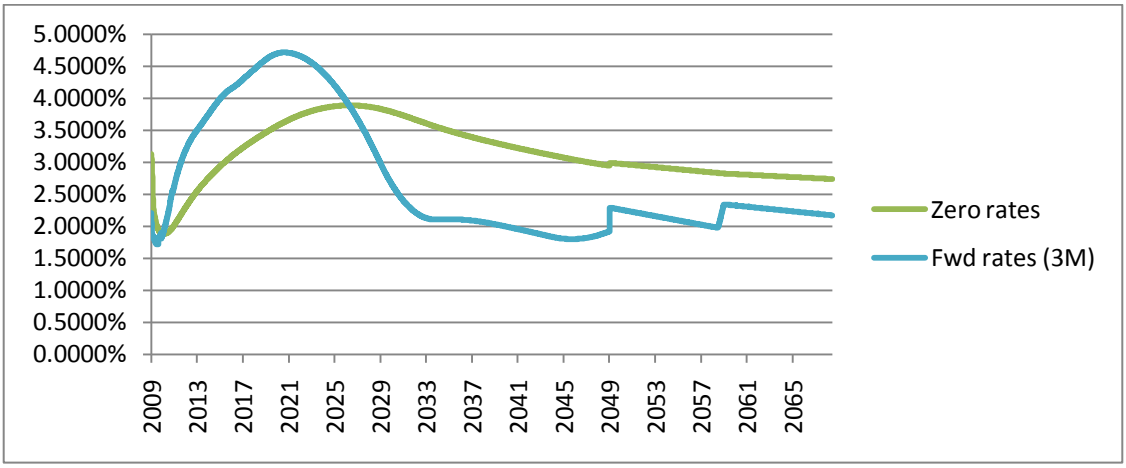


Figure 6: EUR Forwarding Curve 6M (Data from Dr. Marco Bianchetti, 2010)

The forward interest rates are the rates of interest implied by current zero rates for periods of time in the future (Hull, 2003). Forward interest rates as well as the zero rate yield curve are calculated from a given par yield curve. Zero rates can be calculated either by a bootstrapping method; where the rates are determined from a known yield curve for the following points in time or they can be calculated by the forward rates (Das, 2006). The forwarding curves presented here are in accordance with the multiple curve framework presented in earlier section, we use these forwarding for different tenors; here 3M and 6M.

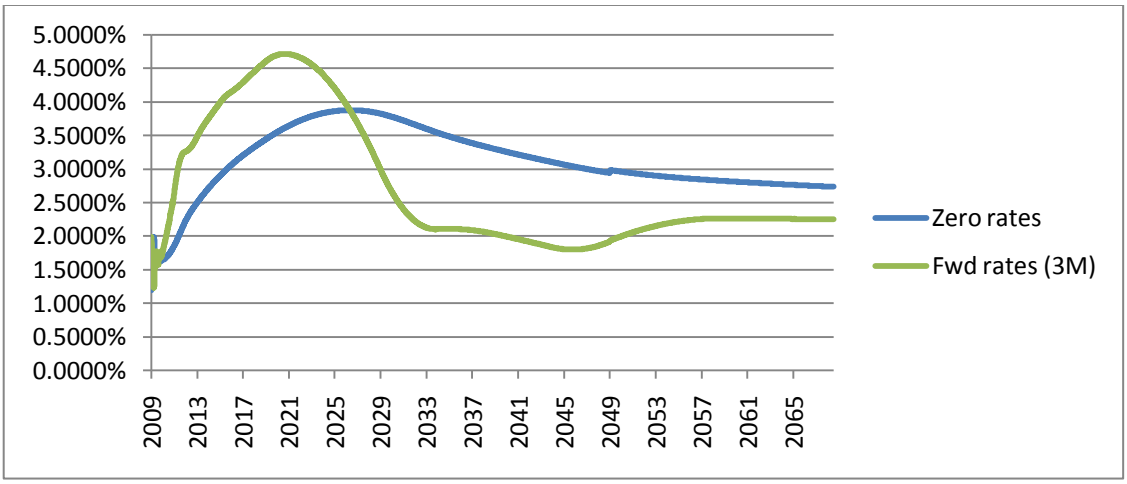


Figure 7: EUR Discounting Curve (Data from Dr. Marco Bianchetti, 2010)

Figure 7 gives us the zero rates and the forwarding rates and we will use these in the multiple curve framework to discount our cash flows, both the floating payments as

well as the fixed payments. Here we can clearly see the difference between the single curve and the multiple curve framework in that multiple forwarding curves are built a well as a unique and separate discounting curve.

