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INTEREST RATE MANAGEMENT

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Declaration:

Herewith I declare that I have written the Master's Thesis on my own and I have cited all sources.

Prague, 31th of May 2016 ……..

Student's Signature

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Abstrakt:

Cílem této diplomové práce je prozkoumat úrokové riziko plynoucí z pohybů úrokových sazeb. Teoretická část je zaměřena na poskytování rozsáhlého přehledu o obecných rysů úrokových sazeb, úrokového rizika a jeho měřicí a zajišťovací systémy. Praktická část je zaměřena na zachycení přírůstků čistého úrokového výnosu banky pomocí modelu GAP. Konečné výsledky jsou shrnuty v závěru této diplomové práce.

Klíčová slova: úrokové riziko, regulace, výnosová křivka, deriváty, gap analyza

Abstract:

The aim of this thesis is to examine the interest rate risk arising from interest rate movements. The theoretical part is oriented on delivering an ample overview of the interest rate general features, interest rate risk and its measurement and hedging systems. The second part is focused on analysing the bank's interest rate exposure from the short term perspective. It is aiming at capturing the bank's net interest income increments using the maturity gap methodology. The final results are summarized in the conclusion.

Keywords: interest rate risk, regulation, yield curve, derivatives, gap analysis.

INTRODUCTION

The current economic environment and especially the low interest rates, kept by Fed at their minimum for almost seven years, represent significant revenue challenges. Furthermore, over the past few years, as a reaction to the financial crisis, the banking industry faced a series of new modifications triggered by multiple changes in regulation and regulatory policy. Many policymakers showed concern in relation to the low interest rate environment. Governor Jeremy C. Stein during his speech in 2013 mentioned that: *"A prolonged period of low interest rates, of the sort we are experiencing today, can create incentives for agents to take on greater duration risk"*[1].

The nature of the banking business exposes banks to interest rate risk. The banks borrow at the short end of the yield curve mainly through different types of transactional and savings deposits and lend at the long end of the yield curve. As history has already shown, the borrowing and lending interest rates can move at different magnitudes, which mainly affects the banks' net interest income. If these changes are not properly managed it can trigger greater interest rate risk, resulting into loss.

Once the effects of the financial crisis started to diminish, the banks' interest rate risk started to grow. In 2014, the banking industry's interest rate risk in USA almost reached its level before the financial crisis[2]. This feature captured the attention of the regulatory authorities, which are focused on preventing losses in case interest rates register path changes. In December 2015, the rates actually registered higher levels and their further growth is expected which makes the interest rate risk to be under even closer supervision and monitoring.

This thesis intends to describe the effects that interest rate movements have on the institutions' performance, mainly on their net interest income. The first chapter depicts the interest rate risk general characteristics. It starts with a briefly introduction of the interest rates and continues with their placement and movements within the economy. Their movements are explained through yield curve's shifts. Furthermore, this chapter

[1] *JEREMY C. STEIN. Overheating in Credit Markets: Origins, Measurement, and Policy Responses [online]. In: . [cit. 2016-05-23]. Dostupné z: http://www.federalreserve.gov/newsevents/speech/stein20130207a.htm*

[2] *Bednar, W., & Elamin, M. (2014). Interest rate risk and rising maturities. Federal Reserve Bank of Cleveland.Economic Commentary, (2014-22), 1-4. Retrieved from http://search.proquest.com/docview/1616472411?accountid=17203*

covers the aspects under which the interest rate risk is arising and increasing. This risk needs to be highly monitored. The actual regulatory requirements are completing this chapter's overview of the interest rate risk characteristics.

The second chapter is focused on measuring the potential interest rate risk the financial institutions and especially the banks are exposed to, by describing several measurement systems. Every system is carrying with it advantages and disadvantages which are briefly explained. The first part is focused on ALM which contains the commonly used gap methodology. The second part covers the VaR methodology, which is able to capture interest rate risk at more complex levels. This risk is properly managed by using various hedging strategies and instruments, which are covered in the third chapter.

The last chapter is an application of the maturity gap model by using real data. For its purpose *Morgan Stanley Bank, National Association* was chosen. It is analysing the bank's net interest income and its exposure to interest rate risk in short run. It breaks down the assets and liabilities into several time buckets based on their remaining maturity or re-pricing dates. Moreover, it examines the bank's interest rate risk exposure within time bands during five quarters and potential future development of the bank's NII within 0-3M time band. The results are summarized in the thesis' conclusion.

1 INTEREST RATE RISK CHARACTERISTICS

The currently challenging environment of relatively low interest rates makes funding of long-term and intermediate-term assets with short-term liabilities significantly risky. This specific business strategy is applicable mainly for the banking industry. It can be the source of major revenues but at the same time, if risks are not managed properly or ignored, it can be the source of massive losses that are directly affecting the bank's revenue and overall capital.

Relatively low interest rates transform the process of generating positive earnings into a very challenging goal. That is why many institutions, especially banks, enlarged the amount of securities with embedded options and increased the maturities on the asset side. Nevertheless, this tactic of generating revenues has increased the interest rate risk exposure of the banks. Simultaneously, risk management programs and strategies have been improved, especially after the financial crisis.

Regulators are requiring from banks a well-developed managing process of interest rate risk as part of the overall risk management process that furthermore corresponds to their capital buffer, revenues, risk profile and complexity of their activities. Running of proper IRR measuring systems, internal controls and stress testing are crucial aspects of healthy business development, especially for those institutions which are characterized by low credit rating.

1.1 INTEREST RATE

Before characterizing the interest rate risk and the relatively complicated hedging methods, this thesis firstly provides an introduction of the interest rates basic concept. For the purpose of a better overview it is inevitable to distinguish their multiple types. For example, government rates are quoted based on government bonds. On the other hand, the interbank rates are quoted and used for transactions between banks such as deposits, swaps etc.

Today we are offered multiple interest rates on financial markets. Every currency has its own interest rates quoted. These quotations include deposits rates, borrowing rates, mortgage rates, student loans, etc. Different types of transactions and financial products have their specific rates that are directly proportional with the bared credit risk. Credit risk is basically the risk that the borrower will suffer a default, and interest together

with principal will not be paid back to the lender as initial contract stipulates. The higher credit risk the higher is the interest rate that is required by the lender. Nevertheless, the level of the spreads between benchmarks and final offered product interest rates depend on more factors such as time to maturity, current economic environment, expected inflation rate, and so on. The main benchmark rates are:

- LIBOR (London Interbank Offered Rate)
- LIBID
- Fed funds rate
- US prime rate
- Government bond rates (US Treasury bonds, UK gilts, German Bunds, French government bonds, Japanese government bonds)

LIBOR is theoretically the rate at which a bank is willing to lend money to other banks, on the interbank money market. It is basically an average interest rate at which panel banks are lending each other funds without any collateral. These are unsecured funds. LIBOR is settled at a relatively low level and is bearing little interest rate risk. There are several types of LIBOR. This benchmark is quoted for five currencies: U.S. dollar, euro, British pound sterling, Japanese yen, and Swiss franc. Moreover, LIBOR is quoted for 7 different maturities. The new quotation is announced every working day at around 11:45 a.m. by ICE Benchmark Administration (IBA)[3]. Each working day the so called panel banks decide and submit the specific interest rate for different maturities at which they can raise a substantial loan on the interbank money market to the Thomson Reuters data collection service just prior to 11:00 a.m. (UK time). The measurement cannot be based on actual transactions. The core reason is that not every bank borrows funds every day for every quoted maturity. Once the estimated rates are collected from all the panel banks, the lowest and the highest quarters of value are eliminated. From the remaining 50 % or the 'mid values' the official LIBOR rate is calculated and submitted.

LIBOR is perceived as being the most significant and mostly used benchmark for interest rates of short maturities upon all benchmarks. It is the core for establishing

[3] *Initial LIBOR was under the administration of the British Bankers Association (BBA). After the LIBOR manipulation scandal it was shifted under the supervision of a new entity, the ICE Benchmark Administration. IBA is activating as an independent subsidiary of Intercontinental Exchange (ICE)*

interest rates for numerous financial products. It is also used as a base rate for financial derivatives such as: options, swaps and futures. On commercial banking level, it is used in the process of setting the interest rates on consumer and corporate loans. In this way, hundreds of trillions of dollars in securities and loans are linked to LIBOR. According to IBA[4], LIBOR is also used to *"provide private-sector economists and central bankers with insights into market expectations of economic performance and interest rate developments"*. Because it is a base rate for a series of financial products, LIBOR is highly monitored worldwide. The entire process of establishing its level and published rates can be easily found on different financial providers' internet pages, for example *global-rates.com*[5] that has been used for the purpose of this chapter.

Although the entire calculation process and responsible institutions for LIBOR quotations are well-known, it didn't stop recently a massive scandal on LIBOR manipulation. There are two main reasons that lead to its manipulation. The first one is to make the interbank loan costs seem lower than they really are. In this way the banks' borrowings would appear healthier even if they are not. The second reason is to raise profits from transactions such as interest rate swaps. The interest rate swaps' float leg is usually set based on LIBOR.

In 2012, an international investigation into LIBOR revealed a widespread plot of its manipulation. Major institutions such as Deutsche Bank, Barclays, UBS, Rabobank, and the Royal Bank of Scotland were involved. In 2015 the investigation continued by exposing all these major financial institutions to civil lawsuits which lead to their shaking trust worldwide. These banks reportedly manipulated LIBOR in order for their traders to make profits on derivative market. For example, Barclays manipulated LIBOR at significant levels before the financial crisis started. The New York Times[6] reported that "*swaps traders often asked the Barclays employees who submitted the rates to provide figures that would benefit the traders, instead of submitting the rates the bank would actually pay to borrow money"* . As a result it is assumed that for a long

[4] *Understanding the Libor Scandal [online]. In: . [cit. 2016-05-18]. Dostupné z: http://www.cfr.org/united-kingdom/understanding-libor-scandal/p28729*
[5] *LIBOR, information about the London Inter-Bank Offered Rate [online]. In: . [cit. 2016-05-18]. Dostupné z: http://www.global-rates.com/interest-rates/libor/libor-information.aspx*
[6] *Understanding the Libor Scandal [online]. In: . [cit. 2016-05-18]. Dostupné z: http://www.cfr.org/united-kingdom/understanding-libor-scandal/p28729*

period this rate was fluctuating up and downward almost entirely based on the traders' position, so they would make profits.

LIBID is the deposit rate within interbank money market. It is the opposite of LIBOR. This is the rate that banks are willing to pay for Eurocurrency deposits.

Fed funds rate is a short-term rate at which US government provides commercial banks with needed funds. A change of this rate will generate a change in all the US short-term interest rates. Same as worldwide, in United States all financial institutions are obligated to keep certain reserves with Federal Reserve Bank. Based on their outstanding assets and liabilities, banks are daily adjusting these reserves. At the end of the day, some of financial institutions are facing surplus of funds while others insufficiency. In order to meet the requirement of keeping a certain amount of reserves with FED, banks are borrowing overnight at an overnight rate. This overnight rate is called Fed funds rate. The funds' demand and supply are usually matched by a broker. This broker will calculate a weighted average out of all rates and will fix an effective federal funds rate. This overnight rate is being supervised by central bank, which is entitled to influence it by its own transactions. In the Eurozone this overnight weighted rate is defined as EONIA and in UK as SONIA. Same as LIBOR, fed funds rate is used for unsecured transactions. But in general, the LIBOR rate is settled at about 6 basis points higher than fed funds rate.

US prime rate is the benchmark against which the corporate and consumer deposit and lending rates are set. This is an index or foundation rate for pricing different types of short-term and medium-term lending products. It is used by numerous lending institutions in US. The prime rate is consistent, which gives the clients the possibility to compare similar debt products offered by competing financial institutions. Every bank is freely entitled to fix its own prime rate. However, it is based on the fed funds target rate. It is almost a certainty that the prime rate will change if the fed funds rate changes. Since the second quarter of 1994, a rule of thumb for the U.S. Prime Rate has been settled as[7]:

$$US\ prime\ rate = the\ fed\ funds\ target\ rate + 3$$

7Prime Interest Rate [online]. In: . [cit. 2016-05-18]. Dostupné z: http://www.fedprimerate.com/

Treasury rates are the rates that are deducted from Treasure bills and Treasure bonds. For the governments, this is the easiest way to borrow in its own currency. Therefore, the US treasury rates are the rates at which the US government is borrowing in USD, Japanese Treasury rates serves for same reason for Japanese government, and so on. Generally, it is assumed that the treasury rates are risk-free, as they denote the yield of government debt. There is a very small chance that a government will default in its own currency. Nevertheless, history is showing a relatively high rate of sovereign defaults. Between major sovereign defaults of recent decades are listed countries such as: Russia (1998), Argentina (2001), Greece (2012), Jamaica (2013). By investing in a government bond, the investor has the certainty, although not of 100 %, that he will receive the coupons and the notional as initially agreed.

T- bills are government bonds of short duration. Usually they are issued for a three month period. For instance, if a T-bill is issued on 10th of February it will mature on 10th of May. However, there are also bills of one-month and six-month maturity on certain markets. At maturity time, the investor will present the bond to the Central bank and will receive the notional value. In UK these bills are denominated in GBP and EUR, in US in US dollars, in Japan in Japanese yen. These currencies are considered to be the most liquid worldwide.

The benchmark rates' volatility leads to the volatility of the other rates in the economy. Hence, it is sufficient to analyse the benchmark rates, in order to acquire a complete market overview. An increasing volatility suggests an increasing interest rate risk, which will lead to rising funds and hedging costs.

1.2 YIELD CURVE

Another essential step toward understanding the aspect and role of the interest rates within financial market is to understand the yield curve structure. Every financial product is set up based on a predefined specific interest rate and it doesn't matter if it is a loan, a deposit or a financial derivative. Moreover, interest rates have a key-role in their evaluation process. Each instrument has its own maturity and this is the reason why interest rates differ from one instrument to another. Yield curve's characteristics should be understood by all market participants, especially by participants on the debt side. As it was earlier mentioned, the interest rate represents the cost that a borrower

should pay, covering the time value of money and the credit risk. These aspects are incorporated and influence the structure of the yield curve in a significant way.

The yield curve presumes the term structure of interest rates, the curve that plots the interest rates for instruments of same credit risk but different maturity. It can be an increasing, decreasing or constant function of time. For the bond issuers and borrowers understanding the yield curve construction is a major factor which will help them dealing with future outstanding liabilities. For the banks, it has a pivotal role in setting the right strategies for its asset-liability management, since every interest rate fluctuation directly affects the bank's revenue and overall capital. It provides the users with the needed information on the state of current expectations of future interest rates level, which directly impact yield curve structure.

The fundamental yield curve within every economy is the government bond yield curve. For the purpose of non-government markets, the yield curves are basically plotted for all types of debt instruments.

The yield curve provides users with information about present expectations regarding future market development. It serves as a good indicator of how may the future market transactions and instruments' value evolve. The bigger upside which marks it as a good indicator it's its easy calculation that can be empirically proved. According to CHOUDHRY[8], the core yield curve functions are:

- *Setting the yield for all debt market instruments;*

The yield curve denotes the cost of money at different future points in time. The basic yield curve is the one deducted from the government bonds. It has the role of a benchmark on the market, from which derive all the other yields for all types of debt instruments. For instance, if a 10-Y government bond is issued at a yield of 2 % then all the other non-government 10-Y bonds will be issued at a higher yield. This difference is known as spread and intends to cover mainly the counterparty risks.

- *Acting as an indicator of future yields levels;*

8 CHOUDHRY, Moorad. An introduction to banking: liquidity risk and asset-liability management. Chichester: John Wiley, 2011. ISBN 0470687258.

As it was mentioned earlier, the yield curve is an increasing, decreasing or constant function of time. Hence it can take various shapes and is mostly reflecting the future expectations of the market participants. The yield curve shape has a key-role in the decision-making process for traders, fund managers and corporates analysts. It's a key element while launching financial projects. Hence it provides information regarding the expected inflation and forward rates, Central Banks are also using yield curves while setting interest rates.

- *Measuring and comparing returns across maturity spectrum;*

This function gives the possibility of comparing the profitability of the investment across different maturities. The yield curve denotes the relative value of the invested amount at each observed point in time. This is a decisive factor while deciding the investing period, would it be profitable to remain on the same position for a longer period or should it be terminated earlier.

- *Indicating the relative value between different bonds of similar maturity;*

This is a method of calculating the spread between the yields of two bonds of the same maturity. The first one is the bond in question and the second bond is the one used for plotting the yield curve. It is a simple technique of finding the overvalued and undervalued bonds and making a profit out of it.

