UPPSALA
UNIVERSITET

U.U.D.M. Project Report 2015:20

An Optimization Of The Liquidity Coverage Ratio

Josephine Werne

Examensarbete i matematik, 15 hp
Handledare och examinator: Erik Ekström
Juni 2015

Department of Mathematics
Uppsala University

An Optimization Of The Liquidity Coverage Ratio

By Josephine Werne

June 7, 2015

1. Abstract

The new reform called the Liquidity Coverage Ratio will shortly be implemented in the European Union by The European Parliament and the Council. The purpose of said reform is to make the banking sector more resilient. The Liquidity Coverage Ratio requires a rather large stock of unencumbered high-quality liquid assets, called HQLA. The HQLA assets are quite stable in their nature and hence does not leave as much room for a large return as before the reform were to be taken in action.

Through Matlab, using the theories of the efficient frontier and value at risk, a code will be created for optimizing the Liquidity Coverage Ratio considering all requirements made by the Basel Committee concerning the different groups of assets affecting the Liquidity Coverage Ratio.

Conclusions drawn will be general since all investors prefer to invest in various types of assets, but nevertheless the main purpose of an optimization tailor-made for the Liquidity Coverage Ratio will be carefully analyzed to help gain knowledge for the new and upcoming reform that affects all companies and industries in the financial sector in the European Union.

2. Foreword

I would like to begin by thanking Simon Måssebäck for the support and helpful insights regarding the Matlab code and writings of this thesis. I would also like to thank Erik Ekström for the guidance of the outlines when writing my Bachelor thesis. Furthermore a big thank you to my family and friends for listening to the never ending talk about coding and mathematics.

Table Of Contents

List of Figures

3. Introduction

The time is coming for industries and companies in the financial sector all over the European Union to consider the new reform called the Liquidity Coverage Ratio (LCR). The new reform will be implemented in the European Union by The European Parliament and the Council with the purpose of making the banking sector more resilient to financial crises. The LCR was developed by the Basel Committee.

It became more and more clear as the financial crisis in 2008 was growing ever larger and deeper that the banking sector lacked an adequate storage of liquid assets to easily be converted into money in times of need. This factor made the financial crisis grow ever larger and the whole world watched on as Lehman Brothers was finally forced to file for bankruptcy. Hence, the LCR was introduced.

Although the LCR will hopefully lead to a more secure and resilient banking sector, it will probably also make larger profits less common. Profits are one of many things that drives persons and industries to excel. This rises an important question; *how can an optimization of the LCR be done to gain as much profit as possible whilst still fulfilling the requirements?*

The LCR is defined to be: (Stock of HQLA)/(Total net cash outflow over the next 30 calendar days) $\geq 100\%$.

A restriction will be made to only review the numerator of the definition. An optimization will be done using Matlab and the theories of the efficient frontier and the value at risk. Since this is a mathematical thesis all theories and information can be found in standardized textbooks concerning financial mathematics, for example: *Investment Science by David G. Luenberger*. It will therefore not be explicitly written out after every section where the information has been found.

4. Background

A new reform will be implemented during 2015 in the European Union by The European Parliament and the Council to make the banking sector more resilient, called the LCR. The goal of the LCR is to ensure that the banking sector will be less sensitive to different shocks in the markets. This reduces the risks of spillover scenarios from the financial sector to the real economy and thus minimizes the risks of large financial crises, such as the world experienced in 2008 and forward.

A problem that arose from the financial crisis in 2008 was that there was not enough assets, liquid or non-liquid, available to the banks or financial institutes. This resulted in a shortage of the transferring of money between financial institutes among other problems and later led to the bankruptcy of Lehman Brothers.

The LCR will guarantee that the banking sector will have an adequate amount of unencumbered high-quality liquid assets, also called HQLA, that can easily be converted into money to meet the liquidity requirements for a 30 calendar days liquidity stress scenario.

The ongoing tensions in the financial markets, an effect from the financial crisis starting in 2008, have set the terms for the introduction of the LCR. It will be phased in step-by-step minding the tensions. It will be required to have a minimum of 60% 1st of October 2015 (1st of January 2015 was recommended by the Basel Committee), 70% 1st of January 2016, 80% 1st of January 2017 and 100% 1st of January 2018. The Basel Committee states the assets includable in the LCR. The assets includable in LCR will also be divided into different subgroups, depending on the nature of the asset. There will be four subgroups:

1. Level 1 assets excluding extremely high quality covered bonds, EHQCB
2. Level 1 assets including extremely high quality covered bonds, EHQCB
3. Level 2A assets
4. Level 2B assets

Level 1 assets excluding EHQCB are usually among the safest assets considering the risks and therefore more liquid, while Level 2B assets usually are the riskiest and so less liquid. Alternatively, Level 1 assets excluding EHQCB usually yield the least profit and Level 2B the most profit.

Not only does there exist subgroups, but these subgroups also have to meet certain constraints:

1. Level 1 assets excluding EHQCB should constitute at least 30% of the portfolio.
2. Level 1 assets including EHQCB should constitute at least 60% of the portfolio.
3. Level 2A assets cannot constitute more than 25% of the portfolio.
4. Level 2B assets cannot constitute more than 15% of the portfolio.

With some assets one also has to consider different haircuts. A haircut means that you cannot assimilate the whole value of the asset if you supposedly have to sell the asset within a short notice. Depending on the asset you have to consider different haircuts, some assets have zero haircut and some have, for example, a 15% haircut. Meaning only 85% of the asset value can be accounted for in your calculations.

