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MURAME method for liquidity risk analysis of banks in Italy

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Contents

Introduction

The outbreak of the US subprime mortgage crisis in summer 2007 had repercussions on global financial markets and economic growth, leading to a real financial crisis. In banking sector, the financial crisis caused bankruptcies as well as the decline of the banks' financial performance despite the banks' proper capital levels. In fact, the Basel Committee which is a regulatory body of the European Union had defined just capital requirements to strengthen the banking system; this was not sufficient to prevent banks solvency problems. As a consequence, after the explosion of the financial crisis, it was necessary to introduce other standards related to liquidity requirements. So, these tensions highlighted both the importance of establishing a good liquidity risk management and the lack of banks' liquidity standards. In fact, for banks is fundamental to have a sufficient level of liquidity to cope with adverse conditions which can cause liquidity difficulties.

Basically, liquidity can be defined as the ability of a bank to fund increases in assets and to meet obligations as they come due, without incurring unacceptable losses. Financial institutions due to their primary role of intermediation are more exposed to liquidity risk respect other sectors. That is the reason for which banks need more monitoring in this area. The intermediation role refers to the banks' activity of granting loans to customers and enterprises to finance their investment and consumption needs. Problems of liquidity may arise when there is a mismatch between assets and liabilities. On the assets side, loans are generally long-term while on the liabilities side, funding sources are short or medium-term. Furthermore, they can arise also when a bank has less credit availability, an increase in withdrawals from depositors or a reduction in assets prices. All of them can trigger liquidity problems in a single bank or, in the worst case, in the entire industry. Because of that, liquidity risk assessment is fundamental to avoid future financial turmoil. In fact, when areas of weakness are detected, especially in liquidity management, the bank itself or the supervisory bodies have to intervene in order to both impede the bank's bankruptcy and reduce the liquidity tensions on other banks. This could prevent that the consequences of a bank's failure spread to the real economy.

The main problem in the evaluation of liquidity risk is that there is not a unique variable or ratio to measure it since it is very complex and can arise from different events. For this reason, in this work we propose a multicriteria method for liquidity risk assessment called MUlticriteria RAnking MEthod (MURAME) which is one of the multicriteria decision aid methods. The latter started their development in 1960s and nowadays, they give support to various types of decisions in different fields, including economic and financial ones. They need a set of alternatives and a set of criteria. In this study, the alternatives are 40 banks operating in Italy while the criterion are 10 financial ratios and the total assets. The criterion that are usually in conflict among them are used to evaluate the alternatives. The innovation introduced by MCDA is the possibility of considering more than one criteria at the same time in order to take complex decisions. To sum up, we use the MURAME in order to rank the banks according to their liquidity risk each year from 2011 to 2017. In the ranking, the banks in the highest positions are less exposed to liquidity risk respect to the banks in the lowest positions. Moreover, it is possible to classify the banks into homogeneous classes of liquidity risk. These results allow us to compare the banks among them and to determine which are the banks more exposed to liquidity tensions.

The remainder of this work is organized in five chapters starting from a qualitative introduction about liquidity risk and concluding with the MURAME application. In chapter one, we defined and explained what liquidity risk is, including its measures, mangement and regulation. In chapter two, we described the multicriteria decision aid (MCDA) methods, focusing more in detail on MURAME and the methodologies on which it is based that are ELECTRE III and PROMETHEE II; this chapter ends by reporting some real case applications in financial field. In chapter three, we pointed out the reasons that led us to the choice of MURAME, together with the liqudity risk measures used. In chapter four, after having explained the alternatives, the criteria and the parameters, we applied the method and commented its results. Finally, in chapter five, we gave some conclusions.

CHAPTER 1 – Liquidity Risk

1.1 Liquidity Risk Definition

The main providers of liquidity to the economy are banks. In recent years, banks increased their size becoming complex institutions that are more exposed to a set of risks respect the past. These risks include the operational[1] and the financial[2] risk. The latter can be divided in three main categories: market risk[3], credit risk[4] and liquidity risk[5]. The global financial crisis showed how severe these risks can be, how they can interact and how they can seriously affect the real economy. Financial institutions due to their role of intermediation, have a higher exposure to liquidity risk respect other sectors. Banks grant loans to customers and enterprises to finance their investment and consumption needs. These loans are, most of the time, funded by deposits, interbank funds and repurchase agreements. In particular, the liquid funding sources can be divided in three categories: selling liquid assets, borrowing funds in the money market and using excess cash reserve. Comparing these sources with the long-term illiquid assets which are commercial loans and mortgages, it's possible to note one of the sources of liquidity risk, in fact, the funding sources are short or medium-term while loans are, most of the time, long-term. An asset is considered liquid when it can be converted quickly and easily into cash without significant losses. Some examples are: cash, reserves representing an excess compared to reserves required by law, securities (government debt, commercial paper) and interbank loans with very short maturity (one to three days). In order to match funding sources maturity with the assets maturity, banks must increase their funding sources maturity or must reduce their loans maturity. The mismatch between maturities of assets and liabilities can lead:

- to a low level of liquidity reserves,
- to improper diversification of funding sources,
- to reduce the level of funding sources stability.

[1] It is the risk that exisitng technology or internal procedure may breakdown and/or that frauds may occur.
[2] It is the risk that existing company's cash flow is inadequate in meeting its financial obligations.
[3] It is the risk of changes in interest rates, exchange rates and other assets prices.
[4] It is the risk that future cash flow from loans and securities held by the banks may not be not paid in full.
[5] It is the risk of unexpected liabilities withdrawals forcing the banks to liquidate assets in a very short period of time and at low prices.

What described above demonstrates that banks must manage the cash inflows and outflows properly otherwise they can damage their own operations and their ability to provide liquidity. In doing so, they face a large amount of uncertainty since bank managers do not know how much liquidity the banks will need. Anyway, they can predict with a good degree of accuracy the probability of deposits withdrawn on any given day. This explains why the bank's balance sheet has the following characteristics: it is normally liquid, it has a high level of transferable assets, it has a large amount of short-term funding and it has a significant amount of contingent liability[6]. In another word, banks have a large portion of assets in the form of cash and marketable securities and a lower portion in long-term illiquid investment or fixed assets.

As said before, liabilities are, generally, short-term and volatile. They can be withdrawn, transferred or presented for repayment. Nowadays, the uncertainty, the market risk and the credit risk are increased by the use of unpredictable and optional wholesale funds[7] as source of funding. Furthermore, Achrya and Merrouche (2009) showed that the UK banks with more wholesale funding and fire sale losses during the beginning of the crisis contributed more to the transmission of shocks to the interbank market. The interbank market allows banks with short-term liquidity needs to obtain funds from other banks with temporary excess liquidity. Anyway, it cannot be efficient in providing liquidity when banks are hit by aggregated liquidity shocks. Comparing the wholesale funding respect to the traditional funding is verifiable that the former is more volatile, more expensive and more sensitive to changes in liquidity that occur in the market. As a consequence, the banks' liquidity risk increases. Other sources of uncertainty arise from activities in off-balance sheet[8] (OBS) commitments such as derivative contracts, loan commitments, leases and letters of credit.

What we said up to now shows that the performance of banks is linked to liquidity risk which depends mostly on the banks' ability to manage their funds and maturity transformation. The banks' financing ability depends on three elements. Firstly, it is

[6] A contingent liability is a liability that can happen depending on the outcome of an uncertain future event. It is recorded in the financial statement if two conditions hold: the contingency is probable and the amount of the liability can be reasonably estimated.

[7] The wholesale funding is an alternative way respect the traditional demand deposits in which banks can borrow additional funds for finance operations and manage risk. Example of wholesale funds are: Repurchase Agreement, Interbank Debt and Certificates of Deposit.

[8] Off-Balance Sheet items are assets or liabilities that do not appear on a bank's balance sheet but they are effectively assets or liabilities of the bank. So that, the bank is not the recognized legal owner of these assets or liabilities or it does not have direct legal responsability for them.

linked to the uncertainty relative to the creditworthiness of the loan portfolio. Higher the uncertainty, lower the banks' financing ability. Secondly, it is linked to the idea that markets have about banks' reputation and credibility. Higher the reputation and credibility, higher the banks' financing ability. The third element is the profitability, higher the banks' profitability, higher the banks' financing ability. From this last element, we can understand that the quantity of liquid resources is strongly related to a liquidity risk-return trade off. This means that even if banks know that they should maintain adequate access to cash or equivalents in order to respond to liquidity calls, they try to minimize liquid balances in order to maximize returns. The reason is that cash reserves do not pay or pay a little amount of interests.

Giving a unique definition of liquidity risk is impossible. In literature, there are many definitions of liquidity risk, from basic to more complex ones. The meaning of liquidity risk is different on the bases of which is the organization that is giving it and in which contest it is used.

Firstly, in order to understand what the liquidity risk is, we need a definition of liquidity. Liquidity, in a broadly way, can be seen as the resource that allows banks to replace their liabilities to meet contractual obligations[9] and to fund growth. Liquidity is useful to cover obligations that cannot be anticipated with any real prediction. The International Organization of Securities Commissions in "Sound Practices for the Management of Liquidity Risk at Securities Firms" defines the liquidity as "*to have sufficient funds to meet obligations as they arise without selling assets, or to have excess liquidity in normal environment and sufficient funding in a stress environment"*. This definition highlights that banks must be able to cover obligations in a normal and in stress situation, but it does not consider the ability to finance the expansion of banks' activities. A definition of liquidity that consider also this latter aspect is provided by the Basel Committee on Banking Supervision in "Sound Practices for Managing Liquidity in Banking Organizations" which defines liquidity as "*the ability to fund increases in assets and meet obligations as they come due, without incurring unacceptable losses"*. A definition provided by European Central Bank is "*Liquidity is understood either as a potential to liquidate assets at their book value or to roll-over the maturing funding sources"*. So,

[9] Contract obligations are those duties that each party is legally responsible for in a contract agreement.

banks can be defined liquid when they are able to obtain funding at economically reasonable level, or sell or pledge an asset at carrying prices, in order to cover expected or unexpected obligation. Thus, financial institutions when manage liquidity must consider both the costs and the time horizon. This means that banks must be able to obtain funds from current operations or from the market at reasonable costs and within a certain point in time. When banks have the inability to do that, liquidity risk arises, and it can generate loss. When banks are not able to fund at low costs, the banks' profitability decreases. This leads us to say that liquidity risk decreases the profitability of banks, both in terms of return on average assets[10] (ROAA) and return on average equities[11] (ROAE). The ability can be impeded because of asymmetries in information and the existence of incomplete markets. In fact, the quantity and quality of information available in a market is linked to the degree of liquidity. When a market is complete, there is not information asymmetry, thus, the possibility of liquidity risk is theoretically zero. In this case, assets are exchanged on the bases of their intrinsic value[12] and the banks that have solvency problems are able to find the necessary funding. Obviously, the hypothesis of no information asymmetry does not hold in the real world. The higher the probability that banks are not liquid, the higher the liquidity risk.

The liquidity risk is included in the financial risk which refers to the risk related to the finance industry. The other risks incorporated in the financial risk are market risk and credit risk. The latter refers to default risk and it is the loss caused by the failure of a counterparties in performing the money that he has borrowed, it is driven by low capitalization, low earning and excessive loan defaults. The market risk is the risk of loss due to changes in market prices.

Focusing on one of the organizations named before, the International Organization of Securities Commissions in "Sound Practices for the management of Liquidity Risk at Securities Firms" defines the liquidity risk as "*the risk to their ability to meet commitments in a timely and cost effective manner while maintain assets and, for some*

[10] Return on average assets measures the profitability of a firm's assets, and it is most often used by banks as a means to gauge financial performance. ROAA is calculated by taking net income and dividing it by average total assets.
[11] Return on average equity measures the company profitability. It is the ratio between the net income and the sum of the equity value at the beginning and at the end of the year, divided by 2.
[12] The intrinsic value is the actual value of an asset based on an underlying perception of its true value including all aspects of the business. This value may or may not be the same as the current market value.

firms, the inability to pursue profitable business opportunities and continue as a viable business due to a lack of access to sufficient cost-effective resources". The European Central Bank gives another definition of liquidity risk, connecting it with the idea of insolvency, "*liquidity risk is the risk that a counterparty or a participant in a payment or settlement system will not settle an obligation at its full value when due. Liquidity risk does not imply that the counterparty is insolvent, since it may be able to settle the required debt obligations at some unspecified time thereafter".* Anyway, liquidity risk and credit risk, as said before, are not independent. The credit risk can induce liquidity risk. If the counterparty fails to perform a contracted transaction, banks do not receive the payment, leading to liquidity deficit. Liquidity risk can be also caused by: market risk, management problems, reputational problems, regulatory difficulties and other exogenous forces. Some examples can be a cyclical credit crunch[13], sovereign events, failure of a related banks and depositor's concern about the solvency of surviving banks. A particular role is played by the quantity and the difficulty in obtaining the information. Investors who want to invest in assets need to evaluate them since they take the underlying risk. Other definitions of liquidity risk provided by the Committee of European Banking Supervisors (CEBS) in "Guidelines on the Application of the Supervisory Review Process" defining it as "*the current or prospective risk to earnings and capital arising from an institution's inability to meet its liability when they come due".*

Based on the definitions described above, liquidity risk can be induced by banks' specific elements such as their financial position or the scope of their operations. Also, the time horizon has a key role in liquidity risk as we will see. Banks must be able to manage properly the mismatch between maturities of assets and liabilities in order to avoid liquidity crisis. Referring to liquidity, the time horizon indicates a specified time in which banks have the capacity to pay their obligations such as when depositors demand immediate cash for the financial claims that they hold in the banks. On the other hand, referring to liquidity risk, the time horizon relates to the banks' future ability to meet their obligations on the basis of the predicting cash inflows and cash outflows.

[13] A credit crunch is an economic condition in which there is a decrease in lending funds to individual and corporations, it usually happens after an expansion phase and it can underline a recession phase.

1.2 Sources of Liquidity Risk

Nowadays, the liquidity risk is increased due to:

- the development of new financial instruments,
- the wide presence of discretion in many instruments[14],
- the development of payment systems operating in real time,
- the extensive use of liquidity enhancement in securitization[15] transactions.

The liquidity risk can be created by a wide range of factors. All these factors can be grouped into two big categories: endogenous forces and exogenous forces.

The endogenous factors are firm-specific, so they are directly within the banks' control. The liquidity risk can arise because of the banks inability to obtain necessary unsecured financing due to their weak credit rating, a deteriorated financial performance or their bad reputation. In fact, weakening the trust that consumers and enterprises have on the bank, can exacerbate the risk of liquidity. In such cases, any negative information regarding the banks can damage their credibility leading to bank run. As said at the beginning of the chapter, banks can incur liquidity risk due to their role of intermediation. They have to manage the mismatch between maturities of assets and liabilities since the average maturity of liabilities is lower than the average maturity of assets and to convert short-term assets and liabilities into longer-term ones and vice versa. This must be done for their own accounts and on behalf of their clients. When banks manage maturity, they must distinguish between contractual and behavioral maturity of liabilities. The latter indicates the realistic time at which the obligations will be presented for repayment, this maturity is not known and will depend on internal and external factors. It reflects how financial institutions' creditors act when the contractual due date of a liability arrives. Since the behavioral maturity is not known, creditors can present their liability for redemption causing an expected withdrawal for banks. On the other hand, the contractual maturity is well known and defined, it is the earliest time at which the obligation can be presented for repayment. The liquidity risk can be also caused by wrong business decisions, a bad

[14] The banks can use deposits and loans looking at their interests without revealing information to their clients.
[15] Securitization is the procedure in which an asset or a group of assets are converted into marketable securities, then the securitized assets are divided among investors.

corporate governance or mismanagement. All of them can lead to a deterioration of banks' credit rating, causing liquidity problem since, for the banks will be more difficult either to borrow or lend money.

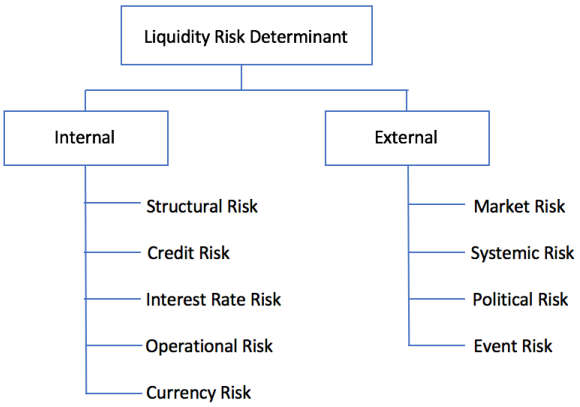
The liquidity problems can be created by both deposit drains and loan requests. Thus, the liquidity risk's reasons can be divided in asset-side and liability-side reason. On the liability-side, liquidity risk happens when banks' liability holders seek cash in their financial claims immediately. In this case, depositors or insurance policyholders make an unpredictable withdrawal that banks must meet either by borrowing additional funds (purchase liquidity management) or liquidating assets (stored liquidity management). This latter can threat the solvency of banks. Normally, banks invest in less liquid or longer-maturity assets (or both). While the major part of assets can be turned into cash easily and without incurring loss, there are some assets that can be converted into cash immediately only at high cost. Such assets can be liquidated only at low fire-sale[16] prices. This means that the asset holders receive a lower price from the sale respect the one that he would receive with a longer time horizon. The fire-sale of assets causes a depression in asset prices and it shrinks banks' assets. The main consequence is that banks obtain funding more constrained. Other drawbacks of using stored liquidity management is that banks must hold low interest rate assets in the form of cash on their balance sheet and it decreases both sides of the banks' balance sheet. In the purchase liquidity management, banks go to the markets to purchase funds such as repurchase agreement market or to issue additional fixed-maturity certificates of deposit or bonds. The use of this approach depends on the cost of purchased funds relative to rates earned on assets. The higher the cost, the less attractive is this approach.

On the asset-side, liquidity risk is linked to off-balance sheet loan commitments. When a borrower uses its loan commitments, then banks must fund the loan immediately creating a demand for liquidity. So, when a loan commitment is exercised by borrower, banks need to provide money immediately to them. Liquidity requirements from take down of funds can be met by running down cash assets, selling liquid assets or additional borrowing.

[16] A fire sale consists in selling assets at heavily discounted prices. In the context of the financial markets, a fire sale refers to a situation where securities that are trading well below their intrinsic value.

The second category of liquidity risk sources are exogenous forces. These are outside the control of the banks and depend on the market and economy condition such as cyclical credit crunch or negative market actions. If the market does not work in an efficient way, it can impede the access of funding for many financial institutions, especially those that depend more on wholesale funding.

The determinates[17] of liquidity risk are summarized in the graph below.



1.3 Connection between Credit and Liquidity Risk

The liquidity risk is not independent on the other risks, in particular it is strictly connected with the credit risk. Their interaction influences in a negative way the bank stability. Banks need a protection as well as depositors. This means that depositors must be protected by banks failures and banks must be protected from financial risks. Cecchetti and Schenholts (2011) include in the financial risks: the liquidity risk, the credit risk, the interest rate risk and the operational risk. More in details, they define:

- liquidy risk as the possibility that depositors will immediately withdraw their deposits,
- credit risk as the borrowers' incapability to repay their loans on time,

[17] The structural risk is the risk of having a bad financial system that makes more vulnerable to a shock; the interest rate risk is the risk that an investment's value will change due to a change in the absolute level of interest rates or in any other interest rate relationship; the currency risk is the risk that arises from the change in price of one currency in relation to another; the systemic risk is the possibility that an event at the company level could trigger severe instability or collapse in the entire industry or economy; the political risk is the risk an investment's returns could suffer as a result of political changes or instability in a country; the event risk is the possibility that an unforeseen event will negatively affect a company, industry or security.

- interest rates risk as the risk linked to the changes in interest rates,
- operational risk as the failing in the banks' computer systems.

Among these risks, the most important are liquidity and credit risk, furthermore, they are closely linked as confirmed by classic theories in microeconomics of banking. The major part of the literature also defines a positive correlation between credit and liquidity risks. The strong connection is based on the core function of banking which is creating liquidity in the economy. Banks execute their primary role by financing consumers or enterprises projects or by opening credit lines (Holmstrom & Tirole; Kashyap et al. 2002). There are many other authors that studied this relationship and they reached the same conclusion. Samartin (2003) and Iyer and Puri (2012) established that these risks are positively related and contribute to bank instability. Diamond and Rajan (2005) agree on the positive relationship. They showed that when banks are not able to meet the depositors' demand because they fund projects with loans, the depositors will claim back their money if the assets become progressively worse in value. Many studies in different countries such as in US, Nigeria, Iran, Central and Eastern Europe also confirmed the positive relationship between liquidity and credit risk. Furthermore, higher the banks' reliability on interbank market, higher the exposure to these risks. Leading to the conclusion that the probability of bankruptcy is higher for banks that rely more on interbank markets or in other words, the risk of bankruptcy is higher for banks that have low liquidity structure and high leverage. Anyway, there are also other studies that do not agree, such as Louati, Abida, and Boujelbene (2015) examined the bahaviour of Islamic and Conventional banks, they found that there is a significant negative relationship between liquidity and credit risk in conventional banks.

1.4 Types of Liquidity Risk

The liquidity risk can be divided into two main classes that are the funding liquidity risk and the markets liquidity risk.

Starting from the funding liquidity risk, the European Central Bank in one of its papers, said that "*funding liquidity risk is driven by the possibility that over a specific horizon the bank will become unable to settle obligations with immediacy*." The banks' funding decision can have an impact on the vulnerability of other banks due to fire sales or counterparty risk externalities. So, following the idea of Perotti and Suarez (2009), even

if the individual bank's funding decision is made taking into account the bank's exposure to refinancing risk, it will fail to internalize its system-wide implications. The funding liquidity risk includes two elements, the first one is future random money inflows/outflows and the second one is future random prices of various sources that provide funding liquidity. The funding liquidity risk happens when banks have not the ability to access funding sources at an economically reasonable cost in order to meet obligations or to finance the lending activity. It follows that the funding liquidity risk is the risk of loss due to the banks' inability to settle obligations with immediacy over a specific horizon. So, the primary source of this category of risk is given by maturity transformation role of banks. Recalling that banks' liabilities have shorter maturities than banks' assets, banks are forced to quickly refinance their assets. Furthermore, this risk is higher as the gap between assets and liabilities average maturity is wider. Starting from this concept of liquidity risk, we can move back to the concept of liquidity, so that banks are illiquid when they are not able to regulate obligations in time. Furthermore, it can lead market counterparties to stop their transactions or to request a higher remuneration in return due to its idiosyncratic character. When the two circumstances happen together, banks can get problems in both the liquidity and the solvency. Up to now, we can reach the conclusion that funding liquidity risk can cause solvency problem. This holds also on the contrary. Asymmetric information on banks' solvency can set off funding liquidity risk. In particular, increasing solvency, without reducing asymmetric information problem would not reduce refinancing risk. The funding liquidity risk can be mitigated by holding a large buffer of highly liquid and good quality assets, that can be used when banks are hit by unexpected funding shocks.

The second category of liquidity risk is the market liquidity risk which is the ability to convert assets, without disrupting their market price, into cash at a short period of time. Market disruptions can limit the sale of liquid assets as means of raising additional capital. Banks must try to reduce or eliminate the possibility to sell liquid assets at a fair price. The market liquidity risk is interconnected with the market risk. For this reason, it often measured and managed by risk management unit which is responsible for assessing market risk rather than the unit responsible for measuring and managing liquidity risk. Market liquidity risk can be generated by a substantial decrease of turnover and sales that results in a major decline of market price.

The liquidity risk can be also divided depending on the economic scenario in which banks are located. The liquidity risk faced by banks in normal operations condition is called going concern liquidity risk; while the liquidity risk that refers to a stress situation is the liquidity contingency risk. The former relates to a situation in which banks are able to meet their liquidity needs using their own funding capacity. In this type of situation, the measurement and the management of liquidity risk presuppose to simulate the evolution of monetary revenues and outflow under the neutral hypotheses regarding the evolution of the corporate magnitudes. The contingency liquidity risk depends on future events or commitments that can modify in a bad way cash requirement causing a loss. It derives from individual or systemic factors which cannot be dealt with through the banks' normal funding capacity. The banks need a specific contingency funding plan formalized ex ante to face these crisis situations.

1.5 Relationship between market liquidity risk and funding liquidity risk

There is a strong relationship between funding and market liquidity risk. Brunnermeier and Pedersen (2009) and Brunnermeier (2009) shown that, in certain conditions, they can be mutually reinforcing leading to liquidity spirals. A liquidity spiral refers to a situation in which the supply of credit is prompt reduced by a falling is asset prices, leading further falls in asset prices. An example of this connection is given when banks use the selling of assets to obtain liquidity if they have difficulties in rollover some of their debt. A downward spiral can begin due to falling in asset prices or a lack of liquidity. In this latter case, the starting point of a downward liquidity spiral happens when a bank has a low level of liquidity and cannot obtain liquidity from the interbank market. As a result, it must sell its assets. If the characteristic of asset markets is frictions, the asset sales cause a fall in asset prices. This, in turn, implies that the banks have to post higher margins. The solution for banks to remain liquid is to sell more assets, which depresses market prices even further and leading to further margin calls and so forth.

This relationship increases and is stronger as the use of wholesale funding increases. The strong connection between the notions of risks stated above, derives by the need to face unexpected cash outflows which can force banks to convert a substantial amount of financial assets into cash. At the end, the damage caused by the liquidity risk will be more marked when banks are forced to suffer potential losses. The effect of the connection

between liquidity and market risk does not damage just the single bank but the whole financial sector. As said above, in certain situations, banks are forced to sell their assets at fire sale which means selling the assets at very low price. This type of sales leads to the reduction of both assets' prices and liquidity in the market. This effect harms other agents in the financial sector which can meet the same liquidity problems since to obtain the liquidity they should necessarily go to the interbank market which, in turn, will have unexpected and huge liquidity withdrawals. Banks can be not able to meet their commitment to other institution such as depositors or hedge funds, due to liquidity problems. This can cause their bankruptcy and the bankruptcy of other banks due to the loss in the interbank market. What we explained just right now shows that liquidity problems can raise systemic risk.

The relationship between the funding and market liquidity risk is increased also due to the transition from an originate-to-hold credit model to an originate-to-distribute model. Anyway, even if banks increased the use of an originate-to-distribute model, M.Bord and Santos (2012) found out that this increase was limited to a large extent to term loans. Bank continued to rely on the traditional model for the credit-line business[18]. In the originate-to-hold model, the loan granted by the individual bank is maintained until it is extinguished. When a bank holds a loan until maturity has some constraints:

- the credit, liquidity and interest rate risk,
- the bank has to hold liquidity reserve,
- the bank has to hold an amount of own capital useful to meet regulatory requirements.

In the second model, the bank that provides the loan transfers to other the risks through loan sale or securitization. So, the originated-to-distribute model introduce the possibility to convert the bank's claims into securities to sell them later on the market. The benefits of this model are that credit risk is transformed into market risk and the credit moves from an illiquid to a liquid product. This allows banks to better manage the liquidity, credit and interest rate risk. Furthermore, since banks can use a lower amount of capital and liquidity reserves to grant a loan, they can increase the return on invested capital. To sum up, the main advantage of this model is to allow a transfer of risk by allowing bank to have a

[18] It is an arrangement between a financial institution and a customer, that established the maximum amount of a loan that the customer can borrow.

better combination of risk-return while it is managing the two sides of balance-sheet. On the other hand, the use of this model has also some drawbacks. Firstly, banks decreased the accuracy of their analysis of the counterparty creditworthiness since they relied on the possibility of disposing the loans granted. Secondly, the securitization created complex products that, the major part of the time, have proved the following characteristics:

- being illiquid,
- having problems in analyzing their compositions,
- having problems in forecasting their cash flows, especially in times of stress in the markets.

So, the securitization must be based on the hypothesis that there is a sufficiently liquid market which allows to sell securitized loans. The risk at which the securitization chain is exposed, is the risk of instability, especially related to changes in investor preferences and liquidity risk. The liquidity risk hits, in particular, the special purpose vehicles[19] which have problems with the maturity mismatch between assets and liabilities. Generally, their balance sheet is characterized by long-term assets and short-term liabilities. These companies are exposed to the market liquidity risk. They have issued financial instruments with short maturity to satisfy the investors' requests. This leads the special purpose vehicles exposed to the risk of roll-over. The roll-over risk is the risk linked with the refinancing of debt, it occurs when the investor does not renew the loan when it reaches the maturity. The banks' liquidity can have two negative impacts from the risk at which special purpose vehicles are exposed. These impacts are connected to the role of guarantor that banks have toward the special purpose vehicles. Firstly, they must repurchase the bad loan, secondly, they must have a plan to give liquidity to the special purpose vehicles when the latter have funding problems.

1.6 Liquidity Risk Measures

Liquidity risk is often considered difficult to measure respect other dimensions of financial risk because of the underlying variables that drive its exposure which can be dynamic and unpredictable. As a result, measuring liquidity risk can be challenging. The

[19] A special purpose vehicle is a subsidiary company with an asset/liability structure and a legal status that makes its obligations secure even if the parent company goes bankrupt. It is a subsidiary corporation designed to serve as a counterparty for swaps and other credit sensitive derivative instruments.

key issue in measuring liquidity risk is that it can derive from a different number of events so that there is not a unique indicator to assess liquidity risk.

Financial institutions use different types of methods including ratios or stress tests to decide how to measure their risk. Depending on which is the nation where the banks located such as Italy, England and so on, financial institutions are required by regulators to produce specific liquidity measures as evidence of their strength. What is in common of all the jurisdictions is that there is not a unique variable or ratio to measure liquidity risk since it is very complex and can arise from different events. Here, the necessity to use a multicriteria method in our analysis.

The measures of liquidity risk vary on the basis of what type of liquidity risk we are considering. The market liquidity risk is related to the market. It can be measured by a financial risk model: the bid-ask spreads[20]. This method is used for exogenous liquidity risk and is based on value at risk (VaR). The output will be a measure of the potential losses.

In chapter 3, a brief literature review of funding liquidity risk measurement is given. For the moment, we just give an idea about the most common liquidity measures. The funding liquidity risk can be measured in three ways:

- Mismatch-based approach which considers the analysis of the cash flows including both cash inflows and outflows. It is realized by examining the liquidity gap.
- Stock-based approach which includes the analysis of the balance sheet structure in order to hold a liquidity stock to prevent future needs. Some of the most used indicators are the reserve liqudity stock, the borrowing ratios, the liquidity ratios, the loan to deposit ratio, the financing gap ratio and the interbank ratio.
- Hybrid approach which combines the two approaches said above.

The analysis of the cash flows is useful to compare cash inflows and outflows on a day-to-day basis or over a series of specified time periods. It allows to manage and provide information about the dynamics of flows. It essentially divides the banks' cash flows by maturity in order to verify if the incoming flows are higher than the outflows. If this

[20] A bid-ask spread is the amount by which the ask price exceeds the bid price for an asset in the market. It is the difference between the highest price that a buyer is willing to pay for an asset and the lowest price that a seller is willing to accept to sell it.

happens, the result is an excess liquidity which can be added to the liquidity already available. In the opposite case, if the difference between incoming and outgoing flows is negative, banks need to finance the gap with available or new resources. The advantage of this method is that it considers the time in which flows occur. The disadvantage is that it does not consider the way in which the cash flows are calculated which is very important since that calculation influences the banks' efficacy. In normal conditions, banks are able to forecast the expected cash flows in a reliable way. Furthermore, they can provide a fairly reliable measure of the net requirement that have to be met at each maturity. These forecasts are more important in period of crisis. Banks must be able to meet their commitments even in bad periods, having in mind that stress situations are sources of liquidity risk.

Focusing more in detail on the second approach, it looks at the assets and liabilities of balance sheet are. It is the most used respect the other methods due to its simplicity. The main idea is that banks must hold a predefined quantity of monetizable assets (in terms of amount and / or type) under any market conditions. There are some ratios that can be computed in order to fulfill this aim. For almost all the ratios, there is not a right parameter to reach or to respect since liquidity risk management is different from one bank to another one, it reflects the choice made by each financial institution. The advantages of this method are the simplicity of the calculation and the monitoring. On the other hand, the drawback, as before, is that the way in which the ratios are calculated influences the efficacy. The balance sheet ratios include: the borrowing ratios, the liquidity ratios, the loan to deposit ratio, the financing gap ratio and the interbank ratio.

There are three borrowing ratios:

1. $\frac{Total\ Deposits}{Borrowed\ Funds}$
2. $\frac{Volatile\ Funds}{Liquid\ Assets}$
3. $\frac{Volatile\ Funds - Current\ Assets}{Total\ Assets - Current\ Assets}$

The liquid assets are given by the sum of cash and marketable securities. The borrowing ratios measure the banks' need to use volatile borrowings to sustain the business. Furthermore, they measure the degree with which liquid assets can be used to repay hot

money[21]. When the ratios are high means that a large amount of deposit turnover or volatile funding in the banks' total plan. This can create liquidity pressure.

Moving to the liquidity rations, the most important are two:

1. $\frac{Cash}{Total\ Assets}$
2. $\frac{Cash+Short-Term\ Investments+Funds\ Sold}{Total\ Assets}$

The cash liquidity ratios are useful to indicate if banks are able to make repayment of very short notice without limiting credit business. The higher the ratios, the more liquid the asset portfolio.

The loan to deposit ratio is given by: $\frac{Total\ Loans}{Total\ Deposits}$

It defines how much the deposits can be used to support banks' core lending. Higher ratio means that the banks rely heavily on the short-term money market, wholesale funding market or equity rather than on core deposits to fund loans. A ratio equal to 1,2 indicates than the banks have to finance part of their loans (let's say the part exceeds 1 that is 0,2) with wholesale markets funding. This can be translated into future liquidity problems. Banks that have strong equity ratios and do not use wholesale funding have a higher loan to deposit ratio. This does not mean than banks face higher risk. Given that customers deposits are always a stable funding source, banks who rely on deposits to finance their credit should be less exposed to liquidity risk. Anyway, very few banks rely on deposits funding, most of them use interbank market or debt markets to match short-term mismatches between assets and liabilities.

The banks' financing gap is given by: $Average\ loans - Average\ deposits$.

When this difference is positive, the banks have to find liquidity to fund the gap. Generally, most demand deposits stay at the banks for a quite long period (more than two years), thus banks' managers can think to use the overall deposits as a source to fund loans. This measure has some limits. It does not reflect and consider two important

[21] Hot money is a particular short-term financing service that banks offer to enterprises. It is a monetary loan that can be short (up to 3 months) or very short (48 hours) expirations in order to fulfill sudden financial needs.

aspects of a bank's structure: firstly, the strategic and cyclical changes in the data since it is a structural indicator, secondly the maturity mismatch between assets and liabilities which is a key element of liquidity risk analysis.

The interbank ratio is: $\frac{Interbank\ Assets}{Interbank\ Liabilites}$

When in the banks' balance sheet there is a huge amount of funding from interbank markets, banks can become subject to severe difficulties in rolling over their debts in periods of distress. The reason is due to the fact that interbank markets rely on short-term maturity. This ratio evaluates the position of banks in the interbank markets. In this sense, it defines if banks are net borrowers or net lenders. A ratio lower 1 means that banks are net borrower in interbank markets, which indicates a difficult liquidity position. The principal limit of this ratio is that it evaluates only one dimension of liquidity risk which is the exposure to short-term funding in interbank markets.

In addition to these measures, the banking sector is now required to compute two additional measures: the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). This is established in the post-crisis Basel III framework. A more detailed description of them is given in the next paragraph.

Liquidity Coverage Ratio: $\frac{High-Quality\ Liquid\ Assets}{Net\ Cash\ outflows\ over\ 30\ Days}$

This measure requires banks to hold sufficient high-quality liquid assets to withstand a 30-day stressed funding scenario.

Net Stable Funding Ratio : $\frac{Available\ Stable\ Funding\ Over\ 1\ year}{Required\ Stable\ Funding}$

The NSFR is a longer-term structural ratio designed to address liquidity mismatches and to encourage a higher reliance on medium and long-term funding.

Both measures, in according to Basel III, must have a value higher than 100% in order to guarantee a good liquidity position. While, for the other measures described, there is no an indication about their optimal value given by regulators.

The indicators described above are not independent, we cannot analyze each of them singularly. In particular, there is an interaction among the Liquidity Coverage Ratio and

the Net Stable Funding. When a bank receives a long-term stable funding, the LCR position increases as well as the NSF. This means a positive dependence between the two ratios.