- *Pricing interest rate derivative instruments;*

The risk-free zero coupon bond yield curve has a decisive role in the process of valuation and pricing of derivatives. Normally, the derivatives are valued by building up a portfolio with the return equal to a risk free interest rate. Sometimes LIBOR is serving as a riskless rate, which is not entirely correct based on the recent manipulations. The LIBOR is set by panel banks which generally have an AA-rating, but this doesn't necessarily make it a risk-free reference rate.

There are several theories that intend to explain the different shapes of the yield curve. Sometimes the curve shape can be explained by using a mixture of hypothesis. Choudhry (2011) distinguishes these three theories[9]:

- *the expectation hypothesis;*
- *liquidity preference theory;*
- *segmentation hypothesis;*

According to the ***expectation hypothesis*** the future development of interest rates depend on the investor's expectations. There are two competing versions of it: *the unbiased* and *the local expectation hypothesis*. The unbiased hypothesis suggests that as unbiased estimators for future spot rates can serve the current implied forward rates. This theory states that if the yield curve is increasing then the bondholders and other market participants are expecting interest rates to grow. By contrast, a decreasing curve indicates that a lowering of rates is expected. Moreover, it states that the long-term interest rates can be calculated as geometric averages of expected future short-term rates.

Alternatively, the local expectation hypothesis suggests that the holding period of return will be the same for bonds of different maturity within a specific category. For instance, a 1-Y and a 10-Y bond will have the same rate of return for a predefined holding period. Therefore, all the bonds regardless of their maturity will generate the same rate of return for the same period of time. The local expectation hypothesis does not take into consideration the multiple shapes of the yield curve. Moreover, it doesn't contain any arguments on how the curve looks like. Another drawback is that it is neglecting all the risks connected to the process of lending money. According to it the lenders don't ask for higher interest rates as the time to maturity and the counterparty risk increase.

The *liquidity preference theory* is explained through bonds' maturity. In praxis same as in theory, with an increasing investment period the risks increase as well. A lender will require a higher rate of return for long-term lending. The higher yield will cover mainly the counterparty risk. Hence, the long-term yields should be higher than the yields at the short end of the yield curve. These features explain the increasing shape of the yield curve. The liquidity preference theory and increasing yield curve can be explained

[9] *CHOUDHRY, Moorad. An introduction to banking: liquidity risk and asset-liability management. Chichester: John Wiley, 2011. ISBN 0470687258.*

through inflation expectations as well. The yield curve is positive-slopped due to increasing inflation expectations.

The yield curve structure may also be explained with *the segmentation hypothesis*. Capital markets have numerous participants including individual investors, institutional investors such as pension funds and mutual funds, municipalities and governments, companies and organizations, banks and financial institutions. These groups of participants divide the yield curve into different segments. Every segment has its own volume of transactions, its instruments and its costs. All these aspects are fixed accordingly, by matching demand and supply of funds within the observed segment. The segments may be sometimes interconnected, but usually are perceived as complete separate markets. Some investors may be active on the short end of the yield curve only while others at the long end of the yield curve. These dissimilarities are explaining the frequent humps in the yield curve.

1.3 INTEREST RATE RISK SOURCES AND CONSEQUENCES

Interest rate risk is just an element of the market risk and a complex risk management process. While analysing institution's performance, equal attention should be paid to all risk types. In real world risks are interconnected. Coyle (2001)[10] divides risk into two main categories: business and financial. These two are further divided into subcategories. Business risk is arising from the declining success of the daily performed operations. It may be the result of a launched competitive product or the rising number of competitors on the market. In order to overcome it, an effective and efficient development and market research should be implemented, which will result into producing more attractive products. Alternatively, financial institutions are facing financial risk, which according to Coyle (2001) has been subdivided into:

- *credit risk;*
- *currency risk;*
- *country risk;*
- *interest rate risk.*

[10] *BRIAN COYLE.,. Introduction to interest-rate risk. Canterbury: Financial World, 2001. ISBN 0852974396.*

All these categories are interconnected and have a great influence on institution's profitability. An accurate and complex analysis will take into account every category equally. The below table is providing a brief description of every type of risk mentioned above.

Table 1 Financial risks' characteristics

Type of financial risk	Characteristics
Credit	Result of late payments, default of counterparties, failure on the side of contractual obligations;
Currency	Unstable income and financial costs coming out from the deposits and loan in different currencies due to appreciation and depreciation
Country	Unstable financial conditions within a particular country, due to adverse movements of a series of economic factors such as: inflation, interest rates, currency value etc.
Interest rate	Unexpected changes of income and costs due to unexpected yield curve movements.

Source: BRIAN COYLE., Introduction to interest-rate risk

For the purposes of this thesis, only interest rate risk will be analysed. It is mainly a result of interest rate movements. This is a significant type of risk, which can generate massive loses or can serve as an important source of revenue and shareholder value. Because it can be the source of huge losses, it is considered as a substantial threat to bank's profitability and capital base.

Interest rates movements affect the revenue by changing the net interest income (NII). Hence interest rate movements influence the assets, liabilities and off-balance sheet instruments. Their fluctuations lead to changes in present value of future cash flows. And this is the main reason why banks need experienced risk management that will maintain the IRR within a range, that can be manageable and would limit loses at an acceptable level.

The asset/liability sensitivity toward interest rate movements can be defined from two perspectives. As already mentioned interest rate risk can affect both: revenue and market value of equity. These two changes can be analysed based on: spread risk and

price risk. This is one type of decomposition of the interest rate risk. The spread risk presumes that the banks, in case rates change, will reinvest their cash flows or roll-over their liabilities at a different rate, which will primarily affect their revenue.

The price risk, on the other hand, presumes that if interest rates change, the bank's assets and liabilities market values will change as well, affecting its market value of equity. The longer is the instrument's duration, the larger is the change in its market value, given a specific change in rates. These two aspects of interest rate sensitivity will be further discussed in the ALM section, while describing the maturity and duration gap models.

COYLE(2001) claims that economic growth influences interest rate levels significantly. But this is not the only factor. They are furthermore influenced by government interventions and the so called 'market forces', mainly the demand and supply for funds in the economy.

Another factor which facilitates rate fluctuations is the capital mobility across countries. Due to the financial market integration and globalization, financial transactions can switch easily from one currency to another in a fairly short time period, causing large discrepancies between interest rates of these countries.

Regardless the fact that interest rate risk is generated by the same factors, each institution is exposed to it at a different magnitude. An institution's risk exposure position depends on either it takes a lender or a borrower position. The next table offers a brief overview of the risk and potential benefit that may experience a company based on the position it takes.

Table 2 Risks and potential benefits

Borrow at	Risk	Potential benefit
Fixed rate	Interest rates will fall	Interest rates will rise
Float rate	Interest rates will rise	Interest rates will fall
Lend at		
Fixed rate	Interest rates will rise	Interest rates will fall
Float rate	Interest rates will fall	Interest rates will rise

Source: own creation

For example, borrowing at a fixed rate is more profitable than borrowing at a variable rate in an increasing rate environment and opposite. The risk varies consistent with the expectations. If rates are considered to be at a peak level and their lowering is expected, then float-rate borrowing will be less risky. By contrast, if rates are believed to be at a bottom point and their rising is expected then the companies will try to borrow long-term, huge amounts at a fixed-rate.

Interest rate risk is one of the most often discussed and monitored. In order to enable its managing and mitigation process, a special attention should be paid to its sources. These are: re-pricing risk, basis risk, yield curve risk and embedded option risk.

- **Re-pricing risk**

Banks are part of almost all financial transactions, and are usually referred to as financial intermediaries. Their re-pricing risk arises from interest rate mismatches. For fixed-rate instruments is generated by the maturity differences and for float-rate instruments from different re-pricing instrument schedules. Due to interest rates fluctuations, banks are facing income and underlying economic value problems. For instance, if a bank is funding a long term fixed-rate loan with a short-term deposit, in case of rising interest rate environment it will face losses from the position and from the underlying value. While the loan was settled for a long time period at a fixed rate, the deposit should be re-priced on a regular basis and every time at a higher rate.

For a better understanding, this type of risk can be explained through a simple example, showed on the picture below.

Figure 1 Re-pricing Risk

Source: FDICchannel;
https://www.youtube.com/watch?v=kdzShoX8KUE ;

For simplicity, let's assume that a bank has one asset and one liability on its balance sheet. The asset is a 15 year Mortgage priced on a 10 year treasury rate and funded by a one year CD priced on a one year treasury rate. The mortgage is set up at 4 % and the CD is bearing a 1 % interest rate. In period 1, the bank is earning a 3% spread. But, short term rates are usually more volatile. If we assume that the CD rates in period 2 will increase to 3 %, then the hypothetical bank will face a decrease in net interest income. While the yield of the mortgage stays the same, at a 4% level, the liability has re-priced and the cost has increased from 1 % to 3%, resulting in a decline of the NII.

- **Yield curve risk**

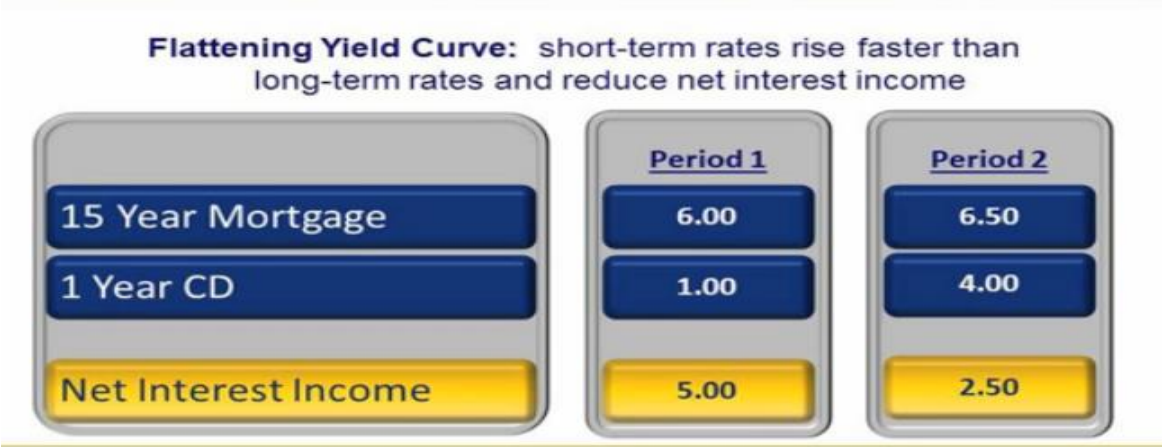
This is the risk caused by yield curve movements from time to time. Yield curve does not have always a parallel movement. As was mentioned earlier, when the yield curve and its theories were described, the yield curve can take generally three shapes. In case short-term interest rates are lower than the long-term rate, the curve is assumed to be normal and positive. By contrast, when short-term interest rates are higher than the long term rates, the curve is negative or it is referred to as inverted curve. And the last shape, when there is no big difference between short and long interest rates, the curve is flat. In case of a positive yield curve, which is considered to be the normal shape on financial market, the investors are demanding a higher return for lending money for long periods

of time, as they are willing to take additional risks. This can serve also as a fact that investors are expecting a strong economic growth and an increase in inflation.

Yield curve risk is associated with the risk of experiencing and adverse shift in market interest rates, which will generate income and underlying economic value losses.

Again, the yield curve risk can be interpreted through an easy example, illustrated on the picture below.

Figure 2 Yield Curve Risk



Source: FDICchannel; https://www.youtube.com/watch?v=kdzShoX8KUE ;

The hypothetical bank has two instruments, one asset and one liability. On the asset side it has a 15 year mortgage priced after a 10 year treasury that is funded with a one-year CD liability that is priced after a one year treasury instrument. In the first period, the bank generates a NII of 5% that is going to significantly decrease if the yield curve flattens. So, if it is assumed that the yield curve flattens in period 2, then both interest rates are going to change. For instance, if the 15-year mortgage will earn 6.5 % and the 1-year CD will be re-priced at 4 %, the NII will decline. For this specific example, it will decline from 5% to 2.5%.

- **Basis risk**

Basis risk arises when interest rates of different assets and liabilities change at a different magnitude. If interest rates of different types change, then this difference is

causing unexpected fluctuations in cash flows and earning spreads between on and off-balance sheet instruments with analogous maturities or re-pricing frequencies.

For a better explanation an easy example from the picture below may help.

Figure 3 Basis Risk

Source: FDICchannel; https://www.youtube.com/watch?v=kdzShoX8KUE ;

In this example, let's assume that the bank has a 5 year loan priced on a 3 month treasury rate. This loan is further funded with a liability priced on a 3 month LIBOR borrowing rate. At the beginning it appears that this bank is well matched because both indexes are based on identical re-pricing frequencies, which is a 3 month period. But in this case, these two types of rates may change disproportionally. If LIBOR increase by 2% but the 3month treasury only increased by 1%, then the NII will decline from 2.25 % to 1.25 %. This decrease will occur despite the matched re-pricing frequency.

- **Embedded option risk**

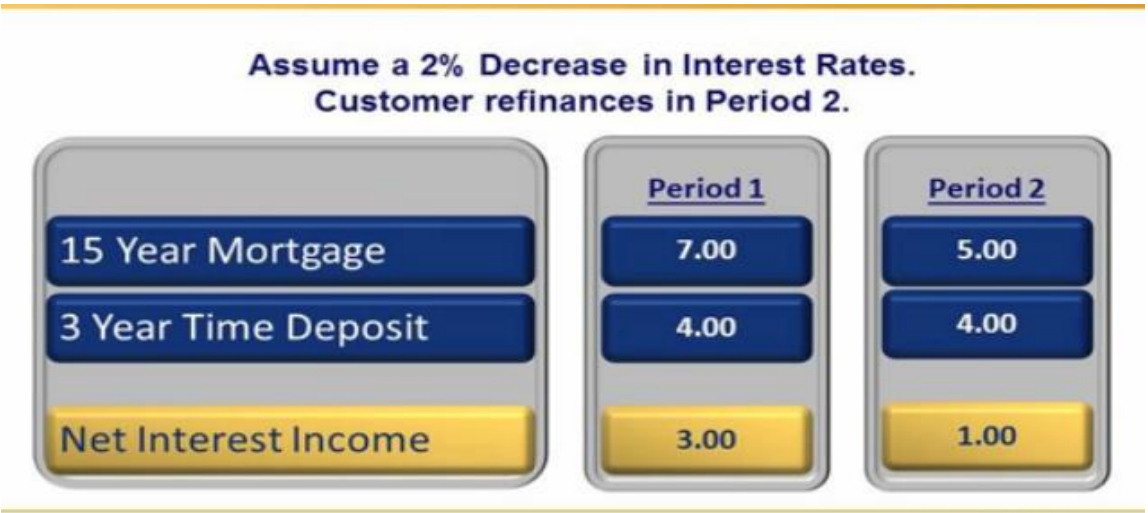
The last, but not least important risk is embedded option risk. It is arising out of premature withdrawal of deposits or prepayment of loans and bonds before their stated maturity dates. All these instruments contain put or call options.

Basically, an option gives the holder the right, not the obligation to sell or buy a financial instrument, foreign currency etc. Options can be traded as a standalone

instrument or can have an underlying financial instrument. They can be exchange-traded and OTC traded. Usually banks use both types of options in trading and non-trading activities, although embedded options are more common for non-trading instruments. Embedded options are usually incorporated into different kinds of bonds, loans, deposits. It gives the borrower the right to prepay the loan before maturity date or withdraw the deposits before the stated maturity, without any penalties. If all these positions are insufficiently hedged, they may generate significant losses, as they carry a significant risk, especially for the seller, generated by the fact, that the holder has the advantage to exercise options when is favourable for him and less suitable for the writer.

The next picture is illustrating a simple demonstration of how embedded option risk works.

Figure 4 Embedded Option Risk



Source: FDICchannel; https://www.youtube.com/watch?v=kdzShoX8KUE ;

This example illustrates a prepayment option risk case. The bank is holding a 15-year fixed mortgage earning 7 % that is being funded by a 3-year time deposit that costs 4%. In period one, the bank earns 3%. However, the rates may experience some changes as if market conditions and economic growth are changing. Let's assume that mortgage rates decline in period 2, from 7% to 5 %. Our mortgage client will try to refinance and prepay the mortgage that now costs only 5%. Even if the bank manages to keep this

client it will now earn just 1% of NII, which is much less than the NII from the first period.

