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THE RELATIONSHIP BETWEEN LIQUIDITY RISK MATURITY MISMATCH, BUSINESS MODELS AND RISK COMMITTEE

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TABLE OF CONTENTS

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"*There is nothing else I want to do in life right now but give myself the best chance I can to be able to chase my dreams*" (Victoria Azarenka)

1. THEORETICAL FRAMEWORK AND RESEARCH SETTING

In this study, we analyze banking liquidity risk through a stock-based indicator, i.e. the loan-to-deposit ratio (LTD), which may include additional relevant information for the EU banking sector. We created an index of maturity mismatch, using the existing lending and deposit gathering relationship during a specific time period, starting from 2011 to 2017. Loans-to-deposits maturity mismatch (LTD_m) is a better indicator whenever we try to get information on liquidity management, based on matching of both inflow and outflow.

The last financial crisis in 2008 underlined the importance of bank regulation and business models, but also demonstrated how important liquidity management is for the overall stability of the banking system. In this field of study, while some scholars provide observations on liquidity creation (Berger and Bouwman, 2009; 2013; Brunnermeier et al., 2012) before and during the crisis, others are focused on profitability performance of different bank business models (Roegngpitya et al., 2014). This study lies between the two. Indeed, it analyzes banking liquidity risk by using a new proxy, which is applied to different bank business models. As a consequence, whether differences in bank business models affect liquidity risk still remains an unanswered question.

This thesis aims to give an answer to this question, and to fill the LTD_m gap by empirically analyzing the main drivers of the LTD_m ratio across 4844 EU banks. Instead of using static balance street ratios which do not account for bank capacity to access funding sources, we believe that measuring flows over time, is the best way to capture changes. Therefore, as a proxy of LTD_m, we divide the short term loans (i.e. three-months) by the long term deposits (i.e. between three and twelve months); whereas, the analysis of chapter 4 employs a maturity mismatch indicator based on long-term funding over demand deposits.

Our contributions are built on the results of several studies which analyze both the causes of banking liquidity risk, and the performance of business models. Most of these studies have yet to consider maturity mismatch in measuring risk, and do not include it in different banking activities.

1.1 Structure of the thesis

In order to conduct the study on the relationship between liquidity risk maturity mismatch and bank business models in the European context, we identified different aspect of influence on the three main business activities, i.e commercial, investment and saving banks in the EU banking system.

As first step, we focused on the key role in lending played by the banks in the economic system. Indeed, we firstly checked out how the different types of loans granted showed in each bank

balance sheet. Through the balance sheet data, we were able to classify both loans and deposits with respect to the time dimension and the type. The classification was made on the interbank loans and customer loans. Time period started from three-months to 5 years loans.

Secondly, we studied the impact of the main drivers of liquidity risk, such as capital and size on my maturity mismatch indicator (LTD_m), with the aim of corroborate previous findings and to fill the gap between business models and liquidity risk. Finally, the study also focused on the impact of the risk committee presence on loans to deposit ratio, identifiying a threshold for the number of risk committee members.

Formally the thesis is composed by four chapters.

The first one is the present introduction in which we gave a general overview of the dissertation explaining the aim of the research, the context in which is conducted and the contributions. Secondly, we set the theoretical framework of the entire dissertation, by providing a detailed analysis of the literature related to "liquidity risk, bank business models" and "corporate governance in banks". Publications issued in accordance with the first two keywords have been investigated by using a co-citation network analysis i.e. Web of Science and then the trends in terms of related literature are presented in the Tables of chapter two.

In the second chapter, we analyzed the drivers of liquidity risk and the impact of different business models. The paper examines the bank liquidity risk while using a maturity mismatch indicator of loans and deposits (LTD_m) during a specific period. It has been investigated how characteristics of a bank, such as size, capital, and business model, are related to liquidity risk, while using a sample of European banks in the period after the financial crisis, from 2011 to 2017.

The third chapter presents an analysis of the relationship between corporate governance characteristics and liquidity risk, especially the presence of risk committee. The paper investigates the impact of risk committee on liquidity risk, focusing on a certain threshold of board members of risk in order to establish if risk committee size has an impact on LTD_m.

1.2 Theoretical Framework

Banking is carried out by companies which operate in order to build a reliable network of relations. Since relationships are built on trust, customer confidence underpins the banking system. In fact, the ties which bind customer and financial institution hold strong as long as commitments are honoured. Whenever there is a breach in trust, repercussions also spread across to other banks. Therefore, it is undesirable for any bank's competitors to be in adverse conditions. In the economic and financial field, the nature of risk refers to the possibility that the outcome of a particular transaction, measured ex post, diverges from the one expected ex ante. For this very reason, the

concept behind risk is connected to the notion of uncertainty; more specifically, an economic agent takes a risk when financial activity is carried out under uncertain circumstances (i.e. the impossibility of forecasting the future).

Banks as well as companies, have an interest in pursuing and obtaining income results. In order to achieve business goals, a bank must accept what is called "financial imbalance", without which such results could not be accomplished. The only case in which an institution cannot report a lack of balance, occurs when assets and liabilities are synchronized, (i.e. when economic results are equal to zero) which cannot be considered for the previous reasons.

Liquidity risk in particular refers to a bank's inability to overcome an unforeseen period of stress caused by an unexpected withdrawal of funds. In fact, the fulfillment of borrower's monetary obligations does not necessarily occurs at the same time as those established. If liquidity risk occurs and it is not predicted in the banking system, the stability of financial institutions can be influenced to the point of triggering a crisis. Indeed, the 2008 financial crisis was the result of mismanagement of liquidity by the banking system, which underestimated this risk. Moreover, stress scenarios jeopardize business continuity and degenerate into a bank insolvency.

One of the characteristics of liquidity risk is *multidimensionality*. This requirement allows banking supervision to identify risk based on causes which create it. Risk can be classified as Market Liquidity Risk, Funding Liquidity Risk and Operational Risk. The first example stems from adverse trends in financial markets; the second is created by the difficulty in maintaining or increasing banking sources of deposits; the third arises from *"inappropriate or failed internal processes, individuals and systems or from outside occurrences"* [1] (BCBS 2011). This latest risk does not consider the reputational risk, rather the legal one.

Banks are naturally exposed to liquidity risk due to the maturity transformation phenomenon, which helps tackle incompatibility between both surplus and deficit units. Proper risk management plays a fundamental role in maintaining stability of both banks and the entire market considering that the financial imbalance of one institution can have systemic consequences on others.

Difficulty in overcoming mismatch situations between maturities can be attributed to different causes, and this generates subcategories of risk. Corporate Liquidity Risk refers to internal or market factors, while systemic events trigger Systemic Liquidity Risk.

Bank risk management should aim at achieving complementary, not mutually excluded goals, through which an ideal a "balance" may be achieved so as to:

- Perform in liquidity conditions, given by the ratio between deposits and loans to reach financial balance;

[1] Basel Committee on Banking Supervision. 2011. Principles for the Sound Management of Operational Risk. Basel: Bank for International Settlements.

- Maintain solvency in order to achieve asset balance, and meet financial commitments in both short and medium term;
- Attain adequate income for economic balance: banking financial performance must be positive to allow return on capital and strengthen activity through self-financing.

There must be an existing trade-off between liquidity and profitability goals. In fact, in order to get maximum liquidity, a bank should not use customer deposits, but if it does not, it would operate at a loss by only paying interest expenses without gaining interest income on capital. On the other hand, to achieve maximum profitability, a bank should use all available funds, to obtain the highest possible remuneration, but will risk strong impact on liquid assets.

Two of the primary functions in banking activity involve the implementation of money and credit. The former consists in holding liabilities on demand (i.e. deposit accounts), created by collecting money and issuing liabilities; the latter, in the transfer of resources within the economic system from units in financial surplus to those in financial deficit. Via the credit function, a bank can fulfil maturity transformation and risk transfer activities, so as to maintain a balance between the dynamics of assets and liabilities, along with the management of related risks. Through liquidity management, a bank's managers are able to outline the boundaries and the operating criteria for the components of assets, liabilities and off-balance sheet items, both in the medium and short term. The management of long-term components has to define the tolerable degree of maturity transformation, and it has to control the commercial policies responsible for liquidity absorption. Moreover, bank fund-raising and both qualitative and quantitative asset policies should be laid down. Finally, the degree of risk-appetite and liquidity risk control mechanisms must be set.

In a prudential perspective, since long-term forecasting is becoming difficult, it is in the bank's interest to reduce the period of analysis. Unlike problems connected to short-term liquidity risk, which arise from the need to fix revenue and expenditure in an economical and timely manner, structural liquidity risk issues can be traced to "*the convenience and opportunity to modify the qualitative- quantitative asset, liabilities and off-balance sheet composition*" [2], acting on the dynamics of future financial flows (Ruozi and Ferrari, 2013).

Liquidity risk can be addressed in normal operations (i.e. going concern liquidity risk) or in stress situations (i.e. contingency liquidity risk), both of which are related to individual or systemic factors. In the former case, risk involves situations in which a bank is able to counteract its own liquidity through deposit-taking. During an ordinary operating scenario, liquidity management simulates the evolution of monetary revenues and expenditures, through hypotheses on the evolution of banking size. In the latter case, contingency liquidity risk is dealt within stress

[2] Ruozi, R., Ferrari, P. 2013. Liquidity risk management in banks: economic and regulatory issues. In Liquidity Risk Management in Banks (pp. 1-54). Springer, Berlin, Heidelberg.

conditions i.e. financial distress, therefore extraordinary measures must be taken; ex ante must be established via a contingency funding plan which rates all possible liquidity tension classifications, identifies the contingency measures and the backup liquidity estimates useful to the bank in order to be able to compensate the liquidity shortage.

There have yet to be strong unanimously approved methodologies made to measure and manage funding liquidity risk, so the matter is tackled differently across countries. The most common models used to measure liquidity risk are the following:

- Stock-based models
- Cash flow based models
- Hybrid type models

The Stock-based approach allows for the measurement of the volume of financial assets that can be quickly liquidated in order to face a possible liquidity crisis. Such an approach creates a simple indicator on the basis of the degree of asset liquidity, built on balance-sheet proxies. Assets are thus classified according to how easily they can be converted into cash or less; while liabilities are either volatile or stable. The Stock approach relies on the CASH CAPITAL POSITION (CPP), which expresses the difference between easily convertible assets and volatile liabilities (Scannella, 2016). When the ratio is high, it implies banking ability to endure liquidity tensions.

The Cash-flow model is based on dynamic analysis, by assessing liquidity on the basis of financial flows generated by management during a specific period. This approach examines the adequate existing relationship of future input and output cash flows expected from banks. The division of different future cash flows, along the maturity ladder (made up of various time frames), is necessary to verify whether a correlation between monetary inflows and outflows exists. For each time period, two liquidity gaps are computed: LGAP, which looks at periodic liquidity, computed as the difference between expected incoming cash flows, and outflows; and CLGAP, or cumulative periodic liquidity, which sums liquidity gap of the corresponding period to those reported in the previous period. If the obtained net flow is positive, the existing provision will increase in additional financial asset; otherwise, there will be a need for resources in order to deal with management needs, since the bank is going to face a severe liquidity risk.

The Hybrid model is an accurate type of cash flow approach, useful for fair cash flow distribution. The bank adjusts securities, by possibly selling or using them as a guarantee in order to gain funding and therefore liquid assets for the earliest maturity. Hybrid models owe their name to the integration of the previous two categories; indeed they sum future cash flows and those that could be obtained by using collateral or the stock of easily convertible assets.

As liquidity risk is considered intrinsic to the banking business, and depends on the internal organization of each bank, it is said to originate from various internal or external components to the bank itself, as well as systemic nature drivers. The financial crisis began during a propitious moment in the US economy characterized by low interest rates and high levels of liquidity; in this favourable perspective of financial growth, American families were particularly willing to risk, borrowing beyond their ability to repay, due to their trust in banks. As a consequence subprime mortgages developed and grew, just as the degree of insolvency in the real estate sector did, which generated asymmetric information. Due to low information quality, along with inadequate risk measurements, banks have never been able to assess the counterparty risk of both investors and savers. Moreover, banks are considered to be fragile due to the mechanism of maturity transformation in which short maturities (i.e. demand deposits) are transformed into longer maturities (long-term loans) in order to create liquidity and promote the efficient allocation of resources for the entire economic system; therefore banks face a continuous trade-off between holding lower yield levels of liquid assets, and implementing them in illiquid high yield assets. The problem arises when liquidity risk spreads across other institutions, thereby becoming systemic.

Generally, the Central Bank has the ability to provide the liquidity required for the financial system thanks to its open market operations; as it holds the monopoly of the monetary base, it can provide liquidity whenever it deems appropriate, in order to meet the demand balance.

Since the financial effects of systemic risk are difficult to predict and because it is widely believed that liquidity is one of the most important components for bank survival, the purpose of this study is to analyze the determinants of liquidity risk to prevent further crises. In order to do this, it has been tested if and how certain factors affect the level of liquidity that a bank normally holds. Some studies have attempted to incorporate macroeconomic variables (i.e. GDP, unemployment rate, inflation) as possible causes of changes in liquidity. The results have shown that the significant factors are microeconomic (i.e. total assets, number of loans, deposits and non-performing loans). However, the literature is not homogeneous on the microeconomic indicators. These ambiguities and contradictions present in the literature are reason for further study, in order to fill the existing gaps.

Structural liquidity shortage in the banking system is an important issue, which has been studied in depth by the Basel Committee and analyzed in the research field.

The Basel Committee on Banking Supervision defines *funding liquidity* as the ability that banks must have to meet their liabilities. The IMF on liquidity refers to "*the institutions' ability to agree on payments in sufficient time*" (IMF 2008)[3].

[3] International Monetary Fund. 2008. Global Financial Stability Report, April. Monetary and Capital Markets Department.

The misapplication of the basic principles of measuring liquidity risk by the banking system alarmed the Basel Committee, which published "*Principles for Sound liquidity risk management and supervision"*[4] in 2008. This document contains a detailed guide on both risk management and funding risk. Subsequently, the regulatory framework was strengthened with the addition of two indicators for minimum liquidity requirements. Banks are facing the necessity to deal with stress scenarios with greater resilience-using stable sources of funding (i.e. high quality liquid assets).

Stress scenario refers to those cases in which both idiosyncratic and market shock occur, e.g. a significant proportion of retail deposit withdrawals (bank-run). Additional grounds for disturbance in the banking scene can also be identified in the losses of short-term funding, in liquidity outflows due to the downside of the rating, as well as in greater volatility and market risk.

The Basel III documentation was published following the principles of transparency outlined in jurisdictional regulations, ensuring clarity both inside and outside of each EU member country. In addition, the provisions of Regulation (EU) 575/2013 (CRR)[5] establish quarterly reports for the NSFR and monthly for the LCR (Article 415 CRR).

LCR came into force 1st January 2015, with a minimum requirement of 60%, intended to increase annually by 10% until it reaches 100%.

$$LCR = \frac{STOCK\ OF\ HQLA}{TOTAL\ NET\ CASH\ OUTFLOW\ OVER\ THE\ NEXT\ 30\ CALENDAR\ DAYS} \geq 100\%$$

In the formula above, the numerator indicates the stock of *"unencumbered"* liquid assets (i.e. the liquidity reserve) which must allow the bank to survive until the 30th day in the observed period; while the denominator quantifies the total net cash outflows over 30 days. High quality liquidity assets (HQLA), are what the committee considers to be "*easily liquidated and converted into cash"*, and lose little or no value during periods of stress. Moreover, an HQLA must have a low default risk as well as a low volatility and correlation to risky assets such as bank bonds. HQLA should be uncumbered assets, i.e. not be burdened with any constraint. There have been individuated two HQLA categories by Basel Committee (BCBS, 2013)[6]:

- Level 1 assets that may be computed without limitation, and benefit from a 100% weighting factor;

[4] Basel Committee on Banking Supervision. 2008. Principles for Sound Liquidity Risk Management and Supervision. Basel: Bank for International Settlements.