Moving outside the balance sheet, other measures of liquidity risk can be provided by endogenous and exogenous stress tests. Stress tests are very useful to understand and to detect areas of weakness before that liquidity problems arise. They allow to verify if the banks are able to manage their payments in bad scenarios.

From the paragraph before, we know that banks tend to minimize the liquid assets during normal times in order to increase revenues. This is particularly dangerous when stressed period happens since the banks may not have sufficient liquid assets to face it. The stress tests can be done in three ways:

1. by analyzing the historically derived statistical distribution tail of liquidity events,
2. by replaying certain disaster events,
3. by manipulating macro-economic variables.

The first way is useful to recognize and to not underestimate the "fat tails" which indicate that in a statistical distribution, tails events have a greater probability of occurrence than is commonly understood. When banks fail in recognizing this fact, they underestimate potential risk effects. The second method uses past disasters events as a guide in order to examine the effects on the internal financial structure and liquidity patterns. It is important to remember that each event is driven by different dynamics and risk factors. The third method to create a stress scenario involves the use of macro-economic variables such as economic slowdown, loss of consumer confidence, rise in inflation or slowdown in earning. All of theme produces a certain impact on the financial institutions' liquidity which can be examined through regression. Thus, during the implementation of a stress test, the banks can rely on a variety of instruments, such as simulation analysis, mathematical programming and forecasting models.

Stress scenario helps banks to face catastrophic event and to reveal if banks' liquidity profile is weak or strong. For banks would be efficient to determine how their positions perform in the absence of endogenous or exogenous stresses in order to properly benchmark the results. Furthermore, regulatory authorities do not define any kind of approaches for the elaborations of stress tests. In this sense, the process of creating a stress

test is institution-independent. The tests should make assumptions about the possible scenarios, incorporating some models of depositor behavior, regulatory sanctions, credit downgrade and so on. In particular, the CEBS defines the scenarios which create liquidity shock concerning the entire system and scenarios which consider problems that can affect only the liquidity of the individual banks. The scenarios that affect the entire market can include: a rarefaction of liquidity in the interbank market, the impossibility of obtaining funds from the most important counterparties that characterize the market, illiquidity of one or more specific markets, difficulties in the market of some currencies considered important for the operation firm. The possible scenarios that affect the individual bank are: less credit availability, an increase in withdrawals from depositors, a decrease in rating, increased haircuts and collateral calls and reductions in assets prices.

Someone can argue why we need a multicriteria method to analyze the liquidity risk if, in literature, there are already a lot of ratios and methods. The reality is that analyzing a single number that comes from retrospective data is not effective for the correct assessment of the random size of liquidity and to consider the rapid evolution of the markets.

1.7 Liquidity Risk Management

Banks are the liquidity providers to consumers and enterprises, for this reason they are subjected to great systemic pressures when they manage their liquidity. Moreover, the need for an efficient liquidity risk management assumed more importance after the recent turmoil on the money and capital markets. Banks' liquidity risk management is an important issue because liquidity shocks at one bank can have contagion effects and can disrupt the efficiency and stability of the money market. It is useful to keep the stability in individual banks and in the entire financial system. The stability breakdown can happen in three ways:

1. A liquidity crisis in one bank can increase uncertainty in the whole markets due to asymmetric information. This can lead to a drying-up of money market liquidity, to bank run, to raise refinancing costs for other banks and increasing uncertainty with regard to future cash flows and market conditions, which in turn, deteriorates liquidity management,

2. The second cause of contagion is the increase of interbank exposures and money market instruments in banks' funding. Bank's counterparties can have liquidity pressure due to bank's liquidity problems,
3. Third, the decrease in the counterbalancing capacity[22] of all banks and their liquidity risk-bearing capacity can be caused by asset fire sales.

Thus, liquidity risk management is one of the most important decision in financial institutions bank governance. It is very complex to manage due to the fact that it is a multi-criteria problem with goals that depend on time horizon, liquidity and solvency outlook. The liquidity risk management is institution-specific. There is not a correct solution to manage liquidity risk but, at the same time, banks can adopt different strategies to control and acknowledge their specific needs. At European level, we can find recommendations and principles rather than requirements for the management of liquidity risk[23]. The exception is given by the Basel III Regulatory package which introduced a minimum requirement for the two measure of liquidity risk said before NSFR and LCR. In fact, when they have a value lower than 100% means that the liquidity position is going to deteriorate. Thus, the coordination of liquidity risk is not characterized by standard rules as credit or market risk. Each bank must develop methods and strategy to manage the liquidity risk in each of the form that it can take, considering that liquidity risk is not independent from the others risk. For instance, a customer who is unable to make a promised payment, he affects the banks' income and profits, and consequently the banks' equity and capital position. The interaction among the various risk make more complicated for banks' manager to coordinate the liquidity risk. In fact, when managers take actions for one type of risk, they must also consider the possible impact of such actions on other risks. The bank's manager in coordinating the liquidity risk must also consider the possible impact of such actions on other risks. In fact, liquidity risk is not independent from the others risk and the interaction among the various risk make more complicated for management of liquidity risk. The strongest relationship is between liquidity risk and insolvency risk. Under the assumption that the bank cannot borrow any more funds in the short-term money markets and it cannot wait to get a better price for its

[22] The counterbalancing capacity represents the shock of unencumered assets or other funding sources which are legally and practically available to the institution in a certain time to cover expected and unexpected funding gaps.
[23] "Principles for Sound Liquidity Risk Management and Supervision", Basel Committee on Banking Supervision, (2008)

assets in the future. When depositors unexpectedly withdraw money in deposits, for instance due to the release of negative news about the profits of the bank, in order to meet this deposit withdrawal, bank uses only cash and selling of its non-liquid assets. So, to cover all the deposit withdrawal, a bank is forced to sell assets at a lower price causing a loss in the balance-sheet. If we suppose that the total capital of the bank is equal to the loss, the latter leaves the banks economically insolvent (i.e. with zero equity capital or net worth).

Managing and monitoring liquidity risks with the right tools helps to reach bank stability. Furthermore, banks managers can have benefits from detecting and improving liquidity risk management strategies, especially for preventing future possible financial crisis. Brunnermeier et al. (2009) suggested a solution to manage liquidity and solvency risks of banks. The mean to solve the problem can be increase capital requirements. On the other hand, Calomiris et al. (2015) stated that requirements on the assets side instead of capital can be more effective. Their main idea was that when banks hold more liquid assets, they can face liquidity risk and better manage all the risks to which they are exposed.

A well-structured approach to manage risks has a key role in banks' success in order to avoid cash flows surprises that can lead to problems. Liquidity risk can be managed through a multi-stage process which is based on developing a proper governance practice:

- Defining and implementing liquidity risk plan,
- Assigning management duties and responsabilities,
- Creating, implementing and monitoring liquidity risk controls

Banks should firstly define their risk tolerance which is the maximum level of risk that banks are willing to accept. The risk tolerance can be determined by forecasting cash inflows and outflows in order to determine liquidity' need in short, medium and long term. The Banking Supervision Committee (BSC) defines "*it essential that banks have a well-documented view of their liquidity risk tolerance and its main determinants, even if they cannot quantify it objectively and precisely*."

An effective management of liquidity involves operational and financial actions with specific duties that relate to a banks' liquidity status. It must be robust, well designed and capable of minimizing liquidity-induced problems. Liquidity risk can never be eliminated entirely, but banks managers have the capacity to define an overall strategy to tolerate risk. The objectives of liquidity risk management are:

- Reducing dependance on internal financial needs, through cash pooling techniques or other optimization tools,
- Balancing the trade-off between liquidity and profitability,
- Optimizing the cost of refinancing,
- Managing the banks' issue of short, medium and long-term financing instruments,
- Managing the incoming and outgoing cash flows to guarantee the banks' solvency.

A good management of liquidity risk should include the capacity of the banks to fulfill their short, medium-long term obligations in both normal and stress conditions. Thus, the risk plan should: indicate how asset and liabilities maturities will be managed in order to support any losses, include other dimension of risk such as credit risk, foreign exchange volatility and so on, determine how exposures influence banks operations and profitability and analyze the costs and benefits of running liquidity risks of varying size.

A powerful liquidity risk management is a key aspect in the banks' investment strategy since banks must remain both liquid and profitable. Banks aim both to maximize their profits and build adequate liquidity buffers against possible fluctuations of their funding. In fact, the close relationship that exists between market, credit and liquidity risk impedes to view the liquidity risk in isolation. Banks with high level of market and credit risk will have a large amount of liquidity risk to manage.

Banks' liquidity risk management policies can be divided in:

- Asset diversification,
- Funding diversification,
- Stress test,
- Contincengy funding plan.

The biggest problem in liquidity risk management is that liquidity shocks have low well-defined probability and high impact. The high uncertainty in defining the probability space and the probability distribution of liquidity shocks is due to the number of observable liquidity shocks and their institution-specific nature. That's the reason for which tail events are approximated by stress tests. Stress tests can be linked to the development of the contingency funding plan. The latter includes all the actions that banks can take to satisfy the funding gap in normal and stress conditions. The plan is

bank-specific since each bank can be hit by liquidity risk in different ways. For this reason, banks must be able to recognize how liquidity risk can influence the banks' performance which depends also on the operating efficiency, overheads and reserves. Example of events that impact on liquidity risk are: the unexpected increase in funding costs, the incapacity to coordinate assets and liabilities maturities or the impossibility to sell financial instruments. However, it is possible to recognize four areas of interests inside the contingency funding plan:

1. Reducing the activities that make cash outflows,
2. Keeping a reserve,
3. Communicating to the markets including investors and customers information about the bank's liqudity position,
4. Defining an acceptable risk tolerance.

The contingency funding plan can be determined by forecasting cash inflows and outflows in order to determine liquidity' need in short, medium and long term as well as the risk tolerance.

Proper monitoring and reporting capabilities are essential to guarantee an active management of liquidity. For financial institutions, having access to real-time data is another absolute requirement to ensure an effective management.

Traditionally, banks coordinated liquidity risk through reserve requirements on bank deposits. Liquidity reserves are useful to satisfy banks' commitments in stress periods, but they have a cost. It is the cost-opportunity that banks face since they cannot invest that money in profitable projects. That's the reason for which banks should define a trade-off between the costs to eliminate risk and the risk tolerance.

Nowadays, there are also other regulatory mechanisms such as the increased diversifications in bank's funding sources and in activities undertaken by banks. In particular, it is important to diversify the sources in order to avoid that banks depend too much from a single source. The reason is easy to understand, if a bank relies from one source, when that source is no more available, the bank can incur liquidity problem. The diversification depends on three elements: the bank's balance-sheet structure, the bank's characteristics and the bank's funding policy.

As said before, one of the method to mitigate risk is having a liquidity reserve. The liquidity buffer aims to alleviate the maturity gap between assets and liabilities and to allow banks to continue their activity when bad periods come. As a consequence, the elements that compose the liquidity reserve must be available when the banks need them. This can happen when the liquidity problem regards both the single financial institution or the whole system. Banks are expected to manage their liquidity reserves, stress tests and contingent funding plan based on their specific necessity. The major part of liquidity buffers comprise cash, central bank reserves and securities excluding covered bonds. The three components of liquidity buffers must be extremely high liquidity and credit quality. Focusing on large banks, they tend to hold higher shares of central bank reserves. Anyway, the composition of liquid assets depends on the individual bank and each bank must sustain liquidity buffer to cover net outflows. The Committee of European Banking Supervisors (CEBS) defines the liquidity buffer as "the *short end of the counterbalancing capacity under a "planned stress" view. It needs to be available outright over a defined short period of time (the 'survival period')".* The survival period indicates the time period for which a bank would be able to use its liquidity buffer to cope with crisis, while taking other measures to ensure its longer-term survival. The liquidity buffer depends on three elements:

1. The severity and characterists of stress scenario,
2. The time horizon fixed as survival period,
3. The characteristics of assets which compone the reserve.

An active management determines the funding mix and the volume of liquid assets that are used as a counterbalancing capacity against funding outflow. The counterbalancing capacity represents the shock of unencumbered assets[24] or other funding sources which are legally and practically available to the financial institutions in a certain time to cover expected and unexpected funding gaps. A funding gap in generated when cash inflows are lower than cash outflows, this difference must be covered by the counterbalancing capacity. In this sense, it can be represented by the short-term liquidity reserve. Alternatively, banks can also postpone the maturity. As said before, a reduction of counterbalancing capacity can be caused by asset fire sale. The sum of the

[24] Unencumbered assets are asset that are free and clear of any encumbrances, such as creditor claims or liens. An unencumbered asset is much easier to sell or transfer than one with an encumbrance.

counterbalancing capacity with the liquidity gap gives as a result the Net Liquidity position which can be negative or positive.

1.8 European Liquidity Risk Regulation

A large number of national banking regulators and supranational organizations have established rules and recommendations to protect and encourage liquidity. The role of regulators is very important, especially after the financial crisis of 2007-2008. At that time, the systemic risk regulation, especially the liquidity risk regulation, was inadequate to properly control financial institutions. We can think at the crisis as the starting point for new regulatory initiatives for liquidity risk. In fact, until that moment, there wasn't a direct and precise regulation in the management of liquidity risk as there was for credit and market risk. The new regulatory framework has been developed in order to foster a better environment. The realization of this aim is fostered by conducting regular inspections, promoting competition, avoiding fragmentation, minimizing costs, harmonizing accounting treatment and ensuring proper capital allocations. Allen and Gale (2004) stated that liquidity risk regulation is necessary when financial markets are incomplete, emphasizing that all interventions inevitably create distortions. Banks do not need just conditions on capital requirements for their stability, it is also fundamental having a strength bank liquidity position. In fact, at the beginning of the crisis, financial institutions faced liquidity problems despite they fulfilled adequate capital levels due to an inefficient liquidity risk management. Authors as Tirole (2011) and Acharya, Shin, and Yorulmazer (2011) proposed that liquidity must be explicitly regulated.

Nowadays, the most important regulatory initiative that regulates liquidity risk in Europe is the Basel III reform, in fact, it is the only one that provides quantitative measures for liquidity risk. There are also other regulations, which focus on qualitative rules, given by:

- the European Banking Authority (EBA), in particular from CEBS, with the following documents:
    - "Second part of CEBS' Technical Advice to the European Commission on liquidity risk management" (2008) which contains 30 recommendations for credit institutions, investment firms on liquidity risk management and supervision,

    - "Guidelines on Liquidity Buffers & Survival Periods" (2009) which establish the appropiate composition of liquidity buffers to avoid liquidity stress and the business models' change for a period of at least one month,
    - "Guidelines on Liquidity Cost Benefit Allocation" (2010) which was written after the recommendations in Directive 2009/111/EC of the European Parliament and of the Council of 16 September 2009 and Recommendation 2 in CEBS's technical advice to the EU commission on liquidity risk management. Its aim is to provide high level guidance to institutions on the elements to be considered when creating or reviewing adequate liquidity cost benefit allocation mechanisms.
- the European Parliament and the Council with Directive 2013/36/EU of 26 June 2013 which repealing Directive 2006/48/EC. The new directive regulates the activity of credit institutions and the prudential supervision of credit institutions and investment firms,
- the European Commission with the Delegated Regulations (EU) 2015/51 of 10 October 2014 to supplement Regulation (EU) No. 575/2013 of the European Parliament and the Council with regard to liquidity coverage requirement for credit institutions.
- the Basel Committee with "Principles for Sound Liquidity Risk Management and Supervision" (2008) which provides a detail guide on how manage the funding liquidity risk and get better the whole risk management.

The first International agreement regarding liquidity risk was in 1992 with Basel I. That year, the Basel Committee for Banking Supervision posed the problem of ensuring minimum standards for liquidity risk management in the main international banks. The agreement was stipulated just to disclose a report containing the most appropriate measurement and management standards. In 1999, the proposal for new capital adequacy framework to replace Basel I started. In 2004 Basel II agreement was published but updated and completed with elements up to the final version in 2006. It provided that liquidity risk should be included among the risks of the second pillar. The second pillar is one of the three pillars on which Basel II Accord is based. It regulated liquidity risk without giving quantitative rules but just considering it as a principle. The crisis underlined the weakness of the liquidity risk measures under Basel II. The main issue was

linked to the lack of effective instruments in place, Basel III was written due to the failure of Basel II. Thus, Basel III is built on Basel I and Basel II documents, but it tried to perfect them in order to allow the banking sector to deal with financial stress. The idea behind Basel III was to enhance the banking regulatory framework.

Liquidity was one of the central issues discusses in the implementation of Basel III. The first version of Basel III was published by Basel Committee on Banking Supervision in late 2009, giving banks more or less three years to satisfy all the requirements. In fact, banks were forced to maintain proper leverage ratios and keep certain minimum capital requirements in response to the credit crisis. It represented a huge step forward in the international regulation of banks.

The aims of the new requirement are:

- reducing excessive maturity mismatches,
- increasing the quality and consistency of the regulatory capital,
- removing pro-cyclicality[25],
- ensuring that banks hold enough liquid assets to survive during bad periods,
- reducing the banks' exposure on liquidity risk,
- increasing strengh and stability of banking sector.

The Basel Committee on Banking Supervision developed new rules which were focused on: minimum requirements for stress testing, new standards for bank capital adequacy and prudent treatment of market liquidity risk. Under Basel III, banks should have a more robust structure in place that allows them to show cash flows coming from assets, liabilities and off-balance sheet contingencies in a relevant time horizon.

Regarding the new liquidity measures, Basel III introduced two ratios that all regulated banking institutions must fix. They are the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). Their goal is to ensure that banks maintain a sufficient amount of stable liquidity, so that, individual institutions and the marketplace will be strong enough during the next financial crisis. A bank is adequately liquid when it is able to meet its cash commitments in time of crisis. The Committee decided to introduce these

[25] The procyclicality inicates the financial system's tendency to amplify the ups and downs of the real economy.

two global minimum standards to strengthen the capacity to absorb unexpected losses of banks and to finance and to manage short, medium and long-term structural liquidity imbalances in banks' balance sheet.

The first measure that we are going to describe is the Liquidity Coverage Ratio. Its formula is:

$$\frac{HIGH - QUALITY\ LIQUIDITY\ ASSETS\ \ (HQLA)}{TOTAL\ NET\ CASH\ OUTFLOW} \geq 100\%$$

This ratio promotes a more robust handling of liquidity by requiring banks to preserve enough unencumbered high-quality liquidity assets to meet a 30 days liquidity stress scenario. Thus, it is a short-term indicator which helps to avoid situations of stress between assets and liabilities. A good value of LCR must be higher than 100%. This measure must cope with cash outflows that could result in acute stress. LCR has been introduced on January 2015, after an observation period. LCR has been introduced on January 2015, after an observation period. From that period, banks must phase it until January 2019. The minimum requirement changes every year from 2015 until reaching 100% in 2019.

	January 2015	January 2016	January 2017	January 2018	January 2019
LCR minimum	60%	70%	80%	90%	100%

The total net cash outflows is the difference between the total expected cash outflows and the minimum between the total expected cash inflows and the 75% of total expected cash outflows. The total expected Cash Outflow is obtained by multiplying outstanding balances of liabilities and off-balance sheet commitments by the rates at which they are expected to run off or be drawn down. The total expected Cash Inflow is given by multiplying the outstanding balances of various categories of contractual receivables by the rates at which they are expected to flow under the scenario up to an aggregate cap of 75% of total expected cash outflows. An example of cash outflow can be a deposit's withdrawal. The choice of the 30 days time horizon is due to the fact that it is the right period within which the banks should be able to reduce their tensions.

The HQLA considers all the assets that can be easily and immediately converted into cash at little or no loss of value. So, the high-quality assets refer to assets who keep their

liquidity-generating capacity without incurring large discounts in sale or repurchase agreement market due to fire-sales even in period of market stress. The fundamental characteristics of HQLA are: low risk, ease and certainty of valuation, low correlation with risky assets, listed on a developed and recognized exchange, active and sizable market, low volatility and flight to quality. Basel III distinguishes between two broad classes of assets in the HQLA: Level 1 and Level 2. Level 1 assets include high quality and liquid assets such as cash, bank reserves and government securities. They can account for 100% of the pool and are not subject to a haircut under the LCR. National supervisors still have some discretion on haircut based on their duration, credit and liquidity risk. Level 2 assets include lower-rated government securities, corporate bonds and covered bonds. They can comprise up to 40% of the HQLA pool. The supervisors require to have a LCR report at least monthly and more frequently as the need arises. In the table below, a better description of the Level 1 and Level 2 assets is given.

Level 1 Assets
• Coins and bank notes • Qualifying marketable securities from sovereigns, central banks, Public Sector Entities (PSE), and multilateral development banks • Qualifying central bank reserves • Domestic sovereign or central bank debt for non-0% risk-weighted sovereigns
Level 2A Assets
• Sovereign, central bank, multilateral development banks, and PSE assets qualifying for 20% risk-weighting • Qualifying corporate debt securities rated AA- or higher • Qualifying covered bonds rated AA- or higher
Level 2B Assets
• Qualifying Residential Mortgage-Backed Security (RMBS)[26] • Qualifying corporate debt securities rated between A+ and BBB- • Qualifying common equity shares

Moving to the second minimum standards, it is the Net Stable Funding Ratio. It ensures stability over the medium and long term by encouraging more funding though stable

[26] Residential mortgage-backed securities are a type of mortgage-backed debt obligation created from residential debt, such as mortgages, home-equity loans and subprime mortgages.

financing sources, discouraging too much reliance on short-term funds. Its aim is to avoid the imbalance in the breakdown by maturity of assets and liabilities. Thus, it is a medium-term indicator that controls the balance between assets and liabilities. The formula is given by:

$$\frac{AVAILABLE\ STABLE\ FUNDING}{REQUIRED\ STABLE\ FUNDING} \geq 100\%$$

Looking at both the nominator and denominator, the former is the Available Stable Funding which is the amount of equity and liabilities expected to be reliably available over 1 year under stressed conditions. The denominator is the required stable funding which depends on the bank's individual assets and contingencies. The Available Stable Funding (ASF) is calculated by assigning the carrying value[27] of a bank's capital and liabilities to one of five categories. The amount assigned to each category is multiplied by an ASF factor (100%, 95%, 90%, 50% and 0%). The Available Stable Funding in the sum of the weighted amounts. To have an idea of the liabilities included in the available stable funding, we will describe the components of the 100% ACF factor which includes:

- The total amount of a bank's capital excluding Tier 2 instruments[28] with residual maturity of less than one year,
- Other capital instruments and liabilities with effective residual maturity of one year or more.

The Required Stable Funding (RSF) is based on the liquidity risk profile of the banks' assets and Off-Balance Sheet (OBS) exposures. The amount is calculated by assigning the carrying value of an institution's assets to a categories list. The amount assigned to each category is then multiplied by its associated RSF factor (100%, 85%, 65%, 50%, 15%, 10%, 5%, 0%). The total RSF is the sum of the weighted amounts added to the amount of OBS activity multiplied by its associated RSF factor. As we did for the ACF, the components of the 100% RSF factor are provided:

[27] A carrying value is the difference between the original cost and the accumulated depreciation. If a company purchases a patent or some other intellectual property item, the formula for carrying value is original cost less amortization expense. Intangible assets must be reviewed for impairment, which is a permanent decline in the value of intangible assets, and the decrease in value must be expensed immediately.

[28] Tier 2 is composed of items such as revaluation reserves, undisclosed reserves, hybrid instruments and subordinated term debt.

- NSFR derivative assets net of NSFR derivative liabilities if NSFR derivative assets are greater than NSFR derivative liabilities,
- All assets that are encumbered for a period of one year or more,
- 20% of derivative liabilities,
- All other assets that are not included in the above categories, including non-performing loans, loans to financial institutions with a residual maturity of one year or more, non-exchange-traded equities, fixed assets, insurance assets, subsidiary interests and defaulted securities.

The introduction of NSFR is not simultaneous with the introduction of LCR. The Net Stable Funding has become a long-term structural indicator since 1 January 2018 after an observation period.

In addition to these measures, there is another regulatory framework which introduces a more precise and consistent view of liquidity internationally. The Committee, under Basel III, developed monitoring metrics that can be considered as the minimum types of information that supervisors should use. These monitoring metrics can be useful to capture specific risks. The areas of monitoring are five, but the Committee is actually working in order to evolve the monitoring tools, in particular relating to the intraday liquidity risk.

1. Contractual maturity mismatches

Banks should make a valuation of maturities mismatch in order to understand basic aspects of bank's liquidity needs. This metric defines that banks must report contractual cash and security flows in the relevant time bands based on their residual contractual maturity. It helps banks to compare liquidity risk profiles among them and to highlight when potential liquidity needs could arise. So, it gives a basic knowledge about contractual commitments.

2. Funding concentrations

This metric helps supervisors to evaluate liquidity risks that could arise from unexpected withdrawn of one or more funding sources. This metric defines that funding concentrations can be measured in two way: using either funding liabilities sourced from

each significant counterparty[29] as a percentage of total liabilities or funding liabilities sourced from each significant product/instrument[30] as a percentage of total liabilities, the metric defines that banks are required to provide a list of asset and liability amount by significant currency[31] in order to capture the amount of structural currency mismatch in a bank's assets and liabilities.

3. Available unencumbered assets

This metric helps banks and supervisors to be more aware about their potential capacity to raise additional secured funds, considering that this ability can decrease in stressed situation. The available unencumbered assets measures the amount of banks' unencumbered assets which are marketable as collateral in secondary markets and/or eligible for central banks' standing facilities.

4. Market-related monitoring tools

This metric defines the data that the supervisors should monitor in order the discover potential liquidity difficulties. Data useful to understand potential liquidity difficulties are: market-wide information (equity prices, debt markets, foreign exchange markets, commodities markets, etc.), information on the financial sector (equity and debt market information for the financial sector broadly and for specific subsets of the financial sector, including indices) and bank-specific information (equity prices, CDS spreads, money-market trading prices, etc.)

5. LCR by currency

The Liquidity Coverage Ratio should be calculated in each significant currency since foreign exchange risk is a component of liquidity risk. The aim of this metric is to monitor and manage the overall level and trend of currency exposure at a bank. This metric defines the LCR as the ratio between the stock of high-quality liquid assets in each significant

[29] It is defined as a single counterparty or group of connected or affiliated counterparties accounting in aggregate for more than 1% of the bank's total balance sheet.
[30] It is defined as a single instrument/product or group of similar instruments/products that in aggregate amount to more than 1% of the bank's total balance sheet.
[31] It is defined as the aggregate liabilities denominated in that currency amount to 5% or more of the bank's total liabilities.

currency and the total net cash outflow over a 30-day time period in each significant currency[32].

Looking at another regulation provided by Basel Committee, in "Principles for Sound Liquidity Risk Management and Supervision", it is established that banks must set some indicators to help the identification of increased risk or vulnerabilities in their liquidity risk position. These indicators are called "Early Warning" and they can be qualitative or quantitative. Some examples are:

- Rapid asset growth, especially when funded with potentially volatile liabilities,
- Growing concentrations in assets or liabilities,
- Decrease of weighted average maturity of liabilities,
- Negative trends or heightened risk associated with a particular product line, such as rising delinquencies,
- Significant deterioration in the bank's earnings, asset quality, and overall financial condition,
- Negative publicity,
- A credit rating downgrade,
- Stock price declines or rising debt costs,
- Difficulty accessing longer-term funding,
- Difficulty in placing short-term liabilities.

The Early Warning indicators must signal any triggers which can cause the bank to provide additional liquidity support or bringing assets into the balance sheet.

1.9 Italian Liquidity Risk Regulation

Banks contribute to economic development and to the improvement of standards of life by providing various services. Typical services include take deposits or other repayable funds from the public and grant credits for your own account; provide investment services; provide payment services and issue electronic money. Thus, they need a regulation not only at European level but also at national level.

[32] A currency is considered "significant" if the aggregate liabilities denominated in that currency amount to 5% or more of the bank's total liabilities.

In particular, for liquidity risk, the aim is to contain the contagion of systematic risk into banks' liquidity. The specific quantitative rules imposed by Basel III are flanked by national rules.

Focusing on Italy, Bank of Italy must supervise banks to ensure monetary and financial stability. The regulation of Banks' activities is governed by "*Testo Unico Bancario*" (TUB), Bank of Italy and "*Comitato Interministeriale per il Credito e Rispamio*" (CICR). The latter can decide, on a proposal from Bank of Italy, about principles and criteria for the exercise of supervision. Furthermore, Bank of Italy, in agreement with CONSOB, regulates the transparency of contractual conditions in banking and financial transactions. Other provision can be provided by the RMVU, the RQMVU and the CRR. Each of them gives some provisions on liquidity risk, even if it is based mainly on the document "*Banca d'Italia*, *Disposizioni di vigilanza prudenziale per le banche*, circ. n. 285 del 17 Dicembre 2013 e successivi aggiornamenti". In addition to the national legislation, Italian banks must respect the European legislation which has been already described.

The regulation related to bank liquidity risk is based on a qualitative approach which relies on control, reporting systems, internal management and monitoring of liquidity positions. Moreover, the supervisory rules require that as the size and complexity of intermediaries increases, an adjustment of the control and mitigation system. Thus, the main idea is that the structure of liquidity risk management must take into account the different structure levels, especially for banks which have significant cross-border transactions. The authority's aim is to develop a comprehensive system of liquidity principles and requirements to guide intermediaries in managing the risk more rigorously.

Even if the Italian regulation does not provide specified indicators such as LCR or NSFR, it is in line with Basel III recommendations. In fact, financial intermediaries must conduct stress test to assess both the impact of adverse events on the risk exposure and the adequacy of liquidity buffers in qualitative terms and to define early warning. Bank of Italy establishes the guidelines that all Italian banks must follow when they set the management of liquidity risk. The latter includes measuring, mitigating and controlling liquidity risk. The maturity transformation limits introduced in 1993 and unique in their nature, have been abolished in 2006 since they were considered excessively binding and inefficient in capture the liquidity needs. The Italian authority focuses more on the funding liquidity risk regulations since it has idiosyncratic character and can quickly

trigger actions from the market participants which make harder to conclude the normal transactions.

The identification and measurement of liquidity risk must be done in both current and prospective way. Thus, there are two proxies used to spot the exposure to the risk and the possible instruments for mitigating and controlling. The first one is the valuation of the net financial position in normal and stress situations which is, essentially, the estimation of cash flows, through the construction of maturity ladders that consider the balance of expected cash flows. A maturity ladder is useful to analyze the net funding requirements. It can be also used to compare a bank's future cash inflows to its future cash outflows over a series of specified time periods. Example of cash inflows are maturing assets, saleable non-maturing assets and established credit lines that can be tapped. Example of cash outflows include liabilities falling due and contingent liabilities, especially committed lines of credit that can be drawn down. This first valuation is prospective since it considers the likely development of cash flows associated with above and below-the-line brokerage. Banks must adopt different time horizon when they estimate their needs:

- for short-term liquidity, banks must adopt a time horizon of maturity at least one month,
- for the long-term liquidity, banks must adopt a time horizon of maturity at least equal to those used to measure the interest rate risk.

When the estimation of expected cash flows and outflows are calculated by using internal methodologies, banks must follow the principles of reasonability and prudence. When the quantification of the liquidity requirement resulting from the application of prudential rules is higher than the one resulting from internal methodologies, banks must be informed regarding the underlying assumptions such as methodologies and the controls carried out.

The second proxy is the construction of contingency funding plans which define, as said above, the roles, the responsibilities, the measure, the intervention strategy and the management of a crisis situation. Furthermore, they must identify the events to which tensions of liquidity are associated.

After this brief description about the Italian supervisor position about liquidity risk, we can describe which tools it proposes to mitigate this risk. There are three ways to mitigate the liquidity risk:

- Liquidity reserves,
- Operational limits,
- Diversification of both funding sources and renewal deadlines.

Talking about the liquidity reserves, financial intermediaries must constantly keep an amount of liquidity reserves that must respect some criteria. It has to be:

- at least sufficient to guarantee the compliance of the prudential rules,
- adequate to respect the defined risk tolerance,
- cash, free deposits held in central banks, readily liquid assets such as financial instruments that can be used for refinancing with central banks, other financial assets such as second-line reserves[33].

There are other principles that banks must satisfy as avoiding maintaining in their liquidity reserves activities which price and liquidity are correlated with the performance of securities, maintaining reserves activities which adequacy of readily liquid assets is frequently checked, especially when significant changes occur in market conditions. Finally, banks must have adequate procedures for the collateral management in order to appreciate, in any moment, the amount and the quality of liquidity reserves for each group member, jurisdiction and currency in which they operate.

The second method to reduce the liquidity risk is using operational limits[34]. These limits are determined in relation to the tolerance threshold defined by the body with strategic supervision function, considering both the objectives and operational complexity of the intermediary. Moreover, when the bank is determining its limits, it must be considered the results of stress tests, furthermore, it must constantly update them to take into account changes in the strategy and intermediary operations. In particular, referring to structural liquidity, bank adopts limits expressed in terms of ratios such as loans to deposits ratio, lending to borrowing ratio or leverage. As said before, the limit on the transformation of maturities has been eliminated years ago in order to improve the efficiency in capture liquidity needs.

[33] Second line reserves are characterized by high liquidity in stress situations for longer time horizons, without incurring significant losses with respect to the book value (fire sales).
[34] The operational limits in this case are a kind of threshold determined by the bank.

The last way includes the diversification of both the funding sources and the renewal deadlines. Banks must adopt strategies and procedures to limit the excessive concentration of funding sources and ensure adequate diversification of liabilities' maturity. It's obvious that financial intermediaries must have adequate knowledge of their financial structure and be aware of the risk factors that may influence it over time. There are four elements considered during the identification of funding concentration:

- the degree of dependence on a single market or on an excessively small number of markets (counterparties) such as interbank or bond issues,
- the concentration on particular technical form such as repurchase agreements or securitizations,
- the relevance of operations in currencies different from euro,
- the amount of expiring liabilities compared to the total amount of liabilities

The identification of funding concentration is, then, updated periodically in order to ensure the consistency with the evolution of intermediary operations

The supervision of intra-daily liquidity must be managed with adequate strategies by intermediaries which participate in payment, settlement and clearing systems. The aim is to prevent the incapability in fulfill banks' obligations in both normal and stressful business condition. This must be guaranteed regardless the type of settlement used in payment and in which the banks operate predominantly. The intra-daily liquidity management includes:

- the continuous monitoring and control of cash flows, providing reliable and timely forecasts of them within the single working day,
- the preparation of specific liquidity reserves for intraday operations, which can be used to face stressful situations,
- the definition of specific actions to be undertaken in the event of sudden illiquidity of the markets, with a clear definition of the roles and responsibilities of the organizational units involved (Contingency Funding Plan),
- the definition of stress scenarios that involves at least an important operator's default who participates in the payment and settlement systems of the securities on which the intermediary is exposed.

Banks are required to plan a Contingency Funding Plan (CFP) not only to face intra-daily liquidity but also to face difficult situation in funding liquidity. CFP defines the strategies to use and the ways in which banks can obtain sources of funding in stressful situations. The Contingency Funding Plan must contain at least:

- the various types of liquidity stresses in order to identify their nature (systemic or idiosyncratic);
- the identification of the responsibilities of the corporate bodies in emergency situations, these decisions are periodically reviewed and brought to the attention of all the structures potentially involved;
- the "back-up liquidity" estimates that, in the presence of adverse scenarios, are able to determine with sufficient reliability the maximum amount that can be drained from the various sources of financing.

Banks are required also to have an internal control system to manage liquidity risk. For the short-term liquidity which is lower than one year, banks must gather information:

- on the trend of financial flows coming from all the business or group units,
- on the progress and composition of the activities that can be used to meet the needs of funds.

For the long-term liquidity, which is more than one year, it's necessary:

- to know the medium/long-term funding and funding transactions and
- to periodically monitor the financial statement for the management of the Asset & Liability Management (ALM).

There is a "second level of control" which is the liquidity risk management. Its functions are based on the principle of separation between the operational and control. Thus, the risk management functions are: defining the policies and processes to manage liquidity, verifying compliance with the limits imposed on the different banks' areas and proposing risk mitigation initiatives to the bodies with strategic supervision and management functions. Example of risk management functions are defining and making stress tests or controlling the compliance of operating limits for assuming liquidity risks.