Every type of IRR presumes its own measurement system. Banks should be able not only to identify these types of risks but also to measure and monitor them properly. Because every risk is characterized by a different complexity degree, the measurement systems are mainly designed to satisfy this feature and to be able to capture the consequences connected to them.

For example, European Banking Authority (EBA) attributes to every type of risk a measurement method based on its overall complexity. The next picture offers an overview of the methods that are the most convenient for each risk type.

Figure 5 Measurement systems for each type of IRR

Component	Method	Focus
Repricing risk	Gap analysis	The volume of mismatches in different time bands
Yield curve risk	Gap analysis, partial durations	The dispersion and concentration of mismatches in different time bands
Basis risk	Inventory of instrument groups based on different interest rates	Use of derivatives and other hedging instruments in terms of different bases, convexity and timing difference neglected by gap analysis
Option risk	Inventory of all instruments with embedded options	The volume of mortgages, current accounts, savings and deposits where the customer has the option to deviate from the contractual maturity

Source: European Banking Authority
https://www.eba.europa.eu/documents/10180/1084098/EBA-GL-2015-08+GL+on+the+management+of+interest+rate+risk+.pdf ;

European Banking Authority also suggests that banks should use more measurement techniques, but at least one economic value measure and at least one earnings-based measure. Furthermore, banks are required to develop and use more sophisticated models, able to capture all interest rate risk types. Sophisticated models would presume more tenors or time bands, more complex data input and a more detailed feedback about future business development. The measurement models are further discussed in the next chapter - *Interest rate risk measurement approaches.*

1.4 REGULATORY REQUIREMENTS

In 2004, the Basel Committee on Banking Supervision issued the *Principles for management and supervision of interest rate risk*, which was a revised version of the initial form, from September 1997. Within these principles, the Committee basically set up its requirements and expectations for banks, regarding identification, monitoring, measuring and controlling of interest rate risk. Principles 1 to 13 intended to be of general application for IRR management, with no distinguishing being made between IRR rising from trading and non-trading activities. These principles were mainly aimed to establish the process of managing interest rate risk, including asset liability management, internal controls and development of business accordingly to the set up interest rate risk limits. By contrast, principles 14 and 15 are treating only interest rate risk within the banking book.

Although the principles have a general application, used by numerous international banks, every bank has its own specific approaches, based on the complexity and the activities undertaken. The exact application is also chosen in accordance with supervisors, which are monitoring and responding to interest rate risk based on their own techniques and grounded agreements with external auditors.

Furthermore, *The Principles for Management and Supervision of Interest Rate Risk* suggested to all banks to create reserves aimed to cover the losses experienced from interest rate risk. In case of insufficient reserves, the supervisors are supposed to require an increase in capital accordingly to the undertaken risk or to close a part of its positions that cause interest rate risk. A combination of these two requirements is also possible.

These principles are available worldwide in order to facilitate an integrated supervision framework for interest rate risk. The main reason for issuing and implementing it, was the intention to improve IRR assesing process. Moreover, it serves as a healthy contribution to the robustness of the financial market as a whole. As already mentioned, there are 15 principles that are merged into these groups[11]:

[11] *BASEL COMMITTEE ON BANKING SUPERVISION. Principles for the Management and Supervision of Interest Rate Risk [online]. In: . [cit. 2016-05-18]. Dostupné z: http://www.bis.org/publ/bcbs108.pdf*

- *Board and senior management oversight of interest rate risk;*
- *Adequate risk management policies and procedures;*
- *Risk measurement, monitoring and control functions;*
- *Internal controls;*
- *Information for supervisory authorities;*
- *Capital adequacy ;*
- *Disclosure of IRR;*
- *Supervisory treatment of IRR in the banking book;*

An important part of the risk management process is the internal control. The risk management board is responsible for ensuring of establishing a proper internal control system, tested by independent review and validation procedures. Moreover, these principles accord ample attention to risk limits that are usually settled together with mitigation strategies[12].

In June 2015, Basel Committee on Banking Supervision revised the existing principles and new regulatory requirements have been introduced. The Committee intended to cover the weaknesses of existing principals and aimed for their adjustment to current market conditions. Through the consultative document *Interest Rate Risk in the Banking Book from 2015,* it was introduced a new treatment for supervision of IRR in the banking book and regulatory capital adequacy for it. This revision took place predominantly due to two reasons. The first reason was to help the banks into creating proper capital provisions that will serve as insurance for losses, which is of extreme importance in currently low interest rate market environment. The second reason aims for inhibiting capital arbitrage between the books. Furthermore, it is also prohibiting within appropriate limits, the capital arbitrage between similar portfolios within the banking book.

This new proposal is offering two possibilities for managing IRR within banking book. The first possibility is the standardised Pillar 1 that is covering the minimum capital requirements. The second option is the Pillar 2 approach. It is a more enhanced

[12] *Mitigation strategies are usually established and used when interest rate risk level exceeds the acceptable bounder. Furthermore, they are ensuring that action plans are developed and would serve as a right approach for managing the arising risk. Risk limits are subject to regular review and so are the mitigation strategies. They can't remain static over extended periods of time, since the bank's earnings, complexity and risk profile are fluctuating.*

approach which also includes features of *Market Discipline* (Pillar 3). The Pillar 1 framework presumes an integrated approach that is supposed to increase the accuracy and consistency. Its implementation gives as advantage the internationally comparability of capital sufficiency. Nevertheless, there are different legislations around the world which makes the implementation of a common approach quite challenging. Alternatively, Pillar 2 aims to overcome this obstacle. It has the advantage of adjusting the IRR managing approach across various jurisdictions.

Pillar 2 could be an enhanced alternative for Pillar 1 and work as a standalone framework or could further serve as an improvement to it. Its framework contains information and solutions to these matters:

- advanced procedures for calculation of capital adequacy, based on the risks undertaken within baking book and nature of the banking activity;
- direction and the rightful assistance for supervisory responses, with robust presumptions on capital requirements and capital consequences in case of its inadequacy;
- proper disclosure requirements;
- a precise implementation program with an effective quantitative assessment framework.

The BCBS also revised the high-level management principles for IRR within the banking book. Pillar 2 framework incorporates 12 high-level principles that intend to replace the 15 principles set up in 2004. The first 9 are of general application and apply on interest rate risk generated by the non-trading activities. Alternatively, principles 10 to 12 set up the approaches and treatment of diverse issues used by supervisory authorities. These principles are again of general application but their level of application will depend on specifics such as: undertaken risks, the nature and complexity of the bank's activities, the bank's size and economic significance.

2 INTEREST RATE RISK MEASUREMENT APPROACHES

Every bank is using its own IRR measurement models, that are supposed to capture and asses all types of interest rate risk. The norms and assumptions of the used models should be clear and transparent. These models should be capable of providing eloquent measures of the risk the bank is exposed to, in order to design an adequate hedging

strategy. They are chosen and developed in accordance to the complexity and amount of the undertaken activities.

Basically, the risk measurement system should provide details of the impact of the rates change on the bank's earnings and economic value. Based on *Principles for the Management and Supervision of Interest Rate Risk* issued by *Basel Committee on Banking Supervision* a measurement model should[13]:

- Assess all material interest rate risk associated with a bank's assets, liabilities, and off balance sheet positions;
- Contain generally accepted financial concepts and risk measurement techniques;
- Have well-documented assumptions and parameters.

The measurement systems are set up for all sources of IRR: re-pricing, yield curve, basis and embedded option risk. These risk types, typical for the banks' activities, will dominate their cumulative risk profile. Measurement systems are also set up to provide a special treatment to the bank's holdings that considerably affect the cumulative risk position, even if they do not denote a significant concentration. For instance, instruments with embedded options should be handled with special treatment.

Because every business activity it's characterized by its own complexity, different modelling technics are being used, starting from basic calculations to complex, sophisticated simulations that are capable of capturing and reflecting different market scenarios.

This chapter captures general characteristics of the mostly used measurement systems. Since the scope of this thesis is mainly to analyse the bank's interest rate risk from the perspective of the NII, a special attention will be given to the maturity gap analysis as this model suits this type of risk.

2.1 ASSET LIABILITY MANAGEMENT

Mismatches arising from different maturity and duration between asset and liability sides give raise to various market risks. For an accurate business expansion, these risks

[13] *BASEL COMMITTEE ON BANKING SUPERVISION. Principles for the Management and Supervision of Interest Rate Risk [online]. In: . [cit. 2016-05-18]. Dostupné z: http://www.bis.org/publ/bcbs108.pdf*

need to be identified and monitored properly. These frequent reviews are effectively carried out through an asset liability management system (ALM). The authority responsible for reviews of the complex composition of assets and liabilities items is called The Asset Liability Management Committee (ALCO). It is formed by the heads of Treasury and Risk management, CFO and senior management personnel. The number of ALCO members depends on the measure and complexity of the business nature and on the balance sheet structure. In case the disproportion connected to assets and liabilities mismatches expose the bank to massive risks, ALCO is assessing the risk factors and suggests corrective actions. The ALM process firstly initiates an examination of the risk within every time bucket.

The nature of banking activity is exposing banks to multi-dimensional risks. It embraces interest rate risk, credit risk, operational risk and liquidity risk. Since this thesis covers just the interest rate risk, this chapter will also cover just one type of market risk- the interest rate type.

By definition ALM[14] intends to cover the management techniques for interest rate and liquidity risks. It is also observing the changing construction of the balance sheet, which is mainly influenced not just by market factors but also by cost-effectiveness targets and regulatory constraints. The disproportion between assets and liabilities, which exposes banks to severe loss are a major concentrating area of the ALM.

Theoretically, normal market conditions imply an increasing yield curve, where long-term interest rates are much higher than short-term rates. The positive slopping shape of the yield curve gives the banks a profit opportunity if a suitable strategy is used. In this case, banks collect the necessary amount of funds on the short end of the yield curve and lend them on the long end of the yield curve. Banks can raise a nice profit from these spreads. Nevertheless, there is the risk that the short-term rates will increase and the strategy will become less attractive or end-up with a loss. These types of risks are the major area of ALM desk activity.

14 CHOUDHRY, Moorad. Bank asset and liability management: strategy, trading, analysis. Singapore: Wiley, 2007. ISBN 9780470821350.

Risk arises every time a maturity mismatch between assets and liabilities occurs. It is not always a negative factor. It can generate a loss or a profit. A profit is ensured whenever the banks have a positive gap and simultaneously interest rates are going up. Therefore, the net asset worth will increase as well. That's why an active assessment is needed from the ALM desk side. The asset-liability structure of the banking book should always correspond to the market conditions. Nevertheless, these adjustments are very tough to implement.

For a prosper development, ALCO will ensure the preparation and implementation of the interest rate risk policy. ALCO formulates not only the risk policy but also the overall balance sheet management policy. This policy includes the bank's outcomes under different possible market scenarios.

Every business entity has its own internal arrangements and special targets. These aspects are differentiated by the nature of their activity. However, there are some definite procedures, which make the ALM system a common arrangement. A mutual factor is the performing and presentation of particular reports for ALCO. These reports intend to deliver an ample overview of what may happen to balance sheet under various interest rate shifts scenarios. Usually, they consist of[15]:

- A comparison of the actual net interest income (NII) and the one predicted that was presented during previous ALCO meeting. In case of massive discrepancy, the proper analyses are provided. This report is offered in a shape of a gap report, including all the time buckets and individual products.
- The assumptions and conclusions undertaken while forecasting, and the impact the business units heads had on it. An important downward is the assumption, that the book position would be the same for the whole forecasting period. Transactions are made on a daily basis, and as a consequence the book is eventually changing. So, in real world this assumption is unrealistic.
- Certain interest rate scenarios are presented. These are generated under different market circumstance simulations, such as: various yield curve shifts, extreme scenarios.
- Latest revenue results.

[15] *CHOUDHRY, MOORAD. BANK ASSET AND LIABILITY MANAGEMENT: STRATEGY, TRADING, ANALYSIS. SINGAPORE: WILEY, 2007. ISBN 9780470821350.*

- Under certain circumstances, the launching of new products may also be the subject of an ALCO meeting.

The ALM desk has evolved through time. The traditional ALM role, characteristic for the past was the managing of the risks generated by the banking book instruments. Nowadays, to this traditional function new roles have been added. Nevertheless, there are numerous financial institutions that are still prioritizing traditional ALM desk, which contains[16]:

- *Interest rate risk management.* This function corresponds to analysing the bank's interest rate exposure caused by maturity and duration gap, and the yield curves non-parallel shifts. Within this role, ALM will analyse the book's instruments and set the corresponding risk limits. Apart from interest rate risk measurement, ALM is also responsible for the hedging strategies.
- *Liquidity and funding management.* In order to meet regulatory requirements, banks are obligated to keep a certain amount of funds as short-term instruments. These are short-term banking assets, usually also called the liquidity book. Resulting from multiple analyses of the balance sheet construction, interest rates movements and market conditions, the ALM desk, in order to minimize the risk, will adjust the composition of the liquidity book, by either increasing the amount of short-term in assets or decreasing it.

- *Reporting on hedging of risks.* The function of reporting and delivering management information on the interest rate exposure is also attributed to ALM desk. The frequency of delivering is usually one week.
- *Setting up risk limits.* ALM desk is also responsible for setting up the fluctuation range of interest rate risk. These limits need to be monitored closely, or the book's position may record a loss.
- *Capital requirement reporting.* This role presumes a periodic reporting to authorities regarding meeting the capital limits requirements. This includes as well the reporting of capital using.

[16] *GHOSH, Amalendu. Managing risks in commercial and retail banking. Singapore: John Wiley & Sons, 2012. ISBN 9781118103531.*

Due to permanently changing conditions and growing operations' conditions, ALM desk is enhancing new functions and responsibilities. Some of the functions have been merged and integrated into ALM desk agenda. The new roles may include:

- Besides the traditional techniques, used for assessing risk exposure, new tools are prioritized. Recently, VAR technique is becoming popular.
- For a better assessing and clear overview of the total risks, financial institution is exposed, market risk and credit risk are being integrated.
- Enhancing new risk-adjusted tools for measuring profits.
- Optimization of portfolio return
- Diligent monitoring and assessing of balance sheet balance. This role may include asset securitization decisions, hedging not only interest rate risk exposure but credit exposure as well, decision on using credit derivatives for hedging purposes, managing liquidity book, decisions on stock lending and repo operations.

The ALM's duties contain, as already mentioned the responsibility of managing the balance sheet structure, in a suitable way that would minimize the interest rate risk exposure. This target function can be reached through gapping techniques, which are the simplest methods that measure the NII changes as a result of interest rate movements.

2.1.1 MATURITY GAP MODEL

One of the simplest and oldest approaches of measuring IRR exposure is the maturity gap model, which is the distribution of the interest-sensitive assets and liabilities into predefined gaps called also 'time buckets', based on maturity (for fixed-rate) or re-pricing (for floating-rate) schedule. The size of the time bucket is calculated as interest rate sensitive assets minus interest rate sensitive liabilities that mature or re-price within the given gap. This indicator gives the re-pricing risk that the bank is exposed to. The narrower the time buckets are, the more accurate the results are.

This model is a static technique, which is mainly associated with the net interest income targeting. It is able to capture the NII's increments if interest rates change. Although, ceteris paribus, an increase in rates generate an increase in interest income and simultaneously an increase in interest expense.

The interest rate movements have a bigger impact on bank's NII from short run perspective. In the long run, the new instruments on both sides, assets and liabilities, are booked at new rates. Table 3 offers a detailed overview of the dependence of NII's change on the gap size.

Table 3 GAP Summary

GAP	Change in interest rates	Change in interest income		Change in interest expense	Change in NII
Positive	Increase	Increase	>	Increase	Increase
Positive	Decrease	Decrease	>	Decrease	Decrease
Negative	Increase	Increase	<	Increase	Decrease
Negative	Decrease	Decrease	<	Decrease	Increase
Zero	Increase	Increase	=	Increase	None
Zero	Decrease	Decrease	=	Decrease	None

Source: Bank Management, Koch and MacDonald(2009);

Within maturity gap model, and for the purpose of the later bank's analysis, an interest earning asset or an interest bearing liability instrument is treated as interest sensitive within a specific maturity bucket, if it satisfies one of these characteristics:

- Its maturing date falls into this time bucket;
- Has a partial or principal payment within this bucket;
- It is re-priced during this interval.