Once the multiple curve framework is used to construct multiple forwarding curves and unique discounting curves, using bootstrapping methods, it will show us the differences between calculating with the single curve framework. It will also help us analyze the degree of liquidity and credit issues involved in interest rate derivative pricing. It is also helpful to show us the differences in profit and loss that we come across when switching between the single and multiple curve frameworks (Bianchetti, 2010).

4.3 OIS; an alternative or replacement for LIBOR

As we have mentioned throughout this paper, that the LIBOR/OIS spread increased because of the credit crisis and the increase in counterparty risk of banks, we will here mention why and how the LIBOR can be replaced or how we can evolve and start using a new index to price derivatives.

The LIBOR has been, for a long time, the benchmark rate used to price numerous financial products. However, with the credit crisis, market practitioners have realized that the LIBOR may not be the right rate to use. This is due to the fact that banks have several other rates to use for funding, such as the Federal Reserve where the cost has been more and more reflected in the OIS. The LIBOR has previously been used to reflect interbank credit, however, now it is more a reflection of transactions in the credit risk market. Mustafa Chowdhury, a U.S interest rate analyst at Deutsche Bank, is confident that these issues will evolve into the use of a new index that is more connected to treasuries (www.risk.net).

5 Conclusion

The following section is directly connected to our purpose and this section will use the analysis in order to answer the purpose of the thesis and our research questions. Lastly, we will present some possible further studies.

The purpose of this thesis has been to compare and analyze the single curve and the multiple curve frameworks used to price interest rate derivatives and to discuss the advantages of the multiple curve framework. We also describe how the overall derivative market has been affected by the 2007 credit crisis.

The conclusion from the comparison of the single curve and multiple curve methods of pricing interest rate derivatives is that the multiple curve pricing has shown to be more suitable for pricing interest rate swaps after the credit crisis. It is not just that it is more suitable during a crisis, it also is the correct way due to discrepancies in the market which at times can seem negligible. The multiple curve method is indeed more demanding to compute, however, it is much more beneficial in terms of reduced risk due to the use of multiple algorithms. Using multiple algorithms will reduce the risk caused by the increased spread of data used and also using multiple forwarding curves and a separate discounting curve leads to more precise and a more correct price.

Before the credit crisis, the single curve framework was appropriate. Although spreads did exist before the credit crisis, they were insignificantly small. However, the insignificancy and the fact that there was only one parameter, it was not a cause of biased results. When the spread increased, it caused increased counterparty credit risk and the single curve pricing method was no longer sufficient. The results became unreliable. It provided "dirty" results as it did not distinct the underlying tenors (maturities), i.e. all of the underlying factors were combined. This made it hard to trace and interpret the causes of changes and fluctuations.

The multiple curve framework has provided a more secure and adequate way of pricing interest rate swaps and other derivates. We obtain more accurate curves that are adapted to the "new" market situation. The use of curves of different interest rate instruments that are set in a likewise manner in the underlying rate provides reduced risks. Especially in times like these when we face a large LIBOR spread, the multiple curve framework provides a more secure and reliable result. In addition, the LIBOR is no longer

risk free, which leads to the OIS being a more accurate and reliable rate to use. However, one fact that Marco Bianchetti pointed out for us was that the LIBOR increase was due to the unwillingness from banks to lend out money and overall there was a supply shortage of funds in the market. After governments paid help packages to banks the OIS/LIBOR spread decreased somewhat, stabilizing the spread. Now that the financial markets are experiencing more stable ground and paying back their help packages, one can think if we again will experience a supply shortage of funds in the market and that the OIS/LIBOR spread will increase drastically again.

Another way in which financial institutes are hedging the risks that have become more apparent is by using CSA agreements when entering into derivative transactions. Handelsbanken Capital Markets expressed that they use CSA agreements to protect them against loosing funds if one party defaults in the agreement and they also mention that they see a wider use of CSA agreements now than before the credit crisis. This is a clear indicator that banks and market players have become more cautious with their financial products and investments as an effect of the credit crisis.

5.1 Further Studies

Due to the time limits and the delimitations and due to the fact this is a bachelor thesis, possible further studies would be to investigate this on a more advanced level. This would be done by the statistical programs we planned to use from the very beginning to acquire primary data to work with. Calculating a hypothetical contract and analyzing the exact difference between single curve and multiple curve framework.

We believe that primary data would not have generated a higher quality of the paper. However, it would have increased the level of in-depth and relevance. Since the post credit crunch pricing is still somewhat under progress it would have been a substantial contribution to the paper to conduct a simple form of proposition of ourselves. The word simple, in this sense, refers to the fact that we would not expect ourselves to come up with an idea of pricing such as the professors in this field have done.

