TUNISIAN BANK ASSET-LIABILITY MANAGEMENT: A CANONICAL CORRELATION ANALYSIS

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Abstract

The aim of this paper is to analyze asset-liability management behaviour in Tunisian banks between 2000 and 2014. The liberalization process in the Tunisian economy coupled with global developments exposed banks for various kinds of risks (interest rate risk, liquidity risk, exchange risk, operational risk etc...) which have a direct impact on their profitability and efficiency. Then asset liability management is one of a most important tool for decision making that sets out to maximize stakeholder value and an instrument to measure the sustainability of the financial sector in a country.

A sample consisting of public, private, and foreign banks operating in the Tunisian territory was considered and the multivariate statistical technique, canonical correlation analysis has been used to capture the nature and strength of the relationship between the assets and liabilities in these banks. Assets analyzed were subdivided into fixed assets, liquid assets, short-term loans, long-term loans, short-term securities and long-term securities; and liabilities into net worth, borrowings, short-term deposits and long-term deposits.

From the analysis, different degrees of the association have been found among various constituents of assets and liabilities and among banks. In most cases, there has been a poor and judicious matching of assets and liabilities in terms of their explicit cost and revenue as well as their maturity and liquidity. It is further observed that most Tunisian banks were asset-managed: these banks were actively managing assets and liabilities and were dependent on how well the assets are managed.

Keywords: Asset-Liability Management, Tunisian Banks, Public Banks, Private Banks, Foreign Banks, Canonical Correlation Analysis

1. INTRODUCTION

A relatively young sector, the Tunisian banking sector was born after the country's independence in the 1950's and has gone through major transformations. Over the years, this sector remained and will continue an important pillar of national economic financing and its ability to create jobs. In fact, in this country economy is financed in the majority by indebtedness by 24 banks, 21 resident banks monopolize a part of 90.1% of total assets, 92.2% of loans and 95.6% of deposits. In 2013, total assets of commercial banks represented 97% of the Gross Domestic Product (GDP). Among these banks, 11 are quoted on Tunisia Stock Market. They are the Banque Nationale Agricole (BNA), Banque de l'Hbitat (BH) and Société Tunisienne de Banque (STB) whose capital is mainly detained by the state, the Attijari Bank, Arab Tunisian Bank (ATB), Union Internationale des Banques et Union Bancaire de Commerce et de l'Industrie (UBCI), whose capital is mainly foreign, as well as private banks like the Banque Internationale Arabe de Tunisie (BIAT), the Banque de Tunisie (BT) and Amen Bank (AB). As for the non-quoted banks, they are to the number of ten. They are the Arab Banking Corporation (ABC), the Banque de Financement des Petites et Moyennes Entreprises (BFPME), the Banque Tuniso-Koweitienne (BTK), the Banque Tuniso-Libyenne (BTL), the Banque Tunisienne de Solidarité (BTS), the CITY BANK, the Société Tuniso-Saoudienne d'Investissement et de Développement

(STUSID Bank), the Banque Zitouna, the Banque Franco-Tunisienne (BFT) and the Tunisian-Qatari Bank (TQB) recently become Qatari National Bank (QNB), following the acquisition by the Qataris of the Tunisian involvement in the capital. Al Baraka Bank who had until 2013 an offshore bank statute has just gotten the approval for an activity on shore that became efficient since 2014.

In this sector, deposits are the banks' biggest funding source. In 2011, the growth rate of deposits reached only 5%. This compares to relatively strong loan growth of almost 14%, which has left banks in a challenging position to attract enough resources to support the increase in lending (European Investment Bank, 2013). For a better collection of resources, banks concentrated on the extension of their agency network with the goal to come closer better of the population. Banks quoted monopolize more than 92% of the global network with more than 1 326 agencies. The network of banks non-listed nearly doubled in three years from 58 agencies and representations in 2009 to 109 in 2012. On this period, Attijari Bank, BIAT and Amen Bank, recorded the strongest evolutions of their networks, with 47 new agencies for Attijari Bank, 38 for the BIAT, and 33 new agencies for the Amen Bank. Borrowings and special resources are the second biggest Tunisian bank funding source. The evolution of this constituent remained on average weak until 2011reaching 8% of bonds. The evolution accelerated in 2012 to reach 9%. The third Tunisian bank funding source is the equity. These entities are implied since 2008 to strengthen their stable and long-term resources to face regulatory requirements in equity in relation to the level of risk supported and to maintain a dynamic of growth of their activities. Then, banks maintained a rate of distribution of their profits inferior to 50% until 2012 and several banks as the BNA, the BT and the ATB operated increases in capital.