The first step of the gap technique is to establish the gapping period. Usually it can be a day, week, month, quarter. For more accurate analyses, shorter gaps periods are being used. However, short gaps are considered to be more difficult, timely consuming and expensive for the risk management purposes, since every operating day would be involving hedging decisions.

Nevertheless, the Basel Committee requires in the standardised approach under Pillar 1 a fragmentation into 19 gap maturities, accordingly to Figure 6. Hence, all interest rate sensitive instruments should be slotted according to their maturity or re-pricing date

into their fair bucket. In theory, the maturity can be fragmented into a different number of time buckets.

Figure 6 Time Buckets Intervals

	Time bucket intervals (M: months; Y: years)							
Short-term rates	Overnight	O/N< t^{CF} ≦1M	1M< t^{CF} ≦3M	3M< t^{CF} ≦6 M	6M< t^{CF} ≦9 M	9M< t^{CF} ≦1 Y	1Y< t^{CF} ≦1.5Y	1.5Y< t^{CF} ≦2Y
Medium-term rates	2Y< t^{CF} ≦3Y	3Y< t^{CF} ≦4Y	4Y < t^{CF} ≦ 5Y	5Y< t^{CF} ≦6Y	6Y< t^{CF} ≦7Y			
Long-term rates	7Y< t^{CF} ≦8Y	8Y < t^{CF} ≦ 9Y	9Y < t^{CF} ≦ 10Y	10Y< t^{CF} ≦ 15Y	15Y< t^{CF} ≦ 20Y	t^{CF} > 20Y		

Source: Interest rate risk in the banking book - consultative document; http://www.bis.org/bcbs/publ/d319.pdf;

Fixed rate instruments are slotted into the rightful time bucket according to the maturity date. The entire principal falls into that time bucket. Alternatively, the floating rate instruments' principal falls into the time bucket according to its first re-pricing date. The entire notional is attributed to the first time bucket and the later time buckets are ignored.

For every gap period it is characteristic a calculation of the interest income and interest payment. This is calculated by deducting the interest outflows from the interest inflows. In case the differential between inflows and outflows within the gap is zero, then there is basically no interest rate risk or it is close to zero. .

The maturity gap model presumes 2 types of gaps: periodic and cumulative gaps. Periodic gaps measure the potential income reflecting interest rate changes. Cumulative gaps, on the other hand, measure aggregate interest rate risk. An increasing cumulative gap indicates an increasing sensitivity. If the sensitivity statement is showing that the instruments on the asset side are being re-priced faster than the bank's liabilities, then the bank has an asset-sensitive position, and vice versa. If the statement is showing that the liabilities imply a higher re-pricing frequency, then the bank has a liability-sensitive position.

The interest rate sensitivity gap is defined as difference between the bank's assets and liabilities and is given by:

$$Gap = \Sigma RSAs - \Sigma RSLs$$

where:

$\Sigma RSAs$ - is the sum of interest rate sensitive assets;

$\Sigma RSLs$ - is the sum of interest rate sensitive liabilities.

Furthermore, the maturity gap model contains the calculation of the gap ratio and net interest margin (NIM). These are core elements while delivering final results. The gap ratio is used for a more simplistic interpretation of the individual gaps. It is calculated as: $\Sigma RSAs/\Sigma RSLs$. If this ratio indicates higher values than 1 or 100%, then the risk sensitive assets exceed risk sensitive liabilities and this gap will generate an increase in NII if interest rates go up. And the opposite, this gap will generate a loss if interest rates decrease.

The net interest margin is calculated as:

$$NIM = \frac{(investment\ return - interest\ expense)}{average\ earning\ assets}.$$

The size of net interest income (NII) is direct proportional with the interest rate changes. The net interest income variation is given by:

$$\Delta NII = Gap * \Delta r$$

This formula highlights that net interest income will increase in case interest rates go up and decrease otherwise. Hence the NII escalates in case of a positive gap and drops when the gap reaches negative values. An immune portfolio to interest rate risk is considered a zero gap portfolio. The gap and accordingly the NII are functions of the clients' demand for loan and deposit products, the future changes in interest rates and the bank's operating strategy. Hence, NII is changing based on the proportion of interest-earning assets and interest-bearing liabilities, regardless of the interest rate changes. The NII can be calculated for every maturity bucket or at an aggregate level.

Banks may use this model only in the short run, while assessing their interest rate sensitivity in the maturity buckets up to three months. The model presents both, advantages and disadvantages. The main advantages are:

- relatively simple calculations;
- results are easy to interpret;
- gives relatively good results even for small changes in interest rates.

On the other hand, the model represents downwards, such as:

- insufficient capturing of interest rate risk associated with current accounts;
- ignores the different changes in interest rates of assets and liabilities with the same maturity (basis risk);
- ignores the un-parallel movements of yield curve;
- ignores the cumulative impact that changes in market interest rates have;
- ignores the time value of money;
- ignores the bank's instruments which contain embedded options.

The maturity gap analysis is a static measure technique. The assets and liabilities are perceived at their current volumes at a certain date and their change is neglected. Furthermore, the maturity gap model implies a series of assumptions. One of the assumptions is that all the instruments assigned to one time bucket have the same maturity and re-pricing date. The model also assumes parallel shifts. In real world, the interest rates of different maturities change at different magnitudes. As a result, the yield curve does not always have a parallel movement.

The model captures mainly re-pricing risk and partially yield-curve risk, although the yield-curve risk presumes a parallel movement. On the other hand this model ignores the basis risk. Besides the basis risk, this model also ignores the embedded option risk, which is nowadays more common for the current offered products. The initial settlements are not always kept. In case, the interest rates will decrease, consumers will refinance their debt at a lower price. This will lead to a massive prepayment of loans and as a result will directly impact the NII. This is a typical situation for embedded instruments. Here, the client has the right to exercise the option once the interest rate change may seem profitable. Hence the cash flow and NII are affected.

The maturity gap analysis is a short-term focus on interest rate risk. It provides the financial institution's gap. Furthermore the ALM receives a nice picture of the gap, which is further used for a preventive analysis of different scenarios. Based on this gap picture, the ALM may want to engage in various strategies or contracts in order to adjust their interest rate sensitivity.

This model will be further applied on real data in the practical part of this thesis, where it will capture the bank's interest rate risk and the changes in NII.

2.1.2 DURATION GAP MODEL

Duration gap model is another methodology aiming to measure the interest rate sensitivity of the bank's products. It is showing how a percentage change in interest rates will affect the bank's position. This change in value is also measured as a percentage. It covers mainly the price risk, calculating the instruments' market value changes in connection to interest rates' movements.

Within duration gap model, the instruments' sensitivity towards interest rate risk is perceived as the impact of changing rates on the market value of equity. The longer the duration is, the larger is the change in value for a given change in interest rates.

Duration is measured in time units and shows the exact time needed for the repayment of an investment through its incoming cash flows. The instrument duration is affected by coupon rate and current yield. The greater the maturity is, the greater the duration is. Therefore, the price sensitivity is also high. Before characterizing the duration gap model, the duration concept needs to be introduced. There are two main types of duration: Macaulay's duration (D_{Mac}) and Modified duration (D_{Mod}).

Macaulay's duration was firstly introduced in 1938, by Frederick Macaulay[17]. It is the simplest form and it is measured in years. It is changing in case, the yield to maturity or current interest rate changes. D_{Mac} is interpreted as the time needed for recovering the costs of an investment. This recover is possible thanks to the received cash flows. It is

[17] *Frederick Macaulay. In: Wikipedia: the free encyclopedia [online]. San Francisco (CA): Wikimedia Foundation, 2001- [cit. 2016-05-19]. Dostupné z: https://en.wikipedia.org/wiki/Frederick_Macaulay*

basically taking into account the present value of the future coupons and the notional amount. It measures the instruments' price volatility. It can be calculated by using[18]:

$$D_{Mac} = \frac{\frac{1 \cdot CF}{(1+i)} + \frac{2 \cdot CF}{(1+i)^2} + \cdots + \frac{n \cdot (CF+N)}{(1+i)^n}}{P};$$

where *CF* represents the cash flows (coupons), *n* is the time period for each cash flow and notional amount (*N*) received and denoting also the number of periods till maturity, *P* stands for the instrument's price and *i* denotes the yield to maturity. A price change of an instrument will be calculated as:

$$dP \cong -D_{Mac} \frac{P}{(1+i)} di;$$

Modified duration is a modification of the $D_{Mac.}$ It is calculated as:

$$D_{mod} = \frac{D_{Mac}}{(1+\frac{i}{n})};$$

where: *i* is the yield to maturity and *n* is the coupon periods per year. It is used for measuring of interest rate sensitivity of different instruments. A change in price, using D_{mod} , can be calculated using the next formula:

$$dP \cong -D_{mod} \cdot P \cdot di;$$

As already mentioned, the duration gap model can be applied to measure the sensitivity of the bank's economic value of equity to interest rate movements. It is usually referred to as **change in equity value**. This method implies an initial duration calculation for each instrument on balance sheet and off balance sheet. The derivative instruments are also included. Once the individual durations are calculated, the weighted average duration is calculated for assets and liabilities and off balance sheet instruments. The duration gap is calculated as[19]:

$$Duration\ gap = DA - DL \cdot (RSL \div RSA);$$

[18] *STÁDNÍK, B. Teorie a praxe dluhopisů [online]. In: . [cit. 2016-05-18]. Dostupné z: http://kbp.vse.cz/wp-content/uploads/2012/12/St%C3%A1dn%C3%ADk_Teorie_a_Praxe_dluhopis%C5%AF.pdf*

[19] *GHOSH, Amalendu. Managing risks in commercial and retail banking. Singapore: John Wiley & Sons, 2012. ISBN 9781118103531.*

where:

DA – is the assets weighted average (WA) duration;

DL - is the liability WA duration;

RSA – rate sensitive assets;

RSL – rate sensitive liabilities;

By using the duration gap, banks are able to estimate the equity change, if interest rates change. In case asset duration is greater than liability duration, the bank's assets are more sensitive and will indicate a higher volatility. This value modification can be computed as following:

$$Change\ in\ market\ value\ of\ equity = -Duration\ gap \times [\Delta i \div (1+i)] \times market\ value\ of\ assets;$$

If the DA is greater than DL, the equity value declines when the interest rates will go up and vice versa. The value of equity will increase if interest rate will fall. In case the duration gap is zero, the market value of equity will remain unchanged. The sensitivity of the market value of equity is direct proportional with the duration gap size. The greater the gap, the greater the increment change of the market value of equity in relation to interest rate movements.

As already mentioned, a zero duration gap is riskless and a non-zero gap generates risk. In case of a positive gap, an increase in rates will lead to loss. This loss is supposed to be covered by bank's capital buffer. Sometimes, losses can even exceed the level of the available capital and the bank can face bankruptcy. In real world, such simplistic assumptions are inappropriate.

From a theoretical point of view a zero gap can be easily reached. In case of a positive duration gap, it can be reached by increasing liabilities' duration and lowering the assets' duration. In other words, the bank should aim for bigger interest rate sensitivity on the liability side and for lower interest sensitivity on the asset side. The only problem is that the bank can't change or dictate the terms of its own assets and liabilities. Everything depends on clients' preferences. Every customer has his own needs and the bank can't convince him to place his money in a longer-term deposit. In case the bank refuses to accept a short-term deposit, due to the fact that this will lead to a duration gap

escalation, the client will just go next door depositing his money at a convenient term. Correspondingly, the bank can't refuse a long term loan to highly rated clients. If the bank provides long-term loans, the interest rate asset sensitivity will increase and if the bank refuses it, clients will just go to a concurrent bank and borrow money from there.

Same as maturity gap model, duration gap model presents advantages and disadvantages. The main pluses are:

- durations of individual assets and liabilities are additive, characteristic that facilitates the interest rate risk measurement of the entire bank's portfolio;
- it is working with the present value of each cash flow;
- reflects the interest rate risk for a longer period of time;

On the other side, the downwards of the model are:

- duration calculation is quite difficult and requires accurate prediction of all cash flows associated with individual assets and liabilities;
- duration calculation and the accuracy of the results are influenced by the rate used for discounting the cash flows;
- duration varies over time, recalculations need to be done, hence hedged items and hedging instruments need to be changed as well;

To sum up, the duration gap model can be a pivotal tool for minimizing the impact, the interest rate shifts have on bank's financial position. The duration of all the instruments is fluctuating over the time. Therefore, a resetting of asset and liability duration is needed occasionally. The resetting will allow a more effective hedging against interest rate shifts. For an ample analysis, besides duration factor, banks will also take into account convexity.

2.2 VALUE AT RISK

Value at risk is another tool of measuring interest rate risk. It is usually known as a loss quantile of the profit/loss distribution. Today, we are offered a wide range of VaR models. For the purpose of this thesis just some of them will be characterized. These are: historical method, the variance-covariance model and Monte Carlo simulation. These models are known and worldwide used thanks to their simplicity and validity.

Due to the fact that these models are basically performing simulations, result validation against the market is inevitable.

VaR is widely used among financial institutions and regulators while setting the capital requirement in relation to the bearing risk. Until the financial crisis from 2007, was believed that the market turn of events are always predicted by VaR. Unfortunately, financial crisis proved that this method is breakable during a down turn of market events.

Basically, VaR can express the statement that the loss will not be more than *Y* dollars in the next *N* days with *x* % certainty. Witzany (2013)[20] is characterizing VaR as the answer to the question: *"How large a loss can we suffer on a portfolio (or business activity)? And what is the probability of such a loss?"* This approach is known for its simple interpretation and complexity of estimation.

Witzany (2013) is explaining the concept of VaR through an example. He is taking a portfolio and denotes it as $V=V(x)$, where x is the vector of market factors. Vector's components $x=x(t)$ are known at time t, but unknown in the future. If a period of time is denoted as Δt starting from point t to $t+\Delta t$, then the portfolio value for this exact period will be equal to $\Delta V=V(x(t+\Delta t))-V(x(t))$. Resulting from this equation it is obvious that $V(x(t+\Delta t))$ is the unknown part and must be treated as a random variable and so it is ΔV. VaR can be easily calculated in case we have the full probability distribution of ΔV. Therefore, if full probability distribution is known, then on a probability level α, the loss cannot be greater than $q_{1-\alpha}$, which represents the critical loss for the random variable ΔV and ΔV representing the change in portfolio's value. Quantile takes normally negative values, but VaR is defined as a positive value. Here we are actually offered two kinds of VaR, absolute and relative:

$$VaR^{abs}(\Delta t, \alpha) = -q_{1-\alpha} ;$$

$$VaR^{rel}(\Delta t, \alpha) = E[\Delta V] - q_{1-\alpha} ;$$

The relative VaR version is defined for longer periods of time and takes into consideration the expected portfolio profit.

[20] *WITZANY, Jiří. Financial derivatives: valuation, hedging and risk management. Ed. 1st. Prague: Oeconomica, 2013. ISBN 978-80-245-1980-7.*

2.2.1 HISTORICAL METHOD

Historical VaR is the most popular model due to its simplicity. In 2010, Perignon and Smith[21] mentioned that almost 73 % of the banks that use VaR methodology give priority to historical model. It can be compared to Monte Carlo but the difference is mainly created by the samples that are being used for outcomes. Historical VaR uses historical samples which are considered to be more reasonable than the random samples used in case of Monte Carlo simulations. This is the model that uses the past data in order to predict the future. For a better understanding Hull (2008)[22] is explaining it with one simple example.

VaR should be calculated for a portfolio. For this purpose it should be used: a confidence level of 99 %, a 1-day time horizon and 501 days of data. The first stage of VaR calculation is to identify the main variables that have a direct impact on this portfolio. The next step is to collect the values of these variables for the past 501 days. This model will provide us with 500 alternative scenarios for this case. These scenarios intend to illustrate what may actually happen between today and tomorrow. Each scenario will show either the percentage change in all variables' values are the same as between 2 consecutive days from the past. In this way, the price change of the portfolio between today and tomorrow can be calculated. Also, this expresses the probability distribution. The probability distribution is based on the portfolio's daily value changes. The 1st distribution's percentile represents the 5th worst daily change. This percentile will define the loss estimated by the VaR model. In case the data series are valid and constitute worthy market information, the portfolio managers are 99 % certain that the occurred loss on the portfolio for the next day is not greater than the amount estimated by VaR model.