[5] Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL amending Regulation (EU) No 575/2013 as regards the leverage ratio, the net stable funding ratio, requirements for own funds and eligible liabilities, counterparty credit risk, market risk, exposures to central counterparties, exposures to collective investment undertakings, large exposures, reporting and disclosure requirements and amending Regulation (EU) No 648/2012.

[6] Basel Committee on Banking Supervision. 2013. Basel III: The Liquidity Coverage Ratio and liquidity risk monitoring tools. Basel: Bank for International Settlements.

- Level 2 assets distinguished in:
- "*Second level of type A*" assets, subject to a maximum limit of 40% of the total HQLA stock, to which a 15% haircut of 15% is applied.
- "*Second level of type B*", subject to a maximum limit 15% of the total HQLA stock, to which a 50% or 25%, haircut is applied.

The Net Stable Funding Ratio (NSFR) is the second indicator which the Basel Committee introduced on prudential banking supervision. Its inclusion aims at a reduction in the risk of financing, in a one year time frame. This required indicator came into effect last January 1, 2018, following an extensive period of observation.

$$NSFR = \frac{AVAILABLE\ STABLE\ FUNDING}{REQUIRED\ STABLE\ FUNDING} > 100\%$$

The numerator includes assets, preferred shares and liabilities with maturities equal to or greater than one year and unsecured wholesale funding, which would remain with the institution for an extended period. The denominator is calculated based on the liquidity characteristics of the institution's assets. Despite the introduction of the aforementioned requirements, liquidity risk continues to be a difficult measure to determine.

Indeed, the use of the indicators alone would seem to be reductive due to the monitoring tools that each institution can use with the authorization of the Committee. These tools do not fall within the requirements regulated by Basel 3, but are added to give a more realistic quantification of liquidity, and to relay additional information on individual liquidity risk profiles of each bank to the Supervisory Authority.

The supervisory authorities must be constantly informed on the progress of the indicators and immediately notified if the LCR falls below 100%. These authorities may or may not support investments that can impact the group's liquidity, based on the LCR standard.

Along with LCR, the tools used to better assess the liquidity risk of a bank came into force on 1 July 2015 and are as follows (BCBS, 2013):

I. *"Contractual maturity mismatch"*
II. *"Concentration of funding"*
III. *"Available unencumbered assets"*
IV. *"LCR by significant currency"*
V. *"Market-related monitoring tools"*

Our analysis focuses on "*Contractual maturity mismatch*", as we develop the liquidity risk indicator, considering maturity mismatch of both loans and deposits. Imbalances between inflows and contractual liquidity outflows indicate the volume of liquidity that a bank could potentially need to collect in each of these time frames. According to Basel III, such a tool allows better understanding of the extent to which a bank depends on the transformation of maturities in existing contracts. Once data is obtained from the misalignment of contractual deadlines, information on the categories outlined in the LCR can be provided.

It may be necessary to "*separately report some additional accounting information, such as non-performing assets or non-performing loans"* (BCBS 2019)[7]. Any guarantee received from the customer should be reported separately by the bank, which can re-engage it under the right of re-use (rehypothecation), along with the amount of those guarantees reused at each reporting date. As a result, it will be possible to establish when a loans to deposit relationship mismatch occurs.

Information provided by banks is not accompanied by hypotheses; indeed, supervisory authorities can use their own hypothesis to control for risk by examining maturity mismatch. Moreover, since contractual maturities do not involve behavioural hypotheses, it is not possible to forecast expected flows in strategy programs.

As stated in the Sound Principles on Basel III regulation, banks should conduct a comprehensive and structured analysis of maturity mismatch, monitoring liquidity risk of current operations in both regular and tense situations. Banks should also be able to indicate how gaps might be filled according to internal maturity mismatches.

The 2nd tool, Concentration of Funding, "*aims at identifying relevant sources of wholesale funding, such that their disappearance would lead to liquidity problems"* (BCBS, 2013). It is therefore intended to promote the diversification of funding sources recommended in the Committee's Sound Principles (2008).

The aim of the 3rd tool is to *"supply to supervisory authorities the information about the quantity and the main features of unencumbered assets at bank disposal, which may be pledged to raise HQLA or additional guaranteed funding in secondary markets or are eligible at central banks and, as such, could be additional sources of liquidity for the bank"* (BCBS, 2013).

In order to detect potential currency mismatches, banks and supervisors should also assess *LCR by significant currencies −4th tool.* Lastly, high frequency market data −5th tool, with little or no time lags assist banks in identifying potential liquidity difficulties with the use of early warning system indicators.

[7] Basel Committee on Banking Supervision. 2019. Supervisory Review Process. Liquidity monitoring metrics. Basel: Bank for International Settlements.

Reacting to past events, considerable progress has been made thanks to applied macroeconomic policies; indeed, macroprudential measures allowed banks to build up reserves, discouraged the granting of risky loans, and strengthened the resilience of the financial system (BCBS, 2018). Even if stress tests before the financial crisis did not lead to useful information for systemic banking risk, macroprudential measures achieved their purpose in strengthening the financial system. Basel's new liquidity requirements achieved their purpose too, especially with LCR, which was applied in the EU in January 2018.

The European Banking Authority (EBA, 2018) showed that LCR is composed primarily of 46% outflows from wholesale deposits, of which 38% are non-operational and 8% are operational. Moreover, the EBA underlined the lack of clarity in LCR implementation and regulatory provision. Hence, banking liquidity monitoring must consider the maturity ladder in implementing Basel Committee standards (BCBS 2009); because additional approaches can favor forecasting, LTD_m offers information for further assessing liquidity risk in granting long-term loans, considering short-term or long-term deposits.

Liquidity strategies and cash management are based on available deposit-gathering to cover shortfalls or meet normal payments. The renewal of deposit concept, highlighted by the EBA, reminded us of the importance of the lending and deposit relationship supported by our indicators, whose policy implications could help in clarifying a bank's liquidity situation during the trade cycle, that is, when deposits are expected to be used and renovated by others.

As already pointed out, duration (i.e., time dimension) constitutes a crucial factor in building different indicators for banks to have knowledge of their positions with respect to liquidity at different times.

The results proposed in this paper aimed at ensuring better monitoring as well as filling a gap in a new approach to bank liquidity risk, that is, why empirical evidence plays a key role in dealing with new methodologies.

1.3 Research setting

There are several reasons for our decision to analyze liquidity risk in the European banking system and in the period identified. In the EU countries, non-financial companies rely more on bank credit, as a funding source, than in other contexts, such as America, in which financial markets grant finance for business a predominant role.

Although the European banking system is structurally homogeneous, it is characterized by banks with significant operating differences and different levels of risk resilience. Some banks have

better capital instruments and liquid assets than other banks, with different compliance and competitiveness costs.

In some European countries, a significant impact of non-performing loans on banks' balance sheets (Greece, Cyprus, Portugal, Italy, and Bulgaria) and weak economic conditions (e.g., sovereign debt on GPD) affect banks' liquidity risk differently.

In the aftermath of the 2008 Global Financial Crisis, the general idea that governments' response to sovereign debt crisis was inadequate became widespread. The year 2011 is remembered for the tough economic and financial conditions, regarding the growing difficulty for banks in obtaining funds for the various EU Member States. At first, the data showed a monetary expansion, together with copious liquidity.

If the economic recovery progressed with the strengthening of domestic demand in the early part of the year, in the second half of the year, the euro area macroeconomic conditions got worse due to the exacerbation of sovereign debt market tensions. The worsening of this debt and its impact on the banking sector generated new risks for financial stability, which implies a domino effect on the larger countries of the area.

The prospect of global growth and the sustainability of public finances were both affected. Given these circumstances, the Governing Council of the European Central Bank (ECB) was prompted to adopt non-standard monetary policy measures to avoid adverse repercussions and to implement new liquidity provision measures.

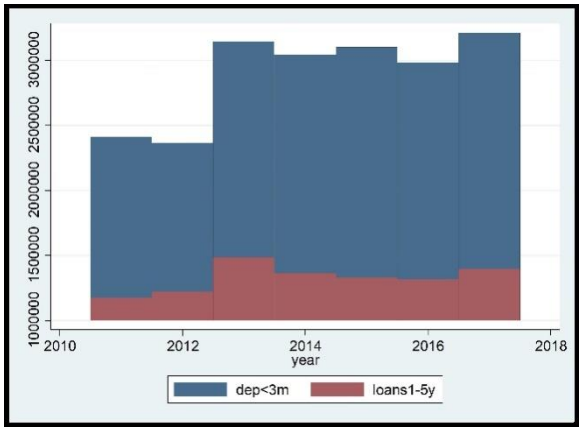
Between September 15th and October 6th 2011, three operations providing dollar liquidity and two additional refinancing options were announced respectively; the former with a duration of three months, the latter with a twelve month expiry. These operations were adopted to promote bank fund-raising, as well as support banks in order to provide credit to both households and non-financial companies.

As we can see from Graph 1, the following years after the crisis, the amount of demand deposits dropped considerably; after that, an increase in deposit gathered increased, as did the loans granted over a long-term period. Overall, the percentage of demand deposits exceeds loans. Even if the ratio may present lower values during the years considered, a more in depth analysis can highlight the liquidity problem due to maturity mismatches of both loans and deposits.

Since banks collect on short term, the higher the demand deposits, i.e. the concentration of liquidity to a shorter term, the higher liquidity risk exposure. If renewal of deposits is not constant over time, granting long-term financing will become increasingly difficult.

Graph 1

Loans to deposit maturity mismatch



Source: Stata 13

Moreover, in the aftermath of the financial crisis, there has been widespread consensus that the absence of principles that effectively managed the governance of financial institutions contributed to the crisis. The European commission highlighted the weak role of the boards of directors during the crisis, as responsible for not having undertaken analyses, and monitored risks. The inability to understand risk exposure, depended on the lack of clarity in the internal division of roles and responsibilities; in particular, the European Commission underlined the issue related to the poor diversification of the board of directors' working environments regarding gender, education, and culture but above all risk culture. The board of directors was not even be able to recognize and monitor the risk appetite of its own bank. Therefore, after the implementation of the first measure – "*on the subject publish director remuneration policies and individual salaries"* (Directive 2004/39/EC)[8]-, on 4 March 2009 a new recommendation by the European Commission was adopted in order to achieve long term results by strengthening governance in ensuring close association between executive remuneration and sound risk management. Subsequently, the Committee published the Green Paper (2010)[9], suggesting the creation of dedicated committees qualified for risk surveillance within the same board.

Lastly, in response to the global financial crisis, the European Systemic Risk Board (ESRB) was created—an EU macro-prudential supervisory body that is responsible for both the detection and estimation of systemic risks, as well as the development of warning systems (ECB 2012).

In light of this consideration, we chose our sample of European banks after the entry into force of the previous Regulation, i.e. from 2011 to 2017.

[8] Directive 2004/39/EC of the European Parliament and of the Council of 21 April 2004 on markets in financial instruments amending Council Directives 85/611/EEC and 93/6/EEC and Directive 2000/12/EC of the European Parliament and of the Council and repealing Council Directive 93/22/EEC

[9] EUROPEAN COMMISSION. Brussels, 2.6.2010.COM(2010) 284 final. GREEN PAPER Corporate governance in financial institutions and remuneration policies

1.4 Literature Review

Liquidity Risk [10]

Although a large growing body of literature on bank liquidity risk is available, throughout the years scholars have implemented different approaches to measuring this risk. Indeed, Tirole (2008) claimed that it was not easy to summarize the risk of liquidity in a single measure. The literature proposed several indicators, aimed at representing the liquidity position of a bank (Barth, 2003; Molyneux and Thornto, 1992; Bourke, 1989). Kosmidou (2005) expressed liquidity risk exposure as the "deposit run off ratio", indicating that a higher value of ratio would mean lower vulnerability in terms of liquid assets. In line with this view, Pasiouras and Kosmidou (2007) defined liquidity risk applied to EU banks, as the share of illiquid assets (i.e. granted loans) covered by short-term liabilities.

Several studies have investigated the phenomenon of liquidity risk from the macroeconomic and microeconomic point of view, highlighting the main determinants and effects.

From the macroeconomic point of view, Van den End (2016) decomposed loans to deposits ratio (LTD) into numerator (loans) and denominator (deposits). He showed that an increase in LTD was due to a loan growth partly financed by non-deposit funding which mostly happens in economic upswing; while the opposite occurred during economic downturn, when the rise in deposits lowered liquidity risk. Demirgüç-Kunt (2003) used the ratio of liquid assets on total assets in order to estimate the effect of regulation and banking concentration. Shen (2009), investigated liquidity risk on both regulation and macroeconomic drivers. A further macro key factor is geography. In fact, developing countries showed quite different liquidity risk causes with respect to developed nations, due to macroeconomic factors such as unemployment, education levels and financial literacy. In this regard, Singh and Sharma (2016) argued that the liquidity problem was a matter of "customer insecurity" rather than bank inefficiency.

From a microeconomic point of view, the literature focus on bank specific factors is twofold: some scholars detected the main drivers of liquidity risk; while, other studies identified which banks' business models were related to performance and profitability (Roengpitya et al., 2017; Mergaerts and Vennet 2016; Beck et al., 2013). Indeed, scholars investigated the main determinants of liquidity risk (Aspachs, 2005; Bonfim and Kim, 2012) by also focusing on efficiency (Fiordelisi, et al., 2011). Matz and Neu (2007) applied the cash capital position and implemented balance sheet liquidity analysis in order to investigate the degree of liquidity of both assets and liabilities.

[10]An extract from the Literature Review has been published in the scientific journal RISKS, MDPI: "Galletta, S.; Mazzù, S. Liquidity Risk Drivers and Bank Business Models. *Risks* 2019, *7*, 89"; DOI: 10.3390/risks7030089.

New studies on the construction of a more comprehensive and dynamic liquidity risk measure started soon after the publications of the document *Principles for Sound Liquidity Risk Management and Supervision* by BCBS (2008). Indeed, Resti and Sironi (2011) contributed to the literature by analyzing funding liquidity risk with three Basel approaches: 1) the stock approach (calculating the cash capital position), 2) the cash-flow approach (difference between convertible assets and volatile liabilities) and 3) the hybrid approach (liquidity gap plus asset disposal). Following the same document, Berger and Bouwman (2009), considered time and cost for the creation of bank liquidity, and found that capital positively contributes to liquidity creation in large banks. In a more recent study, Khan et al. (2017) highlighted that well capitalized banks exhibit lower liquidity risk.

After the 2008 crisis, the Basel Committee on banking supervision introduced a new regulatory framework based on sounder financial standards, with the inclusion of two indicators for the minimum requirements of liquidity: Liquidity Coverage Ratio (LCR) refers to a 30-day timeframe during a significant stress scenario, and Nest Stable Funding Ratio, which helps long-term resilience.

In accordance with the regulatory framework of Basel III, recent research has focused on: maturity mismatches as a liquidity measure, using the maturity ladder (De Haan and Van den End 2013); the difference between quickly convertible assets and liabilities (Valverde et al. 2016; Imbierowicz and Rauch 2014); and, market liquidity conditions (Bai et al. 2018). Bonner et al. (2015) found significant relationships between liquidity buffers and both higher lending volumes and higher interest rates; that is, between the bank size and business model, respectively. Ayadi et al. (2016) indicated lower values in the NSFR in wholesale and investment banks, but higher ones in retail-oriented banks.