The non-listed banks monopolize about 14% of the equity of the banking sector because of their weak size and the limited level of their profits. Their equities declined slightly and overall deficit worsened in years 2011 and 2012. This deficit has been mainly caused by the BFPME that accused a fold of its activity accompanied by a rise of the set of its loads, and in the least measured by the Bank Zitouna. Uses are in 80% constituted by loans. These latter progressed by 8,3% in 2012. This progression is caused by the growth of the overall domestic demand by 9,9%, notably the household demand (10,2%) following the increase of the capacity of indebtedness following the rise of their incomes.

The three public banks hold about 38% of banking assets, 39.1% of credits and 34.2% of deposits. This means that their fate is of immense importance to the country's economic equilibrium. So, these banks attract the interest of many private investors. Such interest has been publicly manifested through the speculations made on the banks publicly traded stock. Nevertheless, the health of these banks has been the subject of public discussion from the early days of 2011. Many analysts and financial experts have expressed their concerns that the Tunisian economy is at great risk if we do not find immediate solutions for the grave situation these banks are facing. Private banks retain 28,1% of the total assets, 29% of credits and 31,9% of deposits, foreign banks detain 30,1% of assets, 29,1% of credits and 31,7% of deposits; and the mixed banks detain 3,1% of assets, 2,8% of credits and 2,2% of deposits.

Since 1970 and with the deregulation and globalization of financial markets, Tunisian banks, like banks across the globe, have been exposed to various types of risk, especially liquidity risk, interest rate risk and change rate risk. Liquidity risk is related to intermediation activity. It designates the probability for a bank not to have funds of its depositors at the moment or these want to withdraw their money or to generate cash to cope with an increase in assets. This risk arises from funding for long-term assets by short-term liabilities and can result in the insolvency of the bank that becomes unable to meet the bank's liabilities as they become due. Then measuring and managing liquidity needs are vital for banks since it can reduce the probability of an adverse situation developing. Interest rate risk is the risk where changes in market interest rates might adversely affect bank's financial condition by affecting both its current earnings and its net worth. Banks obtain finance on the financial markets by other financial organisms. The change rate risk exists when rates, courses of change or quotations vary a lot and bank will support these decreases. These risks are translated by result deterioration, then a decrease of rating. This induces difficulties for banks to obtain funds necessary to finance their activities or obtain them with high costs. Risks may also reduce the bank solvability. Then asset value will be reduced and equity affected. As a result, the objective of maximization of shareholder wealth is not reached anymore. The management of these risks is, therefore, an urgent imperative and requires a financial approach of the balance sheet of the bank. This is then the role of the Asset-Liability Management (ALM).

This practice is developed by the Anglo-Saxon financial institutions from years 1970 and knows a remarkable flight for some years to become an essential component of financial management. It is a systematic approach defined as the management of all assets and liabilities of a bank. It involves an assessment of various types of risks and altering the asset-liability portfolio in a dynamic way of protection to the risk arising out of the asset/liability mismatch. ALM consists of a framework to define measure, monitor, modify and manage liquidity interest rate and change rate risk. Then it is the ongoing process of formulating, implementing, monitoring and revising strategies related to assets and liabilities to achieve an organization's financial objectives, given the organization's risk tolerances and other constraints (the Society of Actuaries, SOA, 2003).

The purpose of this paper, therefore, is to explore portfolio-matching behaviour, in terms of the nature and strength of the relationship between assets and liabilities in Tunisian banks using the multivariate statistical technique, canonical correlation. Then, the remainder of the paper proceeds as follows. In Section 1, we will present the main empirical studies dealing with asset-liability management in banking sectors around the world. In section 2, we will present used methodology and in section 3, we will present and interpret empirical results.

2. LITERATURE REVIEW

There have been a good number of studies relating to asset-liability management in banks. In the following, we present the main results.

Since 1966, Hester and Zoellner had employed

statistical cost accounting (SCA) method on US banks and through their research, they found statistically significant coefficients for most of the categories of assets and liabilities and rejected the null hypothesis that there is no relationship between them.