Like any other models, historical VaR is facing several weaknesses. Wong[23] is stating the following down sides of the model:

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[21] *CHRISTOPHE PÉRIGNON a DANIEL R. SMITH B. The level and quality of Value-at-Risk disclosure by commercial banks [online]. In: . [cit. 2016-05-18]. Dostupné z: http://epge.fgv.br/we/MFEE/GerenciamentodeRisco/2011?action=AttachFile&do=get&target=Artigo77.pdf*

[22] *JOHN C. HULL. Options, futures and other derivatives. 7th ed. Harlow: Prentice Hall, 2008. ISBN 9780135045329.*

[23] *WONG, Max C. Y. Bubble Value at Risk: A Countercyclical Risk Management Approach. Revised Edition.*

- Historical VaR, same as other VaR models can be used only during peacetime in the financial markets. This model will break down in case new information arrives which wasn't specific for the past. Financial crises are serving as a good example, while stating this down side of the model.
- VaR is only an estimation represented by a specific number. This number intends to incorporate the risk for the entire distribution and at the same time it doesn't contain any information regarding the tail shape of the left of the loss quantile.
- The quality of simulated scenarios is direct proportional to the validity and quality of the used data series. The data series shouldn't be stale and at the same the relevant swings should be omitted.
- Historical VaR is stating that the real loss can't be greater than the calculated VaR loss. Assuming actual market condition aspects and the changing environment, there is no certainty that the potential real loss can't be greater than the loss calculated with empirical sample.

2.2.2 THE VARIANCE-COVARIANCE METHOD

The variance-covariance model also known as parametric model was developed by J. P. Morgan's RiskMetrics. The original version was firstly published in 1994. During the years it was adapted to market conditions in order to generate better and more precise results. The original version implies using of normal distribution and EWMA volatility measure.

Variance-covariance method is considered to be one of the simplest VaR method[24]. While calculating it, it is presumed that the risk factors have a normal distribution and portfolio exposures are linear. This approach is widespread mainly because of the small amount of variables that are needed for its calculation. The only variables that are needed are the standard deviation and the mean of the portfolio. The assumption that the returns on the portfolio are normally distributed makes the whole process much easier. The portfolio volatility can be obtained by using covariance matrix and weight

[24] *HAO LI, XIAO FAN, YU LI, YUE ZHOU, ZE JIN a ZHAO LIU. Approaches to VaR∗ [online]. In: . [cit. 2016-05-18]. Dostupné z: https://web.stanford.edu/class/msande444/2012/MS&E444_2012_Group2a.pdf*

vector. VaR modelled in this way is also called normal VaR[25]. The model looks as follow:

$$R_t = \mu_t + \sigma_t Z\,, Z \sim N(0,1);$$

For such a parametric model can be calculated:

$$Absolute\ VaR_\alpha\ (t) = -z_\alpha \sigma_t - \mu_t;$$

$$Relative\ VaR_\alpha\ (t) = -z_\alpha \sigma_{t;}$$

where:

z_α – stands for α-quantile of normal distribution;

μ_t – represents the drift;

σ_t – is the standard deviation of return R_t;

The linearity assumption makes the model simple but at the same time constitutes its biggest drawback. Because of it, the model is not able to provide exact extreme outcomes.

2.2.3 MONTE CARLO SIMULATION

In contrast to parametric VaR, that uses only normal distribution, Monte Carlo VaR is able to generate different scenarios from different known distributions. This is a huge advantage of the model, since the markets represent fat-tails during crises. The exactitude of the result is dependent on various specifics such as: confidence level, observation period, distribution model. The greater the number of simulation, the more exact the result will be.

Monte Carlo simulation technique[26] is characterized as a mathematical technique that is computerized in order to facilitate its use in quantitative analysis, mainly by risk management process. It is widely used by various industries: finance, engineering, energy, oil and gas etc. Monte Carlo simulation facilitates the decision making process and provides it with a wide range of possible outcomes for every chosen path. The main

[25] *CHAN, Ngai Hang. a Hoi Ying WONG. Handbook of simulation and financial risk management simulations and case studies. ISBN 9780470647158.*
[26] *Monte Carlo Simulation [online]. In: . [cit. 2016-05-19]. Dostupné z: http://www.palisade.com/risk/monte_carlo_simulation.asp*

advantage is that it is able to show all the outcomes and potential consequences starting from the most conservative decision to the riskiest ones.

Monte Carlo[27] was named after the Monaco town, known for its numerous casinos. It was developed and applied for the first time by John Von Neumann, Stanislaw Ulam and Nicholas Metropolis, during the World War II. Since then, it was adjusted and applied in different industries. Nowadays, it is predominantly used for risk analyses. These simulations are facilitating the building of different result paths by substituting a probability distribution for every factor with a decisive role for the process and a significant level of uncertainty. The process is run over and over for different samples from the probability functions. Monte Carlo is known for its precision and complexity. Before obtaining the final result, the process can run thousands of simulations. For describing variables' uncertainty, probability distributions are used, such as: normal, lognormal, uniform, discrete, triangular.

Every simulation is based on a different sample computed out of input probability distribution. These samples are called iterations. Every iteration result is recorded. These simulations are performed hundreds or thousands of times. The outcome of the whole process is a probability distribution of possible results. It is providing a much more complex and realistic overview of what may happen.

Same as other models Monte Carlo VaR shows its weakness. Wong (2013) is mentioning several of them:

- The main downturn is considered to be the high technological dependency. It is computationally intensive and numerical techniques are needed to speed it up.
- This model requires a return distribution modelling. As it is well-known, the normal distribution is too idealistic. Monte Carlo VaR offers the possibility of using different tailed distributions which will suit the most the current conditions. The question here stands for how to decide which one of the fat-tailed distribution is the best choice.

[27] *Monte Carlo method. In: Wikipedia: the free encyclopedia [online]. San Francisco (CA): Wikimedia Foundation, 2001- [cit. 2016-05-19]. Dostupné z: https://en.wikipedia.org/wiki/Monte_Carlo_method*

- Model parameters need to be calibrated. The calibration process is disposed to various numerical errors and volatility.
- In case of complex portfolios created of various deals, exotic derivatives, nested Monte Carlo simulation is to be performed. These instruments are usually requiring re-pricing based on Monte Carlo simulation itself. As a result a simulation within a simulation is needed, which increases the complexity of the whole process.

2.2.4 STRESS TESTING AND BACK TESTING

As an additional element to the VaR calculations, plenty of companies also perform the so called – **stress testing**. This implies calculations of the change in the performance of the portfolio under certain extreme conditions. These extreme conditions can reflect some significant downturns of events from the past or just some theoretical assumptions that are being established by the senior management.

Hull (2009) states that the stress testing is designed in a specific way, that would accord substantial weight to all extreme events that did occurred in the past but are virtually impossible due to the market variables' distributions that are assumed. He is also bringing some examples of stress testing. One of them is reflecting the US equity prices. For its calculation, the process would take into consideration the percentage changes of all market variables as of 19th of October, 1987[28].

The actual fast paced and complex environment is forcing financial institutions to improve and implement permanently new risk measurement methodologies. This chapter already mentioned some types of the VaR model. Every model implies its own pros and cons and appears as a proper choice. In the real world though, it's very difficult to find the model that would fit perfectly the company's needs.

In order to choose a proper VaR model, the companies are using the so called **back testing**. Back testing intends to compare the accumulated loss during a specific study period, from the past with the VaR results obtained from the testing of a specific model which will reflect all the data available for the same period of time.

The periods of time for which the actual loss was higher than the one predicted by VaR model are symbolized as exceptions. The exception's relative number theoretically

[28] *The index S&P 500 registered a movement of 22.3 standard deviations.*

should tend to $p = 1 - \alpha$. The difference between the actual number of exceptions and the target number can be calculated by using an appropriate statistic method with a proper p-value.

This difference can be calculated usually with one-tailed or two-tailed tests. One-tailed tests are for example Binomial tests. The two tailed-tests are more complex and generate a more accurate result. As an example can serve the Kupiec's test (1995). It can be interpreted using the next formula (Witzany, 2013):

$$K = -2\ln((1-p)^{n-d}p^{d}) + 2\ln(\left(1-\frac{d}{n}\right)^{n-d}\left(\frac{d}{n}\right)^{d});$$

where:

p – is the exception's probability;

d- number of exceptions;

n- number of trials.

The test is implying a chi-squared distribution with one degree of freedom. If the resulting statistics is higher than 95% quantile, then the hypothesis should be rejected for the corresponding probability level.

3 HEDGING INSTRUMENTS

All market participants are exposed to interest rate risk. Both lenders and borrowers can end up with losses. Market transactions can be performed in two ways; either they are being fixed to a predefined interest rate or to a float rate. Even in uncertain circumstances, the market participants can take the position they need. They can choose either a fixed or float-rate instrument and then change it if necessarily, based on market development and own perception of future changes.

These adjustments are facilitated by using fixed income derivatives and other balance sheet strategies that are widely spread between financial institutions. Balance sheet strategies imply an alteration in assets and liabilities in order to decrease the IRR exposure. Financial derivatives, on the other hand, don't intend to revise the balance sheet structure or initial contracts, but instead they are creating new contracts.

Financial derivatives are also known as off balance sheet hedging strategies. The most common derivatives used to hedge IRR are: caps, floors, forwards, swaps. These derivatives can diminish the bank's overall IRR, if used correctly. For instance, an

interest rate swap can decrease in an effective way the duration of a commercial loan portfolio, thereby reducing the mismatch between assets and liabilities. But, if used incorrectly, derivatives may increase the risk rather than mitigate it. Management should not use derivatives without understanding them properly.

This chapter will provide an overview of the existing balance sheet strategies and financial derivatives used for the purpose of decreasing and hedging interest rate risk.

3.1 BALANCE SHEET ADJUSTMENTS

The most popular interest rate risk hedging strategy is connected to the use of interest rate derivatives. Nevertheless, this is not the only option used by banks. In practice, beside derivatives, there are several key balance sheet strategies. Such strategies include acquiring assets and liabilities that can diminish the pricing and maturity mismatches and option characteristics effects. These are[29]:

- *Asset reconstruction strategy;*
- *Liability reconstruction strategy;*
- *Growth strategy;*
- *Lowering strategy.*

For the ***asset reconstruction strategy*** is typical the substitution of one type of asset items by another type. As it was already mentioned, banking industry is facing a mismatch when it comes to comparing assets and liabilities' maturity. The products on the asset side are granted long term, exceeding several times the products' maturity on the liability side. This strategy implies selling of long-term assets (loans and bonds), and investing this money into short-term assets. In this way, banks are lowering duration on asset side and simultaneously the overall interest rate exposure. The hedging aspect, of this methodology, tends to decrease the bank's profitability. The risk optimization through this methodology is mainly used on developed markets, where securitization became a regular thing.

The ***liability reconstruction strategy*** works in the opposite way. Here, the short term liabilities are replaced by the long term instruments. Through this procedure, banks are

[29] *Prga, I., PhD., & Sverko, I., PhD. (2011). HEDGING INTEREST RATE RISK OF CROATIAN BANKS WITH DERIVATIVE PRODUCTS. Ekonomska Istrazivanja,24(1), 384-392. Retrieved from http://search.proquest.com/docview/993159338?accountid=17203*

increasing duration on the liability side and simultaneously lowering the interest rate exposure. Same as the first strategy, liability reconstruction limits bank's profitability. This is caused by the expensive nature of the long term deposits. Its implementation implies more difficulties. It is very hard to persuade clients to choose long term deposit, due to individual preferences and future uncertainty. Consequently, it is not expected from the management risk to implement and commonly use this strategy.

The ***growth strategy*** involves an asset increasing. This increase mainly consists of buying of short term assets. These assets are funded by the long term deposits. This strategy, same as others, has a direct impact on both, interest rate exposure and bank's profitability. Both will decrease. This strategy, same as liability reconstruction, points toward same difficulty, the expansion of long term deposits. For less developed markets, the only source that substitute long term deposits are received loans from international institutions. Nevertheless, these received loans are expensive and received mainly for regulatory purposes, which makes this strategy problematic to implement and develop.

The last one is the ***lowering strategy***. This strategy involves selling of long term assets and the received money would be used for paying back short term liabilities. This strategy it's very tough to imagine, since it contradicts the banking business strategies. In this current permanently changing conditions and permanent developing markets, it's hard to imagine that a bank would limit its operations.

These balance sheet adjustments go hand in hand with the gap analysis. Gap analysis breaks down the assets and liabilities into band times, offering a clear picture of the balance sheet structure.

3.2 FORWARD RATE AGREEMENT

Forward rate agreement is a contract that implies a certain interest rate for a future contract. This will be a borrowing or a lending transaction of an advance known principal. The agreement is normally based on LIBOR. It is a very popular over-the-counter instrument that can be adjusted for the exact need.

Forward rate agreements can be easily explained through an example (Hull). For example, two companies agreed that X is going to lend money to Y, for a period of time in the future. For this purpose, several conditions are agreed on:

- R_K – constitutes the level of contract interest rate;
- R_F – denotes the forward LIBOR, which is calculated today for the future contact period, starting with T_1 till T_2;
- R_M – is the actual LBOR;
- L- is the notional amount of the contract;

This contract has two outcomes based on either R_K or R_M is greater than the other. If:

- $R_K > R_M$; then the payoff paid at T_2 is : $L(R_K-R_M)(T_2-T_1)$;
- $R_M > R_K$; then the payoff paid at T_2 is : $L(R_M-R_K)(T_2-T_1)$;

In the first case there is a cash flow paid to company X. Similarly, the second case denotes a payment of the extra interest to company Y. Usually the payments are settled at T_1. As a result the payoffs mentioned above are being discounted as well.

Forward rates agreements can be used for purpose of hedging, arbitrage or speculation. For example, if a market participant will expect an increasing interest rate environment, then will enter a FRA contract as a fix interest rate payer. In case his expectations are met, he will end up with a nice profit. By contrast, if his expectations turn out to be wrong, his speculation position will bring a loss.

3.3 INTEREST RATE FUTURES

Interest rate futures contracts are used mainly for hedging purposes. While talking about interest rate futures, it is inevitable to distinguish them on maturity level. On the market we are offered short-term and long-term interest rate futures contracts. The most popular contracts are Treasury bond and Eurodollar futures.

Short-term interest rate (STIR) futures are the equivalent of forward rate agreements. The difference is made by their exchange traded form and a series of other factors resulting from the exchange trade standardisation aspects. While FRA contracts are offering a wide maturity spectrum, STIR futures have a standard length of 90 days. The national amount of an Eurodollar represents 1 million dollars. For Euribor futures, the notional amount is 1 million euros.

The contract profit/loss is calculated on a daily basis. Due to this fact, the payoff formula doesn't incorporate the time value of money. Therefore, the STIR future payoff can be calculated using the following formula (Witzany 2013):

$$Payoff = 10^6(R_K - R_M)\frac{90}{360} = (R_K - R_M) \times 250000$$

Because the time value of money is mistreated, there are slight differences between futures and forward rates. The settlement of the contract takes place on the third Wednesday, of the month, the maturity occurs. The prices are quoted as *100 % - R_K*. This quotation makes the prices to look like prices of discounted zero-coupon bonds.

Another type of interest rate future is the long-term interest rate (LTIR) futures. These contracts incorporate long-term interest rate through the bond prices. The same convention is applied for quoting both, the future and the underlying bond. At the maturity the contacts are settled physically. The aspect that makes LTIR futures different from the others is the fact that the contract is not based on a single underlying asset, for this particular case a bond, but on a series of eligible bonds. The counterparty on the short-side has the possibility to choose the best fitting bond at settlement point, the so called *cheapest-to-deliver*. For the purpose of calculation the cheapest-to-deliver bond, the contract will specify a conversion factor (CF). The counterparty on the long side of the transaction will pay a price equal to (Witzany 2013):

$$F \times CF_i + AI_i;$$

Where: F - is the settlement futures price, CF – is the conversion factor, AI represents the accrued interest and i- is the chosen bond to deliver.

The counterparty on the short position, on the other hand, will deliver the bond, for which the below difference will be equal to zero (Witzany 2013):

$$P_i - F \times CF_i;$$

If this difference will not be zero, an arbitrage opportunity will be possible.

Generally, a futures contract is defined as an agreement between two parties, to exchange a predefined amount of asset on a certain date at an arranged price. These contracts can be used for hedging and speculative purposes. At the interest rate risk banking level it is a good tool to assess the asset/liability gap. It can be used at micro or macro level. The micro-hedge is used for individual assets, while macro-hedge is oriented on the aggregate balance sheet.