In periods of shocks or stress the Basel Committee ensures that falling below the minimum requirement is quite all right. This means that, if in need, financial institutions are allowed to use their stock of HQLA without being reprimanded by the financial supervisory authority.

The definition of the LCR is as follows: (Stock of HQLA)/(Total net cash outflow over the next 30 calendar days) $\geq$ 100%.

The LCR is most likely going to have a rather large impact in the financial sector with its institutions. The large profits prior to the LCR will possibly be no more because of the nature of the HQLA among others. The question now is, how much profit can one make whilst still fulfilling the LCR? That is, while meeting the requirements and constraints, how can one optimize the portfolio and make as much profit as possible?

This thesis will cover exactly that; how much should one allocate in each level of assets in the LCR portfolio for optimal profit and minimal risk.

5. Mean-Variance Portfolio Theory

Making an investment today is not an unusual thing to do, quite the opposite. Both households and companies make investments, either for the near future or for the longer perspective. Regardless the reason why we are making an investment, it is typical that the initial capital outlay is known but not the amount of return.

In this section I will restrict myself to the assumption that there is only a single investment period, that is, I invest my money at time zero and after a period, payoff is attained. This is not always a bad assumption, when for example buying a house you invest money when buying it and payoff is attained when you sell the house, at the end of the period. Although this is true in some cases, for most cases it is not correct to assume a single investment period.

For the analysis part of this section, let us first turn to basic definitions.

Definition: An investment instrument that can be bought and sold is frequently called an **asset**.

□

Suppose now that you purchase, or invest in, an asset at time zero and two years later you sell the asset.

Definition: The **total return** of your investment is: total return $= \frac{\text{amount received}}{\text{amount invested}}$. Call the total return R, the amount received X and the amount invested Y.

□

Definition: The **rate of return** is: rate of return $= \frac{X-Y}{Y}$. Call the rate of return r.

□

Clearly, $R = 1 + r$ and can be rewritten as $X = (1 + r)Y$.

Suppose now that there are n different assets. We can form a **portfolio** with these n

assets. This can be done by allocating an amount Z among the n assets. Continue on by selecting amount Z_i, $i = 1, \ldots, n$, such that $\sum_{i=1}^{n} Z_i = Z$ and Z_i represents the amount chosen to be invested in asset i.

Definition: A **portfolio** is a combination of n assets, where $n \in \mathbb{N}$

□

The amount invested can also be denoted as fractions of the total investment, we can write:

$Z_i = w_i \times Z, i = 1, \ldots, n$

Where w_i symbolizes the **weight** or fraction of asset i in the portfolio.

Definition: The **weight** indicates a percentage composition of the total amount invested in a particular asset.

For obvious reasons, $\sum_{i=1}^{n} w_i = 1$.

□

This leads us to the first theorem concerning Mean-Variance Portfolio Theory:

Theorem: Both the total return and the rate of return of a portfolio of assets are equal to the weighted sum of the corresponding individual asset returns, with the weight of an asset being its relative weight (in purchase cost) in the portfolio; that is,

$$R = \sum_{i=1}^{n} w_i \times R_i \qquad\qquad r = \sum_{i=1}^{n} w_i \times r_i$$

□

As said previously, often the amount of money to be received when selling an asset is uncertain at the time you purchase the asset. The return can therefore be described as random and can be presented in probabilistic terminologies.

Definition: A **random variable** is a variable subject to slight variations due to chance. The random variable can take on a set of different values each associated with a certain probability.

□

A frequently used example of a random variable is that of a six-sided die. Keep this example in mind since I intend to use it often to help demonstrate some definitions.

Example: ***Six-sided die***: The six possible values for the random variable (here the die itself) are either 1,2,3,4,5 or 6. All possible values have the same probability: $\frac{1}{6}$.

Suppose now that X is a random variable that can take on a finite set of values, let the values be represented by $X_1, X_, \ldots$, each value is accompanied by a probability $p_1, \ldots$

Definition: The **expected value**, $\mathbf{E(}X\mathbf{)}$, of a random variable X for the case where X can take on a set of finite values is defined as:

$$\mathrm{E}(X) = \sum_{i=1}^{n} p_i \times X_i$$

Also called **mean** or **mean-value**.

□

Continuation of example: ***Six-sided die***: $\mathrm{E}(X) = \frac{1}{6}(1+2+3+4+5+6) = 3.5$. Meaning that the average value the die will show is 3.5.

The expected value of a random variable is important to know, but one also should know other properties of the random variable such as the **variance**. The variance is a measure of the degree of the possible deviation from the mean-value. This is an important outcome for the calculations and understanding of portfolio theory. Another measure of how much the random variable can deviate from the mean-value is the **standard deviation**.

Definition: The **variance**, $\mathbf{V(}X\mathbf{)}$, and the **standard deviation**, $\mathbf{D(}X\mathbf{)}$, are defined as:

$$\mathrm{V}(X) = (\mathrm{E}((X - \mathrm{E}(X))^2)) \qquad \mathrm{D}(X) = \sqrt{\mathrm{V}(X)}$$

You can simplify the expression for the variance by noticing that:

$$V(X) = E(X^2) - (E(X))^2$$

□

Continuation of example: ***Six-sided die***:

$V(X) = \frac{1}{6}(1 + 4 + 9 + 16 + 25 + 36)$ - $(3.5)^2 = 2.92$ and therefore:
$D(X) = \sqrt{V(X)} = 1.71$

Not all random variables that are of interest are studied alone, most come for example in pairs. These pairs can either be **dependent** or **independent**. The meaning of independence and dependence can easily be imagined by the following illustration; the case where I go to the supermarket combined with that it's raining is not dependent of each other. The case where I go to the supermarket combined with the case that I have no food left is on the other hand dependent of each other. This is a rather easy illustration, but the point is that you get the essence about dependence and independence for the next section.