Gardner and Mills (1991) discussed the principles of asset-liability management as a part of banks' strategic planning and as a response to the changing environment in prudential supervision, e-commerce and new taxation treaties. Their text provided the foundation for subsequent discussion on asset-liability management.

Haslem et al., (1999) used canonical analysis and the interpretive framework of asset-liability management to identify and interpret the foreign and domestic balance sheet strategies of large American banks. They concluded that the least profitable very large banks have the largest proportion of foreign loans, but they focus on asset-liability matching strategies. Conversely, the most profitable very large banks have the smallest proportions of foreign loans but they emphasize foreign balance-sheet matching strategies. In the same year, Haslem et al used canonical analysis and the interpretive framework of asset/liability management in order to identify and interpret the foreign and domestic balance sheet strategies of large U.S. banks in the context of the "crisis in lending to LDCs". In their study, it was revealed that the least profitable very large banks have the largest proportion of foreign loans, but they focus on asset/liability matching strategies.

DeYoung R and Chiwon Yom (2008) used canonical correlation analysis to examine how the relationships between asset and liability accounts at U.S. commercial banks changed between 1990 and 2005. Their results showed that asset-liability linkages are weaker for banks that are intensive users of risk-mitigation strategies such as interest rate swaps and adjustable loans. Asset-liability linkages are stronger at large banks than at small banks, although these size-based differences have diminished over time, both because of increased asset-liability linkages at small banks and decreased linkages at large banks.

For British banks, Kosmidou et al., (2004) found through that liability management contributes more to creating the profitability.

In India, Vaidyanathan (1999) discussed many issues in asset-liability management and elaborates on various categories of risk that require being managed by banks. He concluded that in the initial stages Indian banks were primarily concerned about adhering to statutory liquidity ratio norms. In the post liberalization era where banks moved from administered interest rate structure to market-determined rates, it became important for these banks to prepare themselves with some of these techniques, in order to immunize themselves against interest rate risk. The author concludes that the problem gets accentuated in the context of change in the main liability structure of the banks, namely the maturity period for term deposits. He also observed that many banks had inadequate and inefficient management systems. In 2001, Vaidya and Shahi suggested in particular that interest rate risk and liquidity risk are two key inputs in the business planning process of banks. These two risks were been found important in Indian balance sheets (Charumathi, 2008). Thus, Indian public banks must pay attention to their functioning. They should select borrower very cleverly. Sometimes, the perspective of management also defines the risk profile of banks which further determines the liquidity and profitability tradeoff (Chaudhary and Sharma, 2011). In 2004, Ranjan and Nallari used canonical analysis to examine asset-liability management in Indian banks in the period 1992-2004. They found that, other than foreign banks, all other banks could be said to be liability-managed. Private sector banks were mostly focused on profit generation, while nationalized banks seem to be excessively concerned about liquidity. The Basel committee for banking supervision provides important guidelines for measuring interest rate risk sensitivity. Canonical correlation analysis has been used by Chkrabraborty and Mohapatra (2008) to capture the nature and strength of the relationship between the assets and liabilities in Indian banks. They concluded that majority of banks have a good asset-liability framework in place. Results also indicated a strong relationship between fixed assets and net worth for all groups of banks.

Dash et al. (2005), construct a research on asset-liability management for banks using a linear programming model. Their research focuses on the banks' sensitivity to liquidity, profitability, and interest rate risk. They show an optimal set of assets and liabilities in banks resulting in a growing profitability and constant 23 liquidity position. Their results show that banks in the public sector present the most satisfactory results in accordance with their liquidity and their low amount of interest rate risk. It is stated that the key to success for banks should be the accounting of liquidity, profitability and interest rate risk.

Lileikiene, (2008) highlights the significance of the asset liability management strategy for every bank in order to improve their performance. His research also states that net interest income (NII) is a crucial ratio that every country should take into account. For that reason, there are three NII strategies for a successful asset liability management. The author suggests that banks should be careful before choosing the appropriate ALM strategy for them. Lileikiene states that "Trying to hedge against interest rate fluctuations and instability in the financial market the best option would be zero strategies, because of the bigger NII, the higher risk the bank faces."

Dash and Pathak (2011) proposed a linear model for asset-liability assessment. They found public Indian banks are having the best asset-liability management, a strong short-term liquidity position but with lower profitability. Private banks have a comfortable short-term liquidity position, balancing profitability.