3.4 INTEREST RATE SWAPS

On the financial market a credit rating is attributed to every institution. This rating is a key factor in the process of borrowing and lending. Institutions with a higher credit rating can borrow log run at a lower price. By contrast, institutions to which low credit rating was attributed don't have access to a lot of products and benefits on the market.

Frequently, market participants are willing to exchange their interest rates. Through such a transaction, fixed and float-rates can be exchanged. In a growing interest rate environment, lenders would prefer float-interest rate contracts, as the contract interest tend to be direct proportional with the market development and borrows would be interested to fix interest rate at a certain level. Every borrower/lender has its own expectations regarding the future expansion.

Interest rate swaps (IRS) are the contracts that enable the exchange of interest rates of different maturities and nature. IRS offers the possibility of converting a fixed- rate to float rate and the opposite. Moreover, it can be used in case of two float-interest rates but fixed to different reference-rates. This instrument presumes a paying and a receiving leg, which are periodic cash flows exchanged between the parties. They are calculated based on the notional amount, set for this purpose and interest rates. Its value is equal to zero at the initial stage and increases as contract maturity is approaching.

Interest rate swaps are serving for purposes of hedging and speculation. Hence it is widely spread between the institutions. Corporations are mainly using this instrument within their liability management process. Banks, on the other hand, are using interest rate swaps on the both sides, while managing assets and debt.

3.5 CAPS, FLOORS, COLLARS

Caps and floors are the standard interest rate options. These instruments are traded over-the-counter and are being often incorporated into a series of products, such as: commercial loans and floating-rate notes.

The cap is usually perceived as a maximum rate that the buyer will pay. Therefore, it is representing the upper bound for the floating rates. This upper bound can be periodically reset. Like an option, the cap will gain value only in case the floating rate will exceed the guaranteed rate. The capped rate that is going to be paid at a future point in time is (Witzany, 2013):

$$\min(K_u, R_{M,i}) = R_{M,i} - \max(R_{M,i} - K_u, 0);$$

where:

$R_{M,i}$ →is the floating rate;

K_u →is the upper bound;

The cap's payoff serves as an offset for the increased amount that has to be paid in case the float rate exceeds the upper bound. If the capped loan is denoted with L and the contract time with δ_i, then the payoff will be equal to:

$$Payoff = L \times \delta_i \times \min(K_u, R_{M,i});$$

The interest rate option *floor* is the opposite of *cap.* Floor denotes the minimum interest rate paid by the buyer. While the caps intend to protect the debtor, floors provide to the creditor the guarantee of a minimum interest rate. The nature of the option makes the floor valuable only if the observed rate will fall below the guaranteed rate.

Both caps and floors can be not only incorporated to some products but also traded as individual instruments on the over-the-counter derivative market. For this purpose, they must be valued and priced. A cap can be priced through pricing a series of call options. These options are called caplets. The floors are characterized by the same process. In case of floors, the series' options are called floorlets. The payoff of a single caplet and floorlet are equal to (Witzany, 2013):

Caplet: $L \times \delta_i \times \max(R_{M,i} - K_u, 0)$;

Floorlet: $L \times \delta_i \times \max(K_l - R_{M,i}, 0)$;

The combination of these two instruments is called collar. The collars intend to make the hedging strategy costly free or almost equal to zero. The cost of one instrument, cap or floor, will offset the cost of the other instrument. This approach, of minimizing the cost, can be reached by buying a cap and selling a put. In this way, the premium received from selling the put is invested into a cap. The collar can be evaluated as a function of the future observed rates. When the rate will hit the upper bound, the collar buyer will pay the cap strike and the opposite, when the rate will fall below the lower bound, the collar buyer will pay again a fixed rate.

3.6 SWAPTIONS

The swaption is the combination of two financial derivatives, an interest rate swap plus an option on it. It incorporates the advantages of both derivatives at once, offering a better fit for the market participants' needs. Lately, this instrument has become very popular within many financial institutions, especially between those that offer mortgage loans.

The swaption, thanks to its incorporated option, gives the buyer the right of entering an interest rate swap at a certain date in the future. It gives the advantage of fixing the future costs on an upcoming loan. The buyer will exercise it just in case it becomes profitable. For example, if the swaption's exercise rate is s_k and the market rate at time T is s_T, then the swaption will be exercised only if s_T exceeds s_k . Hence, the maximum payoff that can be reached is equal to max $(s_T - s_k; 0)$.

The overall swaption's payoff, at a certain date in the future *T* with a principal *L*, can be expressed through the next formula (Witzany, 2013):

$$f_T = \sum_{i=1}^{N} P(T, T_i)\delta_i \, Lmax(s_T - s_K, 0);$$

Hull (2009) mentioned that this swap option can be treated similar as a bond option. The swaption can be distinguished based on its enclosing type of option. If the swaption contains a put option, then it gives the buyer the right of receiving a float-rate and paying a fixed-rate. And the opposite, if the swaption encloses a call option, then the buyer have the right of receiving fixed-rate and paying float-rate. The swaptions imply European options.

Furthermore, it can be compared with a forward swap. The differences between these two are that forward swap can be freely entered but at the same time obligates the buyer to exercise the contract even if it's generating a loss, while the swaption gives the buyer the right of exercising it just in case it is favourable but presumes initial costs.

The swaption are generally being quoted on the market as implied volatilities for at-the-money European swaptions. Because the underlying instruments are at-the-money, the exercise swap rate is equal to the forward swap rate.

As discussed in section *1.3 Interest rate sources and consequences,* embedded option will increase, causing a decrease of the assets' duration. If the bank is using IRS for its hedging purposes, than it is forced to continue the exchanging of the swap's payments for a period that exceeds the assets' average life. In order to prevent these types of situations, banks prioritize swaptions. For example, the call on swap gives the advantage to call the swap.

4 AN APPLICATION OF MATURITY GAP ANALYSIS MODEL

This thesis aims to cover interest rate risk in banks and NII change matter. For a clear and understandable interpretation of the calculation process and result evaluation has been chosen the maturity gap model. Maturity gap model serves as a good tool, according to European Banking Authority for the purpose of analysing the bank's interest rate risk and changes in NII from short term perspective. Its general methodology and assumptions have already been discussed within the interest rate risk measurement systems section. For its application was chosen the American bank- *Morgan Stanley Bank, National Association*. The main objective of this chapter is to analyse the bank's net interest income and the interest rate risk rising from its balance sheet structure, over the period 2015Q1 to 2016Q1.

This analysis is based on the secondary data that is available on the bank's web page and Federal Deposit Insurance Corporation site. The bank's performance was analysed over one year and a quarter on. Furthermore, the main attention was oriented to the bank's interest rate exposure over individual time buckets.

The maturity GAP model features and the definition of the sensitive assets and liabilities have already been characterized. Nevertheless, it is appropriate to mention one more time that it is focused on capturing the mismatches between assets and liabilities that are calculated by subtracting the RSLs from the RSAs, within every bucket time at a given date.

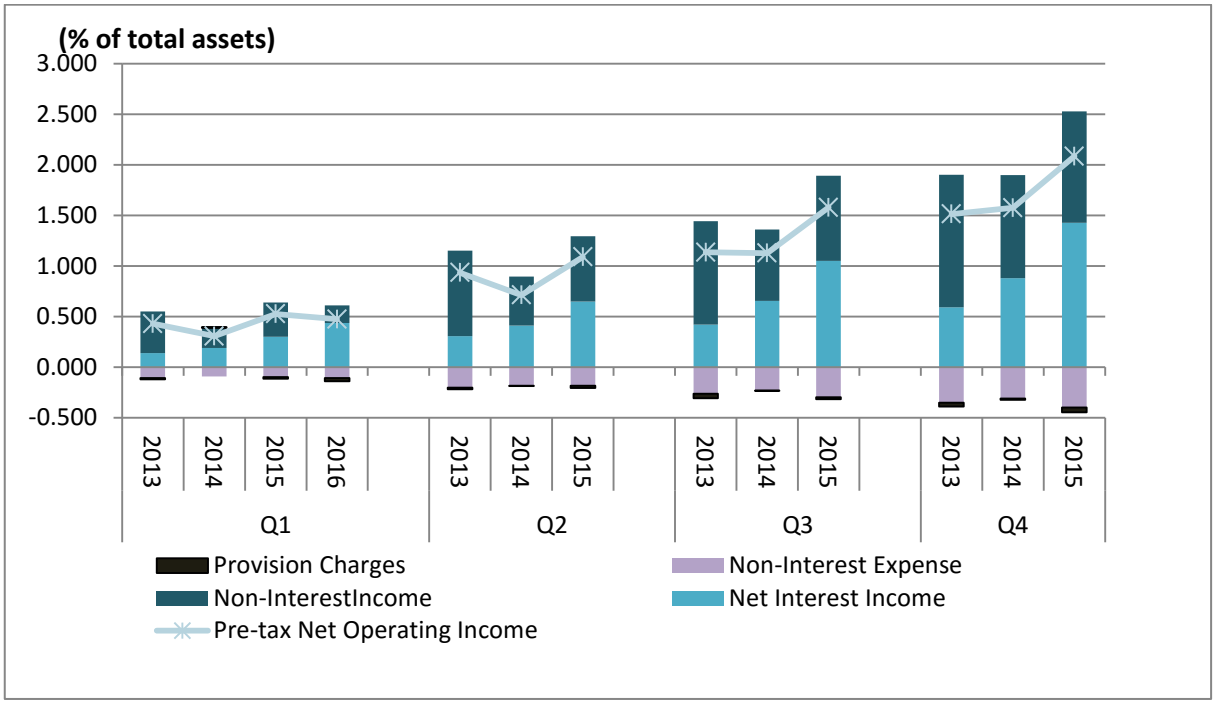
4.1 NET INTEREST INCOME ANALYSIS

Before examining the bank's interest rate risk and NII fluctuations, it is proper to analyse the dependence of the overall bank's profit on the net interest income. For this purpose, will be used several items extracted from the bank's income statement. These items are: net interest income, non-interest income, general and administrative expenses (non-interest expenses), provision charges and pre-tax operating profit. For a more accurate overview, the percentage ratios will be used. All items are represented as a percentage of total assets.

Figure 7 captures the fluctuation ratios of these components starting with first quarter of 2013 to first quarter of 2016. By analysing each quarter across different years, it can be deducted the increasing trend of the net interest income over the years. The other

components show a relatively stable development. Nevertheless, year 2014 depicts lower results compared to year 2013 and 2015.

Figure 7 Examination of Income Statement Items



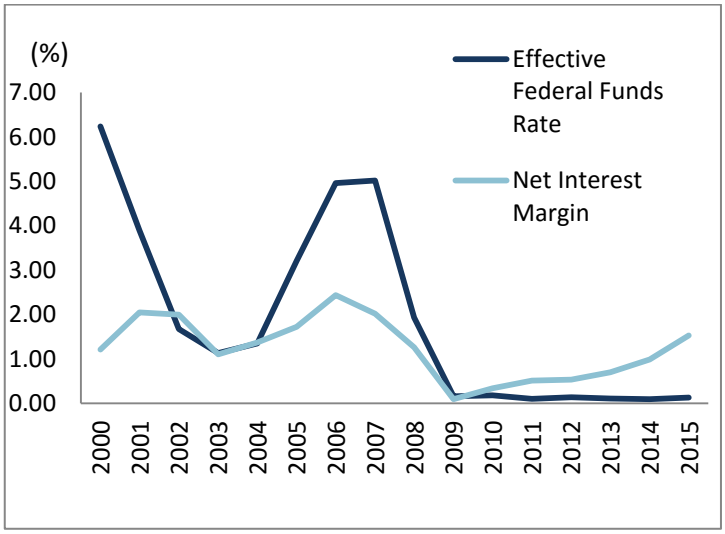
Source: own creation; data FDIC;

The pre-tax net operation income fluctuates for first and second quarter and shows an increasing trend for quarter three and four from one year to another. The increasing trend is mainly driven by the net interest income margin (NIM- ratio of net interest income to total assets).

Figure 8 compares the FEDFUNDS with the bank's NIM over a period of 15 years. The NIM performance ratio seems to follow the FEDFUNDS changes. The correlation between these two data series reaches a significant degree.

To sum up, the bank's pre-tax net operating income's changes are mainly driven by the net interest margin. Furthermore, the development of the net interest margin is highly influenced by the market rates' fluctuations.

Figure 8 FEDFUNDS and NIM



Source: own creation; data FDIC and Federal Reserve Bank;

Table 4 depicts the evolution of some items extracted from the income statement and balance sheet. The bank's interest income is increasing year by year. For the first quarter of 2016, the bank reported an interest income which is 19.65% higher than the interest income of the previous year, same quarter. This discloses that the bank is focused on interest income generation. The interest expense is fluctuating.

Table 4 Selected Items from IS and BS

Selected items from Income Statement and Balance Sheet (dollar figures in thousands)					
Items /Period	2013	2014	2015	2015Q1	2016Q1
Interest Income	*1,095,000.00*	*1,595,000.00*	*2,270,000.00*	*519,000.00*	*621,000.00*
Interest Expense	*483,000.00*	*490,000.00*	*329,000.00*	*137,000.00*	*22,000.00*
Provision: Loan & Lease Losses	*40,000.00*	*17,000.00*	*64,000.00*	*23,000.00*	*44,000.00*
Total Loans and Leases	*26,078,000.00*	*45,366,000.00*	*54,421,000.00*	*49,491,000.00*	*54,243,000.00*
Total Deposits	*89,805,000.00*	*109,275,000.00*	*119,652,000.00*	*109,998,000.00*	*119,548,000.00*
Investments	*75,266,000.00*	*78,755,000.00*	*79,754,000.00*	*75,710,000.00*	*81,264,000.00*
Gross Non-Performing Assets	*1,730,000.00*	*1,407,000.00*	*2,002,000.00*	*1,767,000.00*	*1,648,000.00*

Source: own creation; data FDIC;

A fluctuating trend is also characteristic for provisions. Nevertheless, they are sufficient for a qualitative management of assets. Total loans and leases, total deposits and investments are increasing continuously. The first quarter of 2016 compared to the first quarter of 2015 represent an increase for the total loans and leases of 9.6%; for total deposits an increase of 8.68% and for the total investments 7.33%.

4.2 THE STATIC EXPERIMENT OF APPLYING INTEREST RATE SHOCKS

Table 5 offers an overview of the RSAs and RSLs over the period 2015Q1 to 2016Q1, which are denoted through gaps. During the 2015, the gaps are fluctuating from one quarter to another, and the increments are relatively significant.

If comparing the first quarter of both years, 2015 and 2016, the gap has increased by almost 11.91 %. The net interest income registered an increase as well. In the first quarter of 2016, the net interest income is higher by 56.8% compared to same period of 2015. The net income remained almost the same. The net interest margin, on the other hand, increased from 1.23% in the 2015Q1 to 1.76 % in 2016Q1.

Table 5 also contains an application of the positive and negative shocks, of 200 basis points. For a better overview and comparison, the shocks were calculated for the each quarter of 2015 and the first quarter of 2016. The performance changes were calculated for net interest income, net income and net interest margin. The table provides the information regarding each indicator's level before and after both shocks were applied.

While the net income remained almost unchanged for Q1 of the both years, the net interest income and net interest margin increased. By applying a negative interest rate shock of 200 basis points, each indicator decreased significantly. For example for first quarter of 2016, net interest income decreased to 297,200.00; net income to 109,200.00 and net interest margin to 0.87%.

The net income as a percentage of net interest income for 2015Q1 and 2016Q1 constitutes 110.47% and 68.61% respectively. After the negative shock was applied, this ratio increased to 132.54% for 2015Q1 and decreased to 42.98% for 2016Q1. These results find a proper explanation in the net income structure of both periods. In 2016Q1, the bank was more focused on interest income generation.