The random pairs joint dependence can be usefully summarized by their **covariance**.

Definition: Suppose X and Y are two random variables with mean-values x and y. The **covariance**, **cov**(X, Y), is defined to be:

$$\text{cov}(X, Y) = E((X - x)(Y - y)) = E(XY) - xy$$

If the covariance is zero the pair are said to be **uncorrelated**. Independence between a pair is the same as to say that the pair are uncorrelated. If $\text{cov}(X, Y) > 0$ then they are **positively correlated**. Reversed for $\text{cov}(X, Y) < 0$.

□

Definition: Let X and Y be as above, by linearity:

$$E(X + Y) = x + y$$

$$V(X + Y) = V(X) + 2\,\text{cov}(X, Y) + V(Y)$$

□

Let us now get back to where we started. What does all this have to do with the LCR?

Well, to optimize the LCR you have to be familiar with all the basics before trying to go into the deeper analysis. I have chosen to optimize the LCR by using a model called the Markowitz model, a sub model to the Efficient Frontier, which I will get back to later. Let us first note some things about portfolios, to get a handle on the issue at hand.

Suppose now that there is a portfolio containing n assets with corresponding random rates of returns, $R_1 \ldots,\ R_n$. Each having the expected value $\mathrm{E}(R_1) = r_1, \ldots, \mathrm{E}(R_n) = r_n$. The rate of return for the portfolio is therefore:

$$R = w_1 \times R_1 + \cdots + w_n \times R_n$$

And the expected value is:

$$\mathrm{E}(R) = w_1 \times \mathrm{E}(R_1) + \cdots + w_n \times \mathrm{E}(R_n)$$

Observe that finding the expected value for the portfolio is rather easy once we have access to the expected values for the individual assets contained in the portfolio.

The variance is found by:
(Let σ_{ij} denote the covariance of return of asset i with asset j):

$$\mathrm{V}(R) = \sum_{i,j=1}^{n} w_i \times w_j \times \sigma_{ij}$$

5.1. The Efficient Frontier

The Efficient Frontier is a concept in modern portfolio theory that optimizes portfolios. It is defined to be a set of optimal portfolios that provide the highest expected return given a level of risk or, if you prefer, the lowest risk for a given level of expected return.

Let there be n assets in the portfolio. Visualize forming several portfolios created from every possible weighting scheme. The portfolios created are fashioned by allowing the weighting coefficients w_i range over all possible combinations such that $\sum_{i=1}^{n} w_i = 1$. The set of points that represent portfolios is called the **feasible set**, or if you like, the **feasible region**. (See figure 1)

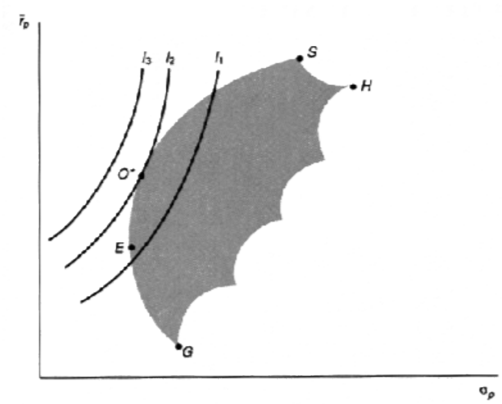

Figure 1: The Feasible Region

The left boundary of the feasible set is called the **minimum-variance set**. The minimum-variance set has a bullet shape as seen in figure 1. The boundary in the bullet shaped set is what constitutes the efficient frontier, see figure 3. There is a point on the minimum-variance set, having the least variance, called the **minimum-variance point**.

The analysis of the efficient frontier is based on the assumption that a person is both **risk averse** as well as, everything else being equal, aiming at maximizing their economic utility. To be risk averse means that given a horizontal line in the return-risk plane an investor will go for the portfolio with least standard deviation for the given mean return (e.g. risk). If the investor goes for some other portfolio on the horizontal line, not corresponding to the least standard deviation, he or she is said to be **risk preferring**.