Prathap (2013) used canonical correlation to capture the nature and strength of the relationship between the assets and liabilities in a sample of nationalized, private, and foreign Indian banks between 1996 and 2004. They concluded that majority of banks have a good asset-liability framework in place. Their study also indicates a strong relationship between fixed assets and net worth for all groups of banks. Most of these banks, unlike foreign banks, are liability-managed banks because they all borrow from money market to meet their maturing liabilities. The private banks are highly aggressive for profit generation and use the short-term funds for long-term investments. In the same year, Sheela and Bastray (2013) examined the effect of Asset-Liability-

Management on Commercial banks profitability in Indian financial market by taking into consideration the two public banks. From the analysis, it is found that the two banks have a good ALM framework in practice. The study also indicates a strong relationship between fixed assets and net worth for both the banks. In 2013 too, Kanhaiya Singh analyzed the impact of measures and strategies Indian banks undertook to manage the composition of asset-liability and its impact on their performance in general and profitability in particular. She concluded that there are serious attempts by banks to minimize the asset liability mismatch since the implementation of Reserve Bank of India (RBI) guidelines in 1997. Banks have made adequate follow up and monitoring arrangements at different levels, individual banks have also fixed maximum tolerance limits under each time bucket for the mismatch for close monitoring. The study suggests much scope for banks to improve profitability by monitoring and reducing short-term liquidity. The further break up of data into smaller rime buckets indicates negative gap. To fill the short-term liquidity gap, banks resort to market borrowings at a higher rate of interest which reduces interest margin and profitability of banks. Banks have greater scope to manage interest rate risk through various techniques.

In a study of the Indian market too, Meena and Dhar (2014) concluded that the liquidity structure of banks in India is stable but the amount of cash they maintain with them can create problems in the long run as deteriorate their profits in consequence.

Toms (2014) makes a comparison of discount rates between an accounting- based risk management approach (ABRM) and the capital asset pricing model (CAPM). Discount rates have often been approached by the CAPM while author strongly suggests that ABRM is a useful model that provides better results, compared to CAPM. Regarding results, it is shown that in the majority of the tested firms, the cost of capital is lower when the accounting-based risk management model is used. In particular, the obtained discount rates are similar in both models (CAPM, ABRM), while the cross-sectional distribution present differences with the use of the two aforementioned models. This fact gives the indication that the discount factors obtained from the capital asset pricing model exaggerate the systematic risk.

In 2014 too, Sun et al. found out that liability management strategy is used for short-term gaps and asset management strategy is applied for long-term gap management by both conventional banks and Islamic banks. Both conventional and Islamic banks found to generally experience positive long-term gaps and negative short-term gap, indicating that banks attempt to use short-term financing to fund for short and long-term loans, advances and investments, correspondingly.

In Tunisia, Chakroun and Abid (2013) make an analysis of a commercial bank's asset liability management for the year 2007. To do this, they implement a Goal Programming (GP) model in order to improve the ALM of the tested bank. The model determines the optimal structure of the balance sheet for the year 2007. To reach their objective, they have analyzed the 2006 bank's balance sheet facing several conflicting goals such as solvency, liquidity, maximizing net interest margin and increasing deposits and loans under the structural, political, and regulatory constraints. The solution of this model involves the minimization of the sum deviations from the target values of goals. Empirical results present some significant differences with current values of the tested bank's balance sheet and strongly support that a 24 Goal Programming approach provides better results compared to the strategy used by the bank. Specifically, the paper indicates that a bank with the use of a GP model can not only enhance its liquidity and maximize its loans and deposits, but also meet its target values efficiently.

Once the essential of empirical studies is presented, we will then present the methodology used to analyze the behaviour of Tunisian banks in the field of asset-liability management.

3. METHODOLOGY

3.1. Data

The dataset consists of annual financial information for a panel of 24 banks and covers the period between 2000 until 2014. These banks are the BNA, BH, STB, ATB, UIB, UBCI, BIAT, BT, AB, ABC, BFPME, BTK, BTL, BTS, BTE, Attijari Bank, City Bank, STUSID, BFT, TQB, BB, BAT, NAIB and IMMB. Most of these banks finances in majority national economy, 21 resident banks of them monopolize 90.1% of total assets, 92.2% of loans and 95.6% of deposits and total assets of commercial banks represented an important part of the Gross Domestic Product (GDP). Financial information is obtained from annual reports of Tunisia's Professional Association of Banks and Financial Institutions.