Table 5 Changes in Performance

Changes in the Performance for the Study Period (dollar figures in thousands)									
Performance Measure	2015Q1			2015Q2			2015Q3		
	Initial Position	**Interest Rate Shock (-2%)**	**Interest Rate Shock (2%)**	**Initial Position**	**Interest Rate Shock (-2%)**	**Interest Rate Shock (2%)**	**Initial Position**	**Interest Rate Shock (-2%)**	**Interest Rate Shock (2%)**
GAP	*13,483,000.00*	*13,483,000.00*	*13,483,000.00*	*12,668,000.00*	*12,668,000.00*	*12,668,000.00*	*14,881,000.00*	*14,881,000.00*	*14,881,000.00*
Net Interest Income	*382,000.00*	*112,340.00*	*651,660.00*	*823,000.00*	*569,640.00*	*1,076,360.00*	*1,375,000.00*	*1,077,380.00*	*1,672,620.00*
Net Interest Margin	*1.23%*	*0.36%*	*2.10%*	*1.33%*	*0.92%*	*1.74%*	*1.46%*	*1.14%*	*1.78%*
Net Income	*422,000.00*	*152,340.00*	*691,660.00*	*881,000.00*	*627,640.00*	*1,134,360.00*	*1,302,000.00*	*1,004,380.00*	*1,599,620.00*

Changes in the Performance for the Study Period (dollar figures in thousands)						
Performance Measure	2015Q4			2016Q1		
	Initial Position	**Interest Rate Shock (-2%)**	**Interest Rate Shock (2%)**	**Initial Position**	**Interest Rate Shock (-2%)**	**Interest Rate Shock (2%)**
GAP	*15,158,000.00*	*15,158,000.00*	*15,158,000.00*	*15,090,000.00*	*15,090,000.00*	*15,090,000.00*
Net Interest Income	*1,941,000.00*	*1,637,840.00*	*2,244,160.00*	*599,000.00*	*297,200.00*	*900,800.00*
Net Interest Margin	*1.53%*	*1.29%*	*1.77%*	*1.76%*	*0.87%*	*2.65%*
Net Income	*1,784,000.00*	*1,480,840.00*	*2,087,160.00*	*411,000.00*	*109,200.00*	*712,800.00*

Source: own creation; data FDIC

4.3 RESIDUAL MATURITY OF ASSETS AND LIABILITIES

This sub-chapter analyses the residual maturity of the bank's assets and liabilities. They have been distributed according to their time to maturity or re-pricing date to a proper time bucket. For their classification have been chosen six time buckets. These are the time buckets that are being used in the banks' call reports issued every quarter and published by the Federal Deposit Insurance Corporation: 0-3M, 3-12M, 1-3Y, 3-5Y, 5-15Y and >15Y.

Furthermore, this sub-chapter contains the simulation of the potential NII changes within the 0-3M time band. The process will be described in the *Methodology* section and the results analysed in the *Results* section.

4.3.1 METHODOLOGY

The call reports available on the FDIC site already contain the breakdowns for several balance sheet items. These items have been already distributed into the rightful time buckets, which will make the results of this GAP analysis more accurate. Although for the rest of the items, specific assumptions have been made. The individual gaps were calculated as a difference between their RSAs and RSLs. These maturity gaps depict mismatches of the bank's inflows and outflows, within time bands at a certain date.

A positive gap is generated by the prevalence of RSAs and can be interpreted as the bank's ability of meeting its short-term debt obligations. Alternatively, a negative gap reveals a shortage of funds. The bank can't meet its upcoming obligations. The time buckets up to one month are denoting the bank's short term liquidity.

As a regular, the banks are not obligated to report the maturity or re-pricing dates for their assets and liabilities. Nevertheless, the Morgan Stanley's call reports for FDIC, as already mentioned, contain the breakdown of some core items needed for this maturity gap analysis. The call reports specify the maturity or re-pricing date for *securities, loans and leases, time deposits, subordinated notes and debentures*. This exact classification was used for the creation of the upcoming tables, containing the residual maturity of assets and liabilities.

The remaining maturity is used for the fixed-rate contracts and the next re-pricing date method is used for the float-rate contracts. The re-pricing date method makes the calculations easier, as the float-rate contracts can be treated as fixed-rate contracts with remaining maturity until the next re-price.

Fed funds sold and re-sale, together with *interest-bearing bank balances* were attributed to the first time bucket of 0-3M. For the *trading accounts assets* was assumed that they are maturing within one year. These funds were allocated to the first two time buckets in proportion of 70:30.

On the liability side, Morgan Stanley has just: *Demand Deposits, Now & ATS Accounts, Money Market Deposit Accounts* and *Time Deposits* only for 2015Q4 and 2016Q1. For the purpose of this analysis, all these accounts were merged into one item: *Total Deposits*.

The *Time Deposits* have a maturity up to five years. Their maturity breakdown was already specified in the call reports. Furthermore, the call reports, for the study period, contain information regarding *Other borrowings* with maturity up to one year, that were distributed to the first two time buckets in proportion of 70:30. The *Other borrowings* with maturity greater than one year were distributed to time buckets: 1-3Y, 3-5Y. The *Subordinated Notes and Debentures* have a maturity greater than 5 years and were attributed to: 5-15Y and >15Y maturity bands in proportion of 60:40.

The call reports offer information regarding the amount of interest bearing and non-interest bearing deposits. The non-interest bearing deposits were added to the item *Total Non-Interest Bearing Liabilities.*

The *Demand Deposits, Now & ATS Accounts, Money Market Deposit Accounts* presume a special treatment. These instruments do not have an initial specified contractual maturity. Furthermore, they may and may not be interest-bearing. In case they are, their interest rate can be continuously adjusted. Although Hannan and Berger (1991)[30] showed that these changes can be very sticky and may trigger a relatively long maturity.

[30] *Hannan, T. H., & Berger, A. N.. (1991). The Rigidity of Prices: Evidence from the Banking Industry. The American Economic Review, 81(4), 938–945. Retrieved from http://www.jstor.org/stable/2006653*

Bearing these characteristics in mind, these funds were divided into two groups[31]: the stable (core) deposits and the unstable deposits. They were split in a proportion of 50:50. The unstable deposits were assumed to have a zero maturity and were attributed to the first time bucket. Moreover, their interest rates are considered to re-prince within a quarter.

The core deposits, on the other hand were distributed into time buckets per guidelines issued by the Basel Committee on Banking Supervision according to the classification from figure 9. They were attributed to the time buckets up to six years under the uniform approach.

Figure 9 Weight of time buckets for core deposits under the uniform slotting

ON	O/N<t_2≦1M	1M< t_3 ≦3M	3M< t_4 ≦6 M	6M< t_5 ≦9 M	9M< t_6 ≦1 Y	1Y< t_7 ≦1.5Y	1.5Y< t_8 ≦2Y	2Y< t_9 ≦3Y	3Y< t_{10} ≦4Y	4Y < t_{11} ≦ 5Y	5Y< t_{12} ≦6Y	$t_{13>12}$ > 6Y
0	1/72	2/72	3/72	3/72	3/72	6/72	6/72	12/72	12/72	12/72	12/72	0

Source: Interest rate risk in the banking book; http://www.bis.org/bcbs/publ/d319.pdf

The potential NII changes will be composed and analysed by using the interest rate simulation. The future short term interest rate is simulated by applying Vasicek model. Vasicek model follows:

$$dr = k(\theta - r_t)dt + \delta dW_t.$$

The k, θ and δ are constants and were estimated by using historical data of effective fed funds rate starting with 2008-10-01 to 2016-01-01, on a quarter bases. Their estimated values that were used for further simulations are:

the long term mean (θ)	0.001344
the mean reverting speed(k)	0.707222
volatility (δ)	0.000516

The interest rate simulation and the ΔNII were simulated by using R programming language.

[31] *Risk management in banking. Fourth edition. Chichester, West Sussex, UK: Wiley, 2015. ISBN 978-1-118-66021-8; p 284;*

4.3.2 RESULTS

Tables 6, 7, 8, 9, 10 depict the residual maturity for balance sheet assets and liabilities. Due to the assumptions that have been made, the results are expected to be different than the real ones.

The model advantages and limitations have already been discussed in the second chapter. Every bank has its own methodology for classifying its instruments into time buckets. Results fully depend on the paths used. For the purpose of this thesis, the used methodology contains several assumptions which will make the results different from the actual bank's results.

These tables are covering the study period starting with 2015Q1 to 2016Q1. Morgan Stanley has shown a positive gap for every quarter for the maturity bucket 0-3M. The rest of the maturity buckets are showing positive and negative values.

From the short-term perspective the bank has an adequate liquidity position. It is able to meet its liabilities on time, since the RSAs exceed RSLs. The bank is safe and it's not exposed to interest rate risk in short run. The gap, maturing in 3 M is fluctuating during 2015 and reaches almost the same level for 2015Q4 and 2016Q1. The 0-3M gap of 2016Q1 has increased compared to 2015Q1, reaching 126% of its value.

The maturity periods: 3-12M, 1-3Y, 3-5Y, 5-15Y and >15Y have shown positive and negative balances and a fluctuating gap ratio though the entire study period. Within these maturity buckets, the bank is facing surplus of funds for positive gaps and insufficiency of funds for negative gaps. The negative maturity gaps expose the bank to interest rate risk and may generate a decrease in NII if the market interest rates will increase.

The GAP ratios are also showing a fluctuation trend for all maturity buckets over the entire study period. The first maturity gap ratio, 0-3M, doesn't show a constant trend. However, it has increased from 127.82% in 2015Q1 to 132.46 % in 2016Q1.

Table 6 Residual Maturity 2015Q1

Residual Maturity as of 31.03.2015 (dollar figures in thousands)								
Assets:	*Total*	*0-3M*	*3-12M*	*1-3Y*	*3-5Y*	*5-15Y*	*>15Y*	*Non-Maturity*
Total Loans & Leases	*49,491,000*	*44,112,000*	*326,000*	*1,440,000*	*1,018,000*	*2,532,000*	*63,000*	
Total Debt Securities	*52,409,000*	*6,089,333*	*1,540,333*	*16,567,334*	*12,455,000*	*8,260,000*	*7,497,000*	
Interest-Bearing Bank Balances	*16,294,000*	*16,294,000*						
Federal Funds Sold & Re-sales	*5,959,000*	*5,959,000*						
Trading Account Assets	*1,048,000*	*733,600*	*314,400*					
Risk Sensitive Assets (RSA)	**125,201,000**	**73,187,933**	**2,180,733**	**18,007,334**	**13,473,000**	**10,792,000**	**7,560,000**	
LN&LS Allowance	- *111,000*							- *111,000*
Total Non-Interest Earning Assets	*1,767,000*							*1,767,000*
Total Assets	*126,857,000*							
Liabilities:								
Total Deposits	*109,581,000*	*57,073,438*	*6,848,813*	*18,263,500*	*18,263,500*	*9,131,750*		
Other Borrowing Mat < 1 Year	*264,000*	*184,800*	*79,200*			-		
Other Borrowing Mat > 1 Year	*1,873,000*			*223,800*	*149,200*	*900,000*	*600,000*	
Risk Sensitive Liabilities (RSL)	**111,718,000**	**57,258,238**	**6,928,013**	**18,487,300**	**18,412,700**	**10,031,750**	**600,000**	
Total Non-Interest Bearing Liabilities	*15,139,000*							*15,139,000*
Total Liabilities & Capital	*126,857,000*							
GAP	**13,483,000**	**15,929,696**	- **4,747,280**	- **479,966**	- **4,939,700**	**760,250**	**6,960,000**	- **13,483,000**
Cumulative GAP		15,929,696	11,182,416	10,702,450	5,762,750	6,523,000	13,483,000	-
GAP Ratio	**112.07%**	**127.82%**	**31.48%**	**97.40%**	**73.17%**	**107.58%**	**1260.00%**	

Source: own creation; data FDIC;

Table 7 Residual Maturity 2015Q2

Residual Maturity as of 30.06.2015 (dollar figures in thousands)								
Assets:	*Total*	*0-3M*	*3-12M*	*1-3Y*	*3-5Y*	*5-15Y*	*>15Y*	*Non-Maturity*
Total Loans & Leases	*53,609,000*	*48,095,000*	*910,000*	*1,439,000*	*1,170,000*	*1,935,000*	*60,000*	
Total Debt Securities	*49,222,000*	*5,736,000*	*1,507,000*	*14,503,000*	*9,489,000*	*8,427,000*	*9,560,000*	
Interest-Bearing Bank Balances	*17,360,000*	*17,360,000*						
Federal Funds Sold & Re-sales	*4,593,000*	*4,593,000*						
Trading Account Assets	*265,000*	*185,500*	*79,500*					
Risk Sensitive Assets (RSA)	**125,049,000**	**75,969,500**	**2,496,500**	**15,942,000**	**10,659,000**	**10,362,000**	**9,620,000**	
LN&LS Allowance	*- 114,000*							*- 114,000*
Total Non-Interest Earning Assets	*1,708,000*							*1,708,000*
Total Assets	*126,643,000*							
Liabilities:								
Total Deposits	*110,257,000*	*57,425,521*	*6,891,063*	*18,376,167*	*18,376,167*	*9,188,083*		
Other Borrowing Mat < 1 Year	*271,000*	*189,700*	*81,300*					
Other Borrowing Mat > 1 Year	*1,853,000*			*211,800*	*141,200*	*900,000*	*600,000*	
Risk Sensitive Liabilities (RSL)	**112,381,000**	**57,615,221**	**6,972,363**	**18,587,967**	**18,517,367**	**10,088,083**	**600,000**	
Total Non-Interest Bearing Liabilities	*14,262,000*							*14,262,000*
Total Liabilities & Capital	*126,643,000*							
GAP	**12,668,000**	**18,354,279**	**- 4,475,863**	**- 2,645,967**	**- 7,858,367**	**273,917**	**9,020,000**	**- 12,668,000**
Cumulative GAP		18,354,279	13,878,417	11,232,450	3,374,083	3,648,000	12,668,000	-
GAP Ratio	**111.27%**	**131.86%**	**35.81%**	**85.77%**	**57.56%**	**102.72%**	**1603.33%**	

Source: own creation; data FDIC

Table 8 Residual Maturity Q3

Residual Maturity as of 30.09.2015 (dollar figures in thousands)								
Assets:	*Total*	*0-3M*	*3-12M*	*1-3Y*	*3-5Y*	*5-15Y*	*>15Y*	*Non-Maturity*
Total Loans & Leases	*52,969,000*	*48,350,000*	*386,000*	*1,625,000*	*1,003,000*	*1,605,000*		
Total Debt Securities	*48,200,000*	*5,631,333*	*1,655,333*	*15,664,334*	*8,872,000*	*7,454,000*	*8,923,000*	
Interest-Bearing Bank Balances	*23,807,000*	*23,807,000*						
Federal Funds Sold & Re-sales	*3,791,000*	*3,791,000*						
Trading Account Assets	*156,000*	*109,200*	*46,800*					
Risk Sensitive Assets (RSA)	**128,923,000**	**81,688,533**	**2,088,133**	**17,289,334**	**9,875,000**	**9,059,000**	**8,923,000**	
LN&LS Allowance	- *111,000*							- *111,000*
Total Non-Interest Earning Assets	*1,866,000*							*1,866,000*
Total Assets	*130,678,000*							
Liabilities:								
Total Deposits	*112,078,000*	*58,373,958*	*7,004,875*	*18,679,667*	*18,679,667*	*9,339,833*		
Other Borrowing Mat < 1 Year	*392,000*	*274,400*	*117,600*					
Other Borrowing Mat > 1 Year	*1,572,000*			*43,200*	*28,800*	*900,000*	*600,000*	
Risk Sensitive Liabilities (RSL)	**114,042,000**	**58,648,358**	**7,122,475**	**18,722,867**	**18,708,467**	**10,239,833**	**600,000**	
Total Non-Interest Bearing Liabilities	*16,636,000*							*16,636,000*
Total Liabilities & Capital	*130,678,000*							
GAP	**14,881,000**	**23,040,175**	**- 5,034,342**	**- 1,433,533**	**- 8,833,467**	**- 1,180,833**	**8,323,000**	**- 14,881,000**
Cumulative GAP		23,040,175	18,005,833	16,572,300	7,738,833	6,558,000	14,881,000	-
GAP Ratio	**113.05%**	**139.29%**	**29.32%**	**92.34%**	**52.78%**	**88.47%**	**1487.17%**	

Source: own creation; data FDIC;