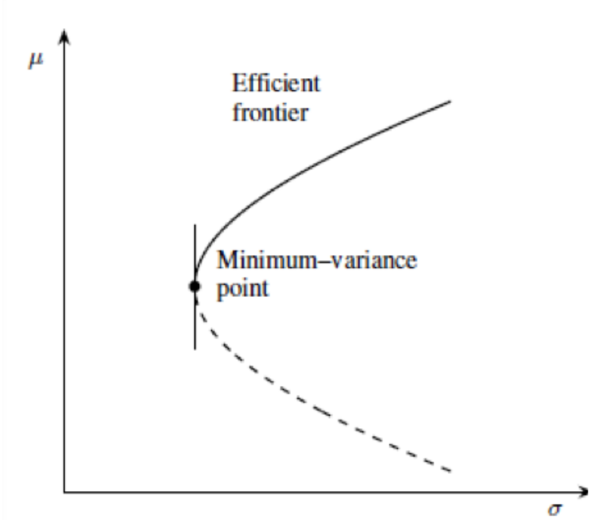

Figure 2: The Minimum-Variance Set

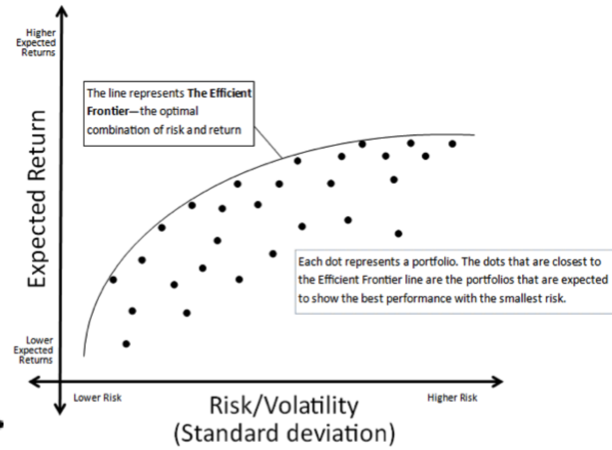

Figure 3: The Efficient Frontier

Consider now the vertical line in the return-risk plane, where there is a given standard deviation, most investors will choose the portfolio on the highest point of this vertical line. The highest point corresponds to the highest return for a given risk. This can also be shown by the indifference curves in figure 1. An indifference curve represents an investor's equal level of satisfaction given a diverse combination of goods; here the goods are the return and the risk.

All assumptions above lead to the conclusion that only the upper part of the minimum-variance set is of interest to investors that are risk averse and aiming at maximizing their economic utility. This upper part is called the **efficient frontier**.

5.2. The Markowitz Model

The **Markowitz model** is a formulation of the mathematical problem; which portfolio should one choose for best profit and least risk; this leads to minimum-variance portfolios. The Markowitz problem stipulates the foundation for the single-period investment theory. Once the problem is presented, it can be solved using numerical methods in different programs such as Matlab.

Consider again n asset with means of return $R_1, \ldots, R_n$ and corresponding covariances σ_{ij}. A single portfolio is created by some set of n weights $w_1, \ldots, w_n$ whose sum is equal to one. To find an optimal portfolio, that is a minimum-variance portfolio, consider the following problem:

$$\text{Minimize } \tfrac{1}{2}\textstyle\sum_{i,j=1}^{n} w_i \times w_j \times \sigma_{ij}$$

$$\text{Subject to } \textstyle\sum_{i=1}^{n} w_i \times R_i = R$$

$$\textstyle\sum_{i=1}^{n} w_i = 1$$

$$w_i \geq 0$$

To solve the Markowitz problem you can make use of the Lagrange multipliers λ and μ.

Theorem: The n portfolio weights w_i for i=1, $\ldots$,n and the two Lagrange multipliers λ and μ for an efficient portfolio having mean rate of return R satisfies:

$$\textstyle\sum_{i.j=1}^{n} w_i \times \sigma_{ij} - \lambda \times R_i - \mu = 0 \qquad (1)$$

$$\textstyle\sum_{i=1}^{n} w_i \times R_i = R \qquad (2)$$

$$\textstyle\sum_{i=1}^{n} w_i = 1 \qquad (3)$$

$$w_i \geq 0 \qquad (4)$$

Constraint (1) having n equations, constraint (2) and (3) having two equations together. This sums up to a total of n+2 equations. Note that all n+2 equations are linear and thus solvable with linear algebra methods.

(Luenberger, 1998)

□

Constraint (4) corresponds to the prohibition of short sales. **Short selling** is when you sell an asset you do not own yourself. You begin by borrowing an asset from the person who owns it. Proceed by selling the asset for an amount X_0, later on you repay your loan by buying back the asset for an amount X_1 and returning the asset to the person who owned it in the first place. If the amount $X_0 > X_1$ you have made a profit, otherwise you have lost money upon the transaction. Therefore short selling is only profitable if the price of the asset declines with time. Short selling is considered a risky investment and is therefore not considered here.

Example: Short sales allowed: Let there be two assets, X and Y, uncorrelated with each other. Furthermore, let $\mathrm{E}(X) = 1$ be the expected return for asset X and $\mathrm{E}(Y) = 3$ be the expected return for asset Y. $\mathrm{V}(X) = \mathrm{V}(Y) = 1$ are the variances for the assets.
X and Y uncorrelated $\Rightarrow \sigma_{XY} = \sigma_{YX} = 0$

From this we obtain that:

$$w_X - \lambda - \mu = 0 \quad \Rightarrow \quad w_X = \lambda + \mu \qquad (1)$$
$$w_Y - 3\lambda - \mu = 0 \quad \Rightarrow \quad w_Y = 3\lambda + \mu \qquad (2)$$
$$w_X + 3w_Y = R \qquad (3)$$
$$w_X + w_Y = 1 \qquad (4)$$

Inserting equation (1) and (2) into (3) and (4) yields:

$$(\lambda + \mu) + 3(3\lambda + \mu) = R \Rightarrow 10\lambda + 4\mu = R \qquad (5)$$
$$(\lambda + \mu) + (3\lambda + \mu) = 1 \Rightarrow 4\lambda + 2\mu = 1 \qquad (6)$$

A rearrangement of equation (6) gives that: $\mu = (1 - 4\lambda)/2$ (7)
Inserting equation (7) into equation (5) leads to: $\lambda = R/2$ - 1 (8)

From this result, inserting equation (8) into equation (7), it is easily seen that:
$\mu = 3/2$ - $R/2$