Bank Business Models[11]

Few studies have investigated the relationship between risk and business models; in particular, they consider default risk rather than specific bank risks. For this reason, in this specific field, the literature is still mixed. With regard to business models, Mergaerts and Vennet (2016) recommended an in-depth investigation of bank business models concerning post crisis regulatory and supervisory practices. A traditional funding structure, namely retail-oriented banks, ensures both profitability and stability banking in the long run. The resilience associated with the latter business model, to a large degree, depends both on the creation of a lasting lending and strong deposits relationship. Benefits from shifting to a retail funded model are also proven by reduction in

[11] An extract from the Literature Review has been published in the scientific journal RISKS, MDPI: "Galletta, S.; Mazzù, S. Liquidity Risk Drivers and Bank Business Models. *Risks* 2019, *7*, 89"; DOI: 10.3390/risks7030089.

default risk, as shown in a study by the European Central Bank (ECB 2016). The ECB study focused on duo "stability-performance" through bank business models, analyzing changes before and after the crisis in the Euro area. Larger and more retail-oriented banks showed a lower default risk; just as what happens for financial institutions adopting a diversification strategy for income sources. During the pre-crisis period, income diversification policy led to an increase in default risk, while throughout and after the downturn the importance of being a larger bank failed. However, there is evidence concerning the riskiness of investment models both before and during the crisis. Banks that appeared to be less risky before the financial crisis, ended up being the riskiest (Hryckiewicz and Kozlowski, 2017). Moreover, holding higher deposits (i.e. relationship deposits) is correlated with low risk, whereas wholesale funding is linked to higher risk (Kok et al., 2016). A study of different bank business models in 15 EU countries, showed that non-traditional activities produced by smaller banks ensure stability, while investment-oriented institutions are more likely to be risk exposed by definition (Köhler, 2014).

Moreover, impact of business models on liquidity risk is expected to be different; in particular, savings banks as opposed to commercial and investment banks, are less likely to suffer liquidity exposure and thus display negative signs.

Thanks to Basel III, the concern for liquidity risk management has grown to widen and deepen the way in which European banks and supervisory authorities deal with a liquidity stress scenario in different banking activities.

Bank board size and risk

The literature has outlined an existing relationship between board size and risk. The foundations of this relationship are to be found in the agency theory and ownership structure (Jensen and Meckling, 1976; De Jonghe and Vennet, 2005); more specifically, agency problems play a serious role in bank risk decisions (Mester, 1991; Hughes et al., 2001). Skilled corporate governance aims at reducing agency problems by aligning managers with shareholders' goals, in the bank's interests. On the one hand, scholars have proven that an increase in board size has also led to an increase in risk (Adams, 2012; Battaglia, Curcio and Gallo, 2014). This is due to the difficulty in pursuing a single goal, as well as in the inability to reach a proper agreement, as there are more different points of views than smaller boards. On the other hand, studies have provided supporting evidence in favour of larger board size (Wang and Hsu, 2013). Reports have shown that during the last financial crisis, banks with larger boards proved riskier (Pathan, 2009; Fortin et al., 2010; Adams, 2012; Peni and Vähämaa, 2012; Beltratti and Stulz, 2012; Wang and Hsu, 2013, Battaglia, Curcio and Gallo, 2014). Conversely, other studies that examined the pre-crisis period found a negative relationship

between board size and risk taking (Akhigbe and Martin, 2008; Erkens et al., 2012; Faleye and Krishnan, 2015). Pursuing this line of research in a study of commercial banks on credit risk, Switzer and Wang (2013) showed that larger boards are associated with significantly lower risk. Moreover, Klein (2002) and De Andrés and Vallelado (2008) pointed out that a larger board would be better at improving the effectiveness of monitoring and control activities, with the possibility of better assessing risk management choices. The larger dimension of the board of directors would be recommended for corporate policies, which benefit from different backgrounds and greater problem-solving activities that can mitigate difficulties in board decisions (Bernile et al., 2018).

Based upon the aforementioned theories, the purpose of this chapter is to provide an overview of the most relevant studies with regard to liquidity risk, and to highlight the pillars of the relevant published literature. Thus, figure 1 and 2 show how our field of study raised the general interest among the scientific community. In particular, these figures report citation for 1.120 results from Web of Science Core Collection between 1985 and 2019. Starting from 2009, i.e. in the aftermath of the Global Financial Crisis, publications and related citations in matter of "Liquidity risk" and "Financial crisis" have been increased more than double and the trends indicate a growing interest within scholars and policy makers until 2018 when the peak was reached.

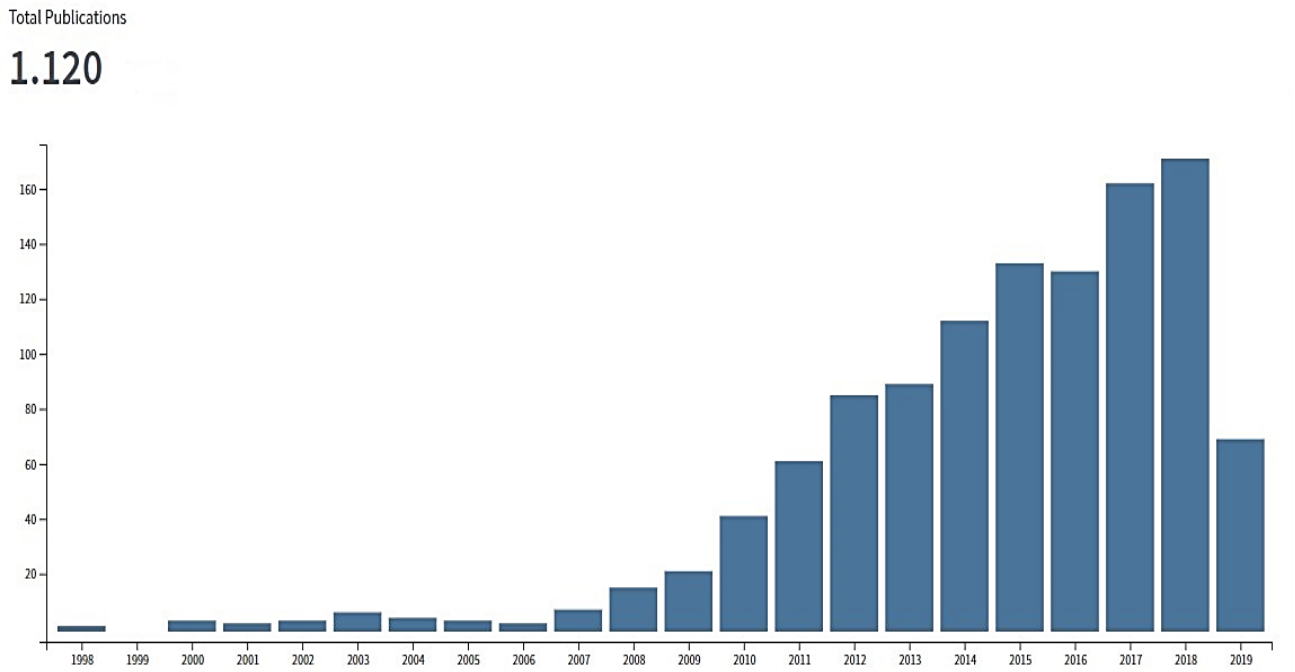


Figure 1. *The plot reports total publications to source items indexed within Web of Science Core Collection.*

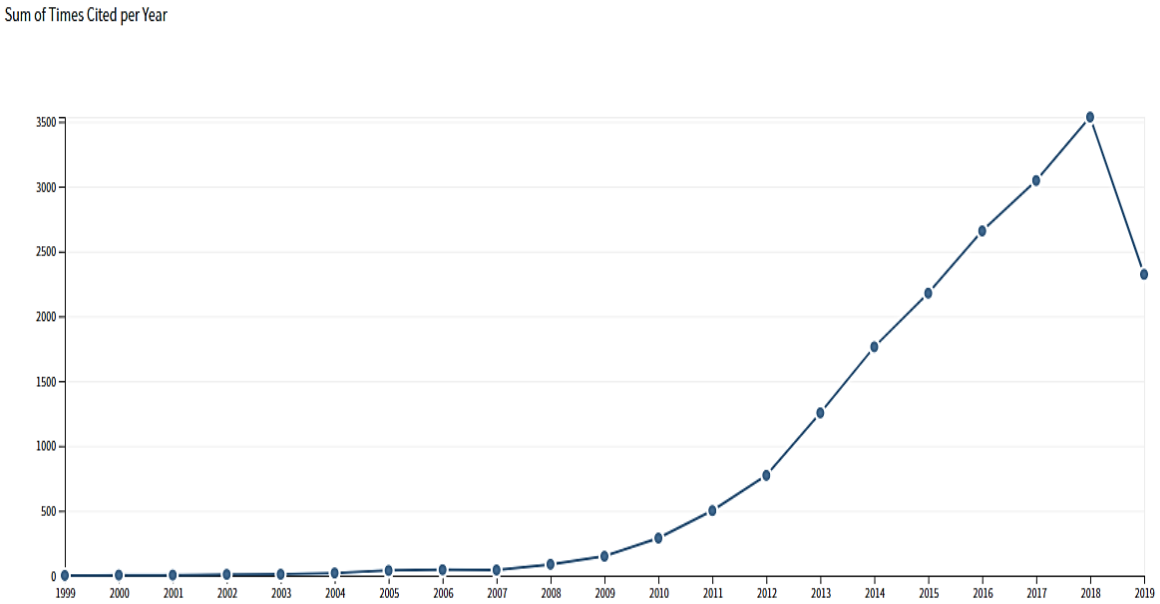


Figure 2. *The plot reflects total sum of citations received yearly by the publication about "liquidity risk" and "financial crisis" to source items indexed within Web of Science Core Collection.*

Bank risk committee and liquidity risk

Board committees are established for better analysing a specific risk area of a financial institution; thus, in order to ensure bank stability, the need for a proper risk committee is increasingly important. Not only does the risk committee examine the current situation of a bank, but it also forecasts the application of future financial operations. In doing so, a risk committee serves as guidance for the board in implementing the proper strategies with regard to capital and liquidity management as well as identifying, monitoring and assessing all other risk: i.e. credit, operational, market and reputational (BCBS, 2015). To strengthen safety measures and set up risk limits, risk management must have proper risk culture, which adjusts to changes in stress situations. Since risk appetite, i.e. the willingness to assume risk, is strictly linked to bank risk capacity and the achievements of objectives, the creation of a risk appetite framework (RAF)[12] is mandatory for any risk committee in order to manage the main banking as well as reputational risks. The presence of a risk committee is foremost for bigger banks in which complex systems make both the assessment and the measurement of bank risk exposure difficult; moreover, the committee may differ based on bank specialization and complexity. Despite its importance, the literature on the presence of a risk

[12] The overall approach, including policies, processes, controls, and systems through which risk appetite is established, communicated, and monitored. It includes a risk appetite statement, risk limits, and an outline of the roles and responsibilities of those overseeing the implementation and monitoring of the RAF. The RAF should consider material risks to the financial institution, as well as to the institution's reputation vis-à-vis policyholders, depositors, investors and customers. The RAF aligns with the institution's strategy. Financial Stability Board, Principles for an Effective Risk Appetite Framework, Basel, 18 November 2013.

committee in financial institutions is limited. As far as risk governance is concerned, Keys et al. (2009) have proven that the more powerful the departments of risk, the less the risk exposure, even over the period 2004-2010 (Lingel and Sheedy, 2012; Ellul and Yerramilli, 2013). On the other hand, the mere presence of risk officers does not automatically support banks in times of crisis; but having more dedicated risk committee meetings positively affects banking performance during a crisis (Aebi et al, 2012). Moreover, the latest study on this subject by Marques and Oppers (2014), showed a negative relationship between the presence of risk committee and bank risk, measured as default risk, equity risk and tail risk. Specifically, banks with an operating risk committee were found to be associated with lower risk-taking.

A risk committee is considered a key factor that may negatively influence risk management decision when proper analysis of the potential risk elements is lacking. Indeed, appropriate risk monitoring activities could lead banks to forecast crisis, or at least, to apply strategic risk decisions in order to protect creditors. In our view, risk committee size affects strategic choices in facing liquidity risk. One explanation could be traced back to effective policies in managing and acknowledging risk, ascribable to the presence of experts who guarantee higher quality in funding-deposit gathering; as a there is greater risk control, which generates a "confidence effect" with regard to depositors, who renew short-term deposits and therefore mitigate liquidity risk. It is expected that, having a risk committee indicates stronger risk management and consequently better corporate governance.

Unfortunately, little is known about risk management committees and in particular, how they can affect bank risk. Thus, in order to extend knowledge on this topic, we analyzed the relationship between risk committee and liquidity risk in our research. Previous studies have chosen a mixed sample of countries: i.e. Africa, Asia, Pacific regions, America. In our view, combining different countries, which have different supervisory statues, might lead to biased results; therefore, we applied our research to the effect of a risk committee on liquidity risk maturity mismatch in European banks.

Against this background the regulatory framework can be improved, overall liquidity conditions changed after the crisis; in particular, the reduction in liquidity risk was mainly due to an increase in the share of short-term deposits gathering activity, which was carried out by financial institutions with new promotional interest rate strategies. Indeed, for the most part, bank funding is made up of demand deposits; if there is a boost in lending growth, and deposits do not grow alike, the funding mismatch may jeopardize the stability of the institution as well as the rate transmission, especially when bank-run phenomena are triggered by a financial crisis.

The remainder of the thesis is structured as follows: Chapter 2 investigates on liquidity risk determinants and different business models with a descriptive analysis of the EU bank data. The study takes in consideration business models specification as bank specialization, indicating the results of the relationship between LTD_m and its main drivers. The research performs a regression analysis with a dynamic panel data model, dealing with the endogeneity issue. The fundamental role of banks in maturity transformation makes the bank vulnerable to liquidity risk. The financial crisis in 2007-2009, highlights the importance of liquidity to the functioning of financial markets and the banking sector. We investigate how characteristics of a bank, such as size, capital, and business model, are related to liquidity risk, while using a sample of European banks in the period after the financial crisis, from 2011 to 2017. While employing a generalized method of moment two-step estimator, we find that the banking size increases the liquidity risk, whereas capital is not an effective deterrent. Moreover, our findings reveal that, for savings banks, income diversification raises the liquidity risk while investment banks reliant on non-deposit funding decrease the exposure to liquidity risk.

Chapter 3 analyzes the relationship between liquidity risk maturity mismatch and the corporate governance characteristics; in particular, if the risk committee presence might affect liquidity risk is investigated, defining a certain threshold of risk committee members per bank. Also in this case, chapter 3 involves the use of a dynamic panel data model estimation, from 2011 to 2017, with a System GMM to address the endogeneity concern. The financial crisis in 2007-2009 highlights the importance of liquidity to the functioning of the financial markets and the banking sector. The empirical results indicate that the presence of a risk committee decreases liquidity risk, especially when a certain threshold of risk supervisors is set.

2. LIQUIDITY RISK MATURITY MISMATCH AND BANK BUSINESS MODELS[13]

2.1 Introduction

The 2007-2009 financial crisis highlighted the vulnerability of banks to liquidity risk and the several implications associated with banking business models. During the crisis, the identification of proper risk management for different business models was challenging (Altunbas et al., 2011). Moreover, banks which exhibited traditional characteristics during the financial turmoil had a "survival advantage" (Chiorazzo et al., 2018). This led to the need for specific regulation regarding both management and measurement of liquidity risk, with a view to achieving greater stability in the financial system.