CHAPTER 2 - Multicriteria Decision Aid

2.1 MCDA Definition

In this work, we use a MultiCriteria Decision Aid (MCDA) method to evaluate the liquidity risk of a sample of 40 Italian Banks on the basis of their balance sheet data. The reasons that lead us to reach this choice were both the possibility to consider simultaneously different criteria that affect the banks' liquidity level and the opportunity of producing results in terms of ranking and sorting. This means that the banks will be scored from the best to the worst and they will be classified into homogeneous rating classes.

The starting point to compute the analysis using a MCDA method is the presence of a multicriteria problem with no single decision, solution or action that is the best for all the variables.

Multicriteria analysis is defined in Bernard Roy[35] as "*a decision-aid and a mathematical tool allowing the comparison of different alternatives or scenarios according to many criteria, often conflicting, in order to guide the decision maker towards a judicious choice*". Thus, the multicriteria decision aid helps the decision maker to solve complex decision problems by developing rules, tools and methods to support him. Basically, we can say that MCDA's aim is to find a solution that is good among a set of alternatives which are generally incomparable using traditional methods such as optimization techniques.

Its huge utilization derives from the fact that MCDA has a large number of advantages. The MCDA's benefits are:

- it helps individual to take decisions by examining the problem's structure in a complex way and considering more than one criteria;
- it gives the same importance to qualitative criteria as well as quantitative criteria;
- it considers the decision maker preferences;

[35]Roy B. 1996. "*Multicriteria Methodology for Decision Aiding*". Kluwer Academic Publishers: Dordrecht.

- it introduces a rigorous but realistic methodological approach.

MCDA methods try to combine at the same time concreteness and mathematical programming techniques while classic optimization techniques tend to describe the problems through the introduction of different hypothesis that sometimes are far from reality.

Once defined the presence of a multicriteria problem, the second step for a multicriteria analysis is the definition of three components:

1. the set of alternatives on which a choice has to be made,
2. the set of criteria against which the alternatives must be evaluated,
3. the method used in the evaluation.

All the alternatives considered in a problem are called "set of potential alternative" and they are denoted by A, while a single alternative is denoted by a, A=$\{a_1, .. a_j, .. a_n\}$. The set of criteria are denoted by C, while a single criteria is denoted by c, C= $\{c_1, .. c_j, .. c_m\}$. Formally, a criteria is an exhaustive and non-superfluous value which describes an aspects of the overall performance of the alternatives and which compares the alternatives among them. The criteria are useful to evaluate the set of A's alternatives. Thus, for each alternative is given a value based on the criteria used. The evaluation of an alternative a_n according to criterion c_m can be written by the following expression: $g_{n,m}$. Let's imagine A which is the set of alternatives composed by portfolios with the same amount of security, C which is the set of criteria composed by the criteria used to evaluate each portfolio such as mean, variance, asymmetry and kurtosis. Then, each portfolio will have an assessment given by each criteria. A multi criteria method allows the comparison of a couple of alternatives in order to determine the optimal portfolio based on the criterion used.

As the name suggests, a multicriteria context requires more than one criteria that must be aggregated. The aggregation of all the decision factors must be appropriate, this is a crucial part of the analysis. Furthermore, the aggregation of criteria must respect the decision maker preferences. To sum up, the decision maker models a set of alternatives using more than one criteria in order to take into account all the possible impacts, consequences or effects on the result. Thinking about everyday life, there are numerous examples of choices in which a group of alternatives must be judged on the basis of many

characteristics. For instance, when a person buys a laptop, he does not simply consider only the model with the lowest price but he evaluates also other characteristics such as central processing unit (CPU), RAM, hard drive, battery, quality of materials, wireless technologies, prices and so on. It is unlikely that one alternative will be better than all the others for each of these criteria, so the buyer will make his choice by accepting a trade-off between the various characteristics. Another example happens during the hiring of new employees, the alternatives are the candidates and the criteria can be the educational degree, professional experience and so on.

2.2 MCDA Historical Background

At the beginning of 1960s, mostly in Europe, the first methods in multicriteria analysis were developed even if, it's in the 1970s that they started to take form, especially the branch of MultiCriteria Decision Making (MCDM). Simon (1957) was the first author who argued that the optimization assumption was not realistic because the decision makers (DM) cope with many difficulties in decision making processes. These problems can be due to incomplete information, limited resources or conflicting interests. The idea of Simon, together with the studies of Koopmans (1951), Kuhn and Tucker (1951) and Charnes et al. (1955) discovered that decision makers prefer to find satisficing solutions rather than optimal solutions. In other words, the decision makers prefer to achieve targets rather than maximize or minimize goals. This idea constitutes the beginning of the multicriteria decision aids, which was consolidated the next years.

In the following years, there were scientific meetings in which many mathematicians explained their researches about this topic such as:

- the First Independent Session specifically devoted to multicriteria research within the 7th Mathematical Programming Symposium (1971) organized by Roy, founder of the initial version of ELECTRE;
- the First International Conference on multicriteria decision making (1972) organized by Cochrane and Zeleny;
- the First Meeting of the EURO Working Group on Multi-Criteria Decision Aid (1975) organized by Roy;
- the First Conference of the International Society on multicriteria analysis (1975) organized by Thiriez and Zionts.

The basic problem concerning a multicriteria decision making was the way by which the decision maker (who, we must specify, is rational) should take decisions, considering his preference. The idea was that a single objective, criteria or point of view is seldom used to make real-world decision. Obviously, MCDA methods did not provide an absolute right solution to solve the problem, but they tried to improve and support its solution. In other words, its aim is to help decision makers in situations where multiple conflicting decision factors must be considered at the same time. Multicriteria analysis is a method closely related to utility theory even if the latter is used to model simple individual preferences. The utility theory has been extended to the multicriteria preferences leading to the Multiple Attribute Utility Theory (MAUT) which will be explained later on. In economics, the preferences are classically represented by an utility function which gives a value to each action following the principle: the more preferable an action, the larger its value. This classical model is very simple but not too realistic. This is one of the reasons that lead to the development of multiple criteria decision aiding.

During the 1980s and 1990s, there were the development and the consolidation of a large number of multicriteria methods for decision-making problems. In particular, in 1985, Roy established that a method for decision-making problems can realize four objects (problematics), specifying that each of them did not necessarily preclude the others. These problematics were:

- problematic 1: the choice of one action from the set of potential actions (choosing),
- problematic 2: the organization of the actions in well-defined classes and in a preference order (sorting),
- problematic 3: the ranking of the actions from the best to the worst one,
- problematic 4: the description of the actions in terms of their criteria's performances (describing).

Summarizing, in a multicriteria context, a decision maker considers a set of alternatives and he looks at the optimal decision considering all the relevant factors in the analysis. The main problem is that the factors are usually in conflict among them leading to a

satisfactory non-dominated decision[36] which is not optimal in the traditional optimization perspective.

In the last ten year, multicriteria decision aid methods had a considerable development and nowadays, specialists, following the idea of Bernard Roy, have divided them into three broad categories:

1. outranking synthesis methods,
2. multiobjective and goal programming,
3. multiple attribute utility theory.

The table below shows the methods included in each of the three broad category.

CLASSIFICATION OF MCDA TECHNINQUES		
Outranking synthesis methods:	**Multiobjective and goal programming:**	**Multiple Attribute Utility Theory:**
ELECTRE methods	Multiobjective programming	Classic MAUT
PROMETHEE methods	Goal programming	UTA
Others		AHP
		Others

Despite the numerous different approaches, all have in common that must be clear about the criteria being taken into account and about their influence on the decision. The latter is determined by assigning a weight to each criteria based on its importance. Before explaining analytically the method useful in this analysis, a small and qualitative description about all the three categories is given. For a more detailed description, let's refer to the book "*Multiple Criteria Decision Analysis, State of Art Surverys*", José Figueria, Salvatore Greco, Matthias Ehrgott (2005).

Starting from the first group of methods, which is the outranking synthesis ones, their aim is to identify the preference that outranks the other. This occurs when one alternative is

[36] A satisfactory non-dominated decision is a decision that is in accordance with the decision maker's system of values and is not dominated by other possible decisions.

"at least as good as" the other in most respects, and not too much worse in any one respect. Thus, it is a relation that enables the decision maker to value the strength of the outranking character of an alternative a_i over an alternative a_k. The outranking synthesis methods are developed in two steps. In the first one, there is an aggregation phase in which they built an outranking relation which is a superiority relationship that represents the preference of an alternative over another based on the decision maker preferences. The second step is an exploitation phase in which the methods use the superiority relations defined in the previous phase to create an ordering of the considered alternatives. Example of these methods are represented by the ELECTRE family of methods and PROMETHEE family of methods. The difference among the various type of outranking methods is given by the way in which the superiority is defined. For instance, based on Roy (1974) definition of outranking, the outranking relationship is represented as a binary relation *S*, defined on the set of alternatives. Based on *S*, a_i is preferred to a_k if in the information about the decision maker preferences and in the problem nature there are enough arguments to state that "a_i is at least as good as a_k and at the same time, there are not enough reasons to reject this statement". This is the idea behind ELECTRE methods.

Moving to the second family, which is the multiobjective and goal programming, it includes the interactive methods as well as the multiobjective programming. The former, as the name suggests, combines phases of calculation with phases of dialogue with the decision maker. We must have in mind that in all the multicriteria procedures, there is an interaction with the decision maker since he is responsible for defining the problem by choosing the alternatives and the criteria. For this reason, in these methods, the decision maker has a crucial role. In fact, he provides additional information regarding his preferences, thus, he gives a huge contribution in the determination of the solution. So, the interactive methods solve MultiCriteria Decision Making (MCDM) problems by exploiting the decision maker who has an essential part in the solution process. Also in this methods, there are two steps, the first one called computational phase in which the system generates "reasonable[37]" solutions in order to provide a first problem solution. The second step in which the previous solution is integrated by additional information provided by the decision maker in order to determine a more preferred solution. There are some critical points in these methods such as: how preference information is gathered,

[37] Reasonable in interactive methods is defined as efficient or nondominated.

how information is used and how the system generates alternatives. Example of interactive system are VIG and VIMDA. The second family of methods comprises in this category is the multiobjective programming (MOP). It is very complex and it has different extensions on the basis of which is the treatment of the fuzziness (confusion) involved in the problems. Basically, it deals with a decision problem in order to maximize or minimize its objective function. The innovation introduced in MOP method is that it considers more than one objective functions since it is difficult to summarize all the points of view of the decision maker in only one objective function.

Finally, the third family of methods has two name, either the unique criterion of synthesis approach or multiple attribute utility theory (MAUT). Its aim is to maximize an utility function which is built by aggregating different points of view into a single input. The aggregation can be made in an additive, multiplicative or mixed way, this choice is important since the decision maker's preferences must satisfy some properties based on which type of aggregation is chosen. An example of approach which belongs in the multiple attribute utility theory is the UTilitès Additives method (UTA). The result of this method is the optimization of a function such as: $U= U(g_1, \dots g_n)$ with g_i that indicates one of the criteria considered in the evaluation. Obviously, this function must be estimated since it is not known. Thus, a problem arising from this last methodology is the estimation of parameters for modelling the preferences. The MAUT methods are able to recognize the superiority of an alternative respect to another one exploiting the utility function $U(a_i)$[38]. In fact, a_i is preferred to a_k when $U(a_i) > U(a_k)$. However, these approaches are not often used in practice due to their strong assumptions, especially the presence of a latent utility function that must be maximized. Furthermore, there are other two drawbacks: it is time consulting and the obtaining of the required information depends on both the willingness of the decision maker to give it and the ability of the decision analyst to elicit it efficiently. These drawbacks lead to the creation of a new family of MCDA methods, the preference disaggregation approach (PDA). They belong in the third category of method (multiple attribute utility theory). The PDA method provides the framework to face these problems by using utility decomposition forms[39] to model the decision maker's preferences. The utility decomposition is done through

[38] The most common utility function is the additive one: $U(a_i) = p_1 * u_1(g_{i1}) + \cdots + p_n * u_n(g_{in})$, where $u_j(g_j)$ defines the utility/value of the alternatives for each individual criterion g_j.

[39] The decomposition of an utility function consists in the separation of the utility function into simple polynomials in order to assess each of them.

regression-based techniques (indirect estimation procedure), furthermore, its parameters are estimated through the analysis of the decision maker's overall preference. By doing so, the model reproduces the global preference model as consistently as possible with the reality by the model. It is widely applied in finance problems, mainly where the problem is ranking and sorting/classification of the alternatives. Examples of these methods are: UTA, UTADIS, MHDIS.

The table below gives a general idea about the elements that MCDA methods need to work.

CRITERIA	WEIGHTS	APPLICATION
The relevant criteria for the decision must be selected and measured by using existing criteria or establishing new criteria through qualitative and quantitative methods.	The weights relative to each criteria must be properly decided by using evidence.	The relevant information must be summarized and structured by using MCDA methods. The latter must be used to identify additional judgements or disagreement between the decision makers.

To sum up, the MCDA methods use a set of criteria and weights to:

- suggest the best choice,
- rank a list of alternatives from the best to the worst,
- test the sensitivity of the choice.

The choice of the criteria being included and which weights to place on each criterion remain a decision maker choice.

For our analysis, we want to rank 40 Italian banks from the best to the worst based on their liquidity risk. Furthermore, we want to group them into homogeneous rating class. So, we need a method which can be used for ranking and sorting. This method is called MURAME and it is a combination between ELECTRE III and PROMETHEE II. Thus, in order to give an idea about how MURAME method works, we will focus more on a detail and quantitative description of these two methods. Furthermore, an analysis of MURAME properties and advantages will be explained in the next paragraphs.

2.3 ELECTRE methods

The acronym ELECTRE means ELimination Et Choix Traduisant la REalitè (ELimination and Choice Expressing the REality). Its origin was in 1965 when Bernard Roy tried to improve the *Méthode d'Analyse, de Recherche, et de Sélection d'Activités Nouvelles* (MARSAN) method in order to overcome some its limitations. ELECTRE I was the first version among all the ELECTRE methods to be created, its aim was to choose the best actions from a given set of actions.

The initial method has evolved since 1960s until its last version ELECTRE TRI and it is still evolving. ELECTRE methods belong in the outranking methods. They comprise two main steps during their application: an aggregation phase in which one or more outranking relations are built in order to compare in a comprehensive way each pair of actions and an exploitation phase in which the methods use the results obtained in the previous phase to create an ordering of the considered alternatives.

In order to proceed with further explanation, let's define:

- a set of *n* alternatives A=$\{a_1, .. a_i, .. a_n\}$,
- a set of *m* criteria G = $\{c_1, .. c_j, .. c_m\}$,
- $g_{i,j}$ is the performance related to criteria c_j of alternative a_i and is a real number,
- $\forall a_i \in$A and $\forall a_k \in$A with $i \neq k$, $g_{i,j} \geq g_{k,j}$ then a_i is at least as good as a_k based on criteria c_j.

Then, considering the classical model, for each couple of alternatives it's possible to identify three outcomes:

- $g_{i,j} > g_{k,j}$ → it means that alternative a_i is better than alternative a_k,
- $g_{i,j} = g_{k,j}$ → it means that alternative a_i is indifferent to alternative a_k ,
- $g_{i,j} < g_{k,j}$ → it means that alternative a_k is better than alternative a_i.

However, in reality, it is not always possible to define with certainty that one alternative is better than another. Most of the time, the decision maker is not able to capture or perceive the difference between the two alternatives.

For instance, let's assume that there are two chocolate cakes, $cake_1$ and $cake_2$. The latter has a little bit more sugar than the other one; even if $cake_2$ has a little bit more sugar, so that it is sweeter than $cake_1$, it's very difficult to notice the difference. So, the decision maker is not able to define with certainty which cake is the best based on his preferences, since he does not notice the difference between $cake_1$ and $cake_2$.

Thus, the main idea under ELECTRE methods is that the preferences are modelled using binary outranking relations, *S* which means "at least as good as". Using this relation, there are four possible relations between the alternatives:

1. $a_i S a_k$ and not $a_k S a_i$ → a_i is strictly preferred to a_k $(a_i P a_k)$
2. $a_k S a_i$ and not $a_i S a_k$ → a_k is stricly preferred to a_i $(a_k P a_i)$
3. $a_k S a_i$ and $a_k S a_i$ → a_i is indifferent to a_k $(a_i I a_k)$
4. Not $a_i S a_k$ and not $a_k S a_i$ → a_i is incomparable to a_k $(a_i R a_k)$

This last preference relation, called incomparability, is useful for situations in which the decision maker is not able to compare two actions.

Furthermore, ELECTRE methods introduced two thresholds called indifference and preference threshold. They are part of the discrimination thresholds which are useful to consider an uncertainty zone in the decision process and in the decision maker's preferences. This zone is between a situation of strict preference and one of indifference. There is also a third threshold called veto threshold. It is useful to discriminate zone of certainty from zone of uncertainty. A better description of these thresholds is given in the next paragraph. While, in the classical model, the three outcomes (preference for a_i, preference for a_i or indifference) are well defined, with no intermediate possibilities. Just to have an idea about the three thresholds, the indifference threshold is the highest difference between the two alternatives that still indicates a situation of indifference between the two alternatives. If the indifference threshold is overcome, it indicates a weak preference for one alternative. The preference threshold is the lowest difference between the two alternatives that indicates a situation of strong preference. If the difference is lower than the preference threshold, it indicates a weak preference for one alternative. The veto threshold indicates the lowest difference between the two alternatives for which it is never acceptable the outranking relation that is in exam. The veto threshold discriminates the alternatives with results too far respect to the other ones.

According to ELECTRE methods, an alternative is strictly preferred to another when their difference is greater than a certain amount p which is the preference thresholds. This quantity allows the decision maker to determine with certainty which of the two alternatives is preferred, highlighting the case in which there is a strict preference. When, on the other hand, the difference between the two alternatives is less than the preference thresholds, two cases are possible: one in which there is a weak preference as called in decision aiding and the other one in which there is indifference. In particular, the latter happens when the difference between the two actions is less than a certain quantity q which must be necessarily less than *p.* This quantity q is the indifference thresholds. When the decision maker moves from a situation of indifference but he is not in a situation of strong preference, he is in a situation of weak preference. The latter occurs when the difference between the two alternatives is greater than the indifference threshold (q) but lower than the preference threshold (p). A better explanation of both thresholds is given by B.Roy, J.R. Figueira and J.Almeida-Dias in "*Discriminating thresholds as a tool to cope with imperfect knowledge in multiple criteria decision aiding: Theoretical results and practical issues*", they defined: "*The preference threshold, p, between two performances, is the smallest performance difference that when exceeded is judged significant of a strict preference in favor of the action with the best performance. This difference (which is by definition non-negative) can be equal to zero (which corresponds to the case of the true-criterion model[40])"* while "*The indifference threshold, q, between two performances, is the largest performance difference that is judged compatible with an indifference situation between two actions with different performances. This difference (which is by definition non-negative) can be equal to zero and it is at most equal to the preference threshold".*

From an analytical point of view, considering the two actions named before a_i and a_k, the introduction of these two thresholds allow the occurrence of three outranking relations in the model preferences:

1. $a_i P a_k$ if $g_{i,j} - g_{k,j} > p_j$ → this is the case in which alternative a_i is strictly better than alternative a_k,

[40] The true-criterion model is a model that does not take into account the impact that imperfect knowledge may have during the definition of a criteria for modeling the preferences of a decision- maker, according to a certain point of view.

2. $a_i Q a_k$ if $q_j < g_{i,j} - g_{k,j} \leq p_j$ → this is the case in which there is a weak preference for a_i,
3. $a_i I a_k$ if $|g_{i,j} - g_{k,j}| \leq q_j$ → this is the case in which the two alternatives are indifferent .

These three cases can be summarized in a table in order to understand better the decision maker's preference:

INDIFFERENCE	WEAK PREFERENCE	STRONG PREFERENCE
$a_i I a_k$	$a_i Q a_k$	$a_i P a_k$
$\|g_{i,j} - g_{k,j}\| \leq q_j$	$q_j < g_{i,j} - g_{k,j} \leq p_j$	$g_{i,j} - g_{k,j} > p_j$

To sum up, the introduction of these thresholds allows to cope with imperfect knowledge in multiple criteria decision aiding. Furthermore, they help the decision maker to tackle, in a realistic way, the preference situations that can be targeted as weak and situations which can be categorized as indifference. Thus, the need to consider the impact of perfect knowledge in modeling the preferences of the decision-maker caused the movement from a true-criterion model in which there are just two possibilities (strong preference or indifference) to pseudo-criterion model in which there are three possibilities (strong preference, weak preference or indifference). This was possible thanks to the introduction of the discriminating thresholds. As defined by Roy et al., 2014 "*The discriminating thresholds allow thus, in case where p > q, to delimit an ambiguity zone in which it is not possible to "cut" between a preference or an indifference in favor of the action with the best performance*".

To determine the value of these thresholds, there is not an unique solution but there are more possibilities, there are mathematical methods as well as methods based on the decision maker's reasoning. The latter means that the thresholds can be determined by the decision maker based on either the optimal value of the criteria or his preferences.

Another important element in the ELECTRE methods is the veto thresholds v_i which is used to evaluate if an alternative a_i is worse than a_k so that it is impossible that $a_i S a_k$

occurs even if the latter relation can be true for all other criteria. This threshold allows to deal with all the cases in which $a_i S a_k$ is totally rejected, in this case, we have:

$$g_j(a_k) = g_j(a_i) + v_j$$

Thanks to the veto threshold, the alternative that has a bad performance following a given criterion, it will receive a low final score. Moreover, it must be higher than the preference thresholds and it is useful to determine the non-discordance index. The non-discordance principle is one of the two notions on which the construction of the outranking relation is based on. The other one is the concordance principle.

Actually, the problems solved by ELECTRE methods are three: choosing one alternative, ranking the alternatives from the best to the worst or sorting the alternatives in well-defined groups defined in a preference order. In financial field, there are several example for each problematic.

CHOOSING	**RANKING**	**SORTING**
Selection of an investment project.	Comparative evaluation and ranking stocks according to their performance.	Prediction of business failure by classifying the firms as healthy or failed .

We can see that ELECTRE can be used to solve three of the four problematics described above that the multicriteria decision aids methods face. Furthermore, we said that there are different types of ELECTRE methods. They do not address all the same problems, but they can be grouped based on the problem solved.

CHOOSING	**RANKING**	**SORTING**
ELECTRE I ELECTRE IS	ELECTRE II ELECTRE III ELECTRE IV	ELECTRE TRI

First of all, despite the fact that the ELECTRE methods are chosen in the analysis based on the problem that they address, all have in common four components: the presence of a set of *n* alternatives A=$\{a_1, a_2, .. a_n\}$, a set of *m* criteria G = $\{c_1, .. c_i, .. c_m\}$ and the presence of the concordance and discordance principle. Furthermore, all the ELECTRE methods have in common the structure in which they operate, in fact, they have an aggregation and exploitation phase, but the way in which the final outranking relation and the results are built and employed depends on the specific ELECTRE method that is used.

In this work, as already mentioned, the method used is MURAME which is a combination of ELECTRE III and PROMETHEE II, thus, we continue the presentation of ELECTRE methods focusing on ELECTRE III.

Let's define the affirmation Q = "*alternative a_i is at least as good as alternative a_k on the basis of criterion c_j*", then, it is verified when it is supported from most of the criteria (concordance concept) but, at the same time, it is argued from other criteria (discordance concept).

To measure the strength and the trustworthiness of arguments that support Q under ELECTRE III method, the concordance index is used $C_j(a_i, a_k) \in [0,1]$. There are two types of concordance index:

- a local concordance index,
- a comprehensive concordance index (or global concordance index).

The difference between them is that the local index is useful to see to what extent "*action a_i outranks action a_k*" based on criterion c_j. Thus, the local concordance index will be calculated for each pair of alternatives and for each of the criteria considered. Since there are *n* alternatives and *m* criteria, the total number of local concordance indices will be: $(n-1) * n * m$. The values that the indices can take range from 0 to 1 in the following way:

$$C_j(a_i, a_k) = \begin{cases} 1 \; if \;\; g_{k,j} \leq q_j + g_{i,j} \\ 0 \; if \; g_{k,j} \geq p_j + g_{i,j} \\ \dfrac{g_{i,j} - g_{k,j} + p_j}{p_j - q_j} \; otherwise \end{cases}$$

Following the considered criterion, when C_j is close to 1, the strength of the arguments that support the affirmation Q is high, so it is true that alternative a_i is not dominated by alternative a_k. On the other hand, when C_j is close to 0, the affirmation Q is false, so a_i is dominated by a_k or alternatively, the decision maker prefers alternative a_k to alternative a_i. In both cases, there is a situation of strong preference. When the index takes intermediate values, there is not a strong preference, but instead there is a weak preference. In this case, the decision maker is in a situation of uncertainty and he is not able to decide which is the best alternative between the two considered. Moving to the global concordance index, it is estimated as the weighted average of the local concordance index of each alternative:

$$C_j(a_i, a_k) = \frac{\sum_{j=1}^{n} w_j C_j(a_i, a_k)}{\sum_{j=1}^{n} w_j}$$

where: $w_j > 0$ is the weight of criterion c_j in other words, it is the importance given to criterion c_j. The global concordance index considers the performances based on all criteria to express in what measure they are in concordance with the assertion $a_i S a_k$, while the local concordance index evaluates one alternative performance respect another one, considering just one criteria.

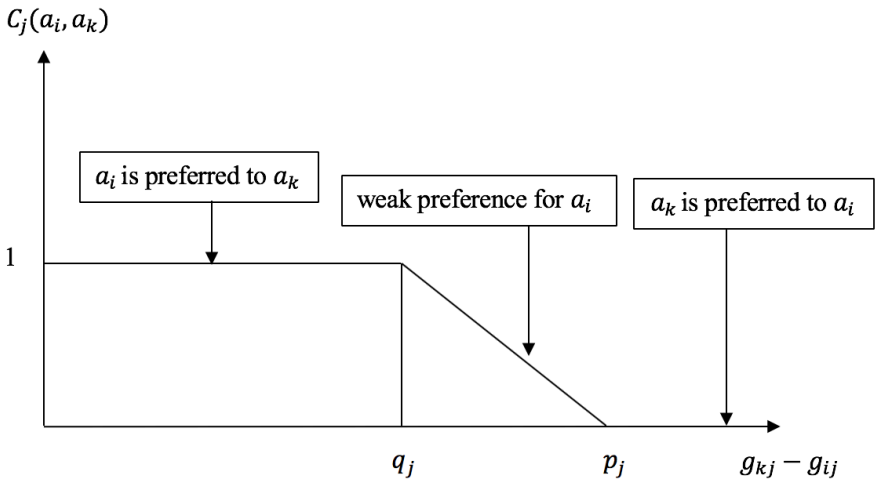


Figure 1: Range global concordance index.

The definition of the concordance index is useful to compute the outranking index $O(a_i, a_k)$ which uses in part the local concordance index. In any case, we need also the discordance index in order to define completely the outranking index.

Moving to the discordance index for the *j*-th criterion $D_j(a_i, a_k)$, it is used to measure the weakness of arguments that support Q. It expresses in what measure the performances of the actions a_i and a_k oppose to the assertion "*action* a_i *is at least as good as action* a_k". As said before, in order to compute the discordance index, we need the veto thresholds v_j. Its function is to consider the cases in which an alternative is worse than another, given a criterion, with $v_j \geq p_j$. It has been introduced to evaluate if, given a criterion c_j, an alternative a_i is worse than a_k, so that it makes impossible the acceptance of $a_i S a_k$ regardless the fact that this relationship could be true for all other criteria.

The difference with the concordance index is that there is not a distinction between the global and local discordance index, there will be just one type of index, so the aggregation is not necessary. As before, the discordance index will be calculated for each pair of alternatives. From an analytical point of view, the values that the index can take, range from 0 to 1 in the following way:

$$D_j(a_i, a_k) = \begin{cases} 1 \; if \;\; g_{k,j} > v_j + g_{i,j} \\ 0 \; if \; g_{k,j} \leq p_j + g_{i,j} \\ \dfrac{g_{k,j} - g_{i,j} - p_j}{v_j - p_j} \; otherwise \end{cases}$$

This index indicates the weakness of the statement "*action* a_i *is at least as good as action* a_k", so it will take its minimum value which is 0, when the difference between $g_{k,j}$ and $g_{i,j}$ is lower than the preference threshold p_j. This is the case in which a_i is strictly preferred to a_k based on criterion c_j, thus in this case the statement Q is true. The discordance index will take a value equal to 1, when the difference between $g_{k,j}$ and $g_{i,j}$ is higher than the veto threshold v_j, thus, in this case the initial affirmation Q is not true, as a result, action a_k is preferred to action a_i. The index will take intermediate values when the difference is higher than p_j, but lower than v_j. Higher the discordance index, higher the opposition of the criteria on the validity of the affirmation Q. When at least one discordance index among all values calculated is equal to 1: the statement "*action* a_i *is at least as good as action* a_k" is considered false and the outranking index is equal to 0.

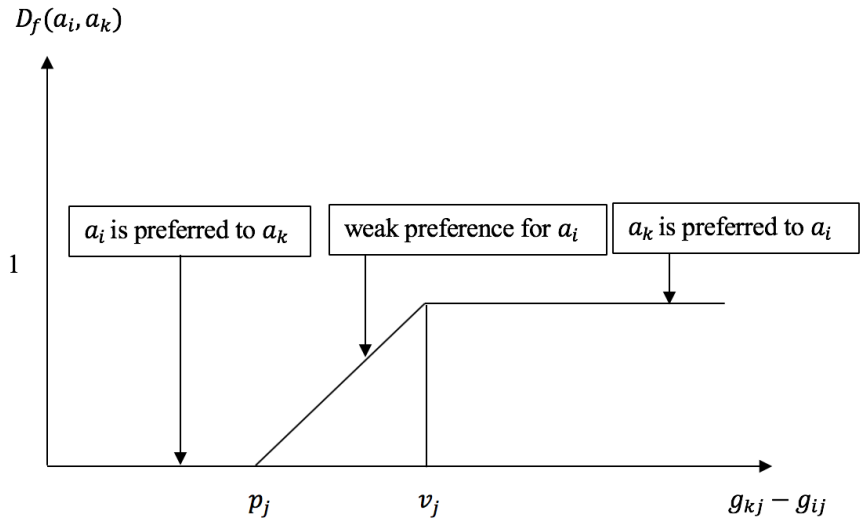


Figure 2: Range discordance index.

When it is not possible to evaluate the performance $g_{k,j}$ or $g_{i,j}$, an innovation introduced by MURAME method is the assumption that $g_{k,j} = g_{i,j}$. The consequence for the concordance and discordance index is that they will be both equal to 1 or 0. In this way, we cannot prefer one alternative to another one.

$$C_j(a_i, a_k) = D_j(a_k, a_i) = 0$$

$$C_j(a_i, a_k) = D_j(a_k, a_i) = 1$$

All the thresholds (veto, preference, indifference) are chosen by the decision maker. Their value has a huge impact on the final result and it must be decided in an appropriate way. In the MURAME application will be explained how these values have been chosen.

Once defined the concordance and discordance index, we can compute the final outranking relation or credibility index O(a_i, a_k) by aggregating them in a proper manner. It allows the construction of a superiority relationship which measures the degree of superiority between two alternatives based on a criteria.

$$O_j(a_i, a_k) = \begin{cases} C_j(a_i, a_k), & if\ C_j(a_i, a_k) \geq D_j(a_i, a_k)\ \ \forall j \\ C_j(a_i, a_k) \prod_{j \in K} \dfrac{1 - D_j(a_i, a_k)}{1 - C_j(a_i, a_k)} & otherwise \end{cases}$$

with K that indicates the group of criteria in which $D_j(a_i, a_k) > C_j(a_i, a_k)$. When the discordance index is lower than the concordance index, then the outranking index will coincide with the concordance index for each j. On the other hand, when the discordance index is higher than the concordance index, the outranking index is the product between the concordance index and the following ratio $\frac{1-D_j(a_i,a_k)}{1-C_j(a_i,a_k)}$ which is lower than 1 by construction. In this latter case, the outranking index can be 0 just when the discordance index is 1, remembering that this means that "*action a_i is at least as good as action a_k*" is not true. It is sufficient that a_i has a worse performance respect to a_k only based on one criteria to avoid considering a_i as better than alternative a_k.

To sum up, the outranking index can take two values: one equal to the concordance index or the other one lower than the concordance index, whose reduction will be proportionate to the discordance index.

All these steps belong to the first stage which involves the development of an outranking relation among the considered alternatives. The second stage is the exploitation phase in which the outranking relations are utilized in order to satisfy one of the three problematics stated before: Choosing, Ranking and Sorting.

What we have explained up to now describes how the first step of MURAME method works. The following step is explained by PROMETHEE II method.

2.4 PROMETHEE methods

The Preference Ranking Organization METHod of Enrichment Evaluations called PROMETHEE method belongs to the outranking methods. Their development started in the 1982 with PROMETHEE I and II methods proposed by Jean-Pierre Brans and presented at the conference at the l'Université Laval, Québec, Canada. Some year later, J.P. Brans and B. Mareschal developed PROMETHEE III and PROMETHEE IV ending their research works with two extensions, PROMETHEE V and PROMETHEE VI.

These methods are used in different kind of field such as finance, medicine, chemistry, tourism, health care and so on[41]. The large utilization of these methodologies derives from the fact that they are easy to use and with interesting mathematical properties.

From a mathematical point of view, a general multicriteria problem can be represented as:

$$max\{g_1(a), g_2(a) \dots g_k(a) | a \in A\}$$

where $A = \{a_1, .. a_i, .. a_n\}$ is the finite set of the possible alternatives and $g_1(.), g_2(.) \dots g_k(.)$ are the evaluation criteria. The decision maker would like to identify an alternative that optimizes all the criteria at the same time. Generally, following the classical method of optimization, there is no an alternative better than the others since there can be problems from a mathematical point of view. Furthermore, there can be difficulties in including the decision-maker preferences. Thus, the additional information provided by the decision maker plays an important role in decision aid in order to consider the individual preferences. The PROMETHEE methods require this information to understand both the decision makers and the analysts, in particular, the requested information consists of:

- information between criteria,
- information within each criterion.

The information that belongs in the first group (information between the criteria) regards the importance of the different criteria. Thus, each criteria will have an associated weight w_i which is non-negative, independent from the measurement units of the criteria and the sum of all weights must be equal to 1. The weights are given following the principle: the more important the criteria, the higher the weight. Furthermore, their assessment is linked to the priorities and perceptions of the decision-maker, so, we can say that it is quite subjective.

[41] Example can be: "*An interval version of PROMETHEE for comparison of building products' design with ill defined data on environmental quality*", Teno TFL, B. Marseschal European Journal of Operational Research 1998; "*An extension of the PROMETHEE method for decision-making in fuzzy environment: ranking of alternative energy exploitation projects*", Goumas MG, Lygerou V., European Journal of Operational Research 2000.

The information that belongs in the second group (information within each criterion) refers to the preference structure of the alternative. Through a pairwise comparison of two alternatives based on criteria c_j which can be maximized or minimized, a preference function is obtained. In fact, the PROMETHEE methods involve a pairwise comparisons of two alternatives called (a_i, a_k) in order to measure the degree of preference for a_i over a_k. When the criteria must be maximized, this comparison is given by the deviation between the evaluation of two alternatives based on a particular criterion and it gives as a result the preference function:

$$P_j(a_i, a_k) = f[d_j(a_i, a_k)] \ \forall a_i, a_k \in \mathrm{A}$$

Where $g_j(a_i) - g_j(a_k) = d_j(a_i, a_k)$. The preference function must satisfy $0 \leq P_j(a_i, a_k) \leq 1$, furthermore, when the preference is 0, the deviation is negative. The shape of the function $P_j(a_i, a_k)$ should be:

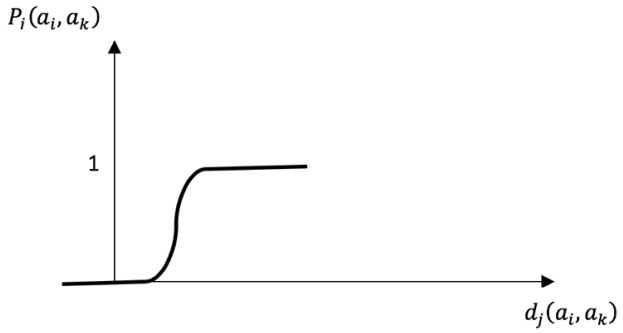


Figure 3: Shape of the preference function

When the criteria must be minimized, the preferences function is the following:

$$P_j(a_i, a_k) = f[-d_j(a_i, a_k)]$$

It's important to note that the preference function and the parameters to fix depend on the type of generalized criteria. In fact, as for the ELECTRE methods, there are three parameter to fix:

- the indifference threshold "q" which is the largest deviation, it is sometimes considered negligible by the decision maker,
- the strict preference threshold "p" which is the smallest deviation, it is sometimes considered sufficient to generate a full preference,

- *"s"* that is an intermediate value between *"q"* and *"p",* it indicates the inflection point of the preference function, when "*s"* is close to "*q"* the preferences will be reinforced for small deviations, in the opposite case, they will be softened.