Now we know that $\mu = (3$ - $R)/2$ and $\lambda = R/2$ - 1

Proceed by inserting these values of λ and μ into equation (1) and (2) to obtain values for w_X and w_Y. This yields:

$w_X = \lambda + \mu = 1/2$
$w_Y = 3\lambda + \mu = R$ - $3/2$

Now, knowing the values of w_X and w_Y, we can calculate the value for R. Inserting the values of w_X and w_Y into equation (4) thus leads to:

$w_X + w_Y = 1/2 + R - 3/2 = 1 \Rightarrow R = 2$

The standard deviation, σ, for the portfolio is given by:

$\sigma = \sqrt{w_X^2 + w_Y^2}$

Inserting the values of w_X and w_Y shows that: $\sigma = \frac{1}{\sqrt{2}}$

Thus, from the calculations above it is obtained that $R = 2$ and $\sigma = \frac{1}{\sqrt{2}}$. We then know the values of the mean rate of return and the standard deviation of the portfolio containing two assets, uncorrelated with each other.

5.3. Value at Risk

Value at Risk (VaR), is a measure of the level of financial risk over a specified time horizon and confidence level for an investors portfolio. When using VaR both time horizon and confidence level have to be specified. For liquid instruments a shorter hime horizon is preferable. For risk averse investors a higher confidence level is recommended, say 99%, if an investor is risk preferring then a lesser confidence level can be chosen for example 95% or even 90%.

The formal definition of VaR is as follows:

Definition: Let α be the confidence level chosen (i.e the risk profile), furthermore let L be the loss of the portfolio and β the smallest number such that $P(L > \beta) \leq (1 - \alpha)$. In other words:

$$\text{VaR}_\alpha(L) = \inf\{\beta \in \mathbb{R} : P(L > \beta) \leq 1 - \alpha\}$$

□

An assumption in the VaR model is that the returns of the portfolio are normally distributed. Under the assumption that the returns are normally distributed the calculations of VaR requires only an estimation of the volatility (e.g. the risk) and a choice of time horizon and confidence level. This makes VaR a fairly easy method to apply, the implementation of it is rather easy and the method is also flexible. VaR is flexible in the sense that the investor herself or himself can choose the inputs based on their own liking.

One can question the reliability and correctness of the normal distribution assumption. It has many benefits; calculations get easier. But how reliable is the assumption? Several observations have been made in that matter and found that it is not consistent with reality. The so called *tails* of the return series are much thicker than what a normal distribution approximates. The fault in the assumption leads to an underestimation of the values of VaR.

6. Method

To optimize the LCR I took use of Matlab. Due to confidentiality I will not be explaining my code in detail nor will I demonstrate it, instead an explanation will be given about the methods in the code and the use of said methods.

The code is built around the efficient frontier. The efficient frontier, as explained earlier in this thesis, is a method of finding the optimal portfolios along the frontier. The efficient frontier assumes two important matters, that an investor is risk averse and that he or she always wants more money everything else being equal. These are well thought out and justified assumptions. If you think about it, you almost always want there to be as low risk as possible for a given return. A soon to be senior citizen would not risk the entire pension for a slightly higher outcome. A working person would not turn down a raise under exactly the same working circumstances that he or she already worked in. The assumptions are justified.

The optimization of the LCR is not based on a simple efficient frontier, in its pure shape. The many constraints of the LCR had to be taken under consideration. Some groups of assets, for example Level 2B assets, are not allowed to constitute up to their possible efficient amount in the optimal portfolio. An obstacle in the thesis therefore was to implement these constraints in Matlab correctly.

Before you optimize the portfolio for the LCR the four different subgroups of assets are optimized on their own. Four efficient frontiers are created, each frontier representing each of the subgroups. This is done because we are only interested in the optimal portfolio for each subgroup to later optimize together as a single portfolio representing the LCR. The question in hand is now, which portfolio to choose as the optimal one after the first four optimizations are done? Two main options are available, either you choose the portfolio with the least standard deviation or you choose the portfolio with the least VaR (these can also coincide). I chose the portfolio with the least VaR. The benefit in choosing the portfolio with the least VaR instead of the portfolio with least standard deviation is that you get a sort of *buffer*.

The value obtained by VaR represents the maximum loss percentage of the entire optimal portfolio. Therefore, if you take in account for that percentage and add it to some constraint then you are ensured that whatever loss the assets will experience the constraints will never fall below allowed maximum/minimum value. This extra percentage is the buffer.

This buffer comes in handy when market prices go up or down. When the market prices go up or down, the optimization and the value for the VaR calculated for the optimal portfolio do not match perfectly anymore with the constraints. A buffer is then useful to make sure that the allocation of the portfolio and the constraints required are still fulfilled. The values for the VaR calculated for the four optimized sub portfolios are also important when implementing these constraints. For example, level 1 assets excluding EHQCB should constitute at least 30% of the portfolio. With that said, when market prices move, it is not a sure thing that your allocation still ensures that level 1 assets excluding EHQCB makes up 30% of your portfolio. Therefore you have to have a buffer for the constraint. With this buffer in mind and with the help of the VaR, maybe 35% of level 1 assets excluding EHQCB ensures on a monthly basis with a 99% probability that you meet the requirement of at least 30% level 1 assets excluding EHQCB.

The VaR is based on an assumption that the returns of the portfolios are normally distributed. Although it has been shown that this is not always a good assumption the value at risk is the best model for the problem at hand and is therefore used anyway.