In the same speed that the popularity of derivatives is increasing so does the need for risk management. Companies that enter into different derivative contracts, sometimes

face a great deal of risk which demands higher investigation and knowledge in the risk segment. Therefore, this could be a case of further study, the risk and how to manage it.

Another topic or viewpoint that could be furthered studied is if there is such a thing as a true risk free rate or if all rates come with some risk. It would be interesting to go into depth and find the most risk free rate that exists.

6 Glossary

Forward Contract - The forward contract is an agreement of selling or buying an asset for a future price in a future time. A spot rate is the agreement to sell or buy the asset today. Using forward contracts on forward exchanges is very popular since they can be used for hedging currency risk and are widely used by the large world banks. The price agreed upon when entering a forward contract is the delivery price (Hull, 2003).

Future Contract - These are most often traded on the exchange market. In these contracts the exact delivery day is not always specified. Instead the parties clarify the period in which the delivery will occur. The party that agrees to pay the underlying asset in the future assumes a long position. The selling party then assumes a short position. The long position is the one owing the derivative and this party will gain if the price goes up. On the other hand, the short position is then the opposite. The seller of the asset or derivative will hence gain from a downward slope of the worth of the asset sold (Hull, 2003).

Options - Options come in two different forms, call options and put options. These two types refer to the right to buy or sell the underlying asset at a certain time. What clearly distinguish options from forward and futures is that the option gives the holder right to do something, though it is not an obligation. Furthermore, it is costless to enter a future and forward contract, it is not costless to enter an option contract (Hull, 2003).

LIBOR - The London Interbank offered Rate is the rate at which banks lend funds between eachother. The rate is set by banks that operate in the United Kingdom and which have the best credit ratings (Mankiewicz, 2008). The banks will then send their quotes to the British Bankers Association who sets the LIBOR rate. The LIBOR is a uncollateralized lending rate.

OIS - The over-night index SWAPS (OIS) is a fixed-for-floating interest rate SWAP, where the floating rate of the SWAP is calculated using a overnight reference rate, for example the EONIA rate (in the Euro market) (Morini, 2009).

EONIA - (Euro Overnight Indexed Average) Is an effective overnight rate computed as a weighted average of all overnight lending transactions in the interbank market, within the euro area by all participating panel banks (euribor.org).

Certificate of Deposit (CD) – A certificate issued by a bank that indicates a specified amount of money that has been deposited. A CD has a maturity date and a specified interest rate and can be issued in any denomination with durations up to five years (www.bloomberg.com).

Tenor – The accounted time until a financial instrument reaches maturity (Ron, 2000).

Principal/Notional Amount – Amount at inception/start of an agreement.

Plain Vanilla Swap – A basic financialderivativesinstrument A swap is an arrangement of swapping a fixed interest rate to a floating or vice versa. It is an agreement between two counterparties, most often two companies or another private part, to exchange cash flows for a period of time that is set (Hull, 2003).

Over the Counter – Market where tradings are typically made over the phone and are contracted between two parties. Most often the parties are two companies or two institutes. The parties most often act as a market maker in this matter. They are the one setting both the sell-price and the buy-price. I.e. they set their own contracts. This tradings are not listed on exchange (Hull, 2003).

Forward Rate Agreement – Is an agreement between two counterparties to lend or borrow at a future specified date with an interest rate agreed upon today. The two parties will enter into an FRA to protect them from movements in interest rates (Das, 2006).

Bootstrapping – A procedure for calculating the zero-coupon yield curve from market data. Zero rates are determined from data; a bonds principal amount, the time to maturity, the annual coupon and the bonds price (Hull, 2003).

Derivative - is a financial contract whose value is based on an underlying asset. It could be e.g. future contracts or swaps (Choudhry, Joannas, Landuyt, Pereira & Pienaar, 2010).

Delta sensitivity - (gama) is the measure of shifts in the yield curve (www.bloomberg.com).

Credit Rating – The evaluation of a company´s or individual´s ability to repay obligations or the likelihood of not defaulting (www.bloomberg.com).

Hedge – A way of eliminate the risk, can be done in many ways, e.g. using derivatives (www.his.se).

Maturity – For a bond it is the date on which the principal amount is to be repaid or when it is due (Jordan , Ross, & Westerfield, 2008; p 193).

Yield – The effective interest rate in the market paid on a bond. This is needed to be able to calculate the bonds present value which is needed to make estimation of the current market value (Jordan , Ross, & Westerfield, 2008; p 193).

Eurodollar – A certificate of deposit in U.S dollars ina bank located outside the U.S. Most Eurodollar deposits are located in London, however, they can be located anywhere outside the U.S (www.bloomberg.com).

Collateral – Means security. Supports the security for a finance activity, e.g. a debt. (Jordan , Ross, & Westerfield, 2008; p 206).