Once defined the evaluation table $g_j(.)$, the weights w_i and the preference function $\{P_j(a_i, a_k)\}$, the PROMETHEE methods can be applied.

As we did for the ELECTRE methods, we will focus on the method that is useful in the construction of MURAME method which is the PROMETHEE II method.

PROMETHEE II method has a similar procedure as PROMETHEE I which involves the pairwise comparison (a_i, a_k) to determine the degree of preference for a_i over a_k and viceversa. This is expressed in the following system:

$$\begin{cases} \pi(a_i, a_k) = \sum_{j=1}^{k} P_j(a_i, a_k) w_i \\ \pi(a_k, a_i) = \sum_{j=1}^{k} P_j(a_k, a_i) w_i \end{cases}$$

The preference index must be between 0 and 1. Furthermore, higher the preference index $\pi(a_i, a_k)$, higher the strength of the preference for a_i over a_k. At the same time, lower the preference index $\pi(a_k, a_i)$, lower the strength of the preference for a_k over a_i In this sense, it is similar to the global concordance index of ELECTRE methods. The preference index depends on two variables: the first one is the specification of the criteria weights w_i, the second one is the preference function $P_j(a_i, a_k)$. The preference function, as described above, is an increasing function, normalized between 0 and 1. When it is close to 1 means a strong preference for a_i over a_k in terms of criterion c_j, while, when it is close to 0 indicates a weak preference for a_i over a_k in terms of criterion c_j.

After this process, the decision maker obtains the comparison for each pair of alternatives, then, it is possible to build a graph called value outranking graph that shows the results. The plot is composed by two elements:

1. the nodes that represent the alternatives under considerations,
2. the arcs represent the preference of alternative a_i over a_k (if the direction of the arc is $a_i \rightarrow a_k$)

For simplicity, we have called a_i as *a,* a_k as *b,* a_m as *c,* and so on in the value outranking graph below.

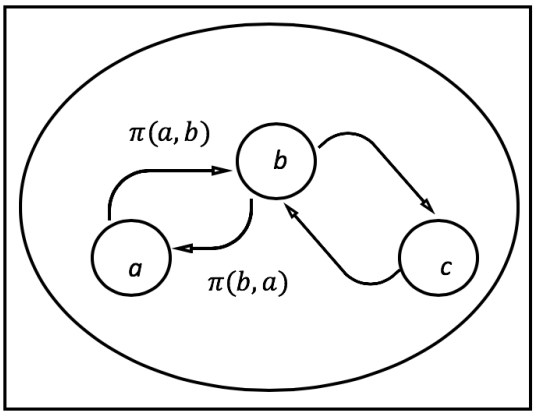


Figure 4: Valued outranking graph

Thus, the arcs connect nodes a_i and a_k; moreover, each of them has an associated flow representing the preference index $\pi(a_i, a_k)$. In particular, there are two flows that represent the strength and the weakness of alternative a_i:

1. the leaving flow which is the sum of all the flows leaving node a_i, it indicates a measure of the outranking character of alternative a_i over all the other alternatives in A, it must be maximized, the better is alternative a_i respect all the other, the higher is the leaving flow:

$$\phi^+(a_i) = \frac{1}{n-1}\sum_{k\in A}\pi(a_i, a_k)\,;$$

2. the entering flow which is the sum of all the flows entering in node a_i, it measures the outranked character of alternative a_i compared to all the other alternatives in A, it must be minimized, the better is alternative a_i respect the other, the lower is the entering flow since the entering flow indicates the weakness of a_i:

$$\phi^-(a_i) = \frac{1}{n-1}\sum_{k\in A}\pi(a_k, a_i)\,.$$

These two flows cannot be represented graphically. Once computed, PROMETHEE II ranks the alternatives by taking the difference between the leaving and entering flow which is called net flows for an alternative a_i:

$$\phi(a_i) = \phi^+(a_i) - \phi^-(a_i)$$

The net flows represents the overall evaluation index of the performance of the alternatives. An higher net flows indicates the most preferred alternatives. This process builds the second part of the MURAME method.

2.5 MURAME method

There are different kind of multicriteria methods, the choice depends on the decision maker's needs and objectives. The specific methodology used in this work is called Multicriteria RAnking MEthod (MURAME).

The MURAME has been originally proposed in Goletsis et. at (2003) as a method for project ranking. It is the combination between ELECTRE III and PROMETHEE II methods. Thus, it can be considered as a sort of hybrid. More in detail, MURAME method is divided in two stages:

- the first phase derives from the ELECTRE III in which an outranking relation is built in order to determine how much a_i is preferred to a_k or viceversa,
- the second phase originates from the PROMETHEE II in which the outranking relations are used to classify the alternatives from the best to the worst.

Its aim is to rank the alternatives in accordance to the outranking-based approaches. So, given a set of alternatives $A = \{a_1, .. a_i, .. a_n\}$, the MURAME method allows to score and consequently to rank them based on a set of criteria. For this reason, it uses the same three indices used in ELECTRE III:

1. concordance index,
2. discordance index,
3. outranking index.

The combination of these three indices leads to a final score for each alternative. The final score for alternative a_i, called final net flow, is given by the formula:

$$\varphi(a_i) = \varphi^+(a_i) - \varphi^-(a_i)$$

where $\varphi^{+}(a_i)$ is the sum of all outranking indices $O(a_i, a_k)$ with $i \neq k$ and it is called leaving flows while $\varphi^{-}(a_i)$ is the sum of all outranking indices $O(a_k, a_i)$ with $i \neq k$ and it is called entering flows. Both outranking indices are computed following the ELECTRE III method's rules. Converting the final score into practice, it allows to create a ranking among all the alternatives. Its meaning is that an alternative having a lower score should be considered to be worse than another one with higher score.

In this work, MURAME method exploits different indicators to evaluate the banks' liquidity risk. In particular, we use it for:

- ranking the banks based on their liquidity risk,
- sorting the banks according to their liquidity risk level,
- ranking the banks inside their liquidity risk class.

In order to proceed with the analysis, the preference, indifference and veto thresholds are not sufficient. It is necessary to compute another parameter which is the so-called reference profile. The latter is a benchmark profiles related to fictitious applicants. It is useful to delimit the rating classes and to serve as comparison with the profiles of real applicants. If we consider a total number of homogeneous rating classes l named $R_1, R_2, \dots R_l$, we will need a total number of reference profiles equal to $l-1$ called $r_1, r_2, \dots r_{l-1}$ in order to divide the ranking into l homogeneous classes. For example if we want to have 3 homogeneous classes, we will need 2 reference profiles to divide the ranking into 3 classes. The banks classification in our study is done according to the following rule:

$$a_i \in R_j \iff \varphi(r_{j-1}) > \varphi(a_i) \geq \varphi(r_j)$$

for j=1,…, l, with $\varphi(r_o) = +\infty, \varphi(r_j) = -\infty$.

A more detailed explanation of the reference profiles computation is given in the fourth chapter. To sum up, to use MURAME method, it is very important to specify in our analysis the values of the: indifference threshold q_j, preference threshold p_j, veto threshold v_j, weights of the criteria w_j and reference profiles r_j. Their specification plays an important role since different values correspond to different results in terms of classification.

Until now, we can say that MURAME is an useful method with particular properties. Firstly, it does not allow the compensation of bad performance, in the meaning that if a criteria gives bad performances to some alternatives, they cannot be compensated from higher performances obtained from other criteria. This characteristic allows us to define MURAME as a non-compensatory approach. On the other hand, an approach is compensatory when it allow the exchange of advantages and disadvantages in order to compensate a bad score or result. Secondly it gives the possibility of considering the decision maker preferences through the indifference, preference and veto thresholds decision. In fact, as we will see in chapter four, the latter can be determined mathematically or they can be determined directly by the decision maker after an analysis of the criteria values.

2.6 MCDA applied in Financial Field

In financial field, the decisions have been taken following an optimization approach in order to choose the best alternative. In reality, it's very difficult to find the optimal choice, since it must be better than all the other alternatives simultaneously. For this reason, it is necessary to evaluate all the alternative at the same time considering different factors. The conclusion is that it is rare that one alternative is better than all the others. As a consequence, the classical techniques have been criticized in the last few year, leading to the born of new instruments.

Certain problems need to be evaluated using approaches that allow the existence of different dimensions of the problem to be considered at the same time. The evaluation of liquidity risk is one of them. It is a continuous process that banks must plan and manage continuously during the bank's life, so it is part of the global strategy of risk management. Liquidity risk depends on internal and external factors such as the market risk or the structural risk, which affect the capacity of the financial institutions to face their obligations. This problem can be overcome by a multicriteria decision aid (MCDA) analysis. It allows the decision maker to treat simultaneously more than one variable which can be, most of the time, contradictory and heterogeneous. So, a multicriteria procedure, such as the one presented in this analysis, constitutes an adequate tool to assist the analyst in:

- summarizing elementary judgements,

- aggregating elementary judgements,
- arriving at an overall evaluation.

These techniques were widely adopted to support different types of real-life decision problems, especially in the field of finance. Among the financial applications of MCDA, examples can be:

- "*Assessing financial risks using a multicriteria sorting procedure: the case of coutry risk assessment*", Michael Doumpos, Constantin Zopounidis (2000),
- "*Multicriteria decision aid in financial management*", C. Zopounidis (1999),
- "*Multiple criteria decision making (MCDM) methods in economics: An overview"* Zavadskas EK, Turskis Z (2011),
- "*Ranking enterprises based on multicriterial analysis*", Zoran Babic, Neli Plazibat (1997),
- "*A MURAME-based technology for bank decision support in credit worthiness assessment*" M. Corazza, S. Funari, F. Siviero (2014). Banks and Bank System,
- "*PSO-based tuning of MURAME parameters for creditworthiness evaluation of Italian SMEs*" M. Corazza, G. Fasano, S. Funari, R. Gusso (2017), Working Paper n 4/2017.

It can be applied not only in finance and economics fields but also in marketing, in medicine, human resources management, environmental, in health care, energy management and finally in the management of production systems. Examples of MCDA applications in field different from finance are:

- "*A multiple criteria model for new telecommunication service planning*", C. H. Antunes, J.Craveirinha and J. Clímaco (1993),
- "*An evaluation of multi- criteria methods in integrated assessment of climate policy*", M.L. Bell, B. Hobbs, E.M. Elliott, H. Ellis, and Z. Robinson (2001),
- "*Multi-criteria DSS for river water quality planning*", A.V. Lotov, V.A. Bushenkov, and O.L. Chernykh (1997).

From the past paragraphs, we know that MCDA methods apply in finance field. Before proceeding with further explanation, a brief definition of finance is given. S. A. Ross in "*The New Palgrave Finance*", (1989) defined "*Finance is a sub field of economics distinguished by both its focus and its methodology. The primary focus of finance is the*

workings of the capital markets and the supply and the pricing of capital assets. The methodology of finance is the use of close substitutes to price financial contracts and instruments. This methodology is applied to value instruments whose characteristics extend across time and whose payoffs depend upon the resolution of uncertainty".

The use of mathematics and operations research in the field of finance started in the 1950s with Markowitz's portfolio theory. Markowitz opened new ways by formalizing and quantifying the concept of "risk". Since then, the attention about the functioning of financial markets increased as well as the existence of financial decision-making problems that require the evaluation of more than one alternative, for instance venture capital investments, financial planning, corporate mergers, risk assessment and so on. The following years, Eugene Fama and Merton Miller sustained the idea that finance served in real-world decision problems in their book "*The theory of Finance*" (1972). The descriptive finance could help in avoiding the acceptance of too easy and unreasonable results just because they are widely shared. Merton reached the conclusion in 1995[42] that "*The core of finance theory is the study of the behavior of economic agents in allocating and deploying their resources, both spatially and across time, in an uncertain environment*".

In the recent years, the idea that a sole objective, criteria or point of view to make real-world decisions was the base for the development of MCDA methods. These techniques were not the only one considered useful for financial decision making, other tools developed with similar aims came from forecasting, decision support systems, fuzzy logic, stochastic processes, simulation and so on. Among all of them, researchers and practitioners focused on MCDA methods since they were considered more precise in evaluating and reporting the financial positions, especially after the development of new complex financial products.

Nowadays, the financial key problems solved thanks to multicriteria decision aid are the risk analysis, the risk management and the performance evaluation. More in detail, it is possible to recognize three basically areas of financial decisions:

1. capital budgeting,

[42] *"Influence of mathematical models in finance on practice: past, present, and future",* Financial Practice and Education, R.C. Merton (1995)

2. corporate financing,
3. financial investment.

The first area includes issues related to the evaluation and the choice of portfolio investment projects, distinguishing profitable from non-profitable opportunities. The second area embodies the analysis of the firm's structure and dividend policy, including topics such as the choice of the securities to issue, the earnings payment, the liquidity management etc. The third area regards problems related to the choice of a portfolio of financial securities with the aim of changing the strategy over time.

There are many advantages of using MCDA in finance: first of all, complex evaluation problems can be structured, reducing the complexity; secondly the criteria in the evaluation process can be both quantitative and qualitative; thirdly the evaluation is transparent and it gives the possibility of considering the decision maker preferences, at the end MCDA is a flexible, sophisticated and realistic methodology. A drawback may be the difficulty in finding software packages specifically designed for financial decision-making problems. As a consequence, the application and successful of MCDA methods in finance is partly linked to the development of software packages that are cheap, user-friendly and support real financial decision making.

In literature, several multicriteria techniques were used in a wide range of activities of banking sector from loan evaluation to credit assessment. We have already named the work of Corazza, Funari and Siviero (2014) which applied MURAME method for bank decision support in creditworthiness assessment. Another applications of MCDA methods in banking sector, Zopounidis and Doumpos (2010)[43] used PROMETHEE II for bank rating in Greece. Classically, bank rating is performed via empirical procedures that combine financial and qualitative data into an overall performance index. The main result of bank rating models under a multicriteria approach is the classification of banks into homogeneous risk groups starting from banks with low profile to banks with high performance. Using a multicriteria model allows both the definition of the risk grades and the development of an overall performance index. The latter can be used to compare the performance of each bank, identifying the strengths and weaknesses of a bank compared to its competitors. PROMETHEE II method was also used for other two types of

[43] "*A multicriteria decision support system for bank rating*", Decision Support Systems 50 (2010) 55-63

comparisons, one from an optimistic point of view and the other one from a pessimistic point of view. In the former case, banks are compared to the ideal bank, this evaluation determines the assessment of the capability of the banks to perform as better as possible. The second evaluation compares the banks to the worst bank, this evaluation determines the assessment of the possibility of the banks to perform as worse as possible.

Going back in time, PROMETHEE II method was also applied by Zopounidis and Kosmidou (2008)[44] to evaluate the performance of commercial and cooperative banks in Greece. Their aim was to consider two groups of banks separately (commercial and cooperative banks) and, for each of them, ranking the banks based on their performance which is calculated based of financial ratios. Moreover, the results allowed a comparison between the two classes of banks. The conclusions were that commercial banks tended to increase their accounts in order to attract more investors and to improve their financial ratios. By doing so, they could increase their competitiveness and maximize their profits. For the cooperative banks, the conclusion were not uniform, since there were banks that were increasing their accounts and banks that were deteriorating their financial index. Another relevant paper was written by Zopounidis, Kosmidou and Doumpos (2002)[45]. They used a multicriteria classification technique, the M.H.DIS method *(*Multi-group Hierarchical DIScrimination) to assess the corporate credit risk. In this work, the credit risk is considered as the risk that arises when an enterprise or consumer does not respond effectively to its loan obligations provided by a financial institution. The valuation of this risk is very important for the financial institutions since they have to evaluate their customers before granting a loan. In fact, the allowance of credit towards firms and customers constitutes the major source of income for the majority of banks. The M.H.DIS method belongs in the MCDA preference disaggregation methods[46]. In this method, there are always a set of alternatives and of criterion. The criteria can be seen from an increasing or decreasing point of view, in the first case, the decision maker can prefer higher values of the criteria, in the second case he prefers lower values of the criteria. The set of alternatives are already classified in a pre-specified classification called training sample. During this predefined process, the method uses a hierarchical procedure starting from

[44] "*Measurement of Bank Performance in Greece*", South-Eastern Europe Journal of Economics (2008)
[45] "*A Multicriteria Hierarchical Discrimination Approach for Credit Risk Problems*" European Research Studies, Volume V, Issue (1-2), (2002)
[46] Other MCDA preference disaggregation approaches are UTA method, UTADIS method, ELECTE-TRI method.

the lowest class. Then, the model should reproduce the classification of considered alternatives in the training sample. This second classification is made by estimating additive utility functions through mathematical programming techniques to respect the pre-specified classification as much as possible. Thus, this method applied in credit risk allows to distinguish three classes of firm based on their credit risk (low, medium and high). The results of this paper are that M.H.DIS method is able to capture corporate credit risk with more efficacy and reliability compared to other methodologies such as statistical or econometrics techniques.

As regard to the methodology used in this study, even if MURAME is quite a recent technique, it has attracted the attention of researchers and practitioners, especially in financial field. Corazza, Fasano, Funari and Gusso (2017) applied this methodology for the creditworthiness evaluation of Italian SMEs. In their paper, MURAME allowed the production of results in terms of scoring, classification into homogeneous rating classes and migration probabilities. They considered as time horizon the beginning phase of the recent economic and financial crisis, from 2006 to 2008. Another example of MURAME application is given by Corazza, Funari and Siviero (2014) which applied it for bank decision support in creditworthiness assessment. They used a sample of 1000 firms which have obtained funding from Banca Popolare di Vicenza between 2001 and 2003 in order to: rank the firms according to their credit risk characteristics, sort them into a prefixed number of homogeneous creditworthiness groups and to estimate the probabilities of both default and transition.

These examples are just a few applications of multicriteria methods in banking sector, there are many other papers in literature, especially if we consider the whole finance field and not only the financial institutions. Thus, the conclusion is that there are many publications addressing the topic of multi-criteria techniques in finance, mainly in the last decade. Furthermore, this trend is expected to continue, as financial decision making processes will increase, requiring the incorporation of more suitable appraisal techniques. The goal of all these theoretical-empirical papers is to show the evidence that these new methodologies have a potential impact to solve real financial problems. The complex decisions can be solved thanks to the MCDA methods capacity of considering a set of criteria which can be tangible or intangible in the evaluation of alternatives. In this way, they fit more properly and more realistically the company financing decision.

CHAPTER 3 – MURAME and Liquidity Risk Measures

3.1 The choice of MURAME

In this work, MURAME method is applied in the evaluation of banks' liquidity risk. We took this decision because we need a method with the following properties:

- it must work independently from the criteria characteristics, in the meaning that the criteria can be qualitative or quantitative, independent among them and with different unit of measure,
- it must obtain, given a set of alternatives (the banks), a ranking of the alternatives,
- it must consider the decision maker's preferences through the thresholds (preference, veto, indifference),
- it considers different weights to each criteria.

After having defined our purposes, we reached the conclusion that the best approach to use is the MURAME even if there is not a multicriteria decision aid method better than the others.

The main reason for which we decided to use a multicriteria method is that liquidity risk cannot be measured by considering just one variable or indicator. Obviously, this is not sufficient to accept the use of a MCDA method for the analysis, it is also fundamental that MURAME agree with the Italian and European regulation. Starting from the latter, the most important regulatory initiatives that regulate liquidity risk are:

- the "*Basel III-The Net Stable Funding Ratio*" (2014) and the "*Basel III: The Liquidity Coverage Ratio and Liquidity Risk Monitoring Tools*" (2013) which are the only reforms that provide quantitative measures for liquidity risk,
- the "*Principles for Sound Liquidity Risk Management and Supervision*" (2008) published by the Basel Committee which provides, as the name suggests, a guideline for the management and supervision of liquidity risk.

The Net Stable Funding Ratio and the Liquidity Coverage Ratio are two well-known indicators for measuring the liquidity risk, they were introduced in 2010, in "*Basel III-*

International framework for liquidity risk measurement, standards and monitoring". Their formula and meaning has been already explained in the first chapter. Since 2010, each member of the European Union had a period of time in order to introduce and respect them. Thus, they can be considered as a minimum standard requirement to avoid liquidity tensions. Looking at the other regulation, principle 5 states that "*A bank should have a sound process for identifying, measuring, monitoring and controlling liquidity risk. This process should include a robust framework for comprehensively projecting cash flows arising from assets, liabilities and off-balance sheet items over an appropriate set of time horizons*." Referring to the measuring activity, the Basel Committee allows banks to employ a wide range of measurement tools since there is no single measure that quantifies the whole liquidity risk. Thus, under this regulation, banks should evaluate their liquidity risk exposures by assessing the structure of the balance sheet (material assets, liabilities and so on), cash flows and future liquidity positions[47] considering also off-balance sheet commitments. To conclude the European Regulation states that a single measure is not sufficient to comprehensively determine liquidity risk. It defined the two ratios (LCR and NSFR) to take into account two aspects of liquidity risk that are the capacity of reacting against liquidity pressures in the short-term and in the long-term. These two requirements have the aim of ensuring the stability of financial institutions; moreover, they requir to the banks to hold more liquid assets and to issue more long-term debt.

Moving to the Italian regulation, the main provisions are mainly in "*Disposizioni di vigilanza prudenziale per le banche*, *circ. n. 285 del 17 Dicembre 2013 e successivi aggiornamenti*", Bank of Italy. It defines that the risk management includes: identifying, measuring, monitoring and controlling liquidity risk. Focusing on measuring, liquidity risk should be identified from a current and perspective point of view in order to determine the probable future behavior of cash inflows and outflows. The difference respect to the European Regulation is that the national regulation does not provide any indicators as those formulated by Basel Committee. The starting point for recognizing the cash flows is the composition of a maturity ladder. The latter allows the quantification of possible deficit or surplus once established a time horizon. Referring to short-term liquidity, banks consider as time horizon at least one months, while referring to long-term

[47] A liquidity position is the difference between the sum of liquid assets and incoming cash flows on one side and outgoing cash flows resulting from commitments on the other side.

liquidity, banks consider as time horizon a number of maturities at least equal to those used to measure interest rate risk.

To summarize, even if the Italian regulation does not impose any tools for measuring liquidity risk, Italian banks and the banks operating in Italy must respect the European regulation. For this reason, the utilization of a multicriteria method is acceptable and coherent with both Italian and European regulation.

Once established that a multicriteria decision aid method is an acceptable instrument to use, we can move to the explanation of the reasons why it is used in this analysis. The decision of using MURAME derives from the objectives of this analysis which are: ranking the banks from the best to the worst and sorting the banks into homogeneous classes based on their liquidity risk. We could use this method also to evaluate the liquidity risk of a single bank but this does not have sense since in this way, a comparison would be impossible. For this reasons, we consider several banks, in order to see the problem from a systemic point of view. Furthermore, the liquidity risk can derive from factors inside the bank activity as well as factors outside the financial institution. Thus, liquidity imbalances can come from both the bank's financial structure and the choices made by counterparties/outside. The latter refers to systemic liquidity risk. In broad terms, systemic risk can be described as the externalities of bank distress onto the rest of the financial system or the real economy (Bernanke, 2009). A typical idiosyncratic factor that causes liquidity tensions is an economic and financial crisis. The crisis decreases the confidence on the solvency of banks (including structurally sound banks) and the sources of funding, spreading the distrust among customers. Financial intermediaries must have an excellent level of liquidity internally, in other words, they must manage their liquidity properly in order to ensure good liquidity conditions for the whole system. This is due to their role of intermediaries on the market. Matz and Neu (2007) wrote "*Too little liquidity may kill a bank suddenly, but too much might kill it slowly*".

Thus, under the assumption that we are considering more than one bank, MURAME is a good method to evaluate liquidity risk from a systemic risk point of view. When we rank the alternatives from the best to the worst, the banks that are in the last positions can be seen as a threat for the stability of the whole system or, in other words, they can be seen as a trigger for systematic risk.

3.2 Literature Review on Liquidity Risk Measures

According to the definition of liquidity risk examined in the first chapter, it is the bank's inability to face a decrease in liabilities or to fund an increase in assets. Furthermore, Diamond and Dybvig (1983) stated that one of the key reasons for which banks are easily to fail, is their role in transforming maturity and providing insurance as regards depositors' potential liquidity needs.

In literature, the topic of liquidity risk has been considered by many authors, reaching different conclusions about the optimal solution for its measurement. The measurement of a bank's liquidity risk exposure has been initially address by using liquidity ratios, then this traditional technique was supported by econometric techniques. The latter includes methods such as linear regression which allows to link the liquidity risk with its causes by using liquidity ratios as proxy for the computation. Authors as Shen (2009) and Soula (2015) used this method in their works to evaluate the liquidity risk. Shen used an unbalanced panel dataset of 12 commercial banks between 1994 and 2006 to estimate bank liquidity risk and performance model. The applied regression model was two-stage least square (2SLS). The paper's results found that liquidity risk can be caused by liquid assets and by other variables such as external funding, supervisory and regulatory factors and macroeconomic factors. Furthermore, it affects the bank profitability by reducing both the return on average assets (ROAA)[48] and the return on average equities (ROAE)[49] and by increasing the cost of fund. On the other hand, Soula used a risk factor model to measure the bank exposure to liquidity risk. He used a sample of listed banks from the euro area in a period between 2005 and 2012. The results showed that liquidity risk is idiosyncratic and there is high level of heterogeneity across banks in terms of liquidity condition when markets are calm, however, during crisis, the risk tends to be systematic and the heterogeneity reduces.

The second category of liquidity risk measure includes the liquidity ratios. We have already explained some liquidity ratios that can be used from the banks' management in

[48] Return on average assets measures the profitability of a firm's assets, and it is most often used by banks as a means to gauge financial performance. ROAA is calculated by taking net income and dividing it by average total assets.
[49] Return on average equity measures the company profitability. It is the ratio between the net income and the sum of the equity value at the beginning and at the end of the year, divided by 2.

the first chapter. Now, a literature review on these ratios is given. They represent the liquidity risk position of a bank considering individual aspects of this risk. These ratios come from the bank's balance sheet. At the beginning of the studies about liquidity risk measurement, the first ratios used where the liquid assets to total assets ratio e.g. Bourke (1989); Molyneux and Thornton (1992); Barth et al. (2003); Demirgüç-Kunt et al. (2003), the liquid assets to deposits ratio e.g. Shen et al. (2001) and the liquid assets to customer and short term funding e.g. Kosmidou et al. (2005). The meaning of these ratios is that when their value is high, the bank is more reliable and liquid. As a consequence, there are less probability of failure and bankruptcy.

In the following years, new measures were studied, in particular they were used to investigate in three characteristics: the stability of funding, the liquidity of assets and the funding gap between assets and liabilities. For each category, different ratios were developed:

- Acharya and al. (2011) defined the stability of funding as rollover risk which is the possibility for a loss of funding. The ratios used to measure this category are accounting ratios such as the core deposit ratio or the brokered deposits ratio,
- The liquidity of assets can be measured by the share of customer loans over total assets e.g. Pagratis and Stringa (2009), the reserve balance with the central bank e.g. Acharya and Merrouche (2012) and the daily change in the bank reserve deposits e.g. Cocco and al. (2009),
- The funding gap can be the difference or the ratio of illiquid assets funded by demandable debt. Pagratis and Stringa (2009) proposed as measure the liquid assets over short-term liabilities or liquid assets over total debt while Aikman and al. (2011) proposed as measure the customer loans minus short term liabilities over customer loans.

However, many other measures that do not belong in the three above categories have been proposed. Recently, the Basel III Committee indicated two liquidity ratios: Liquidity Coverage Ratio and Net Stable Funding Ratio that we have discussed previously and that each member states of the European Union must respect. As already stated, in Italy there are not measures common accepted since the regulation focuses more on qualitative aspects, furthermore banks must be evaluated based on their individual bank's balance

sheet and strategy, so there is not a common evaluation. Saunders and Cornett (2006) suggested as measure for the liquidity risk exposure a large number of indicators such as:

- The peer group ratio comparisons which consists in the comparison of significant ratios calculated directly from the balance sheet of some different banks. An example could be the comparison of the liquid assets to total assets ratio of two or more banks. This methodology holds, if the banks used as reference have similar characteristics in terms of their size, geographic location and so on.,
- the liquidity index which represents the potential loss that derives from an immediate sale in the market, it is calculated as the weighted sum of the ratios between the price of each asset in the event of a fire-sale and its respective fair market price,
- the financing gap that is the difference between the average total loans granted and the average total deposits are the financing gap,
- the financing requirement that is the sum between the financing gap and the readily convertible liquid assets,
- the liquidity planning.

The next year, Matz and Neu (2007) proposed three other methods to asses liquidity risk: the balance sheet liquidity analysis, maturity mismatch approach and the cash capital position. They saw the liquidity risk as a consequential risk since it arises as a consequence of one or more sharp increases in other financial risk.

Looking at each approach singularly, the balance sheet liquidity analysis involves the evaluation of liquidity of relevant balance sheet items. The relevant assets for the liquidity analysis includes the loans, the receivables, the investments, the trading assets, the reverse repos and the security borrowing. The relevant liabilities are the non-bank deposits, certified liabilities, equity, unsecured bank deposits, trading liabilities and repo. The balance sheet liquidity analysis consists in the comparison of the asset and liability side based on liquidity of the assets and the stability of funding.

The second method proposed is the maturity mismatch approach. It consists in the creation of a maturity ladder including all liquefiable balance sheet and off-balance sheet items. The maturity ladder allows measuring the balance between expected cash inflows and outflows in different time and creating the net financial gap profile. In particular, firstly, it distinguishes four categories of cash flows based on their amount and time.

Category II and IV require additional model assumptions reaching a higher accuracy respect to the balance sheet liquidity analysis. These adjustments are done by considering market experience and product knowledge in different scenarios rather than mathematical calculation. In the table below, it is defined what includes each category. Secondly, from the maturity ladder is possible to identify a liquidity gap profile which is the difference between the net cumulative inflow and the net cumulative outflow. It can be calculated each year, half year, quarterly and so on. The net cumulative inflow comprises: cash, unencumbered securities and all the liquidity available to cover liquidity outflow. The net cumulative outflow includes: loans, retail deposits, deposits from banks, corporations and governments, own capital market funds and off-balance sheet commitment. What is not shown in the gap profile are the equity capital and the participations since they are managed directly from the Board and not from the liquidity management department. The net cumulative liquidity gap indicates the bank ability to cover its outflows by liquidating its unencumbered assets (if the difference is positive). When the difference is negative, it means that the bank has not enough resources to cover its outflows. This does not necessary imply that the banks is insolvent. This analysis comprises also the calculation of the funding ratio which is the ratio between the sum of available funding above n years and the sum of assets maturing above n years. It is useful to analyze the structural liquidity risk in a bank's balance sheet, especially, the long-term funding structure. A normal value should be lower than 100%, furthermore, when it drops under certain limits from one period to the following one, it indicates the bank can be subject to liquidity risk .

CATEGORY I	**CATEGORY II**
Cash flow amount and cash flow timing are deterministic: • Fix rate term loans and mortgages, • Cash, • Fix deposits.	Cash flow amount is stochastic and cash flow timing is deterministic: • Variation margins, • European options.
CATEGORY III	**CATEGORY IV**
Cash flow amount is deterministic and cash flow timing is stochastic: • Traveler's cheques, • Loans with flexible amortization schedule.	Cash flow amount and timing are stochastic: • Revolving loans, • Current account, • American options

The last method is the cash capital position, it is an indicator obtained by subtracting from unencumbered assets the following values: the short-term interbank funding, the noncore deposits and the undrawn commitments. It indicates the vulnerability of bank to liquidity risk and it provides a representation of a static type of liquidity risk, ignoring the dynamics of financial inflows and outflows that can happen in a specific moment and connected with the entire bank management.

Matz and Neu proposed also a qualitative approach for the analysis of the liquidity risk. In fact, a qualitative analysis is at least as important as a quantitative measurement. It incorporates questions that address the following topics:

- the analysis of available IT-system infrastructure,
- the review of management and control process in place,
- the existence of diversified market access for funding.

The liquidity management must give an answer to these issue by increasing the control, the liquidity policies and so on, in order to improve the management of liquidity risk. The Basel Committee on Banking Supervision agreed with this view, in fact, it includes a qualitative analysis of liquidity risk in its disclosure rules. In particular, in "*Principles for Sound Liquidity Risk Management and Supervision*", it states that "*A bank should provide sufficient qualitative discussion around its metrics to enable market participants to understand them*" and "*A bank should disclose additional qualitative information that provides market participants with further insight into how it manages liquidity risk*".

The advantage of these individual methods for bank liquidity risk is that they work at micro level, in this way it is possible to capture the bank ability of facing the fluctuation in funding liquidity all things being equal. Anyway, Poorman and Blake (2005) indicated that using the ratios described above to measure liquidity risk is not sufficient to avoid liquidity tensions or at worst, bankruptcy. The disadvantages of financial ratios as liquidity risk measure are that:

- This type of measures do not consider the whole capacity of banks to access to funding sources during liquidity shocks since the capacity can depend also on other dimensions such as the banks' reputation, the diversification of banks' funding sources or the central bank policy,

- The comparison among banks based on their liquidity risk ratios is neither coherent nor logical since the same level of a given measure for several banks or the same level of an accounting indicator at two different points in time does not necessarily mean the same liquidity risk exposure,
- The liquidity risk ratios have a lack of frequency since they are calculated every year in the annual report of the bank, by doing so, these measures fail in providing a good evaluation of bank individual liquidity risk across time. Most of the time stress events on financial markets occur a few weeks or months, thus, the bank is not able to capture such events using balance sheet ratios,
- The liquidity risk ratios do not interact with the other accounting indicators, on the other hand each ratios is calculated to underline a different aspect of bank potential exposure to liquidity risk,
- Some of the ratios are quite restrictive since they divide the assets and the liabilities based on their liquidity, in reality, each assets or liabilities can have different maturity, furthermore, they can require income or expenses in a different moment respect the maturity,
- Liquidity risk ratios come from the balance sheet, so they do not consider and do not reflect the off-balance sheet commitments which can be as well a source of risk.

Main refinancing operation (MRO)

It refers to a weekly open market operation with a maturity of one week. They are used by the Eurosystem to provide central bank money to banks in the form of short-term collateralized loans. MROs are usually conducted as standard tenders; the main refinancing rate resulting from these operations, together with the interest rates for the standing facilities, make up the Eurosystem's key policy rates.

In order to overcome some of these shortcomings, some studies developed new measures of liquidity risk. These latter consider both the balance sheet characteristic and the funding condition on the financial markets. Abbassi and al. (2013); Craig and al. (2015); Drehmann & Nikolaou, (2013) used the bidding or paid liquidity price of banks in the Eurosystem's weekly Main Refinancing Operations (MRO). The drawback with this measure is that the data are not publicly available. A second measure is the Liquidity Mismatch Index (LMI) proposed by Brunnermeier and al. (2012). It is computed as the sum of balance sheet items weighted

by their market liquidity approached through repo haircut[50] and interbank rates. Berger & Bouwman (2009) developed a measure of liquidity creation which is similar to the MRO and the LMI. Their measure is based on weighting assets and liabilities of balance sheet according to their liquidity.

The literature does not consider only the individual bank liquidity risk measures but also the measures of liquidity conditions for the entire banking sector. These measures refer to the systemic liquidity risk which is the risk of breakdowns in the entire money market. It is commonly measured by:

- market liquidity indices such as the interbank rate spreads. Examples of these spreads are the EURIBOR or LIBOR minus government yield rate of the same maturity e.g. Cornett and al. (2011), Hong and al. (2014) and Hong & Wu, (2012), or an interbank rate minus Overnight Indexed Swap (OIS) rate e.g. Hui and al. (2011),
- by the repo haircuts as suggested in Gorton & Metrick (2012),
- by the spread between German sovereign bonds and German Kreditanstalt für Wiederaufbau (KfW)[51] agency bonds e.g. Schwarz (2014).