The method used can be generalized to a lot of different areas and questions. A lot of investors nowadays prefer to invest in certain assets and dislike investing in others. An example of this is that many investors, when given the option, might choose not to invest in funds that contribute to animal abuse or weaponry. Others prefer to only invest a certain amount of money into the fast food industry etc. All these preferred matters are constraints in some way or another. Therefore my code is applicable in many areas and industries.

7. Analysis

The question in mind in this thesis was *how can an optimization of the LCR be done to gain as much profit as possible whilst still fulfilling the requirements?*. Due to the fact that investors might want to use different assets depending on their risk profile as well as their own likings a conclusive answer could not be reached.

This thesis studied the distribution among the four levels in the LCR. There will not be a general result to lean on when studying the optimization of the LCR portfolio, the question itself is so general in its nature and so the results will be general as well. Too many options in choosing assets is available for the investors. The investors are not restricted to only use assets from a certain country, for example Sweden, or forced to use a certain type of assets for that matter either. Therefore, the optimization depends on which assets the investor is interested in investing in. When the assets in interest are known an optimization can be done with the help of the code written specifically for that purpose.

Results from the code shows how to best allocate the assets in interest and takes a buffer in consideration to prevent falling below both the allowed constraints concerning the distribution among the levels and the allowed percentage of the LCR. This is an important aspect since falling below the minimum requirements is only justified when in periods of shock or stress. If a company where to fall below the minimum requirements when not in shock or stress they would be reprimanded by the country's financial supervisor.

Regardless the fact that a general result will not be represented, some partial results can be. Some of the test runs of the code containing data from yahoo.com as level 1 excluding EHQCB, level 2A and level 2B assets as well as data from riksbanken.se as EHQCB resulted in the following:

Example: Test Run 1: A confidence level of **95%** and a range of **30** possible portfolios were chosen. The optimal portfolio was then found to be:

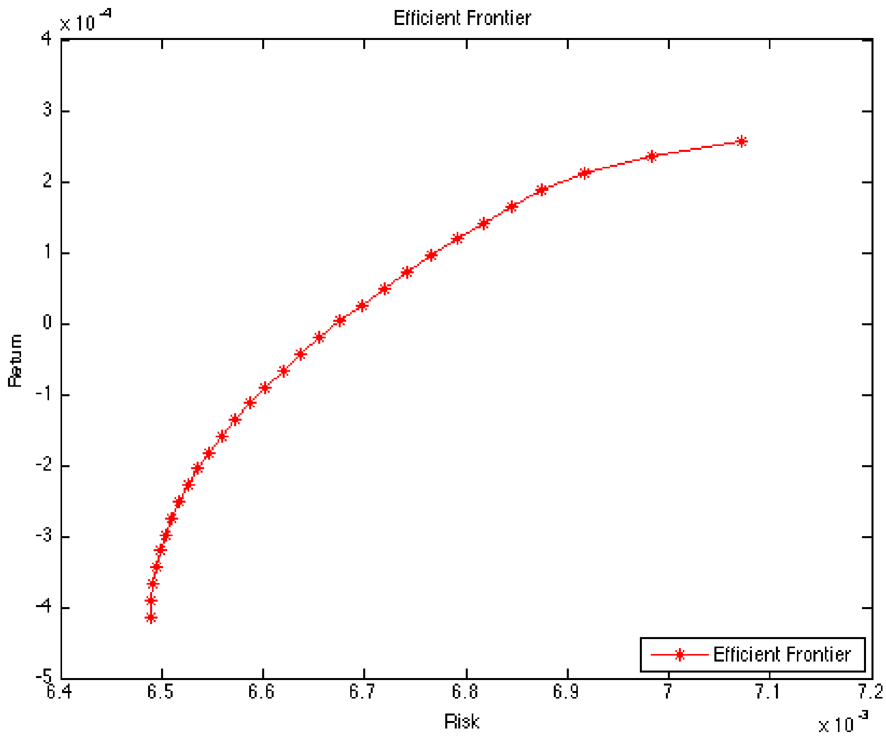

Figure 4: 95% confidence level, constraints applied. Test run 1.

31.02% of the portfolio should be put in level 1 assets excluding EHQCB.
48.60% of the portfolio should be put in EHQCB.
10.20% of the portfolio should be put in level 2A assets.
10.18% of the portfolio should be put in level 2B assets.

Example: Test Run 2: If the confidence level instead of 95% was chosen to be **99%**, everything else equal, then the following results were obtained:

31.41% of the portfolio should be put in level 1 assets excluding EHQCB.
46.10% of the portfolio should be put in EHQCB.
12.14% of the portfolio should be put in level 2A assets.
10.35% of the portfolio should be put in level 2B assets.