Euribor – (Euro Interbank Offered Rate) Is the rate at which euro interbank term deposits are being offered by one bank to another within the EMU zone (www.euribor.org).

Treasuries – Notes or Bonds issued by the U.S Department of Treasury (Jordan , Ross, & Westerfield, 2008; p 209).

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Personal Discussion

Rickard Jonsson, personal discussion, Handelsbanken 2010-05-04

8 Appendix

8.1 Appendix 1: Interest Rate Swap

(Based on Fabozzi, 2005)

Notional Amount: $100,000,000						Swap Rate		6.25706%		
Period	Days in Period	Current 3M Libor	EURODOLLAR CD Futures Price	Futures Rates	Period Forward Rates	Forward Discount Factors	Floating Cash Flow	PV of Floating Cash Flow	Fixed Cash Flow	PV of Fixed Cash Flow
Jan-01	90	5.9								
Apr-01	91		94.1	5.9	1.475	0.985464	1491388.9	1469710.657	1581645.722	1558655.553
Jul-01	92		94	6	1.516667	0.98506	1507777.8	1485251.459	1599026.444	1575136.863
Oct-01	92		93.7	6.3	1.61	0.984155	1533333.3	1509037.824	1599026.444	1573690.035
Jan-01	90		93.6	6.4	1.635556	0.983908	1575000.0	1549654.532	1564265	1539092.284
Apr-01	91		93.5	6.5	1.625	0.98401	1617777.8	1591909.252	1581645.722	1556354.954
Jul-01	92		93.2	6.8	1.718889	0.983102	1661111.1	1633040.95	1599026.444	1572005.416
Oct-01	92		93	7	1.788889	0.982613	1737777.8	1707563.4	1599026.444	1571224.507
								10946168.07		10946159.61

8.2 Appendix 2: Personal Communication Rickard Jonsson, Handelsbanken

Well pricing has changed in such a way that most are now using multiple curves for pricing interest rate swaps, interest rate options, FRAs, etc., depending on whether the floating leg is the 1M, 3M, 6M et c.

Before the financial crisis the difference was for example; the difference between an interest rate swap where the floating leg went against 3M EURIBOR and an identical swap that went against 6M EURIBOR was very small so it was usual to have only one curve per currency. The financial crisis made it necessary to use several different curves in the same currency.

Now the standard is that the implied forward interest rates on the floating leg is calculated from different curves, depending on how often they fix and then discount all cash flows with another curve.

In addition, it has become more important how to build a curve, i.e. which instruments to be included in the different curves. What you want is a curve of course praise back all the instruments included in the curve, but which also gives (relatively) smooth forward interest rates. Depending on the exchange rate, different instruments can be included in the curve building.

Another thing to consider is that even if you have the same input-interest in two different systems, you could get two different answers to what the fixed rate swaps should be on a broken date. It depends on how the various systems interpolates forward interest rates.

This is an area that has no standard, and the banks would probably not say how they actually do but what I have mentioned above can be taken as a general basis of what has changed since the financial crisis.

Part two

I do not find it true to state that banks faced a lack of liquid assets in beginning of the crisis. Some banks suffered liquidity shortage. Though, the majority of the banks had

cash they did not want to lend since they did not know if the party would be existing the day after. So the crux of the counterparty risk was more than a general lack of money.

One exchange the same as before but there is a decreased counterparty risk due to almost everyone having CSA agreements. (Credit Support Annex). This leads to that one looks at the net positions of the banks.

As a short explanation we take an example. Suppose Bank A having a lot of derivative transactions with Bank B and the net positions in terms of market value means Bank B have a dept to Bank A. Bank B then needs to send money, or citypaper to Bank A in accordance to the dept. This is accounted for on a daily basis (usually) and yields a counterparty risk decrease.

In case Bank B will go bankruptcy the next day Bank A keeps the security they received and then faces only the risk at one market day. But, all transactions Bank A has entered with Bank B will probably be worthless and Bank A will have to replace these with alike transactions. This can cause a loss for Bank A, though it will be less worthy than if there had been a CSA agreement.

CSA contracts may look a little different depending on which is the counterparties. There is a so-called threshold of the agreements. This means if the debt is below the threshold it will be no money / bonds transactions between the parties. Depending on how creditworthy counterparty is the threshold can be of varying significance. As you understand it becomes a matter for negotiation with each counterparty.

This has led to a discussion if you will price the derivatives differently depending on whether you have CSA agreement with the other party or not. It is precisely the issues addressed in the article, The Price is Wrong, which was in Risk Magazine.

CSA agreements are nothing new but it has become more focused on it since the financial crisis began.