In 2013, the Basel Committee on Banking Supervision (BCBS 2013) introduced two indicators for the minimum requirements of liquidity. The document concerning the first requirement was published in 2013, "Basel III: The Liquidity Coverage Ratio and liquidity risk monitoring tools", and in 2014, the Basel Committee on Banking Supervision (BCBS 2014) published "Basel III: The Net Stable Funding Ratio".

Although the indicators cover different time frames, they have a complementary effect, i.e. they ultimately perform the same function. Liquidity Coverage Ratio (LCR) refers to high quality short-term cash (HQLA), considering a 30-day time-frame during a significant stress scenario; while Net Stable Funding Ratio (NSFR) aims at decreasing funding risk, considering a time frame of a year. Therefore, we have highlighted the complementary function of the two requirements: the relevance of LCR is due to liquid assets quality during a one-month stress period; NSFR helps long-term resilience during which banks must be able to finance their activities with sufficiently stable sources, and to stabilize both assets and liabilities of the balance sheet.

Following the definitions of these two liquidity requirements, we computed the loans to deposits ratio (LTD) in order to consider at least one of the two significant time spans using maturity mismatches. In this field of study, some scholars have provided observations on liquidity creation before and during the crisis (Berger and Bouwman, 2009; 2016; Brunnermeier et al., 2009). Other studies have not sufficiently investigated the relationship between business models and liquidity risk, but rather the link between profitability and performance in different banking business models (Roengpitya, et al., 2017; 2014).

[13]This work has been published in the scientific journal RISKS, MDPI: Galletta, S.; Mazzù, S. Liquidity Risk Drivers and Bank Business Models. *Risks* 2019, *7*, 89. The current paper is a combined effort of the authors. However, Simona Galletta contributed in conceptualization, software, data curation, writing—original draft preparation; Sebastiano Mazzù contributed in conceptualization and supervision.

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This paper differs from the previous studies because it takes a disaggregated indicator of loans and deposits maturities as liquidity risk proxy, and it investigates the impact of business models on maturity mismatch risk. Moreover, it aims at extending studies on liquidity risk, across an unbalanced panel dataset of 4844 EU banks during a specific period, starting from 2011 to 2017.
We empirically analyzed the main drivers of loan to deposits ratio maturity mismatches (LTD_m), testing if bank size and capital affect LTD_m and verifying the existence of differences in bank business models. Since balance sheet measures do not account for bank capacity to access funding sources, we measured flows over time. This would help in detecting changes through a more accurate approach, instead of using static balance sheet ratios. Therefore, as a proxy of LTD_m, we divided the short-term loans (i.e. three-months) by the long-term deposits (i.e. between three and twelve months).

Considering the loan-deposit relationship maturity mismatch, is a step forward for risk management. As financial institutions consider liquidity risk as an integral part of their operations, they are able to understand whether different types of banks have the same influence on the relationship between the loans granted and the deposit collected. Banks usually face disparate kinds of risk, since their nature changes in accordance with the characteristics of each business. However, holding much more capital and liquidity buffer is needed to tackle future distress (Scannella, 2012). As widely adopted in numerous scientific research, we compared our measure of liquidity risk with several dependent variables.

2.2 Hypotheses and Data

The objective of our analysis is to detect, through the use of maturity mismatch, whether bank size and capital affect liquidity risk, and if there are significant differences between business models. Computing maturity transformation is challenging due to the unavailability of many maturities data on both assets and liabilities sides (De Haan and Van den End 2013).

Literature regarding the main drivers of liquidity risk prospered thanks to other contributions. It has been found that bigger banks are not riskier (Birindelli et al. 2018; Bertay et al. 2013; Mercieca et al. 2007; Demsetz and Strahan 1997). On the other hand, studies have shown that larger banks are less stable (Battaglia et al. 2014; De Haan and Poghosyan 2012). We expect a positive sign for the banking size coefficient, which means that larger banks tend to increase their liquidity risk, thus we posit:

Hypothesis 1. *Banking size is negatively related to liquidity risk.*

In their study, Khan et al. (2017) pointed out that banks benefit from higher level of capital, in diminishing liquidity risk. Thus, a negative sign for capital coefficient is expected, because a higher level of capital mitigates liquidity exposure; hence, we proposed the following:

Hypothesis 2. *Well-capitalized banks should suffer less liquidity risk.*

Concerning the relationship between business models and bank risk, literature is scant. The main evidence focused on default risk rather than other risks. Mergaerts and Vennet (2016) analyzed bank business models with a long term objectives performance. They identified business models through a factor analysis, showing that the impact of individual variables is based on the different business model.

Therefore, the impact of business models on liquidity risk is expected to vary; in particular, savings banks, as opposed to commercial and investment banks, are less likely to suffer liquidity exposure, and thus display negative signs. Accordingly, we posit the following:

Hypothesis 3. *Commercial and investment banks are positively related to liquidity risk, unlike savings banks.*

Whether differences in bank business models affect liquidity risk remains an unresolved issue. We proposed different estimation techniques and dealt with the endogeneity issue, while employing a generalized method of moments estimator as a more suitable approach in this type of study. Moreover, this research differs from previous studies in that it takes a disaggregated indicator of loans and deposits maturities as liquidity risk proxy, and it investigates the impact of business models on maturity mismatch risk.The main dataset considers European banks over a seven-year period, from 2011 to 2017. The banks selected are from the Bureau van Dijk (BvD 2018) Orbis Banks database, excluding central banks. Outlier values are likely to distort the relation given that, all variables—except dummy variables—are winsorized at the 99th percentile[14]—as most of the literature does (Khan et al. 2017; Nguyen et al. 2017; Köhler 2015; Berger and Bouwman 2009). In addition, we showed an LTD_m trend with a time-series graph (Figure A1 in Appendix A) and found that the average values of LTD_m demonstrated that liquidity risk increased up until 2010/2011, whereas it decreased afterward. This is consistent with Bai et al. (2018), who showed that before the financial distress, banks created liquidity to the detriment of post-crisis times, that is, generating instability afterward.

The dataset included both listed and unlisted banks. Table 1 presents the descriptive statistics for the variables. The liquidity risk indicator is the ratio between short-term loans and long-term deposits. Moreover, we include two other dependent variables, that is, total loans over total deposits

[14] Winsor command takes the non-missing values of a variable x ordered such that x_1 <= ... <= x_n , and generates a new variable y identical to x except that the h highest and h lowest values are replaced by the next value counting inwards from the extremes. Barnett, V. and Lewis, T. 1994. Outliers in statistical data. Chichester: John Wiley. [Previous editions 1978, 1984.]

and short-term borrowing (LTDST) and liquid assets over deposit and short-term borrowing (LADST), as liquidity proxies widely used in the literature. We compared these three variables, because we believed that considering maturity mismatch through LTD_m is a better proxy in measuring liquidity risk. As independent variables, we include a natural logarithm of total assets, which accounts for bank size, and TIER, which indicates bank capital and specialization dummies. In accordance with the BvD 2018 Orbis Bank Focus[15] classification (Köhler 2015), we choose commercial, investment, and savings banks as businesses models, including them as specialization variables. The three dummy variables account for bank business models, while taking the value of one when the specialization is equal to commercial, investment, or savings banks; otherwise, the value was zero. The classification of the specialization dummies has been taken from the BvD 2018 Orbis Bank Focus database. In particular, commercial banks' activities are mostly based on the lending and deposits relationship; on the contrary, investment models have a diversified government portfolio, and their predominant activities rely on non-deposit funding. However, commercial and investment banks are both characterized by an investment-oriented business model, which considers shareholders' interests in order to maximize profits (Köhler 2015). Rather, saving banks not only base their activity on the increase of customer deposits, i.e., deposit-oriented, but also on the granting of loans. Indeed, saving banks have a more deposit-oriented business model that is focused on stakeholders' interests.As control variables, we consider cost-to-income for efficiency, two profitability measures (i.e., return on assets (ROA) and net interest margin (NIM)), and risk-weighted assets (RWA), which account for operational, market, and credit risks. Adding this set of variables helps us to deal with the omitted variable problem.

The average level of LTD_m in European banks was 38%. The average natural logarithm of the total assets is 14.65. Return on assets constitutes 3.8% of the total assets. Income structure was expressed as the share of non-interest income in the total operating income, whereas the share of non-deposit funding considers different types of funding, rather than customers. Appendix A shows the data sources and classification for all the variables used in this study. Before carrying out dynamic panel regression analysis, we performed a pair-wise correlation of the variables to check for the presence of multicollinearity. The correlation matrix is presented in Table 2. The correlation can be given by the composition of the variables; as most of them are financial ratios, the total assets are included in their construction. Correlation coefficients in bold are significant at the 5% level, and they are mostly $<|0.5|$, which suggests small or medium strength correlation. Therefore, a severe multicollinearity issue in our data does not exist. The correlation coefficients of the liquidity risk variables were (1) LTD_m, (2) LTDST, and (3) LADST, with the proportion of banking sizes

[15] Bureau van Dijk. 2018. Orbis Database. London: Bureau van Dijk.

being 0.258, 0.247, and 0.239, respectively.

In addition to the pair-wise correlation test of multicollinearity (Table 2), we also conduct the Variance Inflation Factor (VIF) and Tolerance Test Statistics. Table A2 in the Appendix A reports two columns: VIF and Tolerance values, which are the reciprocal of VIFs. This last parameter ranks between zero and one. The higher the tolerance index, the lower the variance that the independent variable shares with the others, and the larger the contribution that it can make to the explanation of the dependent variable. A smaller value, however, indicates a lot of variance with the other variables, so the contribution is usually more limited. A particularly low tolerance value may be indicative of variables that are likely to cause computational problems in the estimation of regression coefficients. However, the low VIF values indicate low collinearity; for high values, the collinearity is high. As a rule of thumb, up to the value 3, the situation can be tolerated; exceeding the threshold, the values between 5 and 10 are indicative of strong collinearity.

Table 1

Descriptive statistics variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
Dependent variables					
LTD_m	2236	.386	.708	.024	7.312
LTDST	2234	73.704	27.159	2.149	246.633
LADST	2236	18.234	20.533	1.336	244.634
Independent variables					
LNTA	2236	14.652	2.165	10.332	20.238
TIER	2236	249.1941	786.086	.3537	3964
NIM	2236	2.064	.852	-.204	7.951
CINC	2236	.766	.185	.0805	1.783
RWA	2236	54.386	15.240	7.679	110.873
ROA	2236	.0038	.0092	-.058	.169
NONINTINC	2236	.3611	.178	-.167	1.065
NONDEPFUN	2236	.1703	.7892	0.000	21.361
COMMERCIAL	2236	.2021	.4016	0	1
INVESTMENT	2236	.0076	.0868	0	1
SAVINGS	2236	.3157	.4649	0	1

We present a summary statistics for the dependent and control variables. Liquidity Risk is alternatively defined as the ratio between loans and deposits maturity mismatch, as overall loans on deposits and short term funding and as liquid assets over deposit and short term funding (liquidity index).

Table 2

Pairwise Pearson correlation coefficients

	1	2	3	4	5	6	7	8	9	10	11
LTD_m	1.000										
LTDST	0.034	1.000									
LADST	**0.215**	**-0.101**	1.000								
LNTA	**0.258**	**0.247**	**0.239**	1.000							
TIER	**0.117**	**0.078**	**0.244**	**0.656**	1.000						
NIM	**-0.092**	0.006	**-0.191**	**-0.299**	**-0.207**	1.000					
CINC	**-0.155**	**-0.294**	-0.017	**-0.211**	**-0.083**	**-0.091**	1.000				
RWA	**-0.113**	**0.040**	**-0.275**	**-0.414**	**-0.330**	**0.489**	**0.079**	1.000			
ROA	**0.040**	0.000	-0.012	-0.017	**-0.029**	-0.005	-0.019	-0.012	1.000		
NONINTINC	**0.066**	**-0.225**	**0.168**	**0.039**	**0.039**	**-0.122**	**0.064**	**-0.029**	**0.076**	1.000	
NONDEPFUN	**0.134**	**0.381**	**0.106**	**0.189**	**0.051**	**-0.165**	**-0.244**	**-0.225**	0.006	**-0.211**	1.000

This table reports the correlation coefficients of all variables used of the EU banking sector during 2011-2017 time period.

Previous findings show that bank stability depends on the bank's income and funding structure. By looking into funding structure, we want to test whether LTD_m depends on other variables, such as bank size and capital. Furthermore, our model includes dummy variables of banking specializations.

2.3 Model and Methodology

Multiple regression analysis allows us to verify the presence of statistics dependence connections between several variables: a dependent and multiple independent variables.

In order to identify what the drivers of loans to deposits ratio maturity mismatch are, we first test the hypothesis of banking size and capital support, on different liquidity risk dependent variables. We thus estimate the following dynamic panel regression model with clustered heteroscedasticity standard errors at the bank-level to account for serial correlation of the dependent variable for each bank:

$$LR_{it} = \alpha_i + \gamma LR_{it-1} + \beta_1 LNTA_{it} + \beta_2 TIER_{it} + \beta_3 SPEC_{it} + \beta_4 ROA_{it} + \beta_5 NIM_{it} + \beta_6 RWA_{it} + \beta_7 CINC_{it} + \delta_t + \varepsilon_{it}$$

LR_{it} is the dependent variable, indicating either the loan to deposits ratio maturity mismatch (LTD_m), or the loan to deposit and short term funding ratio (LTDST), or the ratio between liquid asset and deposit and short term funding (LADST) of bank *i* in year *t*. We add the independent variables for banking size, capital and specialization dummies, to the coefficients associated with the control variables. δ_t, is a year dummy and α_i is a bank specific fixed effect. Including fixed effects takes into account bank characteristics that do not vary over time. Moreover, dynamic panel estimations and using a lagged dependent variable, certainly help mitigate concern about persistency and the correlation of past and future values of error terms.

LTD_m is created to analyze the profiles of loans to customers and interbank, on deposits of the same categories with maturities starting from 3 to 12 months. If the short-term loans (i.e. less than 3 months) are neither covered by the three-month, nor by the long term deposits, the institution's chance of liquidity risk increases. Therefore, the higher the ratio, the less liquid the bank is. Thus, we use LTD_m to account for bank capacity to access funding sources. Since banking activity is characterized by demand deposits funding, determining maturities is the main problem of the banking book composition, where "*duration*" becomes the key factor in portfolio management. Consequently, as required by Basel III, this indicator is optimized for its time reference. This makes LTD_m as compared to global indicators, a better expression of the phenomenon we have chosen to study.

As independent variables, we include a natural logarithm of total assets which accounts for bank size, and TIER indicating bank capital, and a specialization dummy; whereas as control variables we consider cost to income for efficiency, two profitability measures i.e. ROA and Net interest margin (NIM), and risk-weighted assets (RWA) which account for operational, market and credit risks. Adding this set of variables helps us deal with the omitted variable problem. We run a dynamic panel regression with LTD_m, LTDST and LADST as dependent variables; after that we include bank business models to establish how liquidity risk is linked to the nature of banks activities, and whether different business models affect bank liquidity risk taking. We assume that there is a persistence in liquidity risk, so that we add the dependent variable as a lagged regressor to our model.

In accordance with the Orbis Bank Focus classification (Köhler, 2015), we choose commercial, investment and savings banks as businesses models, including them as specialization variables.