These two test runs shows the optimal allocation for two risk profiles based on the particular

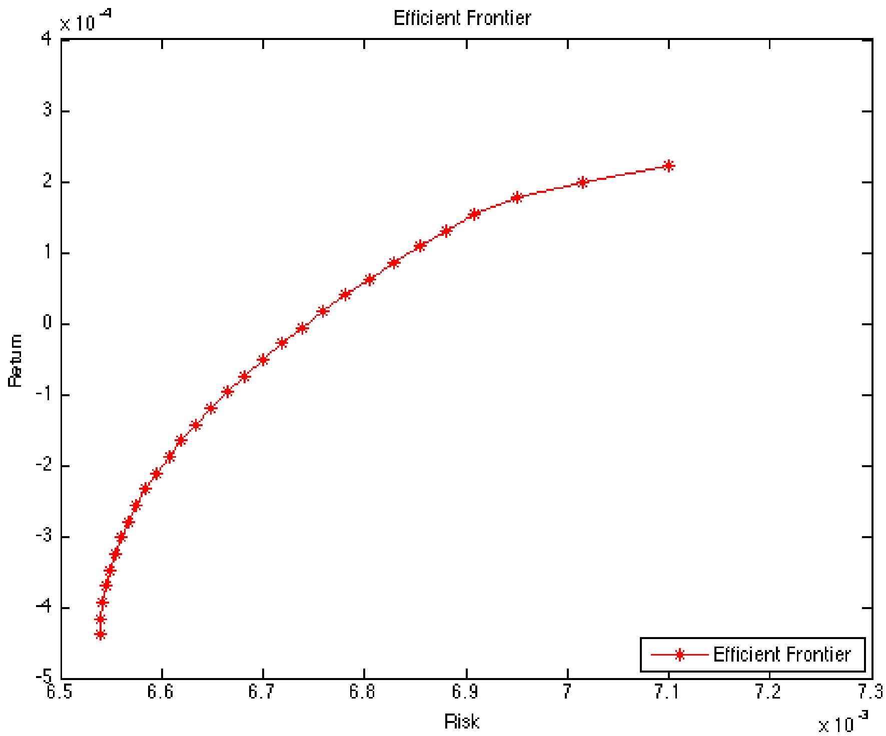

Figure 5: 99% confidence level, constraints applied. Test run 2.

input data used in these two runs of the code. The results do not represent a general result concerning the LCR, but it does represent results of the optimal allocation of the LCR from the specific data input.

Consider now running the same data used in test run 1 and 2 but without the constraints demanded by the LCR. That is, a modification of the code ensuring that, given no conditions the optimal allocation is given as a result. This second code gave the following results:

Example: Test Run 3: A confidence level of **95%** and a range of **30** possible portfolios were chosen, no limitations or constraints considered, gave the results below:

1.43% of the portfolio should be put in level 1 assets excluding EHQCB.
64.14% of the portfolio should be put in EHQCB.

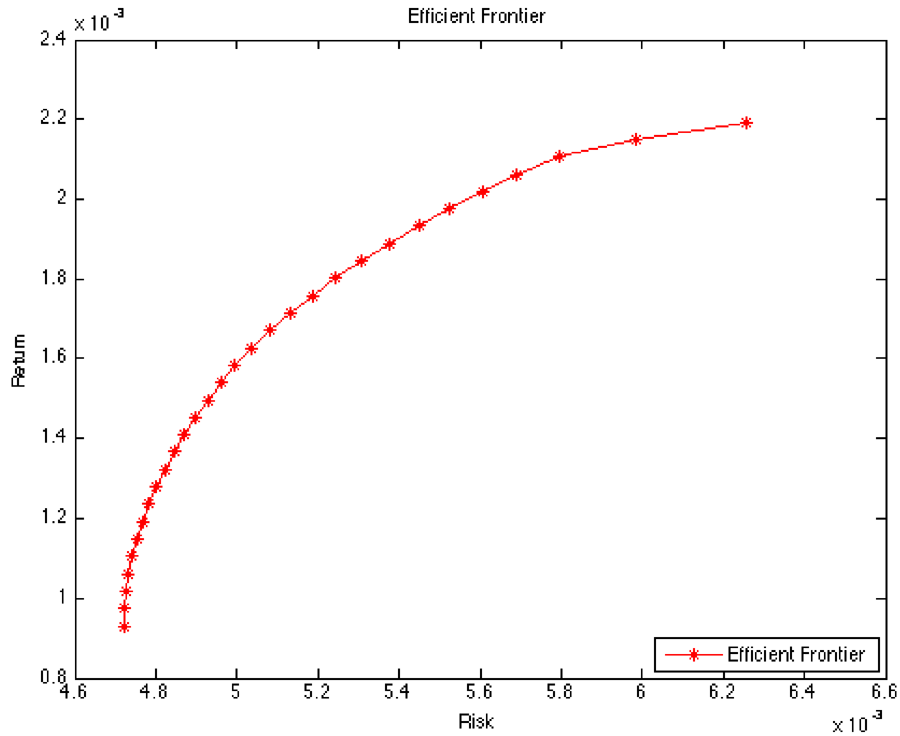

Figure 6: 95% confidence level, no constraints. Test run 3.

18.55% of the portfolio should be put in level 2A assets.
15.88% of the portfolio should be put in level 2B assets.

Example: Test Run 4: Same as test run 3 but with a 99% confidence level instead:

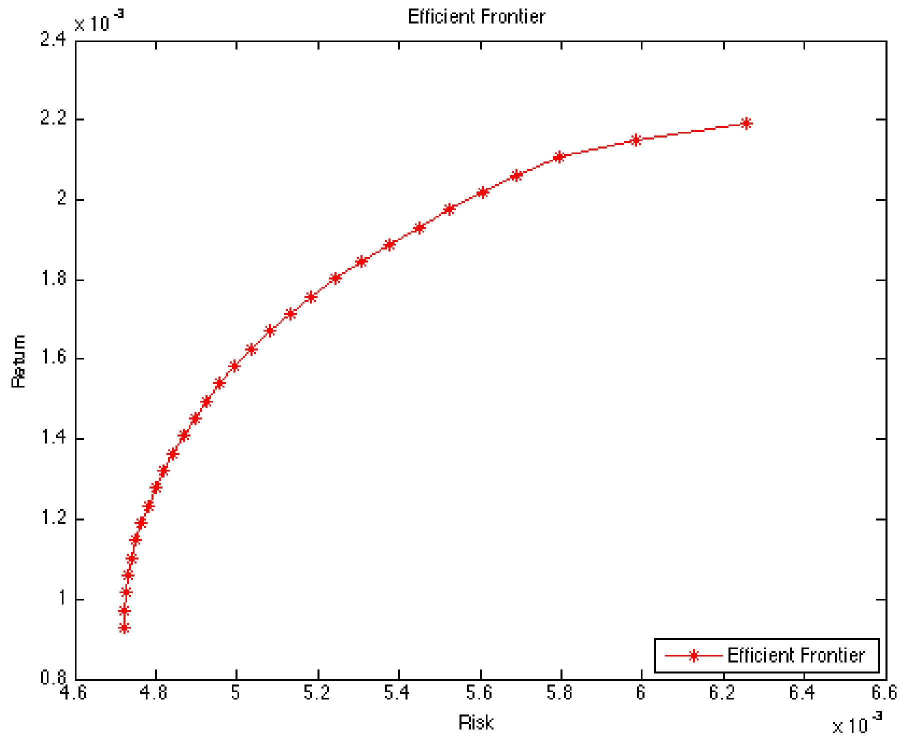

Figure 7: 99% confidence level, no constraints. Test run 4.

2.73% of the portfolio should be put in level 1 assets excluding EHQCB.
61.31% of the portfolio should be put in EHQCB.
20.12% of the portfolio should be put in level 2A assets.
15.84% of the portfolio should be put in level 2B assets.

From these four test runs some observations can be made about the particular data representing the four subgroups of assets available for the LCR keeping in mind that these partial results only stay true for the data input used in these test runs.

Test runs 1 and 2 demonstrate that as little as possible are to be placed in the level 1 assets excluding EHQCB, this can be seen by first remembering the constraint of the at least 30%

placement in these kinds of assets and then observing that only 31.02% respective 31.41% are chosen as the optimal allocation for the given confidence levels. Note also that when leaving the constraints out of the equation, only 1.43% respective 2.73% are to be invested in said subgroup.

On the other hand, the EHQCB seems to be a rather good investment. Nearly 50% are chosen to be the optimal placement when fulfilling the criteria, when not fulfilling the criteria an astonishing 64.14% or 61.31% are to be invested depending on your risk profile.

Comparing test runs 3 and 4 to the criteria of the LCR you can easily note that, in this case, the requirements are not far off from the optimal portfolios chosen, without the consideration of the constraints. When taking the constraints in consideration the picture changes, the level 2A assets no longer seem as good of an investment as before. The balance of the risks and the payoff is now a problem. To still fulfill the LCR and to make an optimal distribution among the subgroups, the highest possible percentage of allowed investment into the level 2A assets are no longer optimal. Instead a shy of 10.20% and 12.14% are the optimal choices for the distribution.

One might be a bit surprised by these results but thinking about it from another perspective makes it rather easy to understand. High risk comes with the possibility of high return, but also with the facing of a potential high loss. The risk of higher loss combined with the choice of the portfolio with the least VaR together with the required constraints of the LCR can result in (as in these cases) the low percentage being placed in the level 2A and 2B assets, as they are often associated with higher risks compared to the other two subgroups.

EHQCB are considered quite safe assets, with that said they can sometimes be associated with a lower return, but reversing the statement they are also associated with a low risk of a high loss. A high loss in EHQCB are also smaller than a high loss in level 2A or 2B assets. The low risk of a high loss indicates that they are an especially good investment considering the LCR and therefore an explanation of the considerable high percentage recommended being placed in these kinds of assets.

An explanation of the extremely low percentage recommended to be invested into level 1 assets excluding EHQCB cannot really be reached. In these cases the assets in EHQCB were simply a better choice when letting go of the percentage requirements. Level 1 assets excluding EHQCB are consider as safe assets, much like EHQCB, and therefore the results are rather puzzling. It must have been that given the data used the other three subgroups were simply better choices given the balance between risk and return. If I had used different data in that particular subgroup then a different result would most likely have been yielded so no specific conclusions about the nature of level 1 assets excluding EHQCB should be drawn by this.

As said before no specific conclusions about the optimal distribution among the subgroups should be drawn by these four test runs. They are exactly as described, test runs. Some investors are more risk averse than others and some are very risk preferring. When deciding how to best allocate your investments, with concern to the LCR, one should therefore first of all choose which assets one are interested of investing in. Second of all choose your risk preference and then third of all simulate, with the help of a code or similar (for example like one created by this thesis), the price series of the assets to gain knowledge of the optimal distribution among the subgroups that constitutes the LCR.

8. Source Reference

Printed sources:

Luenberger, David G., 1998. *Investment Science.* Oxford University Press.

Hull, J, 2007. *Risk Management and Financial Institutions.* Pearson Education.

Mankiw, Gregory N. and Taylor, Mark P., 2014. *Economics.* 3rd edition. Cengage Learning EMEA.

Other sources:

http://www.bis.org/publ/bcbs238.pdf

Data collected from:

www.riksbanken.se (http://www.riksbank.se/sv/Rantor-och-valutakurser/Sok-rantor-och-valutakurser/)

www.finance.yahoo.com (http://finance.yahoo.com/q/hp?s=YHOO)