LIBOR

It is a benchmark rate that some of the world's leading banks charge each other for short-term loans. It stands for Intercontinental Exchange London Interbank Offered Rate and serves as the first step to calculating interest rates on various loans throughout the world. The maturity that it can have are: overnight, one week, and 1, 2, 3, 6 and 12 months.

EURIBOR

It is a reference rate expressing the average interest rate at which Eurozone banks offer unsecured loans on the interbank market.

Overnight Indexed Swap (OIS) rate

Overnight index swaps are an interest rate swap that uses the overnight rate index as the underlying rate for its floating leg and it uses a rate agreed on by the parties involved as fixed rate.

It is interesting to note that, even if the financial ratios and the econometric methods have been mainly adopted for modeling financial problems, recently, a large number of recent

[50] A repo haircut is a sale of repurchase agreement in which a security is sold for cash with the promise of the seller to buy back the security in the future. The buyer assumes both the collateral as repayment should the seller default and the risk if the collateral has a volatile price history. The haircut is a kind of percentage of the market value that the buyer holds back from the cash payment to reduce the price volatility risk and the counterparty risk.

[51] It is a German government-owned developed bank which offers services as housing finance, small and medium enterprise finance, export finance, import finance, foreign investment finance, development aid.

researches introduced new methodologies. They are based on quantitative methods and are able to consider simultaneously the largest possible number of information. We are talking about Multicriteria Decision Aid methods.

3.3 The choice of Liquidity Risk Measures

The starting point for the application of MURAME method which will be developed in the next chapter, is the specification of the evaluation criteria. We have already said that we will use financial ratios for this liquidity analysis but we did not specify which types of indicators yet. The banks' liquidity risk can be measured by different ratios, as explained previously. Anyway, despite all these tools, there is not a standard measure defined by the Italian regulator. Only at international level, there are two indicators that banks must respect. We are talking about the LCR and the NSFR which indicate, respectively, a short-term and long-term measure of banks' liquidity risk. Even though we have described both the importance and the meaning of these two liquidity ratios defined by the Basel Committee, we will not use them in the analysis for the following reasons: we have not available all the information useful to compute the LRC and the NSFR which, let us remember, are calculated, respectively as the high-quality liquidity assets to total net cash outflow ratio and the available stable funding to required stable funding ratio. In fact, we have available the financial statements of 40 banks operating in Italy downloaded from ORBIS[52] in a time period from 2011 to 2017. The financial statements include the balance sheet and the profit and loss account. Anyway, we do not have financial reporting which include information about the banks, their decision, their method for credit evaluation, bank's resources and so on.

The financial instruments in the balance sheet will be measured and classified following the IFRS 9[53] which is the new regulation that replaces IAS 39[54] in phases for annual periods beginning on or after 1 January 2018 with some early application permitted. Until this moment, the financial instruments are managed using IAS 39. Under the previous

[52] ORBIS is a database with a lot of company information from all over the world such as companies's financial accounts, credit scores, ownership structures and details of mergers and acquisitions activity.
[53] It is an International Financial Reporting Standards promulgated by the International Accounting Standards Boards (IASB) which addresses the accounting for financial instruments. It becomes effective in 2018.
[54] It is an international accounting standard for financial instruments released by the International Accounting Standards Board (IASB) which was replaced in 2014 by IFRS 9.

regulation, all financial instruments are initially measured at fair value plus or minus, in the case of a financial asset or financial liability not at fair value through profit or loss, transaction costs. The financial instruments include the financial liabilities and the financial assets. Starting from the latter, the categories of financial assets in IAS 39 were four: held to maturity investments, loans and receivables, available-for-sale and at fair value through profit or loss (FVTPL) which includes trading investments, derivatives and other designed instruments. They could be classified and measured following three principles: at amortized costs, at fair value through profit or loss (FVTPL) and at fair value through other comprehensive income (FVOCI). In particular, for each of them were assigned a specific criteria. The table below summarizes the financial assets classification requirements under IAS 39:

FINANCIAL ASSETS CATEGORIES	CRITERIA
Held to maturity investments	Amortized cost
Loans and receivables	Amortized cost
Held for trading investments, derivatives and other designed instruments	Fair value through profit or loss (FVTPL)
Available-for-sale and other categories did not classify previously	Fair value through other comprehensive income (FVOCI)

IFRS 9 separates financial assets into three categories, those measured at amortized costs and those measured at fair value which includes FVTPL and FVOCI. The classification depends on two conditions to be met:

- the financial assets' contractual cash flow characteristics (SPPI[55] contractual cash flow characteristics),
- the entity's business model for managing the financial assets (business model test).

Each of them has a different meaning for the three categories of financial assets. Let's refer to IFRS 9 for a detail classification. In the table below, a summary of the financial assets classification and what they include are given:

[55] SPPI means "solely payments of principal and interests on the principal amount outstanding".

FINANCIAL ASSETS CATEGORIES	CONTENT
Amortized cost	Investments classified as held to maturity under IAS 39; other debts classified as loans and receivables under IAS 39.
FVOCI	Debt investments and equity investments.
FVTPL	Held for trading investments; derivatives; some loans and receivables and equity investments measured at amortized cost or FVOCI under IAS 39; available-for-sale category under IAS 39.

Moving to the financial liabilities, their classification is basically remained unchanged from IAS 39 except for two elements:

- the introduction of FVTPL classification for derivatives financial liabilities, before they were classified at amortized cost,
- the introduction of FVOCI classification for change in the fair value of a financial liability that is caused by change in the credit risk of that liability, before there wasn't this distinction.

The table below summarizes the financial liabilities classification requirements under IFRS 9:

FINANCIAL LIABILITIES	CRITERIA
Held for trading, designated at FVTPL or contingent consideration recognized by an acquirer in a business combination and derivatives.	FVTPL
Change in the fair value of a liability caused by change in the credit risk of that liability.	FVOCI
Loan commitments and financial guarantee contract[56].	Specific measurement
Other	Amortized cost

[56] A financial guarantee contract is a contract that requires the issuer to make specified payments to reimburse the holder for a loss it incurs because a specified debtor fails in making payment when due, in accordance with the original or modified terms of a debt instrument.

Generally, the financial liabilities are measured at amortized cost, anyway, some specific measurement requirements are given to:

- financial liabilities held for trading, designated at FVTPL or contingent consideration recognized by an acquirer in a business combination. These are measured at FVTPL,
- loan commitments and financial guarantee contracts. These have a specific guidance measurement.

This brief description about how the financial assets and the financial liabilities must be reported in the balance sheet is useful since we use financial ratios computed using the balance sheet values. We will use ratios that are already available in the financial statements and other ratios that are easily computable from the balance sheet values. The financial report or other information reports are not available, anyway for calculating the ratios, we need only the final value reported in the balance sheet, so it is not restrictive to have just the balance sheet and the profit and loss account.

The use of a multicriteria methods involve the utilization of more than one criterion to capture each aspect of the liquidity risk.

LIQUIDITY RATIOS
Interbank Ratio
Net Loans/Total Assets
Net Loans/Total Deposits and Borrowings
Liquid Assets/ Deposits and Short-Term Funding
Liquid Assets/ Total Deposits and Borrowings
Liquid Assets/Total Assets
CAPITAL RATIOS
Tier 1 Ratio
Equity/Total Assets
PERFORMANCE RATIOS
ROA
ROE
SIZE
Total Assets

Figure 5: Balance Sheet indicators

The variables or criteria adopted in this evaluation process are the set of balance sheet indicators used by the bank in its liquidity risk analysis plus other values that as we will see afterwards, are considered relevant in literature. The balance sheet indicators that will be used consider several areas, mainly related to the aspects of liquidity, profitability, capitalization and size. Some of these criteria must be maximize, minimize or they must reach a predetermined optimal value.

Before proceeding with the MURAME application, we will do a brief description and discussion of each criteria in order to understand both their optimal value and their meaning.

The first category of ratios are the liquidity ratios. This group include: Interbank Ratio, Net Loans/Total Assets, Net Loans/Deposits and Short-Term Funding, Net Loans/Total Deposits and Borrowings, Liquid Assets/ Deposits and Short-Term Funding, Liquid Assets/ Total Deposits and Borrowings and Liquid Assets/Total Assets.

The interbank ratio is the ratio of money lent to other banks divided by money borrowed from other banks. More in detail, in this paper it is computed as the ratio between the loans and advances to banks and the deposits from banks. Banks with high level of liquidity lend it to the interbank market, vice versa banks with low level of liquidity borrow it in the interbank market. It is very risky for a bank to rely heavily on loans available in this market since maturities are very short and therefore roll-over risk[57] may arise. A value higher than one (that is 100%) means that the bank is net placer rather than a borrower of funds in the interbank market and so, it is more liquid. Even though a bank may judge its position as non-critical because its interbank receivables are higher than its respective debts, the interbank ratio is not sufficient to provide a positive assessment of liquidity risk as it only assesses one aspect of this risk. The ratio tends to have a positive relationship with bank capital, this relationship can be explained by the following steps: when depositors consider a bank reliable due to a high level of capital, banks will face lower costs of funding. Thus, higher the reliance on interbank deposits, lower the interbank ratio. The interbank ratio is used in Bunda and Desquilbet (2009) to measure the liquidity in the interbank market. Their paper focuses on determining the phenomenon

[57] The roll-over risk is the risk linked with the refinancing of debt, it occurs when the investor does not renew the loan when it reaches the maturity.

that affect the liquidity of bank which can be ability in risk management, information asymmetries in the credit market, macroeconomic environment and so on.

The second measure is the net loans to total assets ratio. It measures the net loans as a percentage of total assets, or alternatively, what percentage of assets of the bank are tied up in loans. The net loans are calculated as the difference between the gross loans and the reserves for impaired loans and the non-performing loans. A lower ratio indicates a bank that is not loaned up and with high liquidity. On the other hand, when this ratio is high, the bank can have more difficulties to face unexpected deposits withdrawals as illiquid loans cannot be monetized or, in other words, banks can have greater difficulties to meet their liquidity requirements at short notice. To sum up, the lower the ratio, the less risky a bank may be to higher defaults. This indicator is used in Bunda and Desquilbet (2009).

The next ratio is the net loans and the total deposits and borrowing. It is used to assess a bank's liquidity by comparing a bank's net loans to its total deposits and borrowings for the same period. The net loans are calculated as the difference between the gross loans and the reserves for impaired loans and the non-performing loans. While the total deposits and borrowings include the total customer deposits (current, savings and term), the deposits from banks and the long-term funding. When the ratio is low, it means that the bank can have enough liquidity to cover any unforeseen fund requirements. Anyway, if it is too low, it means that the bank is reducing its earning since it is not investing as much as it could invest. The same holds when the ratio is too high. In this case, the bank could not have enough liquidity to cover unexpected fund requirements. It is a structural indicator, for this reason, it does not capture immediately the strategic change that the bank can do to better its liquidity position.

The fourth indicators is the liquid assets to deposits and short term funding. The liquid assets include cash, trading securities, loans and advances to banks, reverse repos, cash and balances at Central Bank. The deposits and short-term funding include total customer deposits, money market instruments, CDs and other deposits. It is used in Bunda and Desquilbet (2009) to evaluate the maturity mismatch and in Kosmidou, Tanna and Pasiouras (2005) as liquidity risk measure. It is a deposit run off ratio and shows what percentage of deposits and short term funds could be met if they were withdrawn suddenly. When this percentage is high, it means that the bank is more liquid and less vulnerable to liquidity tensions.

The fifth indicator is the liquid asset to total deposits and borrowings. As before, the liquid assets are given by cash, trading securities, loans and advances to banks, reverse repos, cash and balances at Central Bank, while the total deposits and borrowings are given by the total customer deposits (current, savings and term), the deposits from banks and the long term funding. It is a measure of both the deposits matched to investments and the capability of converting them quickly to cover redemptions. It also indicates the amount of liquid assets available to borrowers as well as depositors. The higher this percentage, the more liquid the bank and the less vulnerable to liquidity tensions.

Finally, the last ratio is the liquidity assets to total assets ratio. It measures the banks' ability to absorb liquidity shocks, moreover it a measure of the maturity structure of the asset portfolio. Analyzing this ratio, it is useful to see excessive maturity unbalances. A high value means that the banks are able to cover shocks, so it means that the banks is liquid.

Before moving to the next class of ratios, we should underline two things:

- the total deposits include the customer deposits which are considered a short-term liability since they can be unexpectedly withdrawn,
- the liquid assets to total assets and the net loans to total assets are absolute liquidity ratios, since they consider the amount of liquid assets relative to the total assets, the interbank ratio considers the liquidity in the interbank market while the other measures are relative liquidity ratios since they consider the relationship between liquid assets and liquid liabilities.

Many studies showed that liquidity risk is also affected by other variables. The first studies on liquidity risk were mainly focused on bank runs and financial crisis (Diamond, Dybvig 1983) while recently, researches and practitioners started to be interested in other areas such as profitability, capitalization and the size. For this reason, we take into account also some ratios that analyze these aspects in the MURAME application. The performance measures the ability of the bank to generate revenues capable of covering costs. The level of capital measures the bank's ability to fulfill its short and long-term debts and obligations. Finally, the size is useful to measure bank's magnitude.

Starting from the first category among the three said before, there are many indicators that can measure either the banks' profitability as whole or that can be specific for each

area of the bank. These areas include the financial structure, the operations management, the tax management and the extraordinary management. The European Central Bank defines three traditional measures of the performance: return on asset (ROA), return on equity (ROE) and net interest margin (NIM). In this study, we are interested in the valuation of the systemic liquidity risk of a bank, thus, we decide to use two ratios that measure the bank's profitability as a whole. These are respectively the total assets profitability and the equity profitability, which are the return on asset (ROA) and the return on equity (ROE). The latter is given by the ratio between the net income and the equity. Its value approximates its past value, anyway high ROE does not necessary means that a bank's future ROE will be high as well. On the other hand, low ROE can indicate that the bank's new investments have gained a lower ROE respect the past investments. Thus, we should judge it by not accepting historical values as indicators of future values. It can be compared with alternative investments. The higher ROE, the more efficient management is in utilizing its equity base and the better return is to investors.

The second measure used to analyze the performance is ROA. It is the ratio between the net income and the total assets. It tells us the income earned per euro deployed in the banks. Its value should be high otherwise the bank is not able to maximize its investments, generally, it should be higher than the interest rate offered by central banks. If this does not happen, it means that the bank has paid the borrowed money more than what it gained from the lent money.

The major part of the literature that studied the relationship between the bank liquidity and the performance considered the same profitability measures as this work, that are ROE and ROA, even if looking at the balance sheet, the first sign that something is going wrong is to register negative economic results since this means that the bank is not able to manage costs properly and in accordance to its past revenues (if any). The first papers on the bank liquidity and performance started in 1989 with Bourke who measured the liquidity risk through the liquid asset total assets ratio finding that the liquidity ratio is positively related to the return on assets (ROA). The same liquidity measure but with a different result was used in Molyneux and Thornton (1992) and Barth, Nolle, Phumiwasana and Yago (2003). They found out that the liquidity ratio is negatively related to the ROA. Other liquidity risk measures were used to examine the link with the profitability, for instance Athanasoglou, Delis, and Staikouras (2006) used the net loans

to total assets, reaching the conclusion that this ratio has no effect in neither ROA nor ROE.

The second category of variables that can affect the bank's liquidity are related to the capital position. The capital ratios used in this paper are the Tier 1 ratio[58] and the equity to total assets ratio. The former has been introduced in Basel III and it is given by the ratio between the Tier 1 capital[59] and risk-weighted assets at all times. When the capital is weaker compared to the volume of the bank's risky assets, then a bank could be more vulnerable. Basel III framework defined what the Tier 1 capital includes and its limits. It is composed by the common equity Tier 1 and the additional Tier 1, furthermore, for each of theme, the Basel III framework defined the elements included in each category. The common equity Tier 1 is given by the sum of elements such as the common shares issued by the bank that meet the criteria for classification as common shares, the retained earnings, the accumulated other comprehensive income and other disclosed reserves and so on. The additional Tier 1 consists in the sum of instruments issued by the bank that meet the criteria for inclusion in additional Tier 1 capital, stock surplus resulting from the issue of instruments included in additional Tier 1 capital and instruments issued by consolidated subsidiaries of the bank and held by third parties that meet the criteria for inclusion in additional Tier 1 capital and are not included in common equity Tier 1. Basel III imposed the achievement of some values for the common equity Tier 1 ratio and the Tier 1 capital as it did for the LCR and NSFR. The limits are that:

- common equity Tier 1 ratio must be at least 4.5% of risk-weighted assets until 2018 and must be at least 7% until 2019,
- Tier 1 capital must be at least 6.0% of risk-weighted assets until 2018 and 8% until 2019.

Tier 1 capital ratio gives an idea about the "primary" resources that the bank can use to guarantee the loans that it make to the customers and the risks that may derive from bad loans, impaired loans and so on. Basel III framework proposed also the total capital ratio which is the ratio between the sum of Tier 1 capital and Tier 2 capital[60] to the risk-

[58] It is a measure of the bank's financial strength in order to verify that the bank has an amount of capital in case of unexpected losses such that those that occurred during the financial crisis.
[59] It is the banks' core capital, it is composed by: the paid-up capital, the reserves and the non-distributed profits.
[60] It is the secondary component of bank capital that makes up a bank's required reserves, it is composed by: revaluation reserves, undisclosed reserves, hybrid instruments and subordinated term debt.

weighted assets. The Basel framework fixed also for this ratio a value than must reach which must be higher than 8% until 2018 and higher than 10.5% until 2019. Anyway, the second ratio that we decided to use in this work is the equity to total assets ratio. It is not prescribed by the Basel Committee but many studies showed that it has effects on the liquidity. These effects can be positive or negative:

- the higher the equity ratio, the smaller the amount of liquid assets useful to keep liquid liabilities and liquid assets in balance. This is shown by Kim and Santomero (1998) and Dewatripont and Tirole (1993),
- the higher the equity ratio, the higher the amount of liquid assets useful to keep the liquid liabilities and liquid assets in balance. (Thakor 1996).

We decide to use the equity to total assets ratio because it gives immediately the idea if a bank is financed more from equity or debt, thus, it is more representative of the characteristics of commercial banks. The higher the ratio, the more save the bank is in the event of loss or liquidation. Increase in equity may raise expected earning by reducing the expected costs of external financing (Berger, 1995). The reduction in cost of funding can be obtained also increasing the bank creditworthiness. To sum up, banks with higher equity to total assets ratio will have lower needs of external funding and therefore lower liquidity risk.

Finally, we consider the last criteria, that is the bank's size. It is measured by the total assets. It is useful to capture the relationship between assets' liquidity and the bank's size, thus it captures the impact of the complexity in large organizations such as governance conflicts, complex transactions etc. on bank's liquidity. In literature, there are many authors who used the total assets as measure of the banks' size such as Bunda and Desquilbet (2009) or Angora and Roulet (2011).

There are different explanations for which banks can be large:

- they may increase in order to benefit from economies of scale, thanks to which banks can both reduce their average costs and increase their profitability,
- they may increase in order to exploit diversification, thanks to which banks can operate in a different market segment with lower capital, lower risk and less-stable funding,

- they may increase as a consequence of managerial empire-building, that happens when managers increase the bank size just for raising their wages or for increasing their prestige of running a big company on the market.

From a theoretical point of view, it has been proposed the principle that the bigger the bank, the more liquid it is. This concept comes from the recent idea that big bank can be seen as "too big to fail" (TBTF). In fact, bigger banks can be supported and have more political connection than smaller banks since their bankruptcy could be disruptive and have consequences to the real economy. So, the supervisory bodies are forced to intervene in order to both limit the damages and reduce the bank's liquidity tension. The failure of large banks may generate liquidity tensions in all banking systems. Another reason for which bigger banks are less exposed to liquidity risk is that they can have easily access to funding from the European Central Bank (BCE) in case of emergency. In fact, the latter gives liquidity according to some conditions such as bank's efficiency, rating threshold and so on. Anyway, the concept of TBTF starts to work when banks reach a certain size before which, large banks can be more fragile than small banks. This is due to the fact that large banks tend to have lower capital, less-stable funding, more market-based activities and to be more complex. The consequence of having less-stable funding and lower capital is that large banks are riskier and with high systemic risk. Furthermore, the latter increases as the banks are more engaged in market-based activities or as the banks become more complex. For such banks, the Bank for International Settlements in its 79th Annual Report wrote that "*in the future, a financial firm that is too big or too interconnected to fail must be too big to exist*".

To sum up, a consequence of being too big but not "too big too fail" is to face moral hazard behavior and excessive risk exposure. A moral hazard behavior happens when there is the risk that one party, let us call it α, gets involved in activities that are undesirable from the other party β's point of view since these decisions cause damages and losses to β. Thus, the necessity of avoiding the bankruptcy of major financial institutions by limiting the losses of large banks' equity and liability holders as well as the rewards of managers and traders, is reducing the incentive for both insiders and outsiders to assume risk-taking behavior in the future.

CHAPTER 4 – Problem Setting and MURAME Application

In this chapter, we applied MURAME for the evaluation of banks' liquidity risk. The main output is a ranking of the banks from the best to the worst based on their liquidity risk. In the last positions there will be banks with higher exposure to liquidity risk while in the first positions there will be banks with lower exposure. A multicriteria method can be useful also for classifying the banks into homogeneous classes and for ranking the banks inside the same class. As before, the last class will be composed by banks with higher exposure to liquidity risk while the first class will have lower exposure. Basically, we proceed following three steps:

1. we rank the banks considering all the sample,
2. we classify the banks into homogeneous classes,
3. we rank the banks inside each homogeneous class.

The results from point 1 to point 3 may change since in the first step we are considering all the alternatives while in the third steps we are consider a few number of them, so it is possible that the ranking can have changes by removing some banks. To give a simply idea, let us consider four banks called *A, B, C* and *D*, then let us follow the steps named above. The first rank is *D, B, C, A* while the classification give as result two classes called $\alpha = \{D, B\}$ and $\beta = \{C, A\}$. The third step is to rank again the banks inside their class, now the ranking inside β can give as result: *A,C* and not *C,A* (as the first rank). The reason is due to the fact that *A* and *C* are compared just between them without considering also *D* and *B*. Thus, it can be that *A* is very bad respect to *D* and *B* so that, considering the whole sample space it takes the last position even if *A* is better than *C*. We will study any possible explanation of this phenomenon later on.

This chapter is structured as follow: firstly it defines the alternatives, secondly it explains the criteria, thirdly it determines the parameters and finally there is the MURAME application.

4.1 The Choice of the Alternatives

The MURAME application has been done considering 40 banks operating in Italy from 2012 to 2017 while it considers 38 banks for 2011 since for that year the balance sheets of Cassa di Risparmio di Asti and Mediobanca were not available in ORBIS.

The table below summarizes the sample space. The balance sheets considered for the analysis are either consolidated[61] or unconsolidated balance sheets[62], it depends on what is mandatory for the bank. In any case, both show what is useful for this analysis that is the bank's financial health.

	LIST OF BANKS				
1	Credit Agricole Cariparma SPA	Consolidated BS	21	Allianz Bank Financial Advisors SPA	Consolidated BS
2	Cassa di Risparmio di Firenze SPA	Unconsolidated BS	22	Findomestic Banca SPA	Unconsolidated BS
3	BPER Banca SPA	Consolidated BS	23	Banca Passadore & C. SPA	Unconsolidated BS
4	Banca Valsabbina SCPA	Unconsolidated BS	24	Banca Monte dei Paschi di Siena SPA	Consolidated BS
5	Banca Piccolo Credito Valtellinese	Consolidated BS	25	Banca Agricola Popolare di Ragusa SCARL	Consolidated BS
6	Banco di Sardegna SPA	Consolidated BS	26	Banca di Credito Cooperativo della Marca SCRL	Unconsolidated BS
7	Banco di Napoli SPA	Unconsolidated BS	27	Banca di Credito Popolare SCRL	Unconsolidated BS
8	Banca di Imola SPA	Unconsolidated BS	28	Banca Generali SPA	Consolidated BS
9	Banca del Piemonte	Unconsolidated BS	29	Banca Finnat Euramerica SPA	Consolidated BS
10	Banca del Sud SPA	Unconsolidated BS	30	Banca Popolare Pugliese	Consolidated BS
11	Banca di Cambiano 1884 SPA	Unconsolidated BS	31	IBL SPA	Consolidated BS
12	Banca di Piacenza	Unconsolidated BS	32	Mediocredito Trentino-Alto Adige SPA	Unconsolidated BS
13	Credito Emiliano SPA	Consolidated BS	33	Mediobanca SPA	Consolidated BS
14	Banco di Desio e della Brianza SPA	Consolidated BS	34	Banca Mediolanum SPA	Consolidated BS
15	Cassa di Risparmio di Asti SPA	Consolidated BS	35	Unicredit SPA	Consolidated BS
16	UBI SCPA	Consolidated BS	36	Banca Popolare di Sondrio SCPA	Consolidated BS
17	ICCREA BANCA SPA	Consolidated BS	37	Banco di Credito P.Azzaglio SPA	Unconsolidated BS
18	Banca Sella SPA	Unconsolidated BS	38	Intesa SanPaolo	Consolidated BS
19	Banca Carige SPA	Consolidated BS	39	Banca Galileo SPA	Unconsolidated BS
20	Dexia Crediop SPA	Unconsolidated BS	40	Cassa di Risparmio di Cento SPA	Unconsolidated BS

Before proceeding with the MURAME application, a brief description of each alternative is given. It consists in taking a look of each bank's balance sheet in order to give an idea about the trend of the variables that will be useful in the application which are total assets, liquid assets, equity and total customer deposits. What is in common to all the banks is

[61] Consolidated balance sheet is the combined financial statements of a parent company and its subsidiaries. It includes the financial position of a parent company and its subsidiaries, and it provides a picture of the overall health of an entire group of companies

[62] Unconsolidated balance sheet is the financial statements of an individual company. It represents one company's standalone financial position.

that they give a full range of commercial banking services, they provide loans, insurance policies, mortgage, and related financial products, even if they have different dimensions in term of size, number of employees, exposure to liquidity risk and so on. All these services are a source of profits for the banks.

We follow the order in which the banks are listed in the table with the list of banks:

- Credit Agricole Cariparma SPA. It is the new name of Cassa di Risparmio di Parma e Piacenza SPA. It is controlled by SAS Rue La Boétie which is the shareholding of Crédit Agrigole Group. At the beginning of 2018 has been approaved the incorporation of Cassa di Risparmio di Rimini, Cassa di Risparmio di Cesena, Cassa di Risparmio di San Miniato. The number of branches are 531 spreads in all Italy. Looking at the balance sheet, the total assets increased from 2011 to 2017 of 47,29%, the same occurs for all the other components such as the liquid assets with a percentage of 96,76%, equity with a percentage of 48,66% and total customer deposits with 77,27%.
- Cassa di Risparmio di Firenze SPA is a Group of Intesa San Paolo. It has 208 branches. In its balance sheet, we can see that the value of total assets is remained constant, while, it is interesting to note that the equity is decreased of 57,68% but at the same time the liquid assets had a huge increment of 155,67%.
- BPER Banca SPA is Banca Popolare dell'Emilia Romagna with 828 branches in Italy, the bank itself is the global owner of the corporate group. The total assets increased of 17,94%, the same happened for equity (23,04%) and total customer deposits (39,05%), while the liquid assets decrease of 24,53%.
- Banca Valsabbina SCPA is the global owner of the corporate group with 73 branches. The bank's balance sheet does not show big variation among the years except the customer loans which increased of 76,04%.
- Banca Piccolo Credito Valtellinese is the global owner of the corporate group, furthermore, it incorporates other banks such as Credito Artigiano S.p.A, Cassa di Risparmio di Fano S.p.A, Credito Piemontese S.p.A, Banca dell'Artigianato e dell'Industria S.p.A, Bancaperta S.p.A, Credito del Lazio S.p.A and Banca Cattolica S.p.A. In 2017, the bank showed a negative net income of -328.199€, a similar result was in 2016, 2014 and 2012. The total assets and the total customer deposits decreased respectively of 12,16% and 9,23%. On the other hand the liquid assets increased of 18,28%.

- Banco di Sardegna SPA is a controlled subsidiary of BPER BANCA SPA with 336 branches. The highest variation is in liquid assets which increased of 66,22% while the other variables did not present any significant variation.
- Banco di Napoli SPA is a Group of Intesa San Paolo since 2006. It has 533 branches in Italy. Looking at the balance sheet, the total assets, the total customer deposits and the liquidity assets are increased respectively of 14,18%, 25,00% and 62,46%.
- Banca di Imola SPA is controlled by Cassa di Risparmio di Ravenna SPA with 36 branches in Emilia-Romagna and Toscana. The liquid assets increased of 122,78%, the total customer deposits of 44,19% and the total assets of 22,35%.
- Banca del Piemonte is controlled by Confienza Partecipazioni SPA, it has 44 branches all in Piemonte. Looking at the balance sheet, the most significant increment is in the total customer which increased of 60,54%. Equity and liquidity assets have been remained quite constant among the years while the total assets decreased of 13,03%.
- Banca del Sud is an independent bank with four branches in Campania. The liquid assets and the equity were both unchanged over time while the total assets raised of 55,43% and the total customer deposits of 96,42%.
- Banca Cambiano 1884 SPA is controlled by Ente Di Cambiano Società Cooperativa per Azioni, it has 42 branches. The balance sheet indicates that all the variables considered in this small description are increased.
- Banca di Piacenza, the total assets and the equity remained stable, while the total customer deposits increased of 35,36% and the liquid assets increased of 327,37%.
- Credito Emiliano SPA is controlled by Credito Emiliano Holding. This holding controls also other banks such as Banca Euromobiliare and other types of firms. Similar to the major part of the banks, its liquidity assets increased of 93,24%, as well as the total customers deposits (55,62%), the total assets (23,95%) and the equity (48,77%).
- Banco di Desio e della Brianza SPA is controlled by Brianza Unione Di Luigi Gavazzi E Stefano Lado S.A.P.A which controls also Banca Popolare di Spoleto and other firms. It was born in 1909 and actually, it has 146 branches spreads in Italy. All the variable that we are looking had a huge increment especially the

liquidity assets which increased of 257,62% from 2011 to 2017. Anyway, also in the other variables, the increment was significant: total customer deposits (97,68%), total assets (55,18%), and equity (17,13%).

- A similar behavior for liquidity assets was in Cassa di Risparmio di Asti SPA. Its liquid assets have grown of 131,07%. Here, it's interesting to note that contrary to the major part of the banks, the total assets reduced of 1,33%. The global ultimate owner of this controlled subsidiary is Fondazione Cassa Di Risparmio di Asti.
- UBI Banca (Unione di Banche Italiane) SCPA which is the owner of the corporate group. It was born in 2007 from the merging of Banche Popolari Unite and Banca Lombardia, since then, it incorporated other banks such as: Banca Popolare di Bergamo SPA, Banca di Brescia SPA, Banca Carime, Banca Popolare di Ancora and so on. Looking at the balance sheet, it is immediately evident that it is bigger than the previous one and that there were not huge variation during the year. The highest was in the total customer deposits with 16,53% while total assets, equity and the liquid assets reduced respectively of 9,04%, 5,74%, and 6,99%.
- ICCREA Banca SPA - Istituto Centrale del Credito Cooperativo is part ICCREA Holding from 1994 to 2016. In 2016, ICCREA Bank revered merger with ICCREA Holding to create strong central banks. In the balance sheet, there were significant movement in both the equity which increased of 15,18% and the total customer deposits which decreased of -57,30% from 2016 to 2017. Anyway, considering all the period both variables increased respectively of 14,50% and 173,80%. Looking at the other variables, the liquid assets raised of 50,04%, the equity of 14,50%, the total assets of 28,74%.
- Banca Sella is controlled by Maurizio Sella - Societa' in Accomandita per Azioni and it has 283 branches in Italy. Since 2011, the values increased even if the increments are not significant.
- Banca Carige was born in 1483, nowadays it is a group which includes Banca del Monte di Lucca, Banca Cesare Ponti, Cassa di Risparmio di Savona e Cassa di Risparmio di Carrara. There is a decrease in all the variables that we are looking: total assets (48,51%), total customer deposits (26,50%), equity (26,87%) and liquid assets (6,76%).

- Banca Centropadana-Credito Cooperativo SCRL is an independent company since 1998 through the merger of Banca di Credito Cooperativo del Basso Lodigiano and Banca di Credito Cooperativo di San Colombano al Lambro (Provincia di Milano). The only variable that had a huge increment was the total customer deposits with 86,28%, all the other remained around the value observable in 2011.
- Alliaz Bank Financial Advisors SPA is a subsidiary of Allianz SE, it was called Rasbank SPA until 2007. Today, it has 31 branches in Italy. It is in correlation with the other bank since it has increased its values. More in detail: total assets (24,77%), total customer deposits (34,96%), equity (53,54%), and liquid assets (73,15%).
- Findomestic is controlled by BNP Paribas since 2009 and it is present in the territory with 79 subsidiary. Looking at the balance sheet, there are increment in both the liquid assets (112,15%) and the total assets (56,41%). The total customer loans had an increment but their starting value in 2011 was 0, maybe because that year the bank was completely controlled by BNP Paribas, while the equity reduced (2,47%).
- Banca Passadore & C. SPA is controlled by Passadore Family since 1888. Looking at the variations in assets, customer deposits, equity and liquidy assets, they were respectively of 51,20%, 70,59%, 39,40% and 159,45%.
- Monte dei Paschi di Siena is a publicly quoted company which a controlled subsidiary of Ministero dell'Economia e delle Finanze since December 2016. Its liquidity assets are decreased during the years (47,78%) as well as the total assets (53,58%), the equity (88,04%) and the total customer deposits (84,97%).
- Banca Agricola Popolare di Ragusa SCARL was born in 1889 and it is the global owner of the corporate group. In 2001, it absorbed Banca di Credito Cooperativo di Itaca and in 2003, it absorbed Banca Popolare di Augusta SPA. The balance sheet did not show any significant variation during the years taken into account in the analysis.
- Banca di Credito Cooperativo della Marca SCRL is an independent bank. It was established in 2001 through the merger of Banca di Credito Cooperativo di Orsago and Banca di Credito Cooperativo dell'Alta Marca. In 2017, it absorbed Banca di Credito Cooperativo di Marcon - Venezia SCARL. The biggest variation is in the

total customer deposits which increased of 81,28%, following by total assets (30,10%), equity (12,89%) and liquid assets (-13,17%).

- Banca di Credito Popolare SCRL is a controlled subsidiary of Guacci SPA which is a pharmaceutical company. Its values are all decreased, especially the liquid assets (47,87%) and the total assets (11,49%).
- Banca Generali SPA is a publicly quoted company controlled by Assicurazioni Generali SPA. It was born in 1998 and actually, it has 46 branches in all Italy. The balance sheet shows an important increase in all the variables considered: total assets (83,20%), total customer deposits (119,27%), equity (159,98%) and liquid assets (41,09%).
- Banca Finnat Euramerica SPA is a publicly quoted company, it was born in 1989. The company is the global ultimate owner of the corporate group. Looking at the balance sheet, the highest variation are in the total assets which increased of 189,15% and in the total customer deposits which increased of 400,23%. While the liquid assets decreased of 33,12%.
- Banca Popolare Pugliese is controlled by the company itself. It was established in 1994, the following years it absorbed Banca di Credito Cooperativo di Otranto and Banca del Lavoro e del Piccolo Risparmio SPA. It has 106 branches in the central and southern Italy. Its total assets did not have huge variation from 2011, the same holds for equity. On the other hand, the total customer deposits have grown of 47,47% and the liquid assets of 67,25%.
- IBL – Istitutio Bancario del Lavoro SPA is a banking group which includes IBL Technology S.p.A, IBL Servicing S.p.A, IBL Real Estate S.r.l, IBL Assicura S.r.l. and Lavoro Finance S.r.l. Its values had a growth: total assets (376,69%), total customer loans (388,57%), equity (726,11%) and liquid assets (154,33%).
- Mediocredito Trentino-Aldo Adige SPA is an investment bank founded in 1953. Actually the shareholders are public entity (Trentito – South Tyrol) and banks (Casse Rurali Raiffeisen Finanziaria, Südtiroler Sparkasse – Cassa di Risparmio di Bolzano, Südtiroler Volksbank – Banca Popolare dell'Alto Adige). The total customer deposits and the equity have remained quite stable among the years, while the liquid assets increased of 331,83% and the total assets decreased of 11,61%.