2.4 Results

In this subsection, we investigate the main drivers of loan to deposit ratio maturity mismatch, by estimating a dynamic model with fixed effect regressions using the full sample. Table 3 reports the results of the fixed effects estimation with a dynamic component. Since our dependent variable, namely LTD_m, is made up of loans and deposits at numerator and denominator respectively, a negative sign of the estimated coefficients positively affects liquidity risk, reducing it thanks to lending contractions or a rise in deposit-taking.

Conversely, positive coefficients will raise the ratio, leading to an increase in liquidity risk. Table 3 shows that liquidity risk is negative related to the increase in bank asset size - as indicated by the significant relationship of natural logarithm of total assets, LTD_m and LTD at 1% significance level (see Table 3, panels 1, 4).

The coefficient associated with LNTA indicates that if size increases by 1%, we foresee an increase in liquidity risk by 0.005401. This supports our first hypothesis and is also consistent with the aforementioned theoretical background of larger banks being riskier (Battaglia et al., 2014; De Haan and Poghosyan, 2012).

Moreover, if larger banks increase their lending activity at lower franchise, the probability of moral hazard will rise; whereas holding adequate levels of capital not only contributes to a decrease in liquidity risk but also to a reduction in the incidence of eventual losses.

Depositors always pay the cost of bank inefficiency, which in exchange produces high return for banks; deposit-rate ceilings help reduce risk-taking incentive by increasing franchise in order to enable banks to choose prudent assets and mitigate moral hazard (Hellmann, T. F., et al. 2000).

The negative and high statistical significance of TIER would support our second hypothesis (i.e., well-capitalized banks should suffer less liquidity risk), but, as the coefficient that is associated with capital produced small values (see Table 3, Panel 1), we can conclude that this variable had a lower impact on mitigating liquidity risk than the previous literature had foreseen (Berger and Bouwman 2009).

Specification models 4 to 6 were estimated with random effects in order to account for the bank specialization dummies. This is because, in a fixed-effects panel regression using the –fe option, time-invariant predictors will be cancelled out due to collinearity with fixed effects. "Industry" does not vary within our panels because each bank belongs to the same specialization, and is correlated with fixed effects.

With respect to the business models, savings banks are involved in activities that lower LTD_m by an average of 0.065% (see Table 3, Panel 4). Using the other two dependent variables, commercial and investment banks are the only significant specialization.

These results support hypothesis 3 concerning the impact of different business models on liquidity risk. As for LTDST, the business activities of investment banks contributed to a reduction of liquidity risk. The same happened for both commercial and investment models, with a LATDS dependent variable (see Table 3, Panel 6) being an indicator of liquidity; therefore, a positive outcome has to be interpreted as a decrease in liquidity risk.

Finally, adding a first lag of the dependent variable to all three liquidity measures showed the influence of past values: Liquidity risk was correlated with its own past equivalent. Concerning specification models 7 to 9, we extended the baseline model to test the relationship between liquidity risk and two other variables that account for income and funding structure, which are: (1) non-interest income and (2) non-deposit funding (Köhler 2015).

In doing so, we re-estimated the fixed-effect dynamic panel data model. Again, bank specialization was controlled by bank fixed effects, which dropped our business model dummy variables (see Table 3, Panel 7 to 9).

The findings from the extended model were quite similar to the previous fixed-effects dynamic regression results, with both size and tier retaining the same significant outcomes; that is, if bank size (LNTA) increases by 1%, we can expect liquidity risk to increase by an average of 0.0048.

We inferred that LTD_m increased due to over-diversification and non-deposit funding activities because the coefficients that were associated with both diversification (NONINTINC) and wholesale funding (NONDEPFUN) showed positive outcomes (see Table 3, Panel 7).

Table 3

Dynamic Panel Data Analysis

	LTD_m	LTDST	LADST	LTD_m	LTDST	LADST	LTD_m	LTDST	LADST
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$L.LTD_m$	0.2820			0.8085			0.2854		
	(0.1080)**			(0.0850)***			(0.1079)**		
L. LTDST		0.3884			0.9727			0.3991	
		(0.0571)***			(0.0098)***			(0.0633)***	
L.LADST			0.5965			0.9079			0.5980
			(0.2041)**			(0.0202)***			(0.1945)**
LNTA	0.5401	-6.0381	-13.2721	0.0209	0.3883	-0.0823	0.4846	-4.3064	-10.0064
	(0.0691)***	(4.0090)	(8.5877)	(0.0063)***	(0.1495)***	(0.1242)	(0.0826)***	(2.6639)	(6.3423)
TIER	-0.0003	-0.0004	0.0068	-0.0000	-0.0009	0.0009	-0.0003	-0.0003	0.0082
	(0.0001)***	(0.0024)	(0.0028)**	(0.0000)***	(0.0004)**	(0.0002)***	(0.0001)***	(0.0031)	(0.0036)*
NIM	-0.0990	-0.7606	3.3449	0.0000	-0.7602	-0.1805	-0.0638	-0.9390	3.2162
	(0.0372)**	(1.9519)	(2.9537)	(0.0099)	(0.3057)**	(0.5338)	(0.0224)**	(1.3041)	(2.7034)
RWA	-0.0015	0.3129	-0.2528	-0.0005	0.0439	0.0103	-0.0009	0.2999	-0.2429
	(0.0014)	(0.0869)***	(0.0652)***	(0.0003)*	(0.0164)***	(0.0474)	(0.0015)	(0.0938)**	(0.0538)***
ROA	-0.0080	48.1042	-13.1194	-0.1814	57.1675	-16.4052	-0.1495	48.8407	-21.5145
	(0.2729)	(48.0840)	(18.1641)	(0.2801)	(39.5807)	(19.4139)	(0.2791)	(48.3521)	(24.9992)
CINC	-0.0413	4.6706	2.2975	-0.1138	2.2789	-2.5367	-0.0360	4.5010	2.5975
	(0.0278)	(4.1019)	(2.3471)	(0.0560)**	(1.2334)*	(1.7733)	(0.0305)	(3.5246)	(2.8604)
COMMERCIAL				0.0057	0.1630	1.3475			
				(0.0424)	(0.5053)	(0.3888)***			
INVESTMENT				0.1416	-1.4248	4.6768			
				(0.1437)	(0.5717)**	(1.1602)***			
SAVINGS				-0.0650	-0.2031	0.0166			
				(0.0127)***	(0.3596)	(0.1679)			
NONINTINC							0.0541	-0.0349	6.3599
							(0.0277)*	(3.8817)	(4.1000)
NONDEPFUN							0.0470	-1.4684	-2.5310
							(0.0188)**	(1.0737)	(3.5743)
Obs.	2236	2234	2236	2236	2234	2236	2236	2234	2236
Adj. R-squared	0.12	0.18	0.25	0.76	0.94	0.90	0.12	0.18	0.25
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effect	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes

This table reports the dynamic panel regression results with fixed effects and one lag of the dependent variables which express bank liquidity risk. Clustered heteroscedasticity standard errors at the bank-level account for serial correlation in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ denote significance levels, respectively. Regressions 4 to 6 are performed with random effects to account for the specialization dummies. The potentially endogenous variables are banking size, capital support, profitability indicators and cost-income ratio. The regressions include time (year) dummies.

2.5 Robustness

Once we had proven that the share of these two additional variables might affect risk in business models, our concern was to investigate whether diversification income and wholesale funding have implications for each business model. We proceeded by splitting the sample into commercial, investment, and savings banks. Most of the studies regarding business models are focused on the profitability side, but we wanted to investigate liquidity risk across different banks. The results of the three business models' differences are based on their specialization activities.

Ayadi et al. (2016) outlined the diversity of banks before and after the 2007–2009 crisis through analysis of both multiple performance and risk indicators. The findings indicated that commercial banks relied less on retail activities, whereas they incremented market and interbank activities from 2005 to 2014. As these types of bank increase their share of non-interest income activities, this

result is in line with an over-diversification process leading to higher risk. Indeed, Table 4 indicates that savings banks have a positive and statistically significant share of non-interest income, which means that, as positive values raise liquidity risk, these banks may not benefit from income diversification strategy; indeed, they might suffer from over-diversification. Non-deposit funding decreases LTD_m in savings banks.

Table 4

Bank Business Models Fixed-Effects Panel Regression

Investment Banks	**LTD_m**	**LTDST**	**LADST**
	(1)	(2)	(3)
NONINTINC	1.1460	13.9389	-68.6101
	(0.9923)	(18.1004)	(55.0633)
NONDEPFUN	-0.8317	0.7554	5.0565
	(0.3222)**	(3.3061)	(7.6240)
Obs.	86	85	86
Adj. R-squared	0.86	0.21	0.11
Time fixed effect	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Commercial Banks	**LTD_m**	**LTDST**	**LADST**
	(4)	(5)	(6)
NONINTINC	0.3348	5.9092	11.7311
	(0.2823)	(9.1702)	(12.9405)
NONDEPFUN	-0.1499	10.8639	-38.7673
	(0.3239)	(9.7196)	(21.5307)*
Obs.	452	451	452
Adj. R-squared	0.02	0.10	0.50
Time fixed effect	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes
Savings Banks	**LTD_m**	**LTDST**	**LADST**
	(7)	(8)	(9)
NONINTINC	0.4018	2.3581	-0.9815
	(0.2075)*	(2.7548)	(4.4026)
NONDEPFUN	-0.1421	-0.0239	-2.1704
	(0.0550)**	(0.8127)	(1.1538)*
Obs.	706	706	706
Adj. R-squared	0.07	0.48	0.21
Time fixed effect	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes

It shows the results of our baseline model for investment, commercial and savings banks. Regressions involve panel data analysis and are estimated with bank specific fixed effects. We report the results for non-interest income and non-deposits funding activities of the full regression. Note that we winsorize all bank variables at the 99-percentile level to mitigate the impact of outliers. Time fixed effects and bank fixed effects are included in the regressions. P Cluster standard error at bank-level are reported in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ denote significance levels, respectively.

2.6 Endogeneity

The results obtained from the previous model estimations might be driven by endogeneity. Shifts in business models, or both in the profit generating and funding activities cause changes in liquidity risk.

Moreover, adding an autoregressive component to the Least Square Dummy Variable, produces inconsistent results for a dynamic panel data model with individual effects. This is true whether the effects are random or fixed - Nickell Bias (1981) because the strict exogeneity assumption of the

regressors is violated. Thus, the previous methodology implemented in banks leads to bias results due to simultaneity or omitted variables.

In order to correct and improve our estimation results, we apply a GMM dynamic panel estimator, which fits into the endogeneity issue, differencing regressors (Difference GMM), or instrumenting explanatory variables with internal instruments i.e. their own lags (System GMM).

Both estimators shall be applied where the following conditions are met:

- the process is dynamic;
- time invariant characteristics can be related with explanatory variables;
- the panel dataset is made up of short time (T) and larger observations (N);
- regressors are not strictly exogenous;
- heteroskedasticity and autocorrelation are present within individuals, not across them (Roodman, 2009).

In particular, if the dependent variable is persistent and close to being a random walk, the Difference GMM produces bias and inefficient results in a finite sample, especially when the time span is short. Poor performance is due to the use of weak instruments; therefore, a System GMM estimator has been proposed in order to solve this issue (Blundell and Bond 1998).

It has been proven that some persistence exists in the series. This estimator has a lower bias and a higher efficiency than all of the others do. Given the difficulty in finding proper instruments for the endogenous regressors, System GMM allows for us to deal with a considerable number of endogenous variables, such as bank capital, efficiency, and assets that are instrumented with their own lags. It has been proven that liquidity risk has high persistence levels; thus, we implement System GMM as more suitable than Difference GMM in this type of research.

The findings are confirmed while using two-step System GMM, as proposed by Arellano and Bover (1995) and Blundell and Bond (1998). The results for the bank independent variables are similar to the previous estimations: Larger banks (LNTA) have a significantly higher liquidity risk exposure; hence, banking size keeps its outcomes, losing some significance that is caused by endogeneity, from 1% to 5%.

The coefficient associated with capital is no longer statistically significant, meaning that capital had no influence on maturity mismatch between short-term loans and long-term deposits (see Table 5). As regards control variables, NIM as a profitability measure has a positive statistical significance, which means that, as bank NIM increases, liquidity risk decreases, which could be explained by earnings distortions, due to both asset and liability mismatch maturity (Angbazo, 1997).

Moreover, banks with diversified income may suffer an increase in maturity mismatch index concerning diversification structure. Indeed, both non-interest income and non-deposit funding weakly contribute to raising LTD_m. The lagged dependent variables are also significant, indicating that the bank liquidity risk is persistent. By simply using the LTD_m ratio, the Hansen J statistic accepts the null hypothesis that the instruments are exogenous (see Table 5, Panel 1). Time and industry dummy variables have been used as the exogenous variables for System GMM together with the maximum lag lengths for the endogenous variables.

When considering the second dependent variable, that is, total loans over total short-term borrowings, TIER is statistically significant at 5%, which could be explained by the construction of the dependent variable itself, which takes into account the total amount of loans granted by the banks covered by the total amount of short-term funding, without considering the respective (their) maturity.

It is important to compare the results achieved using our liquidity-risk indicator with respect to the ratios adopted in the literature, as it sheds some light on the importance of maturity mismatch in measuring the liquidity-risk exposure.

Notably, we also ran a pooled regression to compare the coefficients of the lagged dependent variable of System GMM with the previous regressions. We know from the theory that the value obtained from GMM should be between the value of the pooled and dynamic regressions and that this is proven in our research (see Table A3 in Appendix A).

Regarding the bank business models, our results show that savings banks are less prone to suffering from a liquidity risk maturity mismatch. Savings specialization models contribute to lowering the ratio, because the associated coefficient is negative and statistically significant (see Table 5, column 1). Savings banks' activities seem to be the soundest because of their reliance on a retail-oriented model and the differences of the credit portfolio composition.

Moreover, banks that increase their share of non-deposit funding are worse at resisting risk. As proliferation of instruments may overfit endogenous variables and lead to a loss in power, we consider a change in the number of lags in the GMM estimation model as a robustness check. Table 5 (see columns 4 to 6) shows the outcomes of the other robustness test in order to verify that our results are sufficiently robust to withstand changing lags, which considers a shorter lag length. In particular, we run different models with lag 4, which confirmed all the previous findings.

For instance, liquidity risk may occur when bank size increases as well as when there is a higher share of non-deposit funding; thus, banks that rely on different types of funding, rather than on customer deposits, are more exposed to liquidity shortages, which can lead to greater instability and a higher probability of failure as a result (Altunbas et al. 2011).