3.2. Models used in the asset-liability management

Following Rosen and Zenios (2006), asset-liability management strategies can be grouped into four broad categories: single-period static models, single-period stochastic models, multiperiod static models, and multiperiod stochastic models.

As their name suggests, single-period models are concerned with optimal investment over a single time horizon. Their length can vary widely depending on the application. For example, a bank might be concerned with which assets to purchase today to generate a certain target return over a week. In contrary, multiperiod models allow investors to rebalance their portfolios over several periods, adjusting to market conditions and perhaps new investment goals. While single-period strategies may perform well in some settings (Hakansson and Ziemba, 1995), multiperiod models generally too restrictive for most practical applications.

- *Single-period static models*

The models in this category hedge against small well-defined changes from the current state of the variables of interest, such as interest or exchange rates. Portfolios are structured to behave in a predictable and acceptable manner to the investor. In this category, we distinguish Immunization, Dedication and Gap/surplus management. These strategies are standard within the banking and insurance industries. Introduced by Redington (1952) and analyzed recently by de la Grandville (2007), portfolio immunization aims to make a portfolio insensitive to small changes in a specified factor, most frequently interest rate movements. The dedicated portfolio is one in which asset and liability cash flows are fully matched to eliminate exposure to changes in the factor(s) of

interest. Gap measure usually refers to the difference between the value of assets and liabilities, an institution may be interested in minimizing the gap or keeping it within an acceptable boundary. Used typically when there is excess wealth to be invested, Surplus may be defined in the same manner as the gap metric. These strategies are standard within the banking and insurance industries.

To allow greater flexibility and more realistic modelling frameworks, they have been extended to accommodate uncertainty and multiperiod investment horizons. For example, Zenios (1995) discusses how to adapt the static immunization and dedication methods to a stochastic environment by means of Monte Carlo simulations; Monfort (2008) studies immunized portfolios using the surplus measure with random processes for assets and liabilities; Albrecht (1985) and Gajek (2005) investigate portfolio immunization under stochastic interest rates; and Waring (2004a,b) defines an efficient frontier for surplus wealth.

- *Single-period stochastic models*

These models describe the distribution of returns of assets and liabilities due to random market movements. Unlike the static models, stochastic models explicitly incorporate and quantify risk, but they are concerned with uncertainty at the end of a single investment horizon only. The classical MV approach is a prime example of single-period stochastic modelling, where the risk is measured by the variance of the portfolio. Most risk measures used in this category aim at minimizing downside asset movements;

- *Multiperiod static models*

A multiperiod static environment is one where investors can rebalance their portfolios over several periods within a well-defined environment, or where changes in the factors driving model variables are well defined. Multiperiod static models generally rely on variants of risk measures and industry-specific risk metrics. However, without the element of risk, such models are of limited practical use.

- *Multiperiod stochastic models*

These models allow both assets and liabilities to evolve randomly over time following a probability distribution. Investors may change the compositions of their portfolios over the investment horizon possibly reversing their previous decisions due to the evolution of the driving factors. There are a number of ALM frameworks in this category such decision rules, scenario analysis/simulation, stochastic optimal control, and stochastic programming.

Decision rules are strategies to determine portfolio allocation in each time period; they do not change over time. A well-known example is the fixed mix strategy, where at the end of each time period the portfolio manager adjusts the portfolio composition to keep the proportions of assets and liabilities in a fixed. Theoretically speaking, variations of this approach may be optimal for long-term investors even in the presence of transaction costs (Merton, 1990). Decision rules reduce the number of decision variables, which may improve computational efficiency. One drawback of the decision rules approach is its independence from the risk aversion of the investor. However, Mulvey and Ziemba (1998) point out that decision rules can be adapted to reflect changes in risk appetite; for example, they can be used to accommodate greater tolerance for risk with higher levels of wealth (Perold and Sharpe, 1988).