Table 9 Residual Maturity 2015Q4

Residual Maturity as of 31.12.2015 (dollar figures in thousands)								
Assets:	*Total*	*0-3M*	*3-12M*	*1-3Y*	*3-5Y*	*5-15Y*	*>15Y*	*Non-Maturity*
Total Loans & Leases	*54,421,000*	*48,951,000*	*1,046,500*	*2,210,500*	*1,073,500*	*1,129,500*	*10,000*	
Total Debt Securities	*52,481,000*	*5,059,333*	*6,006,333*	*15,930,334*	*8,350,666*	*8,380,667*	*8,753,667*	
Interest-Bearing Bank Balances	*23,924,000*	*23,924,000*						
Federal Funds Sold & Re-sales	*3,169,000*	*3,169,000*						
Trading Account Assets	*180,000*	*126,000*	*54,000*					
Risk Sensitive Assets (RSA)	**134,175,000**	**81,229,333**	**7,106,833**	**18,140,834**	**9,424,166**	**9,510,167**	**8,763,667**	
LN&LS Allowance	- 149,000							- *149,000*
Total Non-Interest Earning Assets	*2,002,000*							*2,002,000*
Total Assets	*136,028,000*							
Liabilities:								
Total Deposits	*117,254,000*	*61,104,688*	*7,320,563*	*19,526,500*	*19,541,500*	*9,760,750*		
Other Borrowing Mat < 1 Year	*91,000*	*63,700*	*27,300*					
Other Borrowing Mat > 1 Year	*1,672,000*			*103,200*	*68,800*	*900,000*	*600,000*	
Risk Sensitive Liabilities (RSL)	**119,017,000**	**61,168,388**	**7,347,863**	**19,629,700**	**19,610,300**	**10,660,750**	**600,000**	
Total Non-Interest Bearing Liabilities	*17,011,000*							*17,011,000*
Total Liabilities & Capital	*136,028,000*							
GAP	**15,158,000**	**20,060,946**	**- 241,030**	**- 1,488,866**	**- 10,186,134**	**- 1,150,583**	**8,163,667**	**- 15,158,000**
Cumulative GAP		20,060,946	19,819,916	18,331,050	8,144,916	6,994,333	15,158,000	-
GAP Ratio	**112.74%**	**132.80%**	**96.72%**	**92.42%**	**48.06%**	**89.21%**	**1460.61%**	

Source: own creation; data FDIC

Table 10 Residual Maturity 2016Q1

Residual Maturity as of 31.03.2016 (dollar figures in thousands)								
Assets:	*Total*	*0-3M*	*3-12M*	*1-3Y*	*3-5Y*	*5-15Y*	*>15Y*	*Non-Maturity*
Total Loans & Leases	*54,243,000*	*51,067,000*	*915,000*	*676,000*	*878,000*	*638,000*	*69,000*	
Total securities	*53,773,000*	*3,622,000*	*1,382,000*	*20,079,000*	*12,859,000*	*7,617,000*	*8,214,000*	
Interest-Bearing Bank Balances	*24,211,000*	*24,211,000*						
Federal Funds Sold & Re-sales	*2,362,000*	*2,362,000*						
Trading Account Assets	*918,000*	*642,600*	*275,400*					
Risk Sensitive Assets (RSA)	**135,507,000**	**81,904,600**	**2,572,400**	**20,755,000**	**13,737,000**	**8,255,000**	**8,283,000**	
LN&LS Allowance	- 189,000							- *189,000*
Total Non-Interest Earning Assets	*1,648,000*							*1,648,000*
Total Assets	*136,966,000*							
Liabilities:								
Total Deposits	*118,109,000*	*61,788,125*	*7,341,375*	*19,582,000*	*19,609,000*	*9,788,500*		
Other Borrowing Mat < 1 Year	*64,000*	*44,800*	*19,200*					
Other Borrowing Mat > 1 Year	*2,244,000*			*446,400*	*297,600*	*900,000*	*600,000*	
Risk Sensitive Liabilities (RSL)	**120,417,000**	**61,832,925**	**7,360,575**	**20,028,400**	**19,906,600**	**10,688,500**	**600,000**	
Total Non-Interest Bearing Liabilities	*16,549,000*							*16,549,000*
Total Liabilities & Capital	*136,966,000*							
GAP	**15,090,000**	**20,071,675**	**- 4,788,175**	**726,600**	**- 6,169,600**	**- 2,433,500**	**7,683,000**	**- 15,090,000**
Cumulative GAP		20,071,675	15,283,500	16,010,100	9,840,500	7,407,000	15,090,000	-
GAP Ratio	**112.53%**	**132.46%**	**34.95%**	**103.63%**	**69.01%**	**77.23%**	**1380.50%**	

Source: own creation; data FDIC;

The overall GAP ratios (RSAs-RSLs) are also fluctuating during the study period. The increments are not significant, with the exception of 2015Q2 and 2015Q3, when it decreased to 111.27% and then sharply increased to 113.05%. Nevertheless it is greater than 100% for all quarters, which means that the RSAs are prevailing. These overall GAP ratios indicate that the bank is not disturbed about a potential parallel increase in the market interest rates. A parallel increase in all market interest rates may bust the bank's net interest margin.

The 0-3M time bucket represents the bank's short term instruments. These instruments through their pricing directly reflect the interest rates at the short end of the yield curve. A positive gap, as in this case, would generate a profit if interest rates rise and the opposite.

For a better overview, this short gap maturity can be analysed in relation with a benchmark rate. The effective fed funds rate can serve again as a perfect example. The next table depicts the evolution of this benchmark for the study period on a daily basis.

Figure 10 Effective Federal Funds Rate

Source: Federal Reserve Bank of New York;
https://research.stlouisfed.org/fred2/series/DFF;

The effective fed funds rate was almost the same for the entire 2015 year, when in December 2015, Fed increased it to a range of 0.25% to 0.5%, after keeping it at its minimum for almost seven years. Bearing this caveat in mind, the banks would want to increase their 0-3M gap, in order not to experience any loss.

This analysis generated a positive gap for the bucket 0-3M maturity. But again it should be mentioned that these calculations are based on several assumptions which make data to differ from the bank's actual real values.

The 0-3M gap for 2016Q1 reached 132.46%. A WSJ survey[32] from April 2016, predict a potential increase of the fed funds rate until the end of 2016. Bearing this caveat in mind, the bank may experience a further increase in NII within this time bucket, as the RSAs exceed the RSLs.

Although, the fed funds rate was at its minimum for a relatively long time and its simulation based on historical data may show an adverse movement in rates. Figure 11 depicts the effective fed funds rate simulation for the next four quarters. For its simulation was used Vasicek model and data starting from 2008-10-01 to 2016-01-01. The figure offers a clear picture of how every path out of 10 is tending to reach the long term mean, equal to 0.001344, denoted through the red line. Hence, the paths show a decreasing trend.

A decreasing trend in effective fed funds rate would generate a decrease in NII within maturity gap 0-3M, as the gap has a positive value due to the higher amount of the RSAs in comparison with the RSLs.

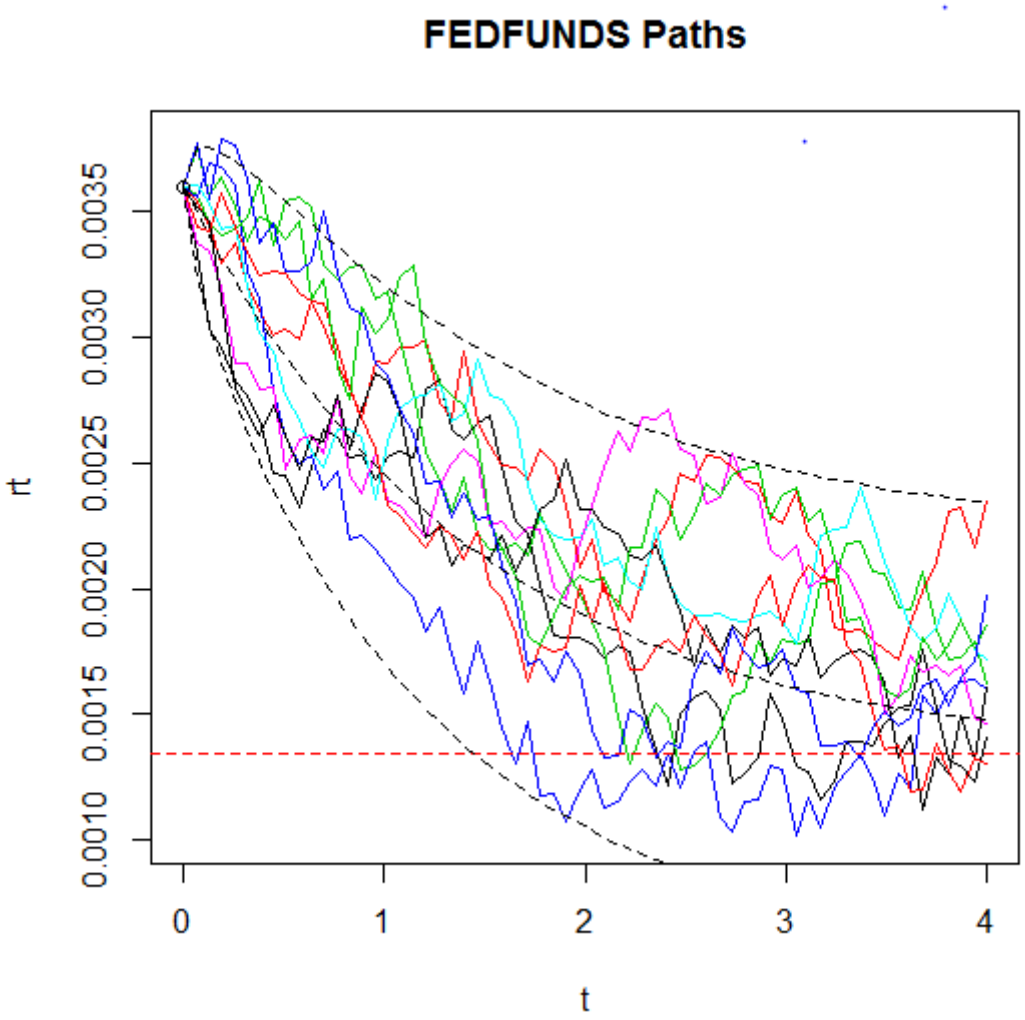
The potential decline in NII can be measured by applying the general maturity gap formula described in the *Interest rate measurement approaches*:$\Delta NII = gap \times \Delta r$. By using the 0-3M gap, equal to 20.071.675 thousands dollars, and the simulated rates, the NII changes can be easily determined. These changes are showed on the Figure 12.

If the rates will actually go back to their level, characteristic for the period before December 2015, then the bank may suffer a loss within this maturity gap in the next year, according to Figure 12, which captures the future four quarters. Of course, these

[32] *WSJ Survey: Most Economists Expect Next Fed Rate Increase in June [online]. In: . [cit. 2016-05-19]. Dostupné z: http://www.wsj.com/articles/wsj-survey-most-economists-expect-next-fed-rate-increase-in-june-1460037602*

hypothetical losses may occur just in case the 0-3M gap remains the same, which is highly doubtful.

Figure 11 FEDFUNDS Simulation



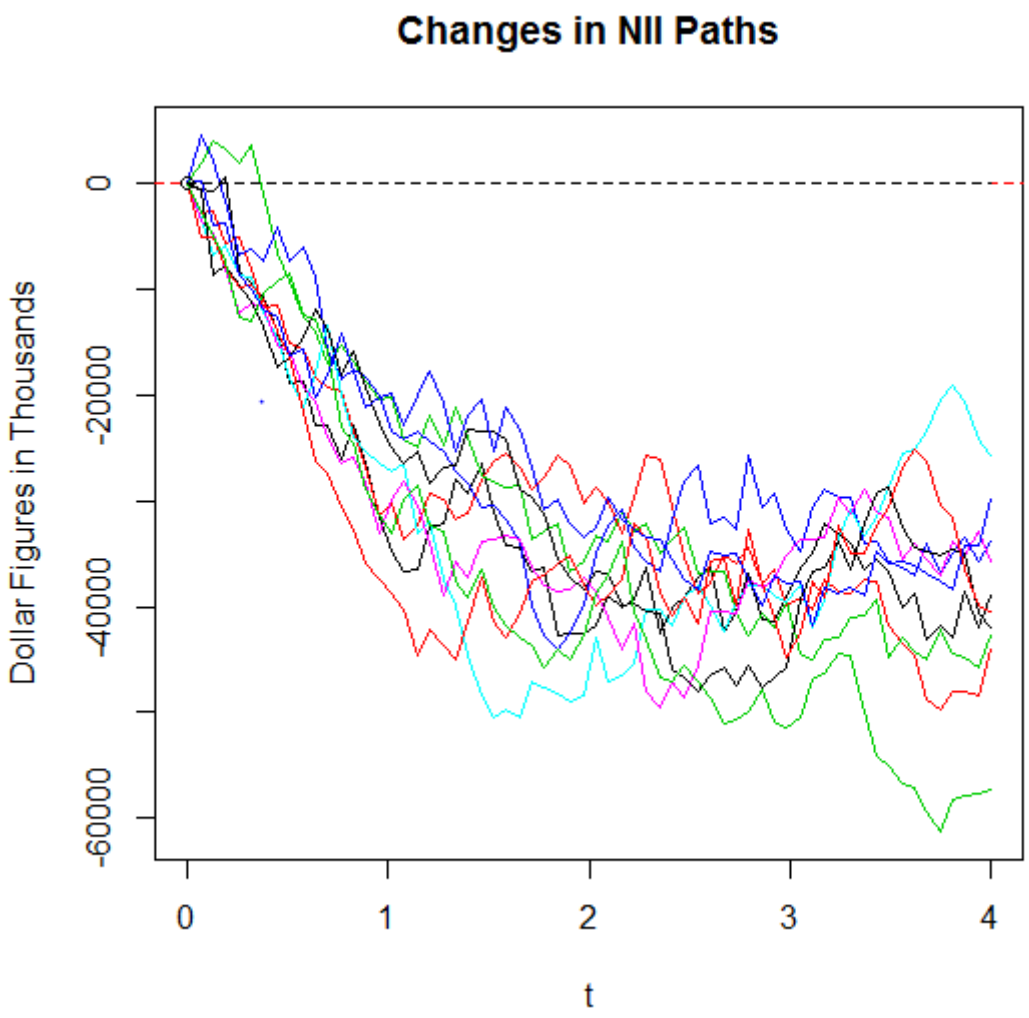
Source: own creation

In a changing interest rate environment the bank will try to adjust its positions or to hedge itself against potential losses. If the rates will decrease the banks would try to increase its RSLs within this time band or decrease its RSAs. Alternatively, for this specific situation the bank may enter into hedging contracts, for example: a long position in futures. In this way, if the rates go down, the lower NII will be compensated by the gains rising from the futures position.

Alternatively, if the rates will actually go up, the bank will experience an increase in NII. In this case, the gap value within this time band may be left as it is, although it

would be considered as a speculative position. Nevertheless, the positive gap would require again a hedging strategy in order to minimize the interest rate risk. In this particular case, would be suitable, for example again a long position in futures. Hence, the higher NII will be offset by the loss generated from the futures.

Figure 12 Potential NII Changes



Source: own creation

Morgan Stanley is known as a bank with complex activities and in order to calculate its exposure to interest rate risk would be needed relatively sophisticated tools. Furthermore, interest rate risk is just an element of the market risk and it can't be assessed just by itself in order to deliver final conclusions.

This analyse is an application of the maturity gap model and was applied on available data under certain assumptions.

CONCLUSION

Financial institutions, especially banks are exposed to different types of risk. Interest rate risk is one of them. The banking industry can't avoid it, since its balance sheet structure presents significant maturity mismatches between assets and liabilities. These mismatches need to be continuously mitigated in order to minimize or prevent losses.

This thesis intended to capture the interest rate risk theme. It offers an overview of interest rates, interest rate risk, IRR measurement systems, IRR hedging instruments. The practical part is an application of the maturity gap model, described in the second chapter. The maturity gap model was applied on real data. As real data, were used the *Morgan Stanley Bank, National Association*'s financials.

The maturity gap model represents a series of downwards, which makes the model less popular nowadays. Nevertheless, it can be applied in short run and the results are easy to interpret due to their simple assumptions and gives relatively good results even for small changes in interest rates. All the assumptions used for the purpose of this thesis were described in the methodology part. Due to their existence, the overall gap analysis may differ from the actual bank's situation.

The model's application begins with the bank's net interest income analysis. The NII was evaluated during three years and it was also connected to the fed funds rate evolution. Furthermore, the interest rate shocks were applied, which generated potential outcomes under severe conditions.

During the main model's step, the bank's assets and liabilities were distributed to time buckets in accordance to their residual maturity. The breakdowns were performed in order to acquire the individual gaps. This distribution methodology was repeated five times. This was mainly needed for evaluating the bank's balance sheet structure across five quarters. Furthermore, the maturity gap 0-3M evolution was analysed and connected to the fed funds rate. The 0-3M maturity gap registered positive values, which during an increasing interest rate environment, experienced in December 2015, may generate an increase in the bank's NII. Although the simulations based on historical data show the opposite. According to simulations the interest rates may go back to their previous level generating a decrease in NII.

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