Table 5

Two-Step System GMM

	LTD_m (1)	LTDST (2)	LADST (3)	LTD_m (4)	LTDST (5)	LADST (6)
$L.LTD_m$	0.4826			0.4888		
	(0.0902)***			(0.0932)***		
L. LTDST		0.9683			0.9671	
		(0.0376)***			(0.0375)***	
L.LADST			0.9660			0.9623
			(0.0406)***			(0.0460)***
LNTA	0.0592	1.1432	0.1060	0.0435	1.1731	0.1202
	(0.0264)**	(0.6764)*	(0.6344)	(0.0228)*	(0.6048)*	(0.5934)
TIER	-0.0000	-0.0022	0.0012	-0.0000	-0.0024	0.0013
	(0.0001)	(0.0012)*	(0.0008)	(0.0001)	(0.0010)**	(0.0008)
NIM	0.1200	-0.4597	0.6707	0.0925	-0.6522	0.7990
	(0.0412)***	(1.2219)	(1.9369)	(0.0476)*	(1.1897)	(1.9498)
RWA	0.0012	0.0102	0.0422	0.0004	0.0158	0.0458
	(0.0022)	(0.0543)	(0.0443)	(0.0023)	(0.0515)	(0.0508)
ROA	-1.9971	101.0904	15.6360	-2.4253	100.7422	17.5565
	(2.3927)	(60.7734)*	(26.2530)	(2.8258)	(55.1719)*	(24.2959)
CINC	-0.1158	8.1081	0.0396	-0.1508	8.4942	0.0132
	(0.1939)	(4.8173)*	(2.9897)	(0.2343)	(4.4902)*	(3.0901)
NONINTINC	0.0867	-6.6916	-5.3309	0.0633	-5.9086	-5.0037
	(0.2192)	(4.3906)	(3.3019)	(0.2398)	(4.4216)	(3.2559)
NONDEPFUN	0.0725	-0.1076	-0.0487	0.0705	-0.0465	0.0046
	(0.0205)***	(0.4988)	(0.2248)	(0.0211)***	(0.4594)	(0.2249)
COMMERCIAL	0.0210	-0.1373	-0.4645	0.0413	-0.1789	-0.6174
	(0.0526)	(1.1381)	(1.4253)	(0.0527)	(1.0821)	(1.3878)
INVESTMENT	0.3447	-3.0834	0.6927	0.3271	-3.2270	1.2480
	(0.6692)	(2.1467)	(3.2415)	(0.6156)	(1.9050)*	(3.3324)
SAVINGS	-0.0563	-0.6842	0.2200	-0.0466	-0.7269	0.2315
	(0.0244)**	(0.5451)	(0.3899)	(0.0216)**	(0.4799)	(0.3839)
Observations	2236	2234	2236	2236	2234	2236
N_g	881	880	881	881	880	881
j	188	187	188	180	179	180
Test for AR(1) (p-value)	0.0170	0.0014	0.0061	0.0171	0.0015	0.0065
Test for AR(2) (p-value)	0.9341	0.8681	0.5996	0.9423	0.8677	0.5925
Hansen Test (p-value)	0.5507	0.2295	0.5344	0.6838	0.2611	0.4454
Time dummies	Yes	Yes	Yes	Yes	Yes	Yes

This table reports the results of the two step S-GMM estimations. The Hansen J-test refers to the overidentification test for the restriction in GMM estimation. The AR2 is the Arellano Bond test for the existence of the second order autocorrelation. Robust standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ denote significance levels, respectively.

2.7 Conclusion

Liquidity risk represents one of the most important causes of the 2007-2009 financial crisis. Since then, banking authorities have imposed new regulations in order to protect banks, and in particular depositors from high exposure to risk, to prevent further financial distress. This study proposes a liquidity risk measure with special attention to the loan to deposit relationship. Time reference is optimized and the risk component is given by the so-called "maturity mismatch".

We carried out our analysis on a European sample of different banking types in the 2011–2017 time period. With the use of our indicators, the results in Table 5 partly corroborate our previous findings: we detected empirical evidence that, as banking size increases, risk also increases, whereas liquidity risk does not decrease with a bank's capital ratio. However, our decision to use a more accurate measure of liquidity risk than those used by other scholars had different outcomes with respect to the aggregated indicators (i.e., LTDST and LADST). These outcomes have an

important effect on the way that a bank may lend or create a long-term lending relationship. Hence, along with a proper differentiation of bank business activities, the use of LTD_m is the most suitable in this type of research. During the crisis, different banking types suffered in disparate ways (Hryckiewicz and Kozlowski 2017). We identified three major business models, proving that the savings model might be the most exposed to maturity mismatch, because its share of non-deposit funds increased. The banks might not benefit from income diversification activities, which weakly increases maturity mismatches. Diversification is not an easy task. In certain circumstances, risk would increase in trying to involve both the largest and the most diverse number of customers, whereas liquidity risk may be supported by ever-growing loan-granting activities. This is consistent with the literature, which considers these types of bank to be more retail oriented. Indeed, the traditional banking model has been proven to have advantages in survival during a crisis (Chiorazzo et al. 2018)—just as it is able to maintain a strong relationship with its customers, thanks to its traditional activities. Moreover, banks aspiring to greater size and profitability must raise their share of diversified funding sources, accepting the trade-off between profitability and risk.

This analysis could be a tangible contribution to the economy through the understanding of the nature of business-model activities and funding strategies. Savings banks have a more retail-oriented business, which accounts for most customer loans and deposits, even though there is a considerable proportion of both interbank and trading activities that are increasingly at risk. In general, banks increase their share of non-deposit funding activity when difficulties in deposit-gathering arise or when a decrease in interest rates no longer makes them attractive to customers. Therefore, wholesale funding might be employed as an additional source of funding for liquidity management. This explains why savings banks or investment banks might reduce the liquidity risk through other sources of funding.

Other important factors that may affect bank liquidity risk could be considered. For instance, bank age (bank life cycle) is one characteristic that may influence profitability as well as risk in banks. Several scholars tend to exclude, for instance, de novo banks from the sample, and control for age in the estimation, since banks at the maturity stage may face different banking landscapes than those at the initial stage of their life cycle. Moreover, how bank governance decisions influence directors' strategies, focusing on the presence of a risk committee in mitigating liquidity risk appetite could be investigated. Therefore, specifically examining the effect of bank life cycles, together with an analysis of both bank governance and board characteristic, is a worthwhile direction for future research on liquidity risk.

3. MITIGATING LIQUIDITY RISK: THE ROLE OF RISK MANAGEMENT COMMITTEE

3.1 Introduction

The last financial crisis revealed the vulnerability of banks if there is a lack of sound governance which supervises main banking choices, and avoids the systemic exposure of both the financial system and the economy itself (Basel Committee on Banking Supervision, 2015). Evidence confirms that the major causes of economic distress were due to both high liquidity risk exposure and poor risk management (Diamond & Rajan, 2009; Kirkpatrick, 2009; Beltratti & Stultz, 2012; Minton, Taillard & Williamson, 2014). From this point of view, risk governance plays a role in banking survival just as much as performance goals and liquidity position. In their revised guidance, the Basel Committee on Banking Supervision (BCBS 2015) defined risk management as the tool to identify measure and control all material risk in a timely manner. Yet, the main studies on governance and risk are addressed to non-financial companies (Ferreira & Laux, 2007; John, Litov, & Yeung, 2008; Laeven & Levine, 2009); in contrast, there is less research on risk governance relationship in financial institutions (Aebi, Sabato, & Schmid, 2012; Adams & Mehran, 2012; Srivastav & Hagendorff, 2016). Several studies have analysed the structure of governance and performance, indicating that bank profitability may be affected not only by balance sheet variables, but also by decision-making and board structure (Pathan & Faff, 2013; García-Meca, García-Sánchez, & Martínez-Ferrero, 2015; Talavera, Yin, & Zhang, 2018).

One of the greatest contributions concerning corporate governance principles for banks belongs to the BCBS (2015) which published a consultative document stressing the importance of strategic decisions implemented by the senior management in support of bank business continuity. Another stream of literature showed mixed evidence in the analysis of board diversity and bank risk. Indeed there are studies supporting board diversification as a major asset because of the variety of culture, backgrounds and expertise (Fama & Jensen 1993; Anderson, Reeb, Upadhyay, & Zhao, 2011; Grove, Patelli, Victoravich, & Xu, 2011). Others argued that the more diversified the board, the higher the price to pay for the bank in terms of both internal hostility and dispute for various decisions (Van der Walt, Ingley, Shergill, & Townsend, 2006).

To date, scholars have not agreed to whether board characteristics such as gender, age and risk management committee positively or negatively influence bank risk. Mixed evidence in the literature has led us to investigate further; therefore, in order to clarify the role of directors and risk committee, we wonder whether the composition of the board of directors, inter alia, the presence and the size of risk committee have an impact on the liquidity risk exposure of European banks.

The corporate governance literature has also highlighted the importance of independent board members, their compensation salary, educational background, the board turnover and its size, the presence of a risk committee (Adams & Mehran, 2012; Erkens, Hung, & Matos, 2012; Marques & Oppers, 2014; D'Amato & Gallo, 2017).

Although most of the findings indicated no significant relationship between independent directors and default risk (Adams & Mehran, 2012; Erkens et al., 2012), some additional studies reach the opposite conclusion, namely a decrease in bank risk is associated with a higher number of independent directors (Wang & Hsu, 2013; Marques & Oppers, 2014).

In order to examine the relation between corporate governance and bank liquidity risk, we considered a sample of 31,255 European banks observations. As proxy for liquidity risk, we used loans to deposits ratio maturity mismatch, i.e. the coefficients considered are based on their long and short-term maturities respectively. Our results showed that liquidity risk is negatively associated with the presence of risk committee and board size, and positively with bank age. Additional analysis on the control variables shows that gender diversity is not a discriminant factor in analysing liquidity risk.

This research contributes to bank governance and risk-taking literature. First, we extended the existing debate on bank risk and governance by analysing board characteristics on liquidity risk. Thus, we expanded the previous literature on bank liquidity risk and governance especially considering European countries. We used a maturity mismatch index to measure liquidity risk, which is a more accurate indicator in showing bank risk exposure on the maturity ladder (Berger & Bouwman, 2009; De Haan & Van den End, 2013). Previous studies assessed liquidity risk as an aggregate value of liquid asset on total deposits without considering any time benchmark (Bonfim & Kim, 2012; Imbierowicz & Rauch, 2014; Van den End, 2016; Khan, Scheule, & Wu, 2017), but we know from theory that measuring liquidity is an ongoing process which cannot be bound in a global indicator. Second, we grouped the members of the risk committee into different categories according to their size. Indeed, the novelty of this study lies in the choice to verify if there exists a certain "optimum" threshold of bank risk committee members a bank will benefit from. Third, since our research is aimed at reducing bank risk, the main results could help policymakers plan and contribute to improving regulatory framework in order to prevent stress situations.

3.2 Hypotheses and Data

Our research aims at highlighting the fundamental role of risk committee in shielding banks against the general liquidity risk. Research in corporate governance has outlined the existing relationship between board size and risk and younger proactiveness that can provide a more accurate analysis of

the risk. Board complexity may also be a cause of insufficient monitoring over control procedures, which is why we showed a renovated interest in bank board size. On the one hand, scholars have proven that an increase in board size has led to an increase in risk too (Battaglia, Gallo, & Graziano, 2014). The numerousness of board members has a positive influence on the liquidity risk to the extent that increases board size. The phenomenon can be explained by the fact that there is greater control over the members who oversee bank's risk areas. Yet another explanation has relied on the combination of senior member experience and younger proactiveness that can provide a more accurate analysis of the risk.

Hence, in the light of these considerations, we want to test:

Hypothesis 1: Larger bank board size is negatively related to bank liquidity risk.

The banking sector holds a significant share of committees, especially those referring to corporate social responsibility (Birindelli, Ferretti, Intonti, & Iannuzzi, 2015; Gennari & Salvioni, 2019). Due to its complexity and competitiveness, agency problems are one of the major issues to build a strong connection with the depositors (Lentner, Szegedi, & Tatay, 2015). In order to establish a customer relationship, banks revised their role aiming at improving their ethic credibility and enhancing social initiative. Therefore, board committees arose for the need of implementing best practice principles, corporate governance guidelines and sustainable finance. At the same time, risk committees are established for better analysing a specific risky area of a financial institution; thus in order to ensure bank stability, the need for a proper risk committee is increasingly important.

Previous studies have chosen a mixed sample of countries: i.e. Africa, Asia, Pacific regions, America. Combining different countries, which have different supervisory statues, might lead to biased results; therefore, we posit our risk committee hypothesis solely on a sample of European banks:

Hypothesis 2: Risk committee is negatively related to bank liquidity risk.

Our Analysis was carried out on a sample taken from 31,255 bank-year observations in Europe by Bank Focus. The period considered spans from 2011 to 2017. Very few studies have investigated governance in a European sample, which is why our research contributes to the existing literature in the field of risk. Due to the unavailability of many maturities data on both assets and liabilities side, computing maturity transformation is challenging (De Haan and Van den End, 2013). We collected both microeconomic as well as governance variables; moreover we created manually risk committee figure variables by collecting information on risk governance organization. Outlier values are likely to distort the relation; given that, all variables are winsorized at the 99th percentile

—as most of the literature does (Khan et al. 2017; Nguyen et al. 2017; Köhler 2015; Berger and Bouwman 2009). Table 6 reports the descriptive statistics for our sample of both listed and unlisted banks.

LTD_m risk indicator is the ratio between long-term loans and short-term deposits. The average level of LTD_m in European banks is 52%. The average natural logarithm of the total assets is 14.76. Return on assets (ROA) constitutes 28% of total assets. Corporate governance structure is expressed by the total number of directors (BOARDSIZE), and the number of risk committee members (RISKCOMM); independent directors account for 29% of the board (INDEP), of which more than half are male, with a 82% presence (MALE). Two dummy variables account for the age of the bank and the board average age, BANKAGE and BOARDAGE respectively. Moreover, we include balance-sheet variables to control for bank size (LNTA), capital (TIER) and profitability (ROA). The data sources and classification for all variables used in this study are shown in Appendix A. Before carrying out dynamic panel regression analysis, we perform pair-wise correlation of the variables, to check for the presence of multicollinearity. The correlation matrix is reported in Table 7. Correlation can be given by the composition of the variables. Correlation coefficients with stars are significant at the 5% level and they are mostly < |0.5|, suggesting a small or medium strength correlation. Therefore, a severe multicollinearity issue does not exist in our data. The correlation coefficients of the liquidity risk variables (1) LTD_m, (2) LTDST and (3) LADST, with the proportion of banking size are 0.258, 0.247, 0.239, respectively.

Table 6

Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
LTD_m	3593	0.5211	1.0687	0.0388	8.4286
LTDST	3593	69.0713	23.5840	0.868	236.591
LADST	3593	18.8461	18.7548	1.378	229.17
RISKCOMM	2986	0.0310	0.6392	0	18
BOARDSIZE	3593	2.7024	1.1628	0	8.8199
INDEP	3593	0.2936	1.5778	0	19
MALE	3593	0.8258	0.15484	0	1
BANKAGE	3593	0.5733	0.4946	0	1
BOARDAGE	3593	0.1015	0.3021	0	1
LNTA	3593	14.7654	1.9449	10.057	20.1709
TIER	3593	15.5347	5.0554	7.33	75.64
ROA	3593	0.2863	0.5309	-5.722	8.565

Table 6 represents the descriptive statistics for all the variables employed in the regression model.

Table 7

Pairwise Pearson correlation coefficients.

	1	2	3	4	5	6	7	8	9	10	11	12
LTD_m	1.000											
LTDST	0.2153*	1.0000										
LADST	0.1381*	-0.1720*	1.0000									
RISKCOMM	-0.0029	0.0359*	0.0803*	1.0000								
BOARDSIZE	0.1027*	0.0973*	0.2817*	0.0673*	1.0000							
INDEP	0.0154	0.0226	0.2520*	-0.0038	0.2957*	1.0						
MALE	-0.0651*	-0.0081	-0.1596*	-0.0507*	-0.4317*	-0.1527*	1.0000					
BANKAGE	0.0558*	0.0977*	0.0906*	0.0386*	-0.0759*	0.0168	-0.0153	1.000				
BOARDAGE	-0.0108	-0.0194	0.0106	0.0039	-0.1288*	0.0986*	0.0991*	0.0256	1.000			
LNTA	0.1912*	0.2950*	0.3108*	0.0530*	0.4859*	0.4086*	-0.1744*	-0.0141	0.0595*	1.000		
TIER	0.0874*	-0.1325*	0.2276*	0.0340	-0.0930*	-0.0238	-0.0514*	0.1016*	0.0117	-0.1079*	1.000	
ROA	0.0118	0.0583*	0.0717*	0.0294	0.1413*	0.0503*	-0.0701*	-0.0252	-0.0108	0.0200	0.1510*	1.0000

This table reports the correlation coefficients of all variables used in the EU banking sector during 2011-2017 time period.