Scenario analysis/simulation: A scenario represents a single coherent forecasted realization of random variables driving the model over the planning horizon. The number of scenarios can be small or large, depending on the application and the available computational power, and the scenarios may be weighted appropriately. The goal is to construct a set of scenarios representing the universe of all possible outcomes, and the challenge is to sample the entire state space in higher dimensions. Simulation is a popular technique in reserves management (for example, Bolder, 2003 and Coche et al., 2006). Related simulation research topics include: generating consistent scenarios, estimating the fat tails that are typical for asset returns, which can be done using extreme value theory, reflecting co-movements and the covariance structure between assets and liabilities and selecting representative scenarios and aggregating these in a meaningful manner to prevent arbitrage opportunities (Klaassen, 1998).

Stochastic optimal control: This method relies on a small number of state variables whose evolution is modelled by a joint Markov process. Because the size of the stochastic optimal control problem grows exponentially with the number of state variables, this approach is limited to situations where the state of the world can be represented by few factors. This becomes quite challenging computationally and may explain why there do not seem to be any practical or commercial applications of stochastic optimal control in asset management. Additional challenges of control problems are: the output is sensitive to the model parameters, as in the MV framework, and approximation errors may arise due to the discretization of the state space.

Stochastic programming: The main difference between stochastic optimal control and stochastic programming is the way in which uncertainty is modelled. While in control problems the state space is frequently continuous (discretized by numerical solvers), stochastic programs usually describe uncertainty by using a branching tree in a discrete-time setting. Each node of the tree represents a joint realization of all random factors, corresponding to a particular outcome of the factors at a point in time in the optimal control set-up. Conditional decisions are made at each node subject to modelling constraints; hence the model expands the decision space based on the conditional nature of the scenario tree.

Stochastic programming has been popular in practice for its advantages over other ALM modelling structures: a tree structure can incorporate scenarios with low probability but high impact without having to generate thousands of new scenarios (Claessens and Kreuser, 2007). Another benefit is that it can accommodate a large number of random factors driving the model since at each node of the tree the realizations of all factors are expressed by a given number of branches. The problem is selecting these few realizations to capture uncertain outcomes adequately and that one requires highly efficient computational algorithms if the problem has many decision periods and variables.

3.3. Model and variable specifications

The approach used to analyze traditions of Tunisian banks in asset-liability management is the canonical correlation analysis (CCA). Developed by Hotelling

(1935, 1936), this approach is the most generalized member of the family of multivariate statistical techniques. It is usually used to make sense of cross-covariance matrices analysis. Whereas multiple regressions predict a single dependent variable from a set of multiple independent variables, canonical correlation simultaneously predicts multiple dependent variables from multiple independent variables. So, in situations with multiple dependent and independent variables, canonical correlation is the most appropriate and powerful multivariate technique.

The finality of canonical correlation is to quantify the strength of the relationship between the two sets of variables (independent and dependent). It identifies the optimum structure or dimensionality of each variable set that maximizes the relationship between these two variable sets. It deals with the association between composites of sets of multiple dependent and independent variables. In doing so, it develops a number of independent canonical functions that maximize the correlation between the linear composites, also known as canonical variates, which are sets of dependent and independent variables. Each canonical function is actually based on the correlation between two canonical variates, one variate for the dependent variables and one for the independent variables. Another unique feature of canonical correlation is that the variates are derived to maximize their correlation. Moreover, canonical correlation does not stop with the derivation of a single relationship between the sets of variables. Instead, a number of canonical functions (pairs of canonical variates) may be derived.

If we have two multivariate sets of variables (vectors) $X = (X_1, ..., X_n)$ and $Y = (Y_1, ..., Y_m)$ of random variables, and there are correlations among the variables, then canonical-correlation analysis will find linear combinations of the X_i and Y_j which have maximum correlation with each other. Then, this technique measures the degree to which one set of correlated variables is useful for explaining the variance in another set of correlated variables.

In the context of bank asset-liability management, this technique is used to capture, in a single summary measure, whether the maturity mix of banks' liability accounts reflects the maturity mix of banks' asset accounts. Moreover, the technique also identifies the most important underlying relationships between and among the individual elements in the two vectors, which allows us to infer which assets banks tend to match with which liabilities in the course of performing asset-liability management. Finally, canonical correlation imposes no structure on the data and makes no assumptions about the causal direction between the two vectors.

More explicitly, canonical correlation analysis determines linear combinations of the various asset accounts that are most highly correlated with linear combinations of the various liability accounts. Moreover, because the complex relationships between and among asset and liability accounts are unlikely to be fully captured by a single set of linear functions, multiple canonical correlations are usually considered, based on multiple pairs of linear combinations that are orthogonal to each other.