- MedioBanca SPA is a publicly quoted company founded in 1946 in Italy even if nowadays it works internationally. The variables that we are analyzing do not present any significant movement. Liquid assets, equity and total customer deposits increased for a value around 14% while total assets decreased for a value around 18%.
- Banca Mediolanum SPA was born in 1997 and it is now publicly quoted. Respect to the previous banks, all the value considered increased a lot: total assets (168,93%), total customer deposits (119, 52%), equity (265,76%) and liquid assets (556,97%).
- Unicredit SPA which is the first bank in Italy for number of branches that are 2.962. It works in Italy but also in Europe. While the total assets, equity and total customer deposits did not change their value a lot, the liquid assets had a variation of 46,84%.
- Banca Popolare di Sondrio SCPA was born in 1871 and it is a publicly quoted. In this case, the liquid assets did not change their value a lot, while total asset raised of 31,75%, total customer deposits increased of 33,89% and the equity 35,93%.
- Banca di Credito P. Azzoaglio SPA is an independent family-run bank since it was always managed under the control of the founder and the descendants. It has 19 branches spreads among Liguria and Piemonte. Looking at the variations in assets, customer deposits, equity and liquidy assets, they were respectively of 62,21%, 84,21%, 25,51% and -10,60%.
- Intesa San Paolo SPA was born in 1998 after the alliance between Banco Ambrosiano Veneto SpA and Cassa di Risparmio delle Provincie Lombarde SpA – Cariplo. Since then, the bank absorbed many banks, the last one is Banca Nuova SPA in April 2018. It is the biggest bank in Italy for market share. Looking at the variations in assets, customer deposits, equity and liquid assets, they were respectively of 15,55%, 52,05%, 9,86% and 72,44%.
- Banca Galileo SPA is an independent bank active since 2002. The variations in assets, customer deposits, equity and liquid assets were respectively of 81,34%, 179,13%, 25, 96% and 314,62%.
- Cassa di Risparmio di Cento SPA which is controlled by Fondazione cassa di risparmio di Cento. Here, total assets and equity have remained quite stable over

time, while liquid assets decreased of -77,52% and total customer deposits increased of 44,30%.

To sum up, the banks that did not have huge variations in the analyzed variables (total assets, liquid assets, equity and total customer deposits) are UBI SCPA, Banca Agricola Popolare di Ragusa SCARL and Mediobanca SPA. While the banks that had variations bigger than 100% are: Findomestic Banca SPA, Banca Passadore & C., Banca Generali SPA, Banca Finnat Euramerica SPA, IBL SPA, Mediocredito Trentino-Alto Adige SPA, Mediolanum, Banca Galileo SPA. The causes of these variations can be explained by looking at the financial reporting ("nota integrativa") which has additional information about the bank. First of all, it identifies the areas of activity in which the banking group is present and which is their contribution to the determination of the net income. Moreover, it explains both the composition of each variable of the balance sheet and how its evaluation has been made. Anyway we do not have available such financial reporting in ORBIS, so we cannot know the real motivations.

4.2 MURAME criteria

A fundamental step for the application of a multicriteria method is the criteria choice. In fact, the use of a multicriteria method involves the utilization of more than one variable to capture the various aspect of the liquidity risk. The use of a multicriteria method gives two advantages, firstly the criteria can be in conflicting among them, secondly it allows to consider the decision maker's preferences. These benefits led us to the decision of using a multicriteria method to evaluate a set of alternatives.

In chapter 3, we have explained the liquidity risk measures that will be used and their optimal value. They come from the balance sheet, furthermore, some of them are directly related to liquidity risk while others are related to aspects such as profitability, capitalization and size. Some of these criteria must be maximized, minimized or they must reach a predetermined optimal value.

The table below shows from a theoretical point of view what is the target for each financial ratio.

	LIQUIDITY RELATED CRITERIA	TARGET
I_1	Interbank Ratio	Higher than 100% (Maximize)
I_2	Net Loans/Total Assets	Minimize
I_3	Net Loans/Total Deposits and Borrowings	Minimize
I_4	Liquid Assets/ Deposits and Short-Term Funding	Maximize
I_5	Liquid Assets/ Total Deposits and Borrowings	Maximize
I_6	Liquid Assets/Total Assets	Maximize
	CAPITAL RELATED CRITERIA	
I_7	Tier 1 Ratio	Higher than 6% (Maximize)
I_8	Equity/Total Assets	Maximize
	PROFITABILITY RELATED CRITERIA	
I_9	ROA	Maximize
I_{10}	ROE	Maximize
	SIZE RELATED CRITERIA	
I_{11}	Total Assets	Maximize above a certain threshold otherwise minimize

The liquidity risk is reduced when the banks have enough liquidity to cover any unexpected withdrawals. In the MURAME application, we need to either maximize or minimize the various criteria, so we need to apply a transformation on the ratios that have a different target. The criteria that requires a transformation is the total assets. As we said in the previous chapter, the total assets must be minimized until a certain point after which they must be maximized. In fact, when we are dealing with a big bank, its failure may deteriorate the whole financial sector, so in order to avoid its bankruptcy, it receives more support from the supervisory bodies or the ECB. This type of bank is defined "too big to fail" and it is systemically important. We need to define the point after which the concept "too big too fail" applies. There is one official Global list of Systemically Important Banks called G-SIBs which is defined by the Financial Stability Board[63] and the Basel Committee on Banking Supervision. Furthermore, the European Banking Authority established that each member state of the European Union must identify at least annually a list of Other Systematically Important Institutions called O-SIIs pursuant to article 131(3) of Directive 2013/36/EU. The latter category includes banks that, due to their

[63] The FSB is an international not-for-profit association which has a key role in promoting the reform of international financial regulation.

systemic importance, are more likely to compromise the financial stability in case of their failure.

In Italy, there are four banks included in the O-SIIs, they are: Unicredit, Intesa Sanpaolo, Monte dei Paschi di Siena and Banco BPM, moreover, Unicredit belongs also in the G-SIBs class. In our study, there are three O-SII out of four. For this reason, we decide to take as threshold T, the minimum value among the total assets of these banks which are:

	Unicredit	Intesa Sanpaolo	Monte dei Paschi di Siena
2011	926.768.744	639.221.000	240.701.971
2012	926.768.744	673.472.000	218.882.170
2013	845.838.444	626.283.000	199.105.906
2014	845.838.444	646.427.000	179.917.528
2015	845.838.444	676.568.000	169.011.977
2016	859.532.774	725.100.000	153.178.466
2017	836.789.724	796.861.000	139.154.192

As we can see, the banks considered O-SIIs have a size bigger than 100.000.000. Looking at the available balance sheets, this threshold of 100.000.000 is exceeded also by UBI SCPA.

	UBI SCPA
2011	129.803.692
2012	132.433.702
2013	124.241.837
2014	121.786.704
2015	117.200.765
2016	112.383.917
2017	127.376.141

In any case, since we should use as threshold, the minimum value among the total assets of the three banks included in the O-SIIs group, we should choose 139.154.192€. Thus, the banks that must maximize their total assets value are those that overcome 139.154.192€. UBI SCPA never overcomes that value but its total assets are very close to it. In order to not exclude banks that are a little bit lower than this theoretical threshold, we decide to use an optimal total assets threshold of 100.000.000€ (I_{11}^{*}). Once established the optimal threshold, we may determine the function that can be used to find the right criteria value for the evaluation. We determine a function that will be maximized:

$$f(I_{11}) = |I_{11} - I_{11}^{*}|$$

This function is called “measure of distance from the optimal value”. It means that higher the value of I_{11} respect to I_{11}^{*}, higher is the difference, it does not matter if the result is negative or positive since we are using the absolute value.

4.3 MURAME parameters

As described in the MCDA framework, in order to apply MURAME and to classify banks according to their liquidity risk, the parameters models which are weights, thresholds and reference profiles must be specified. In this analysis, we follow two methods to find the thresholds.

Recalling some theory about the thresholds, there are three thresholds to establish: preference, indifference and veto thresholds. The preference threshold allows the decision maker to determine which of the two alternatives is preferred, highlighting the case in which there is a strict preference. The indifference threshold allows the decision maker to judge a situation of indifference between two alternatives. The veto threshold evaluates when an alternative is so worse than another one, which is impossible to accept the outranking relationship.

In multicriteria methods, the choice of these parameters is problematic since their value may change completely the results. The procedure suggested by the researchers is not always good from an efficient point of view. In this analysis, in order to see this effect, we decided to compute the analysis using two methodology to determine the thresholds. The first one is a standard procedure used also in “*A MURAME-based technology for bank decision support in credit worthiness assessment*” Corazza, Funari, Siviero (2014), the second one is a decision maker procedure (reasoning method) which means that the thresholds are chosen after a decision maker’s analysis.

In the first method, in order to determine the parameters p_j, q_j and v_j, we must follow two steps: firstly, we have to compute the range $s_j = \max(I_j) - min(I_j)$ for each criteria I_j which indicates the difference between the maximum value that a criteria value can take and the minimum value that the same criteria value can take. Secondly, the values of the parameters can be determined in the following way:

$$p_j = \frac{2}{3}\, s_j,$$

$$q_j = \frac{1}{6}\ s_j,$$

$$v_j = \frac{5}{6}\ s_j.$$

The inequalities satisfy: $q_j < p_j < v_j$ for all *j*. In fact, we know from the literature that the indifference threshold must be lower than the preference threshold and that the veto threshold must be higher than the preference threshold. This implies that the indifference threshold must be necessary lower than the veto threshold. The utilization of this standard methodology can lead to high level of preference, indifference and veto threshold since they depend on the difference between the highest value and the lowest value of the same criteria. Thus, when the divergence is small, the values of q_j , p_j and v_j will be lower respect when the divergence is large.

The introduction of these thresholds is useful for the determination of both the concordance and the discordance index. The former measures the weakness of arguments that support "*alternative a_i is at least as good as alternative a_k on the basis of criterion c_j ".* When the difference between the performance of two alternatives is lower than the preference threshold, alternative a_i is strictly preferred to alternative a_k based on criterion c_j. When the difference between the performance of two alternatives is higher than the veto threshold, a_k is preferred to action a_i. When the difference is between the indifference and preference threshold, the decision maker is in a situation of uncertainty.

Moving to the concordance index, it measures the strength and the trustworthiness of arguments that support "*alternative a_i is at least as good as alternative a_k on the basis of criterion g_j*". When the difference between the performance of two alternatives is lower than the indifference threshold, alternative a_i is not dominated by alternative a_k (or alternatively, a_i dominates a_k). On the other hand, when the difference between the performance of two alternatives is higher than the preference threshold, a_i is dominated by a_k (or alternatively, a_k dominates a_i). In both cases, we are in a situation of strong preference. When the difference is between the veto and preference threshold, there is a weak preference. In this case, the decision maker is in a situation of uncertainty and he is not able to decide which is the best alternative between the two considered.

In the following table, the thresholds using the first method are shown:

2011	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}	I_{11}
p	5,0032	0,5468	0,6440	0,3760	0,3380	0,2752	0,1736	0,1728	0,0244	0,4812	531.310.036
q	1,2508	0,1367	0,1610	0,0940	0,0845	0,0688	0,0434	0,0432	0,0061	0,1203	132.827.509
v	6,2540	0,6835	0,8050	0,4700	0,4225	0,3440	0,2170	0,2160	0,0305	0,6015	664.137.545
2012											
p	5,8333	0,5220	0,6168	0,4207	0,4101	0,3502	0,1814	0,1118	0,0221	0,5542	537.004.401
q	1,4583	0,1305	0,1542	0,1052	0,1025	0,0876	0,0454	0,0280	0,0055	0,1386	134.251.100
v	7,2917	0,6525	0,7710	0,5259	0,5127	0,4378	0,2268	0,1398	0,0276	0,6928	671.255.501
2013											
p	3,5136	0,4828	0,5639	0,3943	0,3791	0,3133	0,1776	0,1084	0,0429	0,9282	481.064.405
q	0,8784	0,1207	0,1410	0,0986	0,0948	0,0783	0,0444	0,0271	0,0107	0,2321	120.266.101
v	4,3920	0,6035	0,7048	0,4928	0,4739	0,3916	0,2220	0,1355	0,0536	1,1603	601.330.506
2014											
p	2,9487	0,4824	0,5098	0,4791	0,4321	0,2818	0,1403	0,1249	0,0375	0,8654	481.620.457
q	0,7372	0,1206	0,1275	0,1198	0,1080	0,0705	0,0351	0,0312	0,0094	0,2164	120.405.114
v	3,6858	0,6030	0,6373	0,5988	0,5401	0,3523	0,1754	0,1561	0,0468	1,0818	602.025.572
2015											
p	5,6845	0,4833	0,4954	0,5024	0,4285	0,2693	0,1409	0,1357	0,0256	0,2411	495.488.407
q	1,4211	0,1208	0,1239	0,1256	0,1071	0,0673	0,0352	0,0339	0,0064	0,0603	123.872.102
v	7,1057	0,6042	0,6193	0,6280	0,5356	0,3367	0,1762	0,1697	0,0320	0,3013	619.360.508
2016											
p	4,5329	0,4821	0,5317	0,6401	0,5137	0,2948	0,1433	0,1335	0,0265	0,5011	498.099.238
q	1,1332	0,1205	0,1329	0,1600	0,1284	0,0737	0,0358	0,0334	0,0066	0,1253	124.524.810
v	5,6662	0,6026	0,6647	0,8001	0,6421	0,3685	0,1792	0,1668	0,0332	0,6263	622.624.048
2017											
p	5,7658	0,4905	0,6897	0,6786	0,5143	0,2991	0,1617	0,1287	0,0319	0,4087	472.942.389
q	1,4415	0,1226	0,1724	0,1697	0,1286	0,0748	0,0404	0,0322	0,0080	0,1022	118.235.597
v	7,2073	0,6132	0,8621	0,8483	0,6429	0,3738	0,2021	0,1609	0,0399	0,5108	591.177.986

It's important to underline that the set of the thresholds plays an important role in the analysis. Looking at the concordance index:

- if the preference threshold is too high, the possibility that the difference will be higher than p_j is low, reducing the cases in which a_i is dominated by a_k,
- if the indifference threshold is too low, the possibility that the difference will be lower than q_j is low, reducing the cases in which a_i is not dominated by a_k.

Looking at the discordance index:

- if the preference threshold is too low, the possibility that the difference will be lower than p_j is low, reducing the cases in which a_i is strictly preferred to a_k,
- if the veto threshold is too high, the possibility that the difference will be higher than v_j is low, reducing the cases in which a_k is preferred to action a_i.

To sum up, the utilization of a standard method is not always efficient since the preference, indifference and veto threshold can be too much high due to a high value of s_j. This can cause distortion in the computation of discordance, concordance, outranking index, leading to bad results in term of ranking and subsequently sorting. The second method which is a reasoning method implies a decision maker choice, in this sense, it is possible to include in the thresholds both the decision maker preferences and what he judges more useful for the definition of the thresholds. It is more focused on an analysis of the criteria in order to find the thresholds more compatible with our indicators. For this reason, we will study each criteria separately, reasoning on what is the best thresholds from each criteria point of view. For instance, if a criteria has a good performance when it has a high value, imposing a high veto threshold allows to reward banks with good outcome.

The starting point is to look at the values, in particular, we should determine which is their range. If it is homogenous, in the meaning that all the values are comprised between two points which are close among them (let's say for instance 1 and 4 or 3 and 9), we can keep the preference, indifference and veto threshold used in the first procedure. On the other hand, if it is not homogeneous, let's say there are certain values between 1 and 4, other values higher than 4 and others lower than 1, we must reason on the values in order to determine a good threshold.

For the criteria of 2017, we decide to intervene in the interbank ratio, the net loan to total deposits and borrowing ratio, the ROE and the ROA. The former has a maximum value of 8,6684 and a minimum value of 0,0197 even if only 11 alternatives on 40 have a ratio higher than 1. A value higher than 1 means that the bank is a net placer rather than a borrower of funds in the interbank market and so, it is more liquid. It is very risky for a bank to rely heavily on loans available in this market since maturities are very short and therefore roll-over risk may arise. After these considerations, we decide to set the

indifference and the preference threshold respectively equal to 0,3 and 0,9 in order to have a high number of alternatives in the area in which no one alternative is strictly preferred to another one since most of the values range between 0,1 and 0,99. In this way, it's easier to grade the outranking and it's stronger the validity of the sentence ", a_i is dominated by a_k" or vice versa. When the decision maker is in a situation of uncertainty, he is not able to decide which is the best alternative between the two considered. Let's remember that an indifference threshold of 0,3 means that when the difference between the performance of alternatives a_k and a_i is lower than 0,03, a_i is preferred to a_k. The veto threshold is set equal to 4 in order to reward the alternatives with an interbank ratio higher than 4. Remembering that a veto threshold of 4 means that when the difference between the performance of alternatives a_k and a_i is higher that 4, a_k is preferred to a_i.

The second ratio has a range between 1,037 and 0,0025 even if most of the values are comprised between 0,2 and 0,7. When the ratio is low, it means that the bank can have enough liquidity to cover any unforeseen fund requirements. We decide to set the indifference threshold equal to 0,2 and the preference threshold equal to 0,7 in order to include a large number of alternatives in the uncertainty zone. The veto threshold is set equal to 0,9 in order to discriminate the alternatives with values higher than 0,9.

We decide to intervene also in the ROA thresholds and in the ROE thresholds. The reason is due to the fact that for both criteria, the thresholds are not included in the range of values which is between 0,0227 and -0,0252 for ROA and between 0,2773 and -0,3357 for ROE. Both criteria must be maximized in order to efficiently manage the bank's equity and the bank's investments. They may have negative values when the bank is not having a profit, thus we must set new parameters that are able to discriminate the banks with a loss since with the standard method, the preference and the veto thresholds are higher than the maximum value among all the ROA and ROE values. In 2017, there were 7 on 40 banks with a loss. The table below summarizes the new threshold decided.

2017	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}	I_{11}
p	0,9000	0,4905	0,7000	0,6786	0,5143	0,2991	0,1617	0,1287	0,0150	0,0800	472.942.389
q	0,3000	0,1226	0,2000	0,1697	0,1286	0,0748	0,0404	0,0322	0,0100	0,0100	118.235.597
v	4,0000	0,6132	0,9000	0,8483	0,6429	0,3738	0,2021	0,1609	0,0200	0,1500	591.177.986

For 2016, we decide to change the interbank ratio, the ROA and the ROE. The interbank ratio range between 6,8276 and 0,0282, even if most of the values are between 0,1 and 0,9 and only 5 values are higher than 4. The new parameters must be able to capture both the uncertainty between two alternatives and the magnitude of the biggest values. For the interbank ratio, we use as preference, indifference and veto thresholds: 0,9, 0,3 and 4.

The ROA and ROE need to be changed because their preference threshold (and as a consequence their veto threshold since $v_i > p_i$ must hold) is higher than the ROE and ROA's maximum value due to the presence of negative values. The thresholds used in the second method are the following ones:

2016	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}	I_{11}
p	0,9000	0,4821	0,5317	0,6401	0,5137	0,2948	0,1433	0,1335	0,0070	0,1900	498.099.238
q	0,3000	0,1205	0,1329	0,1600	0,1284	0,0737	0,0358	0,0334	0,0020	0,1253	124.524.810
v	4,0000	0,6026	0,6647	0,8001	0,6421	0,3685	0,1792	0,1668	0,0100	0,2400	622.624.048

Looking at the criteria for 2015, we notice that the problem with ROA and ROE disappears, furthermore, for each indicator the thresholds calculated with the standard method give good results for capturing extreme values as well as for looking at the uncertainty zone.

Moving to 2014, we cannot conclude the same conclusion as before, in fact, here, the same problem that happened in 2016 and 2017 for ROA and ROE comes back. The problem is that both the veto and preference thresholds are higher than the maximum value. Thus, we need to adjust the thresholds in order to treat in a negative way the banks that do not produce profits. The new thresholds are:

2014	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}	I_{11}
p	2,9487	0,4824	0,5098	0,4791	0,4321	0,2818	0,1403	0,1249	0,0100	0,0800	481.620.457
q	0,7372	0,1206	0,1275	0,1198	0,1080	0,0705	0,0351	0,0312	0,0010	0,0100	120.405.114
v	3,6858	0,6030	0,6373	0,5988	0,5401	0,3523	0,1754	0,1561	0,0200	0,2000	602.025.572

For 2013, the criteria that had a change are: the interbank ratio, the ROA and the ROE. The reasons are the same explained above.

2013	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}	I_{11}
p	2,0000	0,4828	0,5639	0,3943	0,3791	0,3133	0,1776	0,1084	0,0100	0,1000	481.064.405
q	0,5000	0,1207	0,1410	0,0986	0,0948	0,0783	0,0444	0,0271	0,0050	0,0200	120.266.101
v	5,0000	0,6035	0,7048	0,4928	0,4739	0,3916	0,2220	0,1355	0,1000	0,3000	601.330.506

The transformations made for 2011 and 2012 follow the previous reasoning.

2011	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}	I_{11}
p	2,0000	0,5469	0,6439	0,3758	0,3380	0,2753	0,1737	0,1727	0,0243	0,4813	531.310.036
q	0,5000	0,1367	0,1610	0,0940	0,0845	0,0688	0,0434	0,0432	0,0061	0,1203	132.827.509
v	6,0000	0,6836	0,8049	0,4698	0,4225	0,3442	0,2172	0,2159	0,0304	0,6016	664.137.545
2012											
p	2,0000	0,5220	0,6168	0,4207	0,4101	0,3502	0,1814	0,1118	0,0080	0,1000	537.004.401
q	0,5000	0,1305	0,1542	0,1052	0,1025	0,0876	0,0454	0,0280	0,0020	0,0100	134.251.100
v	7,0000	0,6525	0,7710	0,5259	0,5127	0,4378	0,2268	0,1398	0,0100	0,3000	671.255.501

As we can see, the standard method give good preference, indifference and veto thresholds for most of the criteria except in the interbank ratio, ROE and ROA. In any case, with the MURAME application, we can analyze the differences in term of output between the first and the second technique.

As regards to the weights w_j , they will have the same value when each criteria has the same importance in the evaluation, or they can have different values when each criteria has different importance in the analysis. Let's define w_{I_1} as the weight associated to the criteria I_1 and w_{I_2} as the weight associated to the criteria I_2 , then when $w_{I_1} > w_{I_2}$ means that the first criteria is more important than the second criteria. We have seen previously that each of the considered indicator have the capability to capture tensions on banks' liquidity and this is shown in literature by many authors, as described previously. Furthermore, the Italian regulation does not indicate any ratio which can identify more the liquidity risk than other variables. In fact, the national regulation is based more on a qualitative approach which relies on control, reporting systems, internal management and monitoring of liquidity positions. Italian banks can determine the impact of adverse internal and external events on the bank's liquidity through either the stress tests or the contingency funding plan. Thus, in this analysis, we set the weights all equal.

The reference profiles will be used in the second step of the MURAME application, that is when we want to classify the banks into homogeneous classes. It is a kind of benchmark profile related to fictitious applicants and it is useful to delimit the rating classes and to serve as comparison with the profiles of real applicants. In order to determine the reference profiles, we must follow three steps: firstly, we must define in how many classes

l named $R_1, R_2, \dots R_l$ we want to group the alternatives, secondly for each criteria I_j, we compute the empirical quantiles in relation to the total number of classes decided, for instance, let us suppose 5 classes, then we should calculate the quintiles of each criteria distribution, thirdly we put together the quantiles of the same order, obtaining a total number of reference profiles (or fictitious alternatives) equal to $(l-1)$ called $r_1, r_2, \dots r_{l-1}$:

$$\begin{cases} r_1 = (I_1^1, I_2^1, \dots, I_n^1) \\ \dots \\ r_{l-1} = \left(I_1^{l-1}, I_2^{l-1}, \dots, I_n^{l-1}\right) \; l \geq 1 \end{cases}$$

In our case, we have a total number of banks operating in Italy equal to 40 to divide in *l* classes. Looking at the national regulation, there is not any provision related to liquidity risk. However, it is possible to find rules on the subdivision of banks in "*Circolare n.285 del 17 dicembre 2013*".

Class 1	Banks or Banking groups allow to use: IRB system[64] for the calculation of credit risk requirement, AMA method[65] for the operational risk requirement and internal methods for the market risk requirement.
Class 2	Banks or Banking groups that use standard methodologies[66] for the calculation of the credit, operational and market risk requirements. Their total assets (either consolidated or unconsolidated) should be between 3,5€ billion and 30€ billion.
Class 3	Banks or Banking groups that use standard methodologies for the calculation of the credit, operational and market risk requirements. Their total assets (either consolidated or unconsolidated) should be equal or lower than 3,5€ billion.

[64] It is an approach for calculating credit (risk-weighted assets) under Basel II. This approach allows banks to use their internal rating system for credit risk, subject to the explicit approval of their respective supervisors.

[65] It is an approach for calculating regulatory capital for operational risk under Basel II. This approach allows banks to use internal models, based on internal risk variables and profiles to calculate their regulatory capital charge.

[66] A standard methodology for credit risk is the standard approach (SA). This approach allows banks to use a prescribed risk weight schedule, a standard approach for operational risk is the standardized measurement approach (SMA). This approach allows banks to use business indicators (BI) and a financial statement proxy of operational exposure. The standardized approach for market risk requirements is the sum of three components: risk charges, the default risk charge and the residual risk add-on.

The bank subdivision is realized in order to facilitate the application of the principle of proportionality in the Internal Capital Adequacy Assessment Process (ICAAP)[67]. The proportionality principle applies to all the banks in order to ensure that they enforce the provisions based on their characteristics, size, etc. Thus, the banks are divided into three classes: Class 1, Class 2 and Class 3. This subdivision is based on the banks' size and banks' operational complexity. The table below shows what is the difference among the three classes.

On the basis of this classification, we consider 3 liquidity risk classes which means that after having calculated the tertiles for each criteria and aggregated them, we obtain 2 reference profiles r_1 and r_2. The first tertile coincides to the 13th position while the second tertile coincides with the 26th position.

2011	I_1	I_2	I_3	I_4	I_5	I_6	I_7	I_8	I_9	I_{10}	I_{11}
r_1	0,4423	0,6611	0,7488	0,1494	0,0913	0,0761	0,1023	0,0735	0,0024	0,0248	89.890.459
r_2	0,8100	0,7703	0,8784	0,2220	0,1670	0,1423	0,1365	0,0963	0,0042	0,0500	98.149.892
2012											
r_1	0,3588	0,6471	0,7208	0,1115	0,0880	0,0711	0,1030	0,0683	0,0008	0,0123	87.313.803
r_2	0,7817	0,7124	0,8224	0,1626	0,1240	0,1285	0,1313	0,0930	0,0040	0,0425	98.024.142
2013											
r_1	0,2510	0,5843	0,6639	0,0898	0,0687	0,0585	0,1094	0,0653	0,0005	0,0068	87.214.869
r_2	0,8903	0,6776	0,7641	0,1632	0,1282	0,1082	0,1436	0,0905	0,0029	0,0321	97.405.004
2014											
r_1	0,2742	0,5769	0,6481	0,0757	0,0643	0,0559	0,1112	0,0683	0,0019	0,0239	87.436.324
r_2	0,6571	0,6588	0,7515	0,1581	0,1276	0,1128	0,1464	0,0934	0,0035	0,0383	97.147.095
2015											
r_1	0,3380	0,5492	0,6239	0,0731	0,0588	0,0545	0,1276	0,0718	0,0023	0,0259	86.874.137
r_2	0,7788	0,6583	0,7515	0,1303	0,1112	0,1016	0,1432	0,0923	0,0043	0,0494	97.138.822
2016											
r_1	0,2840	0,5449	0,6377	0,0900	0,065	0,0563	0,1208	0,0687	0,0002	0,0030	84.918.962
r_2	0,7316	0,6356	0,743	0,1398	0,1122	0,0988	0,1511	0,0877	0,0033	0,0385	97.146.311
2017											
r_1	0,3638	0,5597	0,6363	0,1085	0,0922	0,0812	0,1256	0,0710	0,0013	0,0178	82.940.270
r_2	0,7458	0,6370	0,7246	0,1970	0,158	0,1383	0,1510	0,0863	0,0040	0,0596	97.148.134

[67] It was introduced under Basel II framework, it is a set of processes and procedures to ensure that the banks has an adequate capital resources in the long term to cover all of its material risks.

After having defined the weights, the thresholds and the reference profiles, we are ready for the MURAME application.

4.4 MURAME application

Once defined alternatives, criteria, weights, thresholds and reference profiles, we have all the necessary information for the application. As we said at the beginning, our aim is:

- ranking the banks from the best to the worst considering all the sample;
- classifying the banks into homogeneous classes;
- ranking the banks from the best to the worst inside each homogeneous class.

We will follow these steps for each year, from 2011 to 2017 in order to compare the banks not only among them (considering both all the sample and the homogeneous classes), but also to analyze the trend inside the same bank, in the meaning that one bank can be in the first positions in 2012 but it can be in the last positions in 2015. We will try to explain the reasons that led to these movements.

4.4.1 Ranking of all the sample space

The first output gives as a result two rankings of all the 38 or 40 banks. The first one was done using the first method for the computation of the thresholds, the second was has done using the second method. As we can see in table 1, the first 2 columns which refer to 2011 have 38 banks since for that year the balance sheets of Cassa di Risparmio di Asti (15) and Mediobanca (33) were not available in ORBIS.

In the next page, table 4.1 shows the result using the first method for the computation of the thresholds.

Table 4.1 – Rank using the first method

2011		2012		2013		2014		2015		2016		2017	
Alternative	Score	Alternative	Score	Alternative	Score	Alternative	Score	Alternative	Score	Alternative	Score	Alternative	Score
29	34,600	35	34,720	10	37,910	7	35,920	29	35,000	6	34,860	35	35,070
7	32,620	7	34,600	39	35,270	39	34,860	35	33,430	7	34,120	38	35,070
35	31,270	21	33,810	7	34,850	10	33,800	7	33,070	34	33,770	34	33,480
21	29,160	29	33,770	18	33,400	35	32,000	34	32,650	29	30,820	7	32,090
17	28,360	10	31,160	29	31,300	6	31,890	10	32,080	39	30,050	6	30,310
10	27,480	39	28,370	17	28,620	29	30,440	17	30,400	35	29,770	33	30,260
39	26,030	28	27,400	6	26,980	21	29,300	39	29,850	17	29,260	29	29,830
28	25,690	17	26,990	28	26,170	34	29,120	28	28,570	10	28,380	39	28,470
34	24,620	38	26,720	34	25,360	17	28,450	33	28,480	33	28,350	17	28,230
6	24,570	11	26,660	20	25,200	11	25,020	6	27,070	21	27,060	21	27,420
11	24,350	34	26,350	35	25,200	38	24,970	38	26,430	18	26,720	28	26,530
27	23,330	6	25,190	38	25,160	20	24,710	18	24,550	28	26,670	10	25,170
18	22,860	27	25,190	11	24,930	33	24,520	21	23,530	38	26,060	18	24,990
23	22,860	33	24,550	21	24,800	27	23,890	27	23,380	27	23,740	25	24,850
30	22,610	20	24,460	25	24,790	23	23,140	9	22,690	25	23,350	23	24,430
37	22,310	25	24,330	8	24,730	28	21,880	25	22,380	9	22,650	30	23,810
1	22,260	23	24,000	0	24,570	26	21,870	31	22,330	12	22,430	4	23,060
8	22,050	37	23,990	33	24,150	37	21,400	20	22,260	30	22,390	12	22,300
38	21,910	8	23,940	27	23,870	25	21,030	23	22,250	15	22,370	1	22,260
9	21,780	9	23,900	37	23,680	12	20,480	36	22,210	26	22,260	13	21,880
40	21,660	26	23,570	26	23,670	9	20,460	37	21,880	4	22,240	32	21,710
25	21,650	30	23,340	31	23,560	31	20,430	11	21,780	20	22,180	3	21,590
20	21,090	32	23,130	23	23,520	32	20,210	24	21,650	8	22,160	8	21,380
3	21,070	1	23,120	30	22,970	8	20,140	1	21,550	11	21,780	26	21,130
4	21,070	2	23,000	32	22,740	4	19,720	12	21,410	31	21,690	9	21,020
31	21,070	16	22,980	12	22,700	18	19,720	30	21,350	3	21,680	15	20,820
13	21,050	13	22,770	4	22,120	36	19,530	26	21,340	36	21,670	40	20,340
36	21,020	19	22,630	1	22,010	13	19,060	8	21,310	23	21,500	31	20,210
2	20,880	18	22,570	14	21,800	1	19,040	15	21,130	13	21,470	37	20,170
26	20,570	4	22,470	15	21,760	16	19,020	13	20,850	1	21,310	16	19,730
19	20,290	3	22,430	24	21,500	3	18,780	5	20,790	37	20,930	36	19,600
14	20,100	14	22,430	40	21,440	40	18,750	3	20,570	40	20,740	20	19,570
12	19,640	12	22,420	13	21,310	2	18,630	4	20,420	19	19,910	14	19,510
5	19,600	36	22,360	36	21,280	14	18,310	40	20,020	16	19,580	11	19,270
32	19,570	40	22,250	5	20,580	5	18,310	16	20,000	14	19,520	27	19,010
22	18,270	15	22,190	3	20,270	15	18,270	19	19,860	2	19,470	19	18,850
16	17,260	31	21,580	16	18,360	19	16,300	14	19,730	32	19,180	2	17,280
24	15,090	22	20,080	22	17,150	22	15,830	22	17,690	5	18,080	5	16,560
		5	19,270	2	17,060	30	15,260	32	17,410	22	17,890	22	15,890
		24	14,270	19	8,020	24	11,710	2	17,310	24	12,700	24	15,090

We can note immediately that the last positions are quite similar for all the years considered. Furthermore, it's very interesting to note the behavior of Monte dei Paschi di Siena SPA (24). In fact, it is in the last position in 2011, 2012, 2014, 2016 and 2017. While in 2013 and 2015, it reduced its liquidity risk and increased its position respectively to the 31th and the 23th position. This low position in the ranking can be due to the presence of both negative ROA and ROE, except in 2015. While in 2013, they are still negative but higher respect the other years. Thus, considering all the criteria simultaneously, even if Monte dei Paschi di Siena is a systematically important institutions (O-SIIs), this does not necessary imply that it will take high position in the ranking. Nevertheless, we are just doing some considerations about the results, we do not know with certainty the real

causes for which the bank is in the last position. For a more detail description, we should have other financial reporting such as “nota integrativa” which has additional information about the bank. Another bank that is among the lowest positions is Findomestic Banca (22). It is last but two in 2011, 2012, 2013, 2014 and 2015, while it is last but one in 2016 and 2015. In this case, we cannot blame ROE and ROA as before, since their values are positive all the years, anyway, this bank has very low liquidity ratios, especially the interbank ratio. In fact, the latter should be higher than 100% in order to indicate a good liquidity position. In this case, it is lower than 100%, so the bank is a net borrower rather than a placer of funds in the interbank market, as a consequence it is less liquid.

Moving to the highest positions in the ranking, we can notice that even if there are differences between one year and the following one, in the first positions there are almost the same banks. In 2011 and 2015, the first bank is Banca Finnat Euramerica (29). The bank dropped reaching the 6th position in 2014 and the 7th position in 2017, anyway it is still a good bank from liquidity risk point of view. The reasons can be found in the balance sheet data but also in the financial ratios. In the former, we can find that the total customer deposits which are a funding source for banks increased by 217,76% from 2011 to 2015. In the financial ratios, we can find high ROE and ROA which means that the bank is efficient in the management of its equity and total assets. Furthermore, also the values of the interbank ratios are very high, reaching their highest value exactly in 2015 with 855.83% and in 2011 with 232,69%. If we look at all the data, we will discover that 855.83% is also the highest interbank ratios among all the 40 banks in 2015. While the lowest is 3,15% which is the value linked to Findomestic Banca (22). Thus, higher the difference between the maximum and the minimum value of performance based on a given criterion, higher the positive effect on banks with high values on that criterion. In 2012 and 2017, the bank with lower liquidity risk is Unicredit (35), the other years, it does not reduces significantly its position, in fact, its lowest position is the 11th in 2013. Banca del Sud (10) was in the 6th position in 2011, the following years it reduced its exposure to liquidity risk achieving the first position in 2013. Since then it dropped, reaching the 12th position in 2017. In fact, despite its liquidity ratios agree with their target (for instance the net loans to total assets ratios that must be minimized, they have a low value), its ROA tends to reduce over time, concluding 2017 with -0,68%. Finally, we can notice that Banco di Napoli (7) is the only bank that always remains in the first four places, even if it takes the first one just in 2014. Also in this case, the interbank ratio plays

an important role. When the interbank ratio is very high, it allows the bank to increase the leaving flow, since it allows the bank to be preferred respect to another one, as a consequence, the bank will have a higher final score. However, the first method does not capture the negative ROA of 2013.