3.3 Model and Methodology

In order to answer the main research question of our study of the relationship between liquidity risk and governance, we developed a dynamic OLS regression model. As widely adopted in the previous literature on bank risk, the dynamic model considers past values of the dependent variable.

$$LR_{it} = \gamma LR_{t-1} + \beta_1 RISKCOMM_{it} + \beta_2 BOARDSIZE_{it} + \beta_3 INDEP_{it} + \beta_4 MALE_{it} + \beta_5 BANKAGE_{it} + \beta_6 BOARDAGE_{it} + \beta_7 LNTA_{it} + \beta_8 TIER_{it} + \beta_9 ROA_{it} + \delta_t + \varepsilon_{it}$$

The dependent variable (LTD_m) expresses liquidity risk through the loans to deposit ratio adjusted for maturity mismatch, i.e. the amount of loans granted in long term over the amount of demand deposits. The higher this ratio, the higher the liquidity risk, since the percentage of loans granted exceeds the possibility to cover up losses with deposits. The shortage of demand deposits continues to endanger bank safety on liquidity side, because of renewal uncertainty by depositors.

The explanatory variables are: board size, and board dedicated to risk management, i.e. risk committee. In particular, board size belongs to the board attributes; for each bank, size was measured as the percentage of directors over the total executives, while the members of risk committee were taken from a Bank Focus database survey, under the heading "DM: Board, committee or department".

To calculate the risk committee members, the directors who belong to the committee of the same bank were summed up. The total risk representatives were calculated in order to verify the key role of the risk committee.

Our analysis also includes several control variables. MALE accounts for the percentage of men on the board, while BOARD AGE takes into account the average age of directors as a dummy variable equal to 1 if directors are seniors. BANK AGE expresses the bank lifespan if it equals 1.

Since the literature has highlighted the importance of capital and banking size for liquidity risk, we controlled for Tier and total asset. We also controlled for the bank's profitability structure, including return on assets as proxy.

The data sources and classification for all variables used in this study are shown in Appendix A4. Since liquidity risk is affected by past values, we added the dependent variable lagged by one period to out model, in order to prove the persistence of liquidity risk over time. We estimated the proposed model with a generalized least square (GLS) random effect (RE) technique (Baltagi and Wu, 1999), which is said to be "*robust to first-order autoregressive disturbances (if any) within unbalanced-panels and cross-sectional correlation and/or heteroskedasticity across panels*"[16] (Pathan, 2009).

[16] Pathan S. 2009. Strong Boards, CEO Power and Bank Risk-taking, Journal of Banking and Finance, pp. 1-22.

Although panel fixed-effect estimation is widely implemented, our research does not require this type of estimation. Whenever we attempted to estimate time-invariant regressors as gender, or independence, they would be absorbed or dropped out 'within transformation' or the 'time-demeaning' process.

Moreover, according to Baltagi (2008), fixed-effect estimation with large observations and relatively small time, causes a loss in degrees of freedom and inconsistency. To overcome this problem, random effect (RE) estimation is proposed in the following section.

3.4 Results

In this subsection we investigate the impact of risk committee on loan to deposit ratio maturity mismatch, by estimating a dynamic model with both random effects and a pooled regression model. Since our dependent variable, namely LTD_m, is made up of loans and deposits at numerator and denominator respectively, a negative sign of the estimated coefficients positively affects liquidity risk, reducing it thanks to lending contractions or to a rise in deposit-taking.

Conversely, positive coefficients rise the ratio, leading to an increase in liquidity risk. Table 8, panel 1 to 3, reports the results of the random effects (RE) estimation with the dynamic component in order to account for bank corporate governance characteristics, which are taken into consideration in the last year of observation (2017).

We chose RE rather than fixed-effects (FE) because the last panel regression option would wipe out the time-invariant predictors due to collinearity with fixed effects. Table 8 shows that liquidity risk is negative in relation to the increase in bank risk committee - as indicated by the significant relationship RISKCOMM, at 1% significance level (see Table 8, panels 1).

The coefficient associated with risk committee size indicates that if the committee increases by 1 unit, liquidity risk is predicted to decrease by 0.02%. This calculation supports our research question and is consistent with the aforementioned theoretical background on the importance of risk committee in corporate governance for banks.

Moreover, the coefficient associated with bank size (LNTA) is also consistent with the stream of literature supporting the claim that larger banks are riskier (Battaglia et al., 2014; De Haan and Poghosyan, 2012). Bank age is positive in relation to liquidity risk, which means that older banks are more prone to suffer liquidity risk exposure. Specification models 4 to 6 are estimated with a pooled regression.

With respect to risk committee, results are similar and LTD_m decreases by an average of 0.018 % (see Table 8, panel 4). The application of the other two dependent variables (LTDS, LADST), confirms that banks could benefit from the presence of a risk committee; in particular whenever there

is a rise in the number of risk committee members, which generates a positive impact on bank liquidity exposure.

Finally, adding a first lag of the dependent variable for all three liquidity measures shows that there is an influence by past values: liquidity risk is correlated with its own past equivalent.

Once we prove that the larger the risk committee, the lower liquidity risk exposure, we want to verify if there is a threshold value for a financial institution benefiting from a certain number of directors belonging to the risk committee. We proceeded to partition risk committee into categories, with five ranges

Thus, we re-estimated the random-effect dynamic panel data model (see Table 9). Specification models 7 to 9 account for these risk committee member categories. Our findings are quite similar to the previous dynamic regression results.

In analzying the different categories of risk committee, our evidence has proven that the fourth category represents the ideal range of risk committee members in order for banks to incur less liquidity risk exposure. This group includes from a minimum of nine to a maximum of fifteen risk committee directors. The coefficient is statistically significant at 1%; therefore it contributes lowering the exposure to liquidity risk by -0.2661. Beyond the fourth group threshold, the coefficient is not significant, which means that a further increase in the number of risk committee directors has no impact on liquidity risk.

This result is in line with the previous theory supporting board complexity as an issue in preventing bank risk (Adams, 2012; Battaglia, Curcio and Gallo, 2014). Indeed, complexity may also be a cause of insufficient monitoring of control procedures, which is why we showed a renewed interest in risk committee size in order to clarify the different size categories.

The control variables showed statistical evidence for both banking age and size, which share the same positive sign, lowering liquidity as they increase by 1%. Indeed, as a bank grows, it affects liquidity risk because of past values persistence. Both "maturation" and enlargement result in more problematic strategy adoption because of liquidity risk persistence and increasingly large banking dimension, which raise risk exposures.

Indeed, if the number of directors (BOARDSIZE) increases by 1%, we can expect liquidity risk to increase by an average of 0,0002 %. This can be explained by the fact that there is greater control over the members who oversee the bank's risk areas.

Yet another explanation may depend on the combination of senior member experience and younger proactiveness, which can provide a more accurate analysis of risk (Zhou et al., 2019; Berger et al., 2014); whereas as the bank grows older (BANKAGE), liquidity risk might negatively be affected, generating higher exposure by 0.05 %.

Table 8

Dynamic Panel regression results

	LTD_m (1)	LTDST (2)	LADST (3)	LTD_m (4)	LTDST (5)	LADST (6)
$L.LTD_m$	0.7064			0.8816		
	(0.0509)***			(0.0349)***		
L. LTDST		0.8896			0.9562	
		(0.0230)***			(0.0132)***	
L.LADST			0.7806			0.9040
			(0.0443)***			(0.0258)***
RISKCOMM	-0.0200	-0.3267	0.6173	-0.0180	-0.4916	0.4994
	(0.0034)***	(0.1099)***	(0.1201)***	(0.0078)**	(0.1147)***	(0.0689)***
BOARDSIZE	0.0209	-0.3137	0.6068	0.0216	-0.2729	0.3513
	(0.0119)*	(0.1795)*	(0.2333)***	(0.0102)**	(0.1048)***	(0.1276)***
INDEP	-0.5910	-65.863	205.848	-0.5566	-77.270	132.282
	(0.4748)	-64.832	(10.4916)**	(0.5381)	-57.931	(5.8102)**
MALE	-0.0413	27.009	-33.585	0.0307	18.547	-20.572
	(0.0785)	(1.6352)*	-23.734	(0.0656)	(0.9169)**	(1.1386)*
BANKAGE	0.0598	0.5310	0.6688	0.0377	0.2552	0.2236
	(0.0250)**	(0.2841)*	(0.3783)*	(0.0193)*	(0.1922)	(0.2428)
BOARDAGE	0.0274	-0.8600	0.1230	0.0231	-0.7709	0.1641
	(0.0522)	(0.3446)**	(0.5833)	(0.0299)	(0.2566)***	(0.3344)
LNTA	0.0274	0.5391	0.4167	0.0105	0.3488	0.1063
	(0.0091)***	(0.1449)***	(0.1564)***	(0.0066)	(0.0824)***	(0.0860)
TIER	0.0054	-0.2509	0.3690	0.0046	-0.1355	0.1924
	(0.0050)	(0.1278)**	(0.1510)**	(0.0034)	(0.0926)	(0.1200)
ROA	0.0075	11.699	-0.4578	0.0068	0.6148	-0.3630
	(0.0137)	(0.3318)***	(0.4801)	(0.0146)	(0.3536)*	(0.3362)
Obs.	2986	2986	2985	2986	2986	2985
Adj. R-squared	0.80	0.94	0.87	0.80	0.94	0.87
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effect	No	No	No	No	No	No

This table reports the dynamic panel regression results with one lag of the dependent variables which express bank liquidity risk. Clustered heteroscedasticity standard errors at the bank-level account for serial correlation in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ denote significance levels, respectively. Regressions 1 to 3 are performed with random effects to account for the time-invariant corporate governance characteristics. Pooled regression results in panel 4 to 6. The potentially endogenous variables are banking size, capital support, profitability indicator. The regressions include time (year) dummies.

Table 9

Additional dynamic panel regression results: liquidity risk and bank risk committee

	LTD_m (7)	LTDST (8)	LADST (9)
$L.LTD_m$	0.7355		
	(0.0465)***		
L. LTDST		0.8809	
		(0.0212)***	
L.LADST			0.7846
			(0.0446)***
RISKCOMM=0	0.0000	0.0000	0.0000
	(.)	(.)	(.)
RISKCOMM=1	-0.0721	-2.6677	6.4607
	(0.0553)	(0.9702)***	(2.3781)***
RISKCOMM=2	-0.0837	-0.2517	3.0301
	(0.1298)	(1.0347)	(1.5265)**
RISKCOMM=3	-0.0656	-0.1938	3.7139
	(0.1350)	(1.4970)	(2.7122)
RISKCOMM=4	-0.2661	0.8496	5.7750
	(0.0719)***	(2.3170)	(2.9998)*
RISKCOMM=5	0.0480	1.2073	3.3186
	(0.0521)	(1.0606)	(1.7483)*
BOARDSIZE	0.0288	-0.2777	0.4487
	(0.0122)**	(0.1642)*	(0.1887)**
INDEP	-0.1473	-0.3521	0.4659
	(0.4612)	(6.4829)	(8.9220)
MALE	-0.0847	2.0952	-1.7098
	(0.0774)	(1.3790)	(2.0688)
BANKAGE	0.0476	0.6010	0.6946
	(0.0221)**	(0.2802)**	(0.3240)**
BOARDAGE	0.0188	-0.7614	0.2081
	(0.0444)	(0.3392)**	(0.5199)
LNTA	0.0238	0.5095	0.2008
	(0.0093)**	(0.1230)***	(0.1893)
TIER	0.0049	-0.2296	0.3624
	(0.0042)	(0.1093)**	(0.1308)***
ROA	0.0103	1.2384	-0.3485
	(0.0142)	(0.3017)***	(0.4246)
Obs.	3593	3593	3592
Adj. R-squared	0.78	0.94	0.86
Time fixed effect	Yes	Yes	Yes
Firm fixed effect	No	No	No

This table reports the dynamic panel regression results with one lag of the dependent variables which express bank liquidity risk. Regressions 7 to 9 are performed with random effects to account for the time-invariant corporate governance characteristics. Control variables used are board size, director's independence, gender, age, bank age, natural logarithm of total assets, capital level and return on assets. The sample consists of different types of banks over the period from 2011 to 2017. Clustered heteroscedasticity standard errors at the bank-level to account for serial correlation in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ denote significance levels, respectively.

3.5 Endogeneity

As widely explained in the methodology section of chapter 2, whenever we deal with a dynamic panel data analysis, the estimation results might be influenced by endogeneity; this because individual effects lead to bias results whether they are random or fixed—Nickell Bias (Nickell 1981).

In order to address this concern, we used a GMM dynamic panel data estimator, which is divided between Difference GMM, i.e. differencing independent variables and System GMM (Blundell and Bond, 1998) that instruments regressors with their lags. While the former led to bias and inefficient outcomes in the finite sample with short time, the latter shows lower bias and higher efficiency. In light of this consideration, we chose to System GMM since it appears to be best suited in our research analysis.

Our Findings were confirmed using a two-step System GMM, as proposed by Arellano and Bover (1995) and Blundell and Bond (1998). The results for the bank independent variables were similar to the previous estimations, namely that banks with a larger risk committee (RISKCOMM) have significantly lower liquidity risk exposure.

The bank life cycle (BANKAGE) is significant, which confirms that that since their date of establishment, older banks are likely to suffer from liquidity risk. Financial institutions which have been operating for a very long time, should have higher performance levels than a newbie because of previously acquired know-how (Niskanen 2006; Petersen and Rajan, 1997); moreover, achieving profitability goals is not possible without considering the trade-off between risk and return.

The lagged dependent variables are also significant, indicating that bank liquidity risk is persistent. The last section of Table 10 displays the results of the tests for first AR(1) and second-order AR(2) serial correlation, together with the Hansen tests. The Hansen J statistic accepts the null hypothesis that instruments are exogenous (see Table 10, columns 1, 2).

Time dummy variables were used as exogenous variables for System GMM together with the maximum lag lengths for the endogenous variables. It is important to compare the results achieved using our liquidity risk indicator with respect to the ratios adopted in the literature, since it sheds some light on the importance of maturity mismatch in measuring liquidity risk exposure.

Notably, we ran a pooled regression (see Table 8, panel 4 to 6) to compare the coefficients of the lagged dependent variable of System GMM with the previous regressions – we know from theory that the value obtained from GMM should be in between the value of pooled and dynamic regressions which is corroborated by our LTD_m results.

As regards main research design, the large number of board members should help in managing exposure thanks to greater control by members. Moreover, a more in depth analysis of risk by

different board executives is in line with the literature which proves a numerous board is able to make better strategy choices affecting risk decisions (Lee et al., 2013; Klein, 2002; De Andrés and Vallelado, 2008).

Even the larger board would lead to board complexity, so our findings suggest that board size does not affect liquidity risk. Outcomes support the relationship between risk committee and liquidity risk, proving that whenever a risk committee exists, it negatively influences liquidity risk, which means that it contributes to lowering risk exposure through decisions made by experts of the risk committee.