Table 4.2 – Rank using the second method

2011		2012		2013		2014		2016		2017	
Alternative	**Score**	**Alternative**	**Score**	**Alternative**	**Score**	**Alternative**	**Score**	**Alternative**	**Score**	**Alternative**	**Score**
29	34,508	7	33,452	10	35,078	7	33,771	6	33,618	34	33,028
7	32,858	28	33,371	39	32,653	39	32,003	34	32,813	7	32,869
35	31,025	34	32,891	28	30,962	10	31,692	39	32,584	38	32,838
21	29,459	35	31,929	29	30,858	35	29,567	7	32,467	35	31,705
17	28,161	29	31,657	17	29,274	6	29,498	18	31,272	29	31,264
10	27,359	10	31,123	34	29,001	28	29,390	28	30,979	28	30,532
39	26,364	21	30,641	18	28,660	34	28,872	10	28,891	39	29,160
28	25,475	39	29,085	31	25,460	31	28,454	29	28,107	33	28,245
6	24,879	17	24,758	6	25,148	29	27,881	33	26,103	6	26,382
34	24,368	38	24,672	8	24,993	21	26,414	17	25,602	25	23,991
11	24,120	25	24,077	20	24,242	17	25,720	21	25,061	17	23,788
27	23,134	27	23,676	11	23,703	11	23,364	38	23,477	23	23,399
18	22,629	11	23,262	9	23,500	20	23,230	22	23,394	31	23,384
30	22,521	37	22,805	23	23,468	33	23,148	31	23,275	1	22,819
23	22,444	23	22,710	26	23,445	38	22,946	27	20,547	21	22,285
1	22,066	9	22,574	27	23,181	23	22,791	9	20,319	18	21,225
37	21,897	20	22,553	15	23,060	27	22,442	26	19,765	10	20,483
8	21,793	26	22,273	30	22,707	37	19,537	1	19,530	9	18,930
38	21,621	33	21,855	1	22,609	18	19,364	30	19,271	16	18,528
40	21,503	30	21,851	21	22,439	12	19,060	23	18,889	13	18,415
9	21,436	1	21,578	25	22,399	25	18,939	12	18,882	2	18,304
25	21,385	22	21,479	37	22,397	9	18,657	36	18,825	14	18,235
4	20,969	13	21,324	12	22,072	36	18,465	15	18,761	26	18,190
20	20,957	8	20,750	33	21,567	4	18,382	25	18,409	22	17,741
3	20,918	32	20,699	13	21,370	13	18,246	13	17,873	36	17,546
31	20,903	14	20,595	36	20,684	32	17,825	8	17,770	30	17,178
36	20,734	16	20,568	32	20,632	15	17,735	4	17,667	8	16,858
13	20,685	31	20,535	4	20,388	1	17,726	3	16,847	37	16,704
26	20,529	15	20,526	40	20,315	26	17,480	11	16,800	15	15,945
2	20,500	36	20,242	14	19,875	8	17,447	37	16,762	12	15,800
19	20,069	2	20,238	5	18,950	22	17,331	40	16,616	40	15,673
14	20,066	18	20,173	3	18,843	40	17,325	2	16,260	3	15,389
5	19,453	12	20,041	38	17,876	14	17,240	14	15,723	32	15,265
12	19,416	6	19,995	16	17,764	3	16,401	32	15,208	11	15,174
32	19,209	4	19,891	22	17,597	2	16,133	20	11,468	4	14,466
22	17,877	40	19,815	24	8,487	30	13,927	16	5,414	27	-3,671
16	17,052	3	19,082	35	8,487	16	13,831	35	4,405	20	-4,813
24	14,839	19	17,227	7	6,565	5	0,349	19	-5,782	19	-5,339
		5	-7,245	2	-7,516	19	-7,830	5	-5,865	5	-6,109
		24	-9,924	19	-9,965	24	-9,959	24	-9,982	24	-9,104

The second method used to calculate the thresholds is a reasoning method in which we specified the preference, indifference and veto threshold based on the values of each criteria. We decide to avoid changing the thresholds in 2015 since the thresholds obtained with the standard method are already in accordance with the criteria values. Table 2 shows the results using the second method for the computation of the thresholds. Starting from the lowest positions, we can immediately observe that there are now negative scores and that Monte dei Paschi di Siena remains the most risky bank in 2011, 2012, 2013, 2016 and 2017. As regards to Findomestic Banca (22), the introduction of the new thresholds reduced its exposure to liquidity risk, especially in 2016. In fact, for that year it is in the 13th position of the rank respect to the 39th position with the standard method. Another interesting effect to note is the behavior of Banco di Napoli (7), it is in the last but two place in 2013, while all the other years it is among the first positions. In particular, it is the bank with the lowest liquidity risk in 2012 and 2014. This change is largely due to the negative ROA in 2013. In fact, the previous method was not able to discriminate banks with negative profits since the veto threshold was too much high respect to the maximum value of the criteria. In 2013, the highest ROA is 2,21% which corresponds to Banca Generali (28). Not by change, the latter occupies the third position, while the last position is taken by Banca Carige (19) which has a ROA of -6,16%.

Moving to the lowest risky banks, it is evident that except for 2012 and 2014 in which Banco di Napoli is at the top, in all the other years there are always different banks in the first position. Furthermore, these banks do big jumps from one year to another one. For instance, in 2016 Banco di Sardegna (6) dominates the first place (as with the first method), while it is at the 34th position in 2012 (with the first method it was in the 12th position). This behavior can be caused by the reduction of preference, indifference and veto threshold for ROA and ROE in order to penalize banks with negative profits, in fact Banco di Sardegna has a loss in 2012. At the same time, the reduction of the veto thresholds can penalize the alternatives with bad results based on a certain criteria, (in case of Banco di Sardegna, the criteria can be ROA) but it can benefit banks with good results based on another criteria (in case of Banco di Sardegna, the criteria can be the Interbank ratio which is 281,41%). Banca del Sud (10) has a similar behavior, in fact, it is first in 2013 (as with the first method), while it is in the 17th position in 2017 (with the first method it was 12th in 2017). Also in this case, the cause can be due to presence of negative profit in 2017 and the reduction of the thresholds for the ROA.

To sum up, we can conclude that generally there are not big differences between the two methods despite the changes in the thresholds. This indicates that each criteria contains a lot of information and thus, the results do not change significantly. Anyway, we can conclude that the second method is better since it allows to discriminate banks with negative profits or banks with criteria values higher than the average. In fact it rewards banks with high performance based on a determined criteria, especially by imposing a low veto threshold. On the other hand, the latter penalizes the alternatives with bad results based on a given criteria.

4.4.2 Classification into homogeneous classes

The second step of the MURAME application consists in the classification of the banks into homogeneous classes based on their liquidity risk. In order to realize this aim, we use the reference profiles (RF) calculated previously. The latter, as already said, is a kind of benchmark profile related to fictitious applicants which is useful to delimit the rating classes.

In the tables below, there is the summary of the rating classes. There are two tables since we classified the ranking obtained from both the first method and the second method. We decided to divide the banks into three rating classes called: *Class 1*, *Class 2* and *Class 3* where *Class 1* includes the banks that are lower exposed to liquidity risk, on the other hand, *Class 3* indicates the banks that are more exposed to liquidity risk.

Classification using the first method							
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
Class 1	14	16	18	15	15	15	16
Class 2	6	10	8	12	15	16	13
Class 3	18	14	14	13	10	9	11

As we can see, *Class 2* has the lowest number of banks in 2011, 2012 , 2013 and 2014. While in 2015, 2016 and 2017 *Class 3* has the lowest amount of banks. *Class 2* is the most numerous just in 2016, *Class 3* has the highest amount of banks just in 2011. All the other year (2012, 2013, 2014 and 2017) *Class 1* is the most numerous. A possible reason for which *Class 1* is the most numerous can be both the presence of a large number of banks with high performance based on some criteria and low preference thresholds. In fact, when the threshold is low, it's easy that the difference between the performance of

two alternatives exceeds the threshold leading to a strict preference. The same can be concluded looking at the classification using the second method for the computation of the thresholds.

Classification using the second method						
	2011	**2012**	**2013**	**2014**	**2016**	**2017**
Class 1	15	15	12	17	15	15
Class 2	7	14	16	12	16	16
Class 3	16	11	12	11	9	9

In 2013, the second method allows to reward the financial institutions with good performances and to penalize more the banks that have a criteria evaluation which can be defined neither good nor bad (*Class 2*).

Now, it's possible to calculate the migration probability which indicates the probability that an alternative moves from one class to another one. That is, the probability that a bank improves or deteriorates its liquidity risk during the years. We calculate these probabilities as the ratio between the number of banks that moved (or stayed in the same class) over the total number of banks in the same class. For instance, from 2011 to 2012, twelve banks remained in *Class 1* which contains fourteen banks using the first method. So, the migration probability is given by $^{12}/_{14} = 0{,}8571$. The same year, one bank moves to *Class 2* and one bank moves to *Class 3*, so their respective probabilities are $^{1}/_{14} = 0{,}0714$ and $^{1}/_{14} = 0{,}0714$. The tables below show the migration probabilities. We must read the table in horizontal, so that $0{,}8571$ is the probability that banks remained inside *Class 1* while $0{,}0714$ is the probability that banks moved to *Class 2* and *Class 3*.

Migration Probabilities for the rank using the first method											
	2011-2012				**2012-2013**				**2013-2014**		
	Class 1	***Class 2***	***Class 3***		***Class 1***	***Class 2***	***Class 3***		***Class 1***	***Class 2***	***Class 3***
Class 1	0,8571	0,0714	0,0714	***Class 1***	0,9375	0,0625	0,0000	***Class 1***	0,7222	0,2778	0,0000
Class 2	0,1667	0,8333	0,0000	***Class 2***	0,2000	0,5000	0,3000	***Class 2***	0,2500	0,6250	0,1250
Class 3	0,1111	0,2222	0,6667	***Class 3***	0,0714	0,1429	0,7857	***Class 3***	0,0000	0,1429	0,8571
	2014-2015				**2015-2016**				**2016-2017**		
	Class 1	***Class 2***	***Class 3***		***Class 1***	***Class 2***	***Class 3***		***Class 1***	***Class 2***	***Class 3***
Class 1	0,8000	0,2000	0,0000	***Class 1***	0,9333	0,0667	0,0000	***Class 1***	0,9333	0,0667	0,0000
Class 2	0,2500	0,5833	0,1667	***Class 2***	0,0667	0,8667	0,0667	***Class 2***	0,1250	0,6875	0,1875
Class 3	0,0000	0,3846	0,6154	***Class 3***	0,0000	0,2000	0,8000	***Class 3***	0,0000	0,2222	0,7778

Migration Probabilities for the rank using the second method											
	2011-2012				2012-2013				2013-2014		
	Class 1	*Class 2*	*Class 3*		*Class 1*	*Class 2*	*Class 3*		*Class 1*	*Class 2*	*Class 3*
Class 1	0,8000	0,0667	0,1333	*Class 1*	0,4667	0,3333	0,2000	*Class 1*	0,8333	0,1667	0,0000
Class 2	0,4286	0,4286	0,1429	*Class 2*	0,2143	0,5714	0,2143	*Class 2*	0,0345	0,6250	0,1250
Class 3	0,0000	0,5000	0,5000	*Class 3*	0,1818	0,2727	0,5455	*Class 3*	0,2500	0,0000	0,7500
	2014-2015				2015-2016				2016-2017		
	Class 1	*Class 2*	*Class 3*		*Class 1*	*Class 2*	*Class 3*		*Class 1*	*Class 2*	*Class 3*
Class 1	0,7647	0,2353	0,0000	*Class 1*	0,8667	0,0667	0,0667	*Class 1*	0,7333	0,2000	0,0667
Class 2	0,1667	0,6667	0,1667	*Class 2*	0,0625	0,8125	0,1250	*Class 2*	0,1875	0,6250	0,1875
Class 3	0,0000	0,2727	0,7273	*Class 3*	0,1111	0,3333	0,5556	*Class 3*	0,1111	0,3333	0,5556

As we can see, the results are quite stable. There were some improvements in *Class 3,* second table between 2011-2012, in fact half banks moved to *Class 2.* While, there were some worsening in *Class 1,* second table between 2012-2013, in fact 33% of the banks moved to *Class 2* and 20% moved to *Class 3.* As regard to the first table, there were significant movements just in *Class 2,* 2012-2013. In those years, 20% of the banks shifted to *Class 1* while 33% dropped to *Class 3.*

At the end of this paragraph, there are the tables with the results. Looking at those tables, it's possible to observe when a bank moves from a class to another one during the years. We will focus on table 4.4 since it was made using the second method. We start the analysis from banks that always remained in their place. Banca Finnat Euramerica (29), ICCREA Banca (17), Banca Galileo (39), Banca Generali (28) and Banca Mediolanum (34) stay in *Class 1* for all the years considered. It is interesting to note that all these banks except ICCREA, had an increment in the total customer deposits higher than 100% from 2011 to 2017. Banca Piccolo Credito Valtellinese (5) and Banca Carige (19) always stay in *Class 3* which contains the banks with higher exposure to liquidity risk. Banca del Piemonte (9) is always in the second class except in 2015 in which it is in the first one, anyway, it is in the lowest bound of *Class 1*, so we cannot conclude with certainty that it reduced its risk that year. This change can be due to the worsening or improvement of other banks which deteriorated the performance of this bank on a given criteria. There are banks that move directly from the first class to the third one without passing through the second one and vice versa. These banks are: Banco di Napoli (7), Unicredit (35) and Banco di Sardegna (6). In this case, the change can be due to significant variation in their balance sheet. For instance, in 2013 and 2016, Unicredit had negative ROA, low capital ratios, moreover some of its liquidity ratios (interbank ratio, liquid assets to total deposits and borrowings ratio and liquid assets to deposits and short-term funding) are low. There are banks that move in all the three classes. These banks are: Banca di Cambiano (11),

Banca di Credito Popolare (27), Banca Sella (18), Banca Popolare Pugliese (30) and Intesa San Paolo (38). It is interesting to note that all of them stay in *Class 3* just once. In particular, Intesa San Paolo is in the third class in 2013, it is in the second class in 2011 and it is in the first class all the other years. Also in this case, we can observe negative ROA in those years and the reduction of the following ratios: Tier 1 ratio, interbank ratios, liquid assets to total deposits and borrowings ratio and liquid assets to deposits and short-term funding.

Table 4.3 – Rank using the first method and the reference profiles

2011		2012		2013		2014		2015		2016		2017	
Alternative	Score	Alternative	Score	Alternative	Score	Alternative	Score	Alternative	Score	Alternative	Score	Alternative	Score
29	36,528	35	36,735	10	39,942	7	37,921	29	37,038	6	36,948	35	37,083
7	34,694	7	36,671	39	37,270	39	36,929	35	35,444	7	36,168	38	37,082
35	33,181	21	35,866	7	36,814	10	35,800	7	35,166	34	35,840	34	35,565
21	31,139	29	35,744	18	35,488	35	34,016	34	34,712	29	32,834	7	34,188
17	30,417	10	33,145	29	33,268	6	33,828	10	34,055	39	32,053	6	32,358
10	29,440	39	30,349	17	30,593	29	32,432	17	32,399	35	31,603	33	32,241
39	28,021	28	29,356	6	28,964	21	31,382	39	31,859	17	31,293	29	31,856
28	27,660	17	28,931	28	28,138	34	31,197	28	30,547	10	30,381	39	30,472
34	26,585	38	28,714	34	27,331	17	30,419	33	30,465	33	30,372	17	30,203
6	26,564	11	28,654	20	27,187	11	26,999	6	29,081	21	29,036	21	29,416
11	26,341	34	28,320	38	27,155	38	26,961	38	28,426	18	28,713	28	28,491
27	25,315	6	27,184	35	27,036	20	26,698	18	26,547	28	28,639	10	27,158
18	24,849	27	27,174	11	26,912	33	26,422	21	25,508	38	28,043	18	26,988
23	24,844	33	26,547	21	26,770	27	25,876	27	25,365	27	25,733	25	26,851
RF2	24,689	20	26,447	25	26,752	23	25,135	9	24,682	25	25,345	23	26,422
30	24,596	25	26,297	8	26,715	**RF2**	24,174	**RF2**	24,633	**RF2**	24,915	30	25,794
37	24,303	**RF2**	26,122	9	26,557	26	23,864	25	24,361	9	24,641	**RF2**	25,240
1	24,252	23	25,989	33	26,141	28	23,863	31	24,308	12	24,416	4	25,016
8	24,045	37	25,984	**RF2**	26,089	37	23,394	20	24,254	30	24,376	12	24,294
9	23,770	8	25,931	27	25,856	25	22,996	23	24,246	15	24,362	1	24,248
38	23,753	9	25,895	37	25,668	9	22,457	36	24,202	26	24,245	13	23,874
RF1	23,652	26	25,565	26	25,645	12	22,452	37	23,871	4	24,227	32	23,682
25	23,623	30	25,334	23	25,489	31	22,352	11	23,773	20	24,164	3	23,580
40	23,410	32	25,119	31	25,476	32	22,199	24	23,642	8	24,145	8	23,370
20	23,080	1	25,117	30	24,960	8	22,134	1	23,522	11	23,770	26	23,113
3	23,059	2	24,982	32	24,729	18	21,709	12	23,389	3	23,663	9	22,992
4	23,041	16	24,977	12	24,688	4	21,708	30	23,349	36	23,659	15	22,809
13	23,032	**RF1**	24,900	**RF1**	24,314	36	21,513	26	23,319	31	23,652	40	22,315
31	23,030	13	24,767	4	24,108	**RF1**	21,170	8	23,293	23	23,490	31	22,194
36	23,001	19	24,622	1	23,992	13	21,059	15	23,110	13	23,459	37	22,161
2	22,791	18	24,554	14	23,769	1	21,022	13	22,840	1	23,279	**RF1**	21,732
26	22,549	4	24,455	15	23,706	16	21,004	**RF1**	22,826	37	22,918	16	21,704
19	22,249	3	24,425	24	23,445	3	20,751	5	22,764	**RF1**	22,894	36	21,590
14	22,048	14	24,418	40	23,420	40	20,721	3	22,538	40	22,738	14	21,501
5	21,566	12	24,392	13	23,302	2	20,568	4	22,417	19	21,821	20	21,458
12	21,546	36	24,345	36	23,250	5	20,277	40	22,014	16	21,524	11	21,258
32	21,464	40	24,250	5	22,553	14	20,265	16	21,971	14	21,449	27	20,913
22	20,098	15	24,170	3	22,234	15	20,245	19	21,807	2	21,402	19	20,707
16	19,086	31	23,523	16	20,239	19	18,162	14	21,680	32	21,081	2	19,221
24	16,735	22	21,935	22	18,933	22	17,672	22	19,510	5	19,959	5	18,403
		5	21,160	2	18,832	30	17,093	32	19,202	22	19,682	22	17,672
		24	15,922	19	9,484	24	13,321	2	19,192	24	14,320	24	16,770

Table 4.4 – Rank using the second method and the reference profiles

2011		2012		2013		2014		2015		2016		2017	
Alternative	Score	Alternative	Score	Alternative	Score	Alternative	Score	Alternative	Score	Alternative	Score	Alternative	Score
29	36,46	7	35,496	10	37,027	7	35,771	29	37,038	6	35,661	34	35,058
7	34,92	28	35,374	39	34,539	39	34,054	35	35,444	34	34,863	7	34,869
35	32,93	34	34,912	28	33,728	10	33,687	7	35,166	39	34,655	38	34,850
21	31,46	35	33,916	29	32,808	35	31,580	34	34,712	7	34,499	35	33,717
17	30,22	29	33,628	34	31,003	6	31,436	10	34,055	18	33,369	29	33,255
10	29,32	10	33,098	17	30,951	28	31,407	17	32,399	28	32,998	28	32,563
39	28,36	21	32,655	18	30,403	34	30,932	39	31,859	10	30,859	39	31,207
28	27,44	39	31,041	31	27,330	31	30,416	28	30,547	29	30,117	33	30,180
6	26,87	17	26,666	6	27,076	29	29,869	33	30,465	33	28,090	6	28,277
34	26,34	38	26,643	8	26,699	21	28,472	6	29,081	17	27,616	25	25,894
11	26,11	25	26,030	20	26,077	17	27,671	38	28,426	21	27,001	17	25,692
27	25,12	27	25,642	11	25,639	11	25,308	18	26,547	38	25,411	23	25,359
18	24,62	11	25,180	**RF2**	25,628	20	25,182	21	25,508	31	25,268	31	25,331
30	24,51	37	24,783	23	25,398	33	25,042	27	25,365	22	25,193	1	24,761
23	24,42	23	24,683	9	25,248	38	24,902	9	24,682	27	22,480	21	24,196
RF2	24,37	**RF2**	24,633	26	25,222	23	24,759	**RF2**	24,633	**RF2**	22,377	**RF2**	23,943
1	24,05	9	24,545	15	24,974	27	24,397	25	24,361	9	22,253	18	23,096
37	23,89	20	24,489	27	24,935	**RF2**	22,843	31	24,308	26	21,692	10	22,174
8	23,79	26	24,241	30	24,480	37	21,492	20	24,254	1	21,435	9	20,837
40	23,49	30	23,822	1	24,401	18	21,331	23	24,246	30	21,208	16	20,458
38	23,47	33	23,790	21	24,373	12	21,000	36	24,202	23	20,771	13	20,328
9	23,42	1	23,548	37	24,222	25	20,851	37	23,871	36	20,754	2	20,192
25	23,35	13	23,291	25	24,203	9	20,610	11	23,773	12	20,751	14	20,159
RF1	23,17	22	23,269	12	23,915	36	20,414	24	23,642	15	20,703	26	20,111
20	22,95	8	22,666	33	23,458	4	20,332	1	23,522	25	20,301	22	19,484
4	22,94	32	22,633	13	23,069	13	20,207	12	23,389	13	19,771	36	19,464
3	22,91	14	22,552	32	22,564	32	19,738	30	23,349	8	19,690	30	19,042
31	22,87	16	22,497	36	22,434	15	19,684	26	23,319	4	19,580	8	18,713
36	22,71	15	22,478	4	22,238	1	19,668	8	23,293	3	18,716	37	18,618
13	22,66	31	22,458	**RF1**	22,117	8	19,335	15	23,110	37	18,696	15	17,813
26	22,51	**RF1**	22,445	40	22,005	**RF1**	19,285	13	22,840	11	18,687	12	17,658
2	22,4	36	22,178	14	21,789	40	19,260	**RF1**	22,826	40	18,549	40	17,539
19	22,03	2	22,136	5	20,867	26	19,238	5	22,764	**RF1**	18,197	**RF1**	17,293
14	22,01	18	22,095	3	20,750	14	19,152	3	22,538	2	18,131	3	17,261
5	21,42	12	21,956	38	19,608	22	19,152	4	22,417	14	17,553	32	17,090
12	21,33	6	21,857	16	19,496	3	18,285	40	22,014	32	16,998	11	17,035
32	21,09	4	21,803	22	19,327	2	17,967	16	21,971	20	13,281	4	16,209
22	19,69	40	21,745	24	10,101	30	15,730	19	21,807	16	6,282	27	-3,689
16	18,88	3	20,996	35	8,902	16	15,462	14	21,680	35	4,418	20	-4,829
24	16,49	19	19,080	7	6,854	5	1,060	22	19,510	19	-5,798	19	-5,357
		5	-7,258	2	-8,661	19	-7,843	32	19,202	5	-5,879	5	-6,115
		24	-9,928	19	-9,967	24	-9,961	2	19,192	24	-9,983	24	-9,107

4.4.3 Ranking inside each class

If we compare the tables without reference profiles and the those with reference profiles, we can note that there aren't big differences in the final ranking. In fact, the biggest variations are in the middle positions, for instance in 2014 Banca di Credito Cooperativo della Marca (26) was 29th in the ranking without reference profiles, while it was 31th in the ranking with references profiles. For this reason, we decided to do a new classification inside each category in order to verify if the banks inside the same class maintain the same order.

For this application, we consider the parameters (weight, preference, indifference and veto threshold) of the second method since it gives better results. Thanks to this analysis, it is possible to see what is the effect of banks with good performance on banks with bad performance and vice versa. To understand better, let us consider three banks: BPER Banca (3), Mediocredito Trentino-Alto Adige (32) and Banca di Cambiano (11). They occupy, exactly in the same order in which they are written (3, 32, 11), the first three positions of *Class 3* in 2017 using the second method. The question is: will they occupy the same positions even considering just *Class 3*? Looking at table 4.6, the answer is negative. When we reclassify the banks inside the same class, the result may change. Focusing on *Class3* in 2017, Banca di Cambiano and MedioCredito Trentito-Alto Adige reserved their positions while all the other banks maintain the same order. If we look at their balance sheets, they are quite similar: they have positive and low ROA, high Tier Ratio 1, low interbank ratio and total assets comprised between 1.000.000€ and 5.000.000€. Anyway, a possible cause of this change is that Banca di Cambiano can have bad performance on some criteria respect to other banks, so that it takes the 34th considering all the sample space. Then, removing banks with better performances, Banca di Cambiano can improve its results, achieving the 33rd position.

4.5 – Ranking inside each class using the second method

Class 1 - 2011		Class 1-2012		Class 1-2013		Class 1-2014		Class 1-2015		Class 1-2016		Class 1-2017	
Alternative	Score	Alternative	Score	Alternative	Score	Alternative	Score	Alternative	Score	Alternative	Score	Alternative	Score
29	10,327	28	8,266	10	6,394	7	11,060	29	8,512	6	8,039	7	-3,580
35	9,840	34	7,462	28	4,976	39	7,772	35	8,383	7	7,461	38	-2,956
7	8,175	7	7,410	39	3,216	35	6,744	34	5,359	34	7,050	34	-2,753
21	3,502	35	7,085	29	2,711	10	6,330	7	5,279	28	6,346	35	-2,749
39	3,143	29	5,628	34	1,257	28	6,055	10	4,718	39	5,247	28	-2,663
10	3,093	10	4,557	17	0,415	31	5,695	33	3,983	18	3,840	29	-2,569
17	2,537	21	3,921	18	-0,409	34	4,138	39	3,647	29	2,482	33	0,308
28	1,794	39	3,019	31	-1,279	29	3,500	17	2,567	10	2,058	39	2,382
34	1,767	38	-0,702	6	-1,481	6	3,392	28	2,049	33	1,689	6	2,966
6	1,054	11	-1,266	8	-2,077	21	2,498	6	1,505	22	0,322	13	4,612
11	0,835	25	-1,277	20	-2,552	17	0,381	38	1,167	21	-0,464	17	4,729
27	-0,035	17	-1,312	11	-2,577	33	0,225	18	-0,467	17	-1,989	23	6,811
23	-0,302	27	-1,852	Class 2 - 2013		20	-0,440	27	-1,302	31	-2,638	25	7,241
30	-0,399	37	-2,679	15	6,208	38	-0,594	9	-2,166	38	-3,091	21	7,885
18	-0,442	23	-2,723	21	5,798	11	-0,733	21	-2,262	27	-4,348	1	8,284
Class 2 - 2011		Class 2 - 2012		23	5,153	23	-0,996	Class 2 - 2015		Class 2 - 2016		Class 2 - 2017	
25	-3,110	22	3,807	25	4,883	27	-1,015	31	5,031	25	5,550	10	7,784
38	-3,511	31	3,220	37	4,856	Class 2 - 2014		25	4,698	9	5,229	22	6,951
37	-3,849	9	3,138	9	4,839	18	1,919	11	4,227	1	5,217	18	5,735
40	-4,066	33	3,087	33	4,775	25	1,443	12	3,919	26	5,125	9	5,003
8	-4,068	30	3,038	27	4,611	15	1,378	20	3,886	23	4,997	14	4,727
1	-4,071	26	3,009	26	4,522	13	1,084	8	3,843	36	4,981	2	4,626
9	-4,098	20	2,997	30	4,430	12	1,067	23	3,782	12	4,955	16	4,575
Class 3 - 2011		13	2,923	12	4,410	37	0,853	37	3,733	30	4,906	13	4,273
2	5,851	1	2,895	1	4,374	36	0,830	15	3,723	15	4,886	26	4,209
4	5,454	15	2,683	13	4,357	4	0,773	30	3,684	8	4,843	36	4,135
20	5,296	14	2,589	32	4,212	9.	0,731	13	3,683	37	4,766	37	3,919
27	5,128	32	2,469	4	4,143	1	0,674	24	3,672	13	4,732	8	3,295
14	5,085	16	2,384	36	4,107	32	0,519	26	3,603	40	4,688	40	3,155
3	4,965	8	2,011	Class 3 - 2013		8	0,241	36	3,577	11	4,601	30	3,113
19	4,961	Class 3 - 2012		7	4,942	Class 3 - 2014		1	3,498	3	4,367	15	2,763
36	4,954	6	2,333	35	4,803	22	3,708	Class 3 - 2015		4	4,367	12	2,658
31	4,941	2	2,072	22	3,757	40	3,434	22	-0,742	Class 3 - 2016		Class 3 - 2017	
13	4,911	12	1,920	40	3,036	14	3,288	4	-0,864	35	4,661	3	4,162
22	4,910	4	1,895	38	2,447	30	2,284	40	-0,866	2	2,340	11	4,130
12	4,868	40	1,849	16	2,276	3	2,115	5	-0,901	32	2,117	32	4,128
5	4,849	18	1,844	5	1,857	2	2,102	3	-0,975	14	1,965	4	2,446
32	4,843	36	1,843	3	1,683	26	1,759	16	-1,034	20	-1,085	27	-3,558
16	3,571	3	1,808	14	1,309	16	1,215	14	-1,054	16	-1,882	20	-3,856
24	2,306	19	0,854	24	-1,159	5	-3,041	32	-1,058	19	-4,793	19	-4,672
		5	-6,513	2	-7,928	19	-7,005	19	-1,136	5	-4,871	5	-5,923
		24	-9,906	19	-9,883	24	-9,859	2	-1,188	24	-9,983	24	-9,132

CHAPTER 5 - Conclusions

In this work, we considered a Multicriteria decision aids methodology for the evaluation of the liquidity risk of 38/40 banks operating in Italy from 2011 to 2017. In particular, the methodology used is the MURAME. Its properties are several: it allows to take into account simultaneously more than one financial indicators derived from the balance sheet of the financial institutions, it allows to rank the banks according to their liquidity risk characteristics, moreover, by means of the use of suitable reference profiles, it allows to sort the banks into a prefixed number of homogeneous groups.

The use of a multicriteria-based approach for liquidity risk assessment gives several advantages, among which it considers the decision maker's preferences through the thresholds choice. This is possible when the thresholds are decided directly by the decision maker and not by following mathematical equations. For this reason, we use two methods for the computation of the thresholds. The first method is a standard method which uses a mathematical procedure (a system of three equations) to obtain the thresholds. The second method is a reasoning method which implies a decision maker choice. The utilization of two approaches allowed us to compare the performances obtained by using the first method with those achieved by adopting the second method. Furthermore, we tried to find and to explain the motivations that caused changes in the final results in each ranking.

Recalling the goodness of the results of the evaluation methodology proposed, they are satisfactory in both cases, since the results are quite similar. This is due to the fact that all the considered criteria give their contribution in the determination of the liquidity risk assessment. Anyway, some improvements come from the second method. In fact, the thresholds that satisfy the decision maker's preferences, allow to discriminate banks with negative profit and to reward banks with good performance based on a given criteria. At the same time, if they are not chosen correctly, they can penalize too much the banks with bad performance. Thus, the choice of these parameters is a tricky point since their value may change completely the results. Finally, the introduction of the references profiles was helpful not only to divide banks into homogeneous classes, but also to rank again the

banks inside the same class. This was very useful to discover that removing some alternatives from the initial sample size, the order in the rank may change.

A suggestion for a future study which can integrate this work on MCDA approaches applied to financial decision-making problems is to hypothesize that each criteria has a different importance on the liquidity risk assessment, as a consequence, there will be different weights. Then, it might be interesting to compare the rank obtained by using the same weights with the one get by utilizing different weights.

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Appendix A

Lists of criteria from 2011 to 2017 .