These results highlight the role of risk committee for liquidity risk, which is inevitably linked to reputation. This finding is consistent with the previous literature on the importance of having a risk committee in a bank for corporate governance (Marques and Oppers, 2014).

Table 10

Two-Step System GMM

	LTD_m (1)	LTDST (2)	LADST (3)
$L.LTD_m$	0.7360		
	(0.1793)***		
L. LTDST		0.9791	
		(0.0384)***	
L.LADST			0.8172
			(0.0550)***
RISKCOMM	-0.0239	-0.5720	0.6428
	(0.0090)***	(0.1036)***	(0.1012)***
BOARDSIZE	0.1083	2.0801	-0.3185
	(0.0797)	(1.1360)*	(1.1252)
INDEP	-4.2609	-51.8256	50.8675
	(3.9305)	(45.1558)	(30.9864)
MALE	0.1714	4.8914	-3.3367
	(0.2158)	(2.6200)*	(2.3391)
BANKAGE	0.0803	0.5558	0.3014
	(0.0357)**	(0.3650)	(0.4188)
BOARDAGE	0.0850	0.9215	-0.5541
	(0.0895)	(0.7708)	(0.8519)
LNTA	-0.0041	-0.6728	0.2727
	(0.0557)	(0.6059)	(0.4758)
TIER	-0.0011	-0.3051	0.3597
	(0.0166)	(0.1229)**	(0.1433)**
ROA	0.0816	0.2009	-0.3769
	(0.0647)	(0.7009)	(0.8309)
Observations	2986	2986	2985
N_g	1037	1037	1036
J	113	113	113
Test for AR(1) (p-value)	0.013	0.000	0.000
Test for AR(2) (p-value)	0.725	0.063	0.686
Hansen Test (p-value)	0.447	0.110	0.050
Time dummies	Yes	Yes	Yes

This table reports the results of the two step System GMM estimations. Hansen J-test refers to the overidentification test for the restriction in GMM estimation. The AR2 is the Arellano Bond test for the existence of the second order autocorrelation. N_g denotes the number of groups, and j accounts for the instruments. Robust standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ denote significance levels, respectively.

3.6 Robustness

Our evidence proved that there might be lagged impacts of the board characteristics on bank liquidity risk; thus, we conduct additional robustness checks. In particular, since the proliferation of instruments may overfit endogenous variables, and lead to a loss of power − as the number of lags approaches to the maximum (Roodman, 2009) −, we considered a change in the number of lags in the GMM estimation model as a robustness check.

Employing the two-step System GMM, we re-estimated the main regression using the variables with four years lags. The outcomes remained similar.

Robustness test, in Table 11, provides specification models 4 to 6, which lag limit was set to four. In addition to using the maximum lag length, which increase the probability of weak instruments, our supplementary analysis confirmed the previous findings.

As we can see from Table 11, changing the lag structure did not affect our main results. The coefficient for the LTD_m remains positive and statistically significant (at the 1% level) as well as the risk committee coefficient.

We have already proven that there is persistence in past values of liquidity risk; in particular, the value of LTD_m slightly increased with respect to the same value in Table 10, column 1. Bank age independent variable changes its coefficient in the robustness test, even if the sign is still positive (at the 1% level).

The small increase in the coefficient associated with bank age confirms the theory that older banks have a greater liquidity risk exposure and this could be linked to the persistence phenomenon of the risk itself.

The coefficient of the risk committee remained steady, showing that it has a positive impact on liquidity risk, since the negative coefficient can be explained mainly by a reduction in the ratio between long-term loans and demand deposits.

Tests for model identification are reported at the bottom of the table: first, the null hypothesis of no first order (AR(1)) autocorrelation is rejected in all model specifications (see Tables 10 and 11), whereas the second-order (AR(2)) autocorrelation is not rejected in specification models 1 and 3, 4 and 6 (see Tables 10 and 11), supporting the rationale for using the two step system GMM model that is well suited just to first-order serially correlated processes (Roodman, 2009).

The null hypothesis of the Hansen test is the exogeneity of the instruments, which is not rejected in regressions 4 and 5 (see Table 11).

Table 11

Two-Step System GMM

	LTD_m (4)	LTDST (5)	LADST (6)
$L.LTD_m$	0.7436		
	(0.1730)***		
L. LTDST		0.9937	
		(0.0378)***	
L.LADST			0.8185
			(0.0551)***
RISKCOMM	-0.0261	-0.6120	0.6768
	(0.0088)***	(0.1004)***	(0.1074)***
BOARDSIZE	0.1497	2.0444	-0.6794
	(0.0933)	(1.5441)	(1.2310)
INDEP	-5.0017	-60.7321	69.9023
	(3.1857)	(34.7150)*	(33.1655)**
MALE	0.3013	4.6775	-3.8524
	(0.2317)	(3.6484)	(2.5705)
BANKAGE	0.0914	0.4888	0.1013
	(0.0395)**	(0.5371)	(0.4364)
BOARDAGE	0.1033	0.9438	-0.7266
	(0.0851)	(0.9379)	(0.9194)
LNTA	-0.0149	-0.7237	0.3589
	(0.0598)	(0.5834)	(0.5053)
TIER	-0.0032	-0.2560	0.3573
	(0.0173)	(0.1212)**	(0.1356)***
ROA	0.0927	0.6335	-0.8307
	(0.0712)	(0.8973)	(0.9005)
Observations	2986	2986	2985
N_g	1037	1037	1036
J	100	100	100
Test for AR(1) (p-value)	0.0122	0.0000	0.0000
Test for AR(2) (p-value)	0.7226	0.0693	0.7215
Hansen Test (p-value)	0.6278	0.1976	0.0365
Time Dummies	Yes	Yes	Yes

This table reports the results of the two step System GMM estimations. Hansen J-test refers to the overidentification test for the restriction in GMM estimation. The AR2 is the Arellano Bond test for the existence of the second order autocorrelation. N_g denotes the number of groups, and j accounts for the instruments. Robust standard errors in parentheses * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ denote significance levels, respectively. In order to avoid endogeneity problems for the numerical variables, we used the variables lags t=1 to t=4 as instruments.

3.7 Conclusion

Corporate governance for banks has a fundamental role in the decision-making process which allows banks to manage risk exposure, to evaluate the efficiency of the board and to strengthen transparency mechanisms. The general objective of this study was to underline the importance of corporate governance in the area of liquidity risk, in which an inappropriate approach to liquidity management strategies left some doubt due to vague regulatory framework as what occurred during the crisis (European Commission, 2010). Using an indicator of maturity mismatch between loans and deposits as a dependent variable, we improved previous studies concerning bank risk and board characteristics. Liquidity risk should not be measured as an aggregated value, because of the difference in maturities given by the bank itself. We identified deposits with maturity less than 3 months or equal to 3, 6, 12 months and 5 years, and applied the same applies for to loans. Against this background, we computed a liquidity risk index based on maturity mismatch; moreover, we confirmed that the most part of bank gathering relies on demand deposits, which rotate quickly

resulting in a rise in liquidity risk raise. Thus, our measure of liquidity risk is based upon on the stock approach, using the loans to deposits ratio as claimed by the literature to be an adequate risk indicator for liquidity (Van den End, 2016; Khan et al., 2017).

Notably, by focusing on the number of directors and the presence of a risk committee, our study provides evidence that board complexity neither leads to a reduction nor to an increase in liquidity risk, whereas banks still need an additional risk committee member in order to handle liquidity to lower risk exposure. The Basel Committee (2015) highlighted the key role of the presence of a risk committee in banks with regard to capital and liquidity management and other different types of risk, namely credit, market, operational and reputational risks. In this study, we supported previous findings on the importance of the creation of a risk committee and we provided evidence that if the size of the risk committee increases, it could be beneficial in terms of liquidity shortages. This result can be connected to the combination of different members' backgrounds and financially-skilled expertise in the committee itself (Minton, et al. 2014.; Anderson et al. 2011; Jensen 1993). Indeed, our data showed that the highest number of directors belonging to a risk committee is 24; even if no threshold was laid down in the Committee Document, we are confident that the presence of a risk committee can help policymaking deal with financial decisions as well as stress scenarios. More precisely, we showed that in our European sample, the banks with between 9 and 15 risk committee members, positively affected liquidity risk. As for the other corporate governance characteristics, the independence of directors from the board, did not lead to a reduction in liquidity risk; the information provided by management to independent directors, can be manipulative and misleading (Kravet and Muslu, 2013; Naciti, 2019). Gender diversity is not a discriminant factor in analysing liquidity risk in our sample of European banks. Even if, previous studies promoted the idea that male figures could better handle risky decisions, there is no evidence in favour of females being risk adverse with respect to males (Schubert, Brown, Gysler, & Brachinger, 1999).

This analysis helps understand the effectiveness of risk committees with regard to the latest Document published by the Basel Committee (2015). Even if the former Document on corporate governance principles for banks *"is intended to guide the actions of board members, senior managers, control function heads and supervisors […] including both Committee member and non-member jurisdictions";* there is no mention of any risk committee size set threshold.

This research contributes to bank governance and risk taking literature. We extended the existing debate on bank risk and governance by analysing board characteristics on liquidity risk. Thus, our research aimed at reducing bank risk, and helping policymakers' plans to improve regulatory framework in order to prevent stress situations. We found a threshold of risk committee supervisors within which liquidity risk diminishes. The board of directors should operate with a "duty of care"

for depositors as well as creditors; in doing so, less risky decisions must be taken to preserve the interests of these parties, and to enhance the ability to face stress scenarios and handle long-term risk.

Banks play a fundamental role in the economic and social development of a territory and for this reason, they relate to the various subjects, public and private, who live and work in the same context. Since stakeholders represent the main parties in financial institutions, they influence banking group and in turn are influenced by it. On the other hand, the banks themselves have an interest in establishing a lasting relationship with society as a whole, which requires consumers' cooperation and trust. Stakeholders, shareholders, customers, employees and suppliers are interlocutors with whom banks relate every day. Therefore, how the perception of all the involved players affects liquidity risk could be investigated. Moreover, it would be interesting to monitor which interaction between numerator and denominator have a great impact in liquidity risk fluctuations whenever we consider maturity mismatch. Thus, specifically examining the change in deposits as well as investment choices is a worthwhile direction for future research on bank confidence risk.

Appendix

Table A1

Description of Variables

Variable	Description	Source
LTD_m	Fraction of maturity mismatch loans divided by deposits	Orbis Banks (2018)
LTDST	Fraction of total loans divided by total deposits and short-term funding	Orbis Banks (2018)
LADST	Fraction of liquid assets over deposits and short-term funding	Orbis Banks (2018)
LNTA	Natural logarithm of total assets for banking size	Orbis Banks (2018)
TIER	Capital Ratio equity divided by total assets	Orbis Banks (2018)
NIM	Difference between interest income and interest expenses relative to the amount of interest-earning assets	Orbis Banks (2018)
ROA	Net income by total assets, as profitability of bank assets.	Orbis Banks (2018)
CINC	Efficiency Ratio: total operating expenses by total operating income. A lower ratio means that the bank is more efficient	Orbis Banks (2018)
RWA	Risk weighted assets over total assets	Orbis Banks (2018)
NONINTINC	Non-interest income divided by total income	Orbis Banks (2018)
NONDEPFUND	Non-deposit funding divided by total liabilities	Orbis Banks (2018)

Table A2

The Variance Inflation Factor (VIF) and Tolerance Test Statistics.

Variable	VIF	1/VIF
$L.LTD_m$	1.12	0.892157
LNTA	2.69	0.372034
TIER	2.1	0.476446
NIM	1.5	0.665971
ROA	1.01	0.987571
CINC	1.22	0.821309
RWA	1.64	0.60795
NONINTINC	1.09	0.918706
NONDEPFUND	1.16	0.865695
Mean VIF	1.5	

Source: Stata Statistical Software

Table A3

Pooled dynamic regression

	LTD_m	LTDST	LADST
	(1)	(2)	(3)
$L.LTD_m$	0.8678		
	(0.0110)***		
L. LTDST		0.9767	
		(0.0058)***	
L.LADST			0.9296
			(0.0073)***
LNTA	0.0131	0.3529	0.0316
	(0.0057)**	(0.1057)***	(0.1064)
TIER	-0.0000	-0.0008	0.0006
	(0.0000)***	(0.0002)***	(0.0003)**
NIM	0.0047	-0.6400	-0.2237
	(0.0105)	(0.1916)***	(0.1977)
RWA	-0.0001	0.0381	0.0195
	(0.0006)	(0.0115)***	(0.0117)*
ROA	-0.0532	0.4297	0.0209
	(0.0141)***	(0.2589)*	(0.2669)
CINC	-0.0010	0.0162	-0.0345
	(0.0004)**	(0.0080)**	(0.0081)***
NONINTINC	-0.0007	-1.7219	0.7997
	(0.0426)	(0.7915)**	(0.8152)
NONDEPFUN	0.0165	0.3652	-0.2621
	(0.0099)*	(0.1896)*	(0.1872)
Observations	2236	2234	2236
R-squared	0.7665	0.9467	0.9007
Year dummies	Yes	Yes	Yes

It shows the pooled regression results of our baseline model. Note that we winsorize all bank variables at the 99- percentile level to mitigate the impact of outliers. Robust standard error are reported in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01 denote significance levels, respectively.

Figure 1

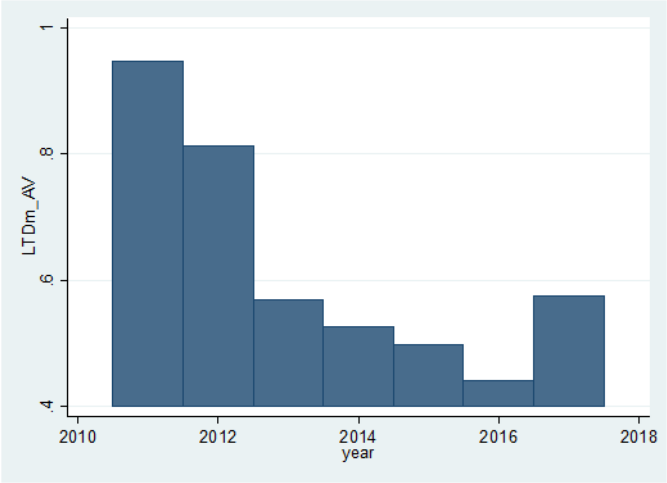

Fig. 1. Average of loans-to-deposits maturity mismatch (LTD_m) of the EU banks. The LTD_m remained stable from the second part of 2010 to 2012, decreased from 2013 to 2016 and increased from 2017.

Table A4

Description of Variables

Variable	Description	Source
LTD_m	Fraction of maturity mismatch loans divided by deposits	Authors' elaboration
LTDST	Fraction of total loans divided by total deposits and short-term funding	Orbis Banks (2018)
LADST	Fraction of liquid assets over deposits and short-term funding	Orbis Banks (2018)
RISKCOMM	Percentage of directors who are in the risk committee	Authors' elaboration
BOARDSIZE	Natural logarithm of total directors	Authors' elaboration
INDEP	Percentage of total directors who are independent	Authors' elaboration
MALE	Percentage of total directors who are male	Authors' elaboration
BANKAGE	Dummy variables of the bank age = 1 if bank has more tha 30 years from the establishment date	Authors' elaboration
BOARDAGE	Dummy variables of the average directors age = 1 if directors are over 60 years old	Authors' elaboration
LNTA	Natural logarithm of total assets for banking size	Orbis Banks (2018)
TIER	Capital Ratio equity divided by total assets	Orbis Banks (2018)
ROA	Net income by total assets, as profitability of bank assets.	Orbis Banks (2018)

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