2011	Interbank Ratio	Net Loans/Total Assets	Net Loans/Total Deposits and Borrowings	Liquid Assets/ Deposits and Short-Term Funding	Liquid Assets/ Total Deposits and Borrowings	Liquid Assets/Total Assets	Tier 1 Ratio	Equity/Total Assets	ROA	ROE	Total Assets
1	0,6499	0,7057	0,8035	0,1825	0,1256	0,1103	0,0867	0,0870	0,0042	0,0485	50709347
2	0,0790	0,7601	0,8977	0,0453	0,0413	0,0317	0,1837	0,1141	0,0117	0,1025	84493587
3	0,5435	0,7966	0,8917	0,1494	0,0993	0,1083	0,0861	0,0768	0,0025	0,0309	39512069
4	0,8100	0,8125	0,9422	0,1257	0,0741	0,0639	0,2004	0,1135	0,0021	0,0181	96589427
5	0,5103	0,7860	0,8784	0,1024	0,0749	0,0670	0,0728	0,0752	0,0024	0,0312	71588510
6	4,1267	0,7563	0,8648	0,2220	0,1779	0,1556	0,1365	0,0926	0,0023	0,0248	82573650
7	7,5264	0,6972	0,8174	0,2625	0,2501	0,3036	0,1510	0,0825	0,0065	0,0792	69349276
8	0,6342	0,7560	0,8331	0,1628	0,0913	0,1223	0,1266	0,0676	0,0040	0,0598	98038749
9	0,1610	0,6857	0,8104	0,1690	0,1121	0,0911	0,1224	0,0735	0,0038	0,0515	97991053
10	1,8136	0,5615	0,8073	0,2759	0,2739	0,1905	0,2868	0,2075	0,0054	0,0260	99922951
11	0,7642	0,7189	0,8652	0,2637	0,2308	0,1940	0,2029	0,1570	-0,0011	-0,0072	99936370
12	0,3635	0,7750	0,8868	0,0343	0,0221	0,0193	0,1261	0,0963	0,0030	0,0306	97271381
13	0,1290	0,6430	0,7488	0,1120	0,0835	0,0717	0,0868	0,0531	0,0031	0,0585	68902695
14	1,0766	0,7872	0,8991	0,0723	0,0456	0,0399	0,1072	0,0927	0,0055	0,0592	91640206
16	0,6328	0,7680	0,8640	0,1435	0,0798	0,0710	0,0909	0,0758	-0,0144	-0,1893	29803692
17	0,6787	0,4149	0,4475	0,5680	0,4634	0,4296	0,0856	0,0524	0,0023	0,0442	74094529
18	0,4702	0,6853	0,7444	0,2851	0,2345	0,2159	0,1147	0,0494	0,0009	0,0186	90219053
19	0,3354	0,5993	0,7428	0,1471	0,0888	0,0716	0,0571	0,0641	0,0042	0,0656	55139943
20	0,7329	0,7771	0,9005	0,1556	0,0843	0,0727	0,1485	0,1165	0,0042	0,0356	98326514
21	2,9493	0,1023	0,1176	0,3184	0,3051	0,2654	0,1250	0,0437	0,0000	-0,0004	96607654
22	0,0215	0,9226	1,0835	0,0215	0,0215	0,0182	0,1983	0,1315	0,0066	0,0499	89890459
23	0,1269	0,6611	0,7296	0,1726	0,1478	0,1340	0,1079	0,1101	0,0050	0,0687	98251790
24	0,4423	0,6091	0,6551	0,2884	0,1686	0,1567	0,1107	0,0456	-0,0195	-0,4270	140701971
25	0,2116	0,8061	1,0048	0,1143	0,0919	0,0738	0,2340	0,1732	0,0085	0,0488	95592054
26	1,0674	0,8360	0,9265	0,1317	0,0844	0,0761	0,1192	0,0886	0,0044	0,0500	98149892
27	0,9003	0,6370	0,7211	0,2479	0,1670	0,1475	0,1513	0,0876	0,0045	0,0509	97553791
28	0,4801	0,2136	0,2361	0,1514	0,1513	0,1369	0,1112	0,0577	0,0170	0,2949	95451111
29	2,3269	0,4408	0,7235	0,5852	0,5261	0,3205	0,3177	0,2966	0,0072	0,0243	99419620
30	1,2878	0,6899	0,7817	0,2196	0,1347	0,1189	0,1023	0,0863	0,0034	0,0395	96616497
31	0,6195	0,6747	0,7789	0,1548	0,1465	0,1269	0,0654	0,0433	0,0033	0,0754	99181940
32	0,0643	0,8363	0,9596	0,0442	0,0191	0,0166	0,1391	0,1183	0,0041	0,0345	98394708
34	0,3940	0,2856	0,3090	0,2126	0,2020	0,1868	0,0941	0,0375	0,0084	0,2247	85087648
35	0,4276	0,6038	0,6699	0,2512	0,1617	0,1345	0,0932	0,0591	-0,0095	-0,1614	826768744
36	0,4140	0,8083	0,8969	0,1592	0,1418	0,1277	0,0777	0,0645	0,0027	0,0414	70717088
37	1,3589	0,7727	0,9039	0,2097	0,1554	0,1328	0,1048	0,0976	0,0024	0,0244	99520093
38	0,4560	0,5894	0,7277	0,3348	0,1784	0,1445	0,1147	0,0747	-0,0127	-0,1702	539221000
39	3,9768	0,7147	0,8695	0,2739	0,1731	0,1423	0,2638	0,1695	-0,0019	-0,0110	99813771
40	0,9061	0,7703	0,8547	0,1903	0,1241	0,1119	0,0894	0,0743	0,0017	0,0226	97570698

2012	Interbank Ratio	Net Loans/Total Assets	Net Loans/Total Deposits and Borrowings	Liquid Assets/ Deposits and Short-Term Funding	Liquid Assets/ Total Deposits and Borrowings	Liquid Assets/Total Assets	Tier 1 Ratio	Equity/Total Assets	ROA	ROE	Total Assets
1	0,7817	0,7122	0,821	0,1603	0,1032	0,0726	0,0943	0,0928	0,0033	0,0353	50677986
2	0,0760	0,7511	0,8889	0,0429	0,0375	0,0349	0,1801	0,1080	0,0004	0,0039	85331824
3	0,3096	0,7795	0,8780	0,1056	0,0763	0,0677	0,0830	0,0773	0,0002	0,0029	38362242
4	0,1747	0,7454	0,8444	0,0442	0,0289	0,0255	0,1308	0,0930	0,0007	0,0079	95853502
5	0,3588	0,7361	0,8183	0,0953	0,0730	0,0657	0,0813	0,0665	-0,0106	-0,1601	70103937
6	2,8441	0,7752	0,8951	0,1552	0,1205	0,2746	0,1481	0,0963	-0,0015	-0,0160	87313803
7	8,7616	0,7098	0,8465	0,2570	0,2430	0,3139	0,1660	0,0813	0,0061	0,0745	69799784
8	0,5174	0,6316	0,6999	0,1586	0,0987	0,1227	0,1486	0,0677	0,0003	0,0044	98044637
9	0,9245	0,6781	0,7760	0,1512	0,0979	0,0711	0,1313	0,0810	0,0041	0,0504	98118497
10	2,5631	0,4851	0,6634	0,4527	0,4507	0,3296	0,2608	0,1844	0,0086	0,0464	99905603
11	1,9727	0,7320	0,8920	0,2443	0,2081	0,1707	0,2082	0,1573	0,0002	0,0010	99914277
12	0,1455	0,7124	0,8224	0,0229	0,0156	0,0135	0,1313	0,1009	0,0014	0,0140	97136004
13	0,1670	0,6714	0,7982	0,1002	0,0780	0,0656	0,0942	0,0646	0,0040	0,0611	69251298
14	0,5671	0,7841	0,8972	0,0608	0,0431	0,0376	0,1211	0,0934	0,0024	0,0254	91137007
15	0,4271	0,6796	0,7387	0,0831	0,0486	0,0447	0,0717	0,0554	0,0027	0,0481	89347464
16	0,3992	0,7014	0,7869	0,1501	0,0877	0,0782	0,1079	0,0799	0,0007	0,0087	32433702
17	0,8472	0,2752	0,2899	0,5608	0,4780	0,4538	0,0927	0,0368	0,0011	0,0307	59954767
18	0,4702	0,7556	0,8165	0,1466	0,1244	0,1151	0,1126	0,0537	0,0007	0,0131	90080192
19	0,2551	0,6111	0,7713	0,1224	0,0789	0,0626	0,0740	0,0746	-0,0013	-0,0170	50674169
20	1,1436	0,7035	0,8271	0,1950	0,1076	0,0915	0,1519	0,1197	0,0048	0,0004	98222929
21	2,5948	0,1373	0,1608	0,6431	0,6272	0,5355	0,1591	0,0487	0,0007	0,0136	95909835
22	0,0116	0,9203	1,0860	0,0120	0,0120	0,0102	0,1972	0,1355	0,0101	0,0744	89920717
23	0,5439	0,6487	0,7208	0,1626	0,1429	0,1285	0,1101	0,1165	0,0052	0,0692	98084359
24	0,2591	0,6488	0,6891	0,1993	0,1205	0,1135	0,0961	0,0295	-0,0146	-0,4945	118882170
25	1,3199	0,7903	0,9906	0,1157	0,0901	0,0719	0,2340	0,1714	0,0068	0,0396	95460765
26	0,9014	0,7845	0,8796	0,1553	0,1067	0,0951	0,1288	0,0903	0,0042	0,0460	98024142
27	0,7200	0,6471	0,7380	0,2557	0,1672	0,1466	0,1497	0,0935	0,0043	0,0457	97535481
28	0,3782	0,1788	0,1947	0,1601	0,1600	0,1470	0,1183	0,0540	0,0182	0,3368	92682735
29	0,8315	0,2881	0,3681	0,3557	0,3232	0,2530	0,3414	0,1972	0,0069	0,0349	99096932
30	0,7609	0,6481	0,7396	0,1739	0,1037	0,0909	0,1030	0,0865	0,0037	0,0425	96429735
31	1,2015	0,5839	0,6408	0,1605	0,1543	0,1406	0,0693	0,0359	0,0032	0,0877	98184837
32	0,0847	0,7433	0,8389	0,0691	0,0395	0,0350	0,1352	0,1044	0,0016	0,0154	98161952
33	0,3302	0,5322	0,5918	0,3471	0,1430	0,1286	0,1149	0,0840	0,0010	0,0122	21320872
34	0,3084	0,2895	0,3212	0,1115	0,1084	0,0977	0,1214	0,0634	0,0185	0,2918	82268840
35	0,6341	0,5903	0,6683	0,2512	0,1617	0,1428	0,1144	0,0717	0,0013	0,0184	826827473
36	0,3683	0,7824	0,8585	0,1320	0,1185	0,1080	0,0759	0,0600	0,0012	0,0207	67650875
37	2,1299	0,6970	0,8047	0,1103	0,0900	0,0779	0,1028	0,0834	0,0041	0,0485	99404357
38	0,4981	0,5592	0,6942	0,3339	0,1793	0,1445	0,1206	0,0745	0,0025	0,0330	573472000
39	4,2675	0,7209	0,8925	0,2338	0,1668	0,1347	0,2702	0,1806	0,0096	0,0532	99805930
40	0,2036	0,6797	0,7563	0,0610	0,0479	0,0413	0,0989	0,0683	0,0008	0,0123	97225359

2013	Interbank Ratio	Net Loans/Total Assets	Net Loans/Total Deposits and Borrowings	Liquid Assets/ Deposits and Short-Term Funding	Liquid Assets/ Total Deposits and Borrowings	Liquid Assets/Total Assets	Tier 1 Ratio	Equity/Total Assets	ROA	ROE	Total Assets
1	0,5433	0,7255	0,8349	0,1237	0,0836	0,0845	0,1094	0,0957	0,0031	0,0328	49837283
2	0,0428	0,7808	0,9090	0,0288	0,0280	0,0240	0,1646	0,0905	-0,0322	-0,3558	87214869
3	0,2030	0,7532	0,8476	0,0760	0,0575	0,0510	0,0861	0,0763	0,0003	0,0034	38241948
4	0,1951	0,7035	0,7909	0,0509	0,0342	0,0303	0,1363	0,0910	0,0018	0,0199	95760730
5	0,2510	0,7426	0,8303	0,0599	0,0479	0,0428	0,0862	0,0703	0,0005	0,0075	72801297
6	3,2205	0,7129	0,8174	0,2185	0,1732	0,2601	0,1655	0,0961	0,0014	0,0149	86794050
7	8,3187	0,6529	0,7572	0,3353	0,3234	0,3015	0,2260	0,0606	-0,0169	-0,2788	72083253
8	0,5456	0,5843	0,6473	0,2678	0,1626	0,1017	0,1739	0,0745	0,0035	0,0474	97785943
9	1,3398	0,6028	0,6926	0,1632	0,1137	0,0508	0,1436	0,0846	0,0027	0,0321	98258331
10	5,2859	0,4071	0,5050	0,6068	0,5841	0,4708	0,2541	0,1499	0,0027	0,0178	99880900
11	0,9346	0,5600	0,6386	0,1874	0,1706	0,1496	0,1739	0,0990	0,0004	0,0035	99863122
12	0,6269	0,6547	0,7618	0,0589	0,0407	0,0350	0,1482	0,1061	0,0025	0,0233	97210612
13	0,1199	0,6323	0,7641	0,0928	0,0725	0,0600	0,0994	0,0684	0,0037	0,0538	68469207
14	0,6298	0,7503	0,8473	0,0517	0,0373	0,0330	0,1182	0,0883	-0,0005	-0,0060	90729709
15	0,0747	0,5527	0,6061	0,0295	0,0192	0,0175	0,0841	0,0653	0,0157	0,2399	87420179
16	0,2750	0,7117	0,8075	0,1145	0,0687	0,0606	0,1323	0,0009	0,0022	0,0245	24241837
17	0,9499	0,2368	0,2482	0,5329	0,4635	0,4422	0,1010	0,0344	0,0008	0,0242	53792051
18	5,2368	0,7138	0,7755	0,1479	0,1282	0,1180	0,1273	0,0550	0,0020	0,0368	89911755
19	0,1494	0,6043	0,7501	0,0818	0,0553	0,0446	0,0583	0,0390	-0,0422	-1,0812	57843726
20	1,1297	0,6337	0,7295	0,1530	0,0899	0,0780	0,1478	0,1064	0,0042	0,0391	97858482
21	0,3669	0,1844	0,2159	0,0703	0,0685	0,0585	0,1288	0,0487	0,0001	0,0029	95866127
22	0,0155	0,9086	1,0617	0,0154	0,0154	0,0131	0,1987	0,1218	0,0083	0,0683	89444534
23	1,4889	0,6635	0,7359	0,1123	0,0998	0,0009	0,1058	0,0779	0,0060	0,0767	97986060
24	0,2659	0,6590	0,6994	0,1757	0,1148	0,1082	0,1062	0,0310	-0,0072	-0,2335	99105906
25	0,8903	0,7276	0,8984	0,1606	0,1249	0,1011	0,2382	0,1611	-0,0023	-0,0140	95336903
26	0,9239	0,7473	0,8395	0,1501	0,1067	0,0961	0,1374	0,0916	0,0032	0,0349	97995648
27	0,2996	0,6074	0,6926	0,2223	0,1447	0,1269	0,1431	0,0891	0,0030	0,0334	97405004
28	0,1306	0,2271	0,2577	0,0910	0,0910	0,0804	0,1422	0,0711	0,0221	0,3111	93397346
29	1,0164	0,2584	0,3153	0,2521	0,2407	0,1973	0,3247	0,1635	0,0049	0,0300	98864754
30	0,4999	0,6339	0,7198	0,1189	0,0732	0,0644	0,1114	0,0887	0,0029	0,0321	96424184
31	0,9020	0,4285	0,4632	0,1706	0,1658	0,1534	0,0722	0,0326	0,0079	0,2429	97108783
32	0,1574	0,7021	0,7904	0,1237	0,0666	0,0592	0,1507	0,1033	0,0007	0,0068	98159971
33	0,3926	0,4999	0,5652	0,4034	0,1787	0,1581	0,1175	0,0954	-0,0025	-0,0260	27158702
34	0,2009	0,2717	0,2983	0,0799	0,0778	0,0709	0,1436	0,0567	0,0165	0,2911	79154146
35	0,5545	0,5948	0,6639	0,2570	0,1767	0,1583	0,1009	0,0593	-0,0161	-0,2707	745838444
36	0,2392	0,7295	0,8020	0,1541	0,1384	0,1260	0,0789	0,0614	0,0019	0,0302	67230073
37	1,8141	0,6648	0,7565	0,0898	0,0758	0,0666	0,1000	0,0750	0,0018	0,0237	99327792
38	0,5105	0,5493	0,6910	0,3199	0,1806	0,1436	0,1225	0,0719	-0,0073	-0,1011	526238000
39	4,5530	0,5141	0,6122	0,5382	0,4302	0,3612	0,2615	0,1503	0,0037	0,0246	99758404
40	0,1229	0,6776	0,7525	0,0368	0,0290	0,0261	0,1101	0,0601	0,0028	0,0398	97225891

2014	Interbank Ratio	Net Loans/Total Assets	Net Loans/Total Deposits and Borrowings	Liquid Assets/ Deposits and Short-Term Funding	Liquid Assets/ Total Deposits and Borrowings	Liquid Assets/Total Assets	Tier 1 Ratio	Equity/Total Assets	ROA	ROE	Total Assets
1	0,4833	0,714	0,8192	0,1115	0,0787	0,0685	0,112	0,0954	0,0032	0,034	47796490
2	0,1781	0,7741	0,9017	0,0639	0,0623	0,0535	0,1630	0,0934	0,0002	0,0020	87702576
3	0,2638	0,7241	0,8299	0,0757	0,0578	0,0505	0,1129	0,0908	0,0005	0,0054	39347080
4	0,1660	0,6737	0,7577	0,0453	0,0312	0,0277	0,1472	0,0908	0,0032	0,0351	95604809
5	0,1735	0,6596	0,7339	0,0536	0,0422	0,0379	0,1097	0,0703	-0,0112	-0,1592	71186444
6	4,2547	0,6530	0,7550	0,2862	0,2311	0,1999	0,1993	0,1016	0,0030	0,0290	87583822
7	8,8137	0,6369	0,7472	0,3602	0,3459	0,3071	0,1747	0,0629	0,0037	0,0588	73078410
8	0,3117	0,5758	0,6450	0,1089	0,0692	0,0618	0,1398	0,0765	0,0002	0,0029	98114963
9	0,5722	0,6118	0,7025	0,0806	0,0596	0,0519	0,1615	0,0893	0,0021	0,0239	98266726
10	4,1154	0,5969	0,6481	0,4570	0,4537	0,3548	0,2803	0,1654	0,0053	0,0318	99888860
11	0,8423	0,5132	0,5816	0,2220	0,2259	0,1984	0,1959	0,0949	0,0035	0,0364	99810925
12	0,2742	0,5996	0,6992	0,0455	0,0343	0,0294	0,1834	0,1053	0,0036	0,0339	97147095
13	0,1040	0,6235	0,7665	0,0985	0,0758	0,0616	0,1112	0,0683	0,0044	0,0639	65205642
14	0,2833	0,7694	0,8559	0,0425	0,0319	0,0287	0,1046	0,0716	0,0031	0,0438	87436324
15	0,1103	0,5790	0,6331	0,0272	0,0177	0,0162	0,1070	0,0626	0,0053	0,0842	87679511
16	0,2513	0,7032	0,7921	0,0760	0,0456	0,0405	0,1233	0,0851	-0,0058	-0,0679	21786704
17	0,7376	0,2219	0,2324	0,5181	0,4568	0,4361	0,1139	0,0343	0,0011	0,0311	50377590
18	0,4702	0,6588	0,7179	0,2022	0,1789	0,1642	0,1081	0,0584	0,0061	0,1041	89433241
19	0,4021	0,6182	0,8216	0,0568	0,0378	0,0285	0,0870	0,0474	-0,0143	-0,3009	61690421
20	1,4378	0,5769	0,6603	0,2317	0,1486	0,1298	0,1363	0,1012	0,0039	0,0383	97393044
21	4,4682	0,2290	0,2690	0,0659	0,0645	0,0559	0,1169	0,0530	0,0010	0,0181	95985508
22	0,0605	0,8829	0,9971	0,0589	0,0589	0,0521	0,1093	0,0973	0,0096	0,0982	87969436
23	1,3989	0,6294	0,7004	0,1087	0,0982	0,0883	0,1340	0,0726	0,0066	0,0908	97685683
24	0,2793	0,6652	0,7110	0,1581	0,1103	0,1032	0,0845	0,0322	-0,0300	-0,9328	79917528
25	0,2116	0,6944	0,8568	0,0904	0,0723	0,0587	0,2256	0,1611	0,0018	0,0112	95360801
26	0,7596	0,6976	0,7776	0,1555	0,1141	0,1024	0,1464	0,0850	-0,0024	-0,0281	97921478
27	1,1972	0,6490	0,7515	0,2075	0,1307	0,1128	0,1290	0,0980	0,0033	0,0338	97633668
28	0,2749	0,2923	0,3370	0,0742	0,0742	0,0643	0,1218	0,0873	0,0262	0,3000	93859760
29	0,7821	0,2218	0,2671	0,1760	0,1680	0,1395	0,2950	0,1490	0,0038	0,0256	98694864
30	1,1045	0,6662	0,7735	0,1167	0,0714	0,0615	0,0000	0,1015	0,0031	0,0306	96607140
31	0,6571	0,3466	0,3664	0,1306	0,1276	0,1207	0,0845	0,0296	0,0108	0,3653	95332298
32	0,1930	0,6868	0,7768	0,1553	0,0956	0,0845	0,1624	0,1086	0,0008	0,0073	98249022
33	0,4614	0,5197	0,6014	0,4219	0,1936	0,1673	0,1108	0,2169	0,0066	0,0581	29536012
34	0,1065	0,1593	0,2795	0,7361	0,6629	0,3780	0,1843	0,0426	0,0075	0,1768	57452124
35	0,6482	0,5574	0,6195	0,2817	0,1915	0,1723	0,1112	0,0626	0,0028	0,0452	744217390
36	0,4703	0,6741	0,7473	0,1298	0,1157	0,1043	0,0976	0,0699	0,0035	0,0503	64381135
37	1,7998	0,5948	0,6585	0,0745	0,0643	0,0581	0,1059	0,0656	0,0019	0,0294	99217563
38	0,6092	0,5246	0,6758	0,3503	0,1971	0,1529	0,1420	0,0697	0,0020	0,0291	546427000
39	4,5530	0,4723	0,5653	0,5750	0,4601	0,3844	0,1985	0,1486	0,0023	0,0152	99738799
40	0,0452	0,5922	0,6523	0,0175	0,0148	0,0134	0,1189	0,0669	0,0028	0,0398	96997227

2015	Interbank Ratio	Net Loans/Total Assets	Net Loans/Total Deposits and Borrowings	Liquid Assets/ Deposits and Short-Term Funding	Liquid Assets/ Total Deposits and Borrowings	Liquid Assets/Total Assets	Tier 1 Ratio	Equity/Total Assets	ROA	ROE	Total Assets
1	0,6688	0,7098	0,8173	0,1303	0,0955	0,0726	0,1138	0,1	0,0045	0,0449	48626823
2	0,1433	0,8372	0,9361	0,0453	0,0444	0,0397	0,1051	0,0569	0,0022	0,0393	88418785
3	0,1969	0,7134	0,8239	0,0522	0,0407	0,0353	0,1134	0,0923	0,0036	0,0388	38738769
4	0,2174	0,6591	0,7422	0,0534	0,0397	0,0352	0,1494	0,0930	0,0019	0,0206	95781621
5	0,3495	0,7081	0,7935	0,0478	0,0391	0,0349	0,1324	0,0813	0,0045	0,0559	73098319
6	4,2547	0,6017	0,6907	0,3524	0,2986	0,2601	0,2142	0,0953	0,0001	-0,0007	87123534
7	8,3187	0,6449	0,7327	0,3525	0,3425	0,2891	0,1689	0,0604	0,0052	0,0866	73408260
8	0,3428	0,5183	0,5668	0,1560	0,1112	0,1468	0,1381	0,0608	-0,0020	-0,0322	98047456
9	0,4576	0,5975	0,6916	0,0720	0,0588	0,0990	0,1621	0,0893	0,0043	0,0486	98224806
10	6,7990	0,5297	0,6712	0,4719	0,4698	0,3707	0,2233	0,1462	0,0087	0,0595	99866342
11	0,2724	0,4686	0,5141	0,0943	0,0871	0,0793	0,1782	0,0735	0,0009	0,0123	99773683
12	0,0851	0,5911	0,6842	0,0218	0,0185	0,0159	0,1834	0,1046	0,0042	0,0405	97075944
13	0,0868	0,6165	0,7568	0,1185	0,0917	0,0747	0,1352	0,0662	0,0044	0,0670	62544701
14	0,3890	0,7663	0,8558	0,0399	0,0327	0,0293	0,1098	0,0753	0,0031	0,0408	87751871
15	0,1828	0,5535	0,6214	0,0253	0,0169	0,0151	0,1281	0,0820	0,0028	0,0339	87723128
16	0,3281	0,7217	0,8193	0,0704	0,0448	0,0395	0,1208	0,0897	0,0012	0,0137	17200765
17	1,5118	0,2728	0,2862	0,4978	0,4398	0,4191	0,1236	0,0353	0,0009	0,0264	51295633
18	4,7259	0,6255	0,6868	0,1955	0,1793	0,1630	0,1467	0,0716	0,0006	0,0078	89234147
19	0,4320	0,7087	0,8111	0,0844	0,0586	0,0512	0,1276	0,0822	-0,0034	-0,0419	69701146
20	0,7788	0,5492	0,6239	0,1261	0,0845	0,0744	0,1432	0,0981	0,0029	0,0298	97444776
21	2,5948	0,2350	0,2760	0,0443	0,0431	0,0367	0,1328	0,0618	0,0050	0,0802	95942761
22	0,0315	0,8923	0,9991	0,0521	0,0521	0,0466	0,1051	0,0895	0,0127	0,1417	86874137
23	0,1269	0,6245	0,6909	0,1240	0,1124	0,1016	0,1335	0,0721	0,0060	0,0835	97587781
24	0,4712	0,6589	0,7237	0,2092	0,1431	0,1303	0,1285	0,0569	0,0023	0,0405	69011977
25	0,2116	0,6647	0,8156	0,1213	0,1061	0,0865	0,2430	0,1593	0,0024	0,0147	95358507
26	0,8495	0,7040	0,7932	0,1235	0,0960	0,0852	0,1500	0,0899	0,0023	0,0259	98009911
27	2,2917	0,6583	0,7717	0,1710	0,1107	0,0944	0,1283	0,1000	0,0041	0,0405	97707486
28	1,2562	0,3143	0,3715	0,0891	0,0891	0,0753	0,1429	0,1041	0,0333	0,3197	93883983
29	8,5583	0,2121	0,2677	0,1377	0,1332	0,1055	0,3137	0,1867	0,0099	0,0529	98620376
30	0,9107	0,6555	0,7565	0,0985	0,0723	0,0626	0,1404	0,0978	0,0024	0,0246	96252567
31	0,3380	0,3934	0,4220	0,0789	0,0773	0,0721	0,1023	0,0427	0,0100	0,2349	94837871
32	0,1567	0,8647	1,0108	0,1120	0,0535	0,0458	0,1784	0,1349	-0,0051	-0,0375	98656118
33	0,4249	0,5250	0,6164	0,3942	0,2041	0,1738	0,1198	0,2389	0,0084	0,0669	29289382
34	0,8774	0,1673	0,2762	0,7754	0,6596	0,3995	0,1966	0,0463	0,0098	0,2119	55289832
35	0,7190	0,5509	0,6106	0,2973	0,2150	0,1939	0,1150	0,0622	0,0024	0,0383	760433375
36	0,4248	0,6752	0,7515	0,1269	0,1139	0,1023	0,1050	0,0746	0,0039	0,0519	64462354
37	1,6394	0,5849	0,6536	0,0713	0,0610	0,0545	0,1321	0,0767	0,0013	0,0174	99213920
38	0,5806	0,5134	0,6622	0,3756	0,2253	0,1746	0,1379	0,0718	0,0040	0,0563	576568000
39	5,4146	0,4697	0,5471	0,4309	0,3571	0,3066	0,2178	0,1268	0,0063	0,0494	99689437
40	0,6891	0,6338	0,6996	0,0731	0,0631	0,0571	0,1180	0,0690	0,0011	0,0246	97138822

2016	Interbank Ratio	Net Loans/Total Assets	Net Loans/Total Deposits and Borrowings	Liquid Assets/ Deposits and Short-Term Funding	Liquid Assets/ Total Deposits and Borrowings	Liquid Assets/Total Assets	Tier 1 Ratio	Equity/Total Assets	ROA	ROE	Total Assets
1	0,8881	0,721	0,8265	0,1277	0,0997	0,087	0,1183	0,0998	0,0041	0,0414	47007996
2	0,8729	0,7951	0,8715	0,1095	0,1076	0,0981	0,1129	0,0556	0,0008	0,0141	88039397
3	0,1407	0,7003	0,7915	0,0469	0,0395	0,0349	0,1389	0,0855	0,0002	0,0029	35039976
4	0,2665	0,6271	0,6994	0,0733	0,0594	0,0533	0,1511	0,0883	0,0009	0,0107	95594565
5	0,4945	0,6843	0,7556	0,0513	0,0438	0,0397	0,1178	0,0690	-0,0129	-0,1871	74530541
6	6,8276	0,6049	0,6925	0,3080	0,2775	0,2424	0,2965	0,1002	0,0049	0,0487	87430776
7	8,3187	0,6376	0,7197	0,3602	0,3452	0,2037	0,1750	0,0566	0,0030	0,0536	72890779
8	0,5691	0,5429	0,5970	0,1841	0,1349	0,0891	0,1462	0,0696	0,0002	0,0030	97961336
9	0,7822	0,5658	0,6472	0,0900	0,0813	0,0855	0,1551	0,0828	0,0029	0,0356	98215330
10	4,1154	0,5813	0,7596	0,2778	0,2763	0,2114	0,2407	0,1540	0,0030	0,0198	99875727
11	0,1995	0,5527	0,6029	0,0584	0,0558	0,0511	0,1547	0,0698	0,0002	0,0027	99773380
12	0,0776	0,5981	0,6834	0,0202	0,0185	0,0162	0,1835	0,1027	0,0044	0,0427	96993839
13	0,1726	0,5986	0,7430	0,1443	0,1122	0,0904	0,1315	0,0625	0,0033	0,0533	60430984
14	0,1173	0,7860	0,8745	0,0176	0,0154	0,0138	0,1104	0,0743	0,0021	0,0278	87634102
15	0,4282	0,5372	0,5972	0,0588	0,0421	0,0379	0,1294	0,0747	0,0019	0,0253	87154748
16	0,2632	0,7286	0,8158	0,0645	0,0453	0,0404	0,1148	0,0806	-0,0075	-0,0933	12383917
17	1,6626	0,2918	0,3072	0,5402	0,0048	0,4560	0,1208	0,0353	-0,0005	-0,0131	53145221
18	5,0733	0,6204	0,6818	0,2293	0,2162	0,1967	0,1541	0,0701	0,0052	0,0741	88740807
19	0,5648	0,6988	0,7817	0,1314	0,0967	0,0865	0,1198	0,0819	-0,0113	-0,1385	73889007
20	0,8166	0,5637	0,6403	0,1398	0,0995	0,0552	0,1429	0,0993	-0,0058	-0,0588	97709520
21	2,5948	0,2053	0,2351	0,2510	0,2438	0,2129	0,1360	0,0523	0,0017	0,0318	95348705
22	0,0282	0,9084	1,0168	0,0462	0,0462	0,0413	0,1059	0,0877	0,0155	0,1766	84918962
23	0,1269	0,6066	0,6644	0,0905	0,0843	0,0769	0,1351	0,0682	0,0057	0,0829	97318581
24	0,2840	0,6965	0,7512	0,1349	0,1056	0,0988	0,0817	0,0422	-0,0211	-0,5002	53178466
25	0,2116	0,6625	0,8091	0,1138	0,1025	0,0839	0,2485	0,1575	0,0000	-0,0002	95419169
26	0,6104	0,6888	0,7683	0,0956	0,0820	0,0735	0,1560	0,0922	0,0040	0,0431	97988343
27	1,2672	0,6257	0,7273	0,2155	0,1466	0,1261	0,1278	0,0915	0,0002	0,0016	97557452
28	0,4070	0,2252	0,2525	0,1272	0,1272	0,1134	0,1668	0,0774	0,0187	0,2411	91643268
29	2,7030	0,1853	0,2192	0,1340	0,1309	0,1107	0,2967	0,1427	0,0055	0,0385	98188418
30	0,4750	0,5971	0,6885	0,0779	0,0650	0,0563	0,1430	0,0945	0,0024	0,0257	96097584
31	0,2450	0,4166	0,4466	0,0741	0,0725	0,0777	0,1086	0,0436	0,0110	0,2514	94441492
32	0,1148	0,7996	0,9230	0,0927	0,0615	0,0533	0,1764	0,1245	0,0002	0,0012	98545362
33	0,4511	0,5426	0,6377	0,3290	0,1667	0,1419	0,1208	0,2355	0,0087	0,0681	30181395
34	1,5602	0,2055	0,3608	0,9777	0,7753	0,4416	0,2001	0,0512	0,0094	0,1830	58028658
35	0,7192	0,5173	0,5931	0,2849	0,2108	0,1834	0,0904	0,0502	-0,0132	-0,2623	759532774
36	0,7134	0,6805	0,7545	0,1204	0,1084	0,0977	0,1112	0,0718	0,0027	0,0374	62803691
37	0,4025	0,5449	0,5964	0,1070	0,0981	0,0896	0,1168	0,0656	0,0011	0,0173	99072343
38	0,7316	0,5030	0,6386	0,3816	0,2436	0,1918	0,1390	0,0680	0,0044	0,0649	625100000
39	4,5530	0,3975	0,4560	0,4300	0,3655	0,3185	0,2100	0,1193	0,0038	0,0314	99658803
40	0,4641	0,6356	0,6988	0,0391	0,0350	0,0318	0,1241	0,0687	0,0006	0,0088	97146311

2017	Interbank Ratio	Net Loans/Total Assets	Net Loans/Total Deposits and Borrowings	Liquid Assets/ Deposits and Short-Term Funding	Liquid Assets/ Total Deposits and Borrowings	Liquid Assets/Total Assets	Tier 1 Ratio	Equity/Total Assets	ROA	ROE	Total Assets
1	1,0253	0,6633	0,7578	0,1937	0,158	0,1383	0,128	0,0955	0,0105	0,1101	33287435
2	0,7614	0,8014	0,8837	0,1112	0,1100	0,0997	0,1110	0,0594	0,0039	0,0650	87379910
3	0,2320	0,6702	0,7539	0,0728	0,0639	0,0567	0,1397	0,0801	0,0025	0,0309	28661193
4	0,1882	0,7069	0,0079	0,0469	0,0402	0,0359	0,1717	0,0888	-0,0014	-0,0152	99845477
5	0,6469	0,6684	0,7280	0,1127	0,0983	0,0902	0,1062	0,0580	-0,0132	-0,2267	75043176
6	4,2547	0,6098	0,6923	0,3352	0,3117	0,2747	0,3282	0,0965	0,0001	0,0005	86531918
7	8,6684	0,6542	0,7172	0,3392	0,3329	0,2133	0,1606	0,0577	0,0050	0,0869	73156626
8	0,7458	0,5597	0,6083	0,2073	0,1660	0,0828	0,1422	0,0693	0,0003	0,0038	98397012
9	0,6382	0,5536	0,6295	0,1114	0,1035	0,0948	0,0857	0,1606	0,0036	0,0418	98222525
10	4,1154	0,5995	0,7842	0,1970	0,1963	0,1501	0,2229	0,1504	-0,0068	-0,0453	99880240
11	0,3638	0,7250	0,7986	0,0784	0,0719	0,0653	0,1207	0,0712	0,0013	0,0188	96626899
12	0,0720	0,5634	0,6363	0,0872	0,0837	0,0741	0,1720	0,0945	0,0034	0,0357	96717381
13	0,2792	0,5945	0,7309	0,1706	0,1375	0,1118	0,1376	0,0638	0,0045	0,0704	58415419
14	0,7140	0,7046	0,7766	0,1173	0,1014	0,0920	0,1165	0,0700	0,0032	0,0459	86004183
15	0,1631	0,6187	0,6973	0,1625	0,1176	0,1034	0,1219	0,0863	0,0028	0,0328	88396332
16	0,4683	0,7249	0,8264	0,1085	0,0827	0,0726	0,1156	0,0785	0,0056	0,0717	27376141
17	0,9293	0,3897	0,4196	0,6148	0,5088	0,4725	0,1216	0,0440	0,0009	0,0212	61872528
18	3,7730	0,5959	0,6588	0,2902	0,2761	0,2497	0,1510	0,0678	0,0012	0,0177	88246326
19	0,6302	0,6322	0,7246	0,1871	0,1487	0,1297	0,1242	0,0910	-0,0158	-0,1734	75080305
20	0,2966	0,5541	0,6213	0,0780	0,0919	0,0552	0,1329	0,0878	-0,0131	-0,1490	97710520
21	2,5948	0,2220	0,2658	0,4548	0,4409	0,3683	0,1335	0,0538	0,0010	0,0178	95433351
22	0,0197	0,9327	1,0370	0,0276	0,0276	0,0248	0,0958	0,0820	0,0150	0,1831	82940270
23	1,6433	0,5939	0,6491	0,2598	0,2512	0,2298	0,1338	0,0671	0,0058	0,0857	97148134
24	0,4727	0,6213	0,6969	0,1982	0,1557	0,1397	0,1478	0,0817	-0,0252	-0,3357	39154192
25	4,1383	0,6675	0,8151	0,1288	0,1197	0,0981	0,2470	0,1590	0,0026	0,0162	95515348
26	0,3676	0,6598	0,7246	0,0608	0,0558	0,0508	0,1436	0,0769	0,0041	0,0536	97403133
27	0,8185	0,6370	0,7244	0,1380	0,0988	0,0869	0,1256	0,0857	-0,0119	-0,1392	97663997
28	0,4913	0,2191	0,0025	0,1203	0,1203	0,1054	0,1854	0,0819	0,0227	0,2773	91008992
29	2,7030	0,2046	0,2439	0,0897	0,0884	0,0741	0,3264	0,1459	0,0222	0,1521	98189474
30	0,2214	0,5591	0,6331	0,2295	0,2007	0,1773	0,1603	0,0895	0,0025	0,0277	95904797
31	0,2825	0,6160	0,6915	0,0778	0,0760	0,0677	0,1240	0,0750	0,0143	0,1909	95792809
32	0,1423	0,7360	0,8449	0,1192	0,0932	0,0812	0,1850	0,1206	0,0021	0,0172	98469199
33	0,6273	0,5503	0,6523	0,4197	0,2335	0,1970	0,1331	0,2371	0,0105	0,0808	29554436
34	3,1379	0,1969	0,3445	1,0455	0,7980	0,4562	0,2191	0,0511	0,0088	0,1720	56733230
35	0,5760	0,5351	0,5969	0,3369	0,2632	0,2360	0,1536	0,0720	0,0069	0,0961	736789724
36	0,3095	0,6188	0,6797	0,0998	0,0922	0,0839	0,1163	0,0665	0,0040	0,0596	58375361
37	0,3678	0,6147	0,6828	0,0855	0,0813	0,0732	0,1293	0,0755	0,0032	0,0418	99160126
38	0,7247	0,5155	0,6467	0,4058	0,2705	0,2156	0,1515	0,0710	0,0092	0,1299	696861000
39	4,5530	0,3755	0,4302	0,4313	0,3727	0,3253	0,2050	0,1178	0,0040	0,0341	99635649
40	0,1246	0,6874	0,7621	0,0284	0,0265	0,0239	0,1352	0,0744	0,0034	0,0461	97242013