The present study aims at studying the Tunisian bank asset-liability management using canonical correlation analysis that measures the strength of the relationship between two sets of variables: assets and liabilities by establishing a linear combination of variables in one set and a linear combination of variables in another set. In our case, the canonical correlation measures the strength of the relationship between assets and liabilities by establishing a linear combination of variables in one set and a linear combination of variables in another set. Bank assets are subdivided bank assets into six accounts (fixed assets, liquid assets, short-term loans, long-term loans, short-term securities, long-term securities) and liabilities into five major groups (net worth, borrowings, short-term deposits, long-term deposits). So,

$$A = As_1 * (Liquid\ Assets) + As_2 * (Fixed\ Assets) + As_3 * (Short\text{-}Term\ Loans) + As_4 * (Long\ Term\ Loans) + As_5 * (Short\ Term\ Securities) + As_6 * (Long\text{-}Term\ Securities),\ \text{and} \quad (1)$$
$$L = L_{i1} * (Net\ Worth) + L_{i2} * (Borrowings) + L_{i3} * (Short\text{-}Term\ Deposits) + L_{i4} * (Long\ Term\ Deposits).$$

4. EMPIRICAL RESULTS AND INTERPRETATIONS

The results of the canonical correlation analysis are presented in Table 1. The first row (R^2) is a measure of the significance of the canonical correlation. This gives the R-squared value of fitting the Y canonical variate to the corresponding X canonical variate. Canonical correlation analysis results show that, in all of the cases, R^2 was important showing that all the correlations are highly significant. Public banks have the best asset-liability maturity pattern.

The canonical loadings give a measure of the strength of the association between asset and liability constituents and indicate the percent of variance linearly shared by an original variate with one of the canonical variates. A canonical loading is considered to be significant if it is more than 40%, and a negative loading indicates an inverse relationship.

As presented in Table 1, results show that different banks have a different degree of association among constituents of assets and liabilities. The bank groups can be arranged in overall decreasing order of correlation: public banks followed by foreign banks and lastly private banks.

In the case of public banks, there is a very strong correlation between fixed assets, liquid assets, and short-term securities from the asset side and net worth from liability side. There is a strong relationship also between short-term loans and short term and long-term deposits. The other strong positive correlation exists between long-term loans and borrowings.

In the case of private banks, strong correlations exist between fixed assets, liquid assets, short-term loans, long-term loans, short-term securities and long-term securities from asset side and net worth, borrowings, short-term deposits and long-term deposits.

In the case of banks controlled by foreign institutions, there are strong positive relationships between fixed assets, liquid assets, short-term loans and long-term loans from asset side and net worth and short-term deposits from liability side. In this case, too, it has been found that a negative correlation between long-term deposits from liability side and fixed assets, liquid assets, short-term loans and long-term loans from asset side.

Table 1. Canonical correlation analysis of assets & liabilities of Tunisian banks

Squared Canonical Correlation (R^2)	*Public banks*	*Private banks*	*Banks controlled by foreign institutions*	*Overall*
	0.9987	0.9323	0.9728	0.9999
Canonical Loadings				
Assets				
Fixed Assets	0.9928	0.9984	0.9137	0.8551
Liquid Assets	0.9900	0.9939	0.8363	0.7708
Short-Term Loans	0.8479	0.9963	0.9929	0.8723
Long Term Loans	0.6407	0.9696	0.9985	0.6492
Short-Term Securities	0.9934	0.9925	0.0082	0.8934
Long-Term Securities	0.9907	0.9959	0.0513	0.9740
Liabilities				
Net Worth	0.9952	0.9846	0.9987	0.9493
Borrowings	0.4830	0.5466	0.0122	0.4453
Short-Term Deposits	0.8385	0.9976	0.9981	0.8429
Long-Term Deposits	0.8242	0.9886	-0.0223	0.7311
Redundancy				
Assets (A)	0.863	0.983	0.631	0.734
Liabilities (B)	0.875	0.965	0.684	0.652

Strong correlations between fixed assets and deposits indicate proper usage of fixed assets and deposits in asset-liability management. However, this could indicate possible liquidity issues, as well as interest rate sensitivity, as fixed assets are of low liquidity and are interest-rate-neutral, while deposits and borrowings include relatively liquid short-term deposits and tend to be interest-rate sensitive. In fact, the fundamental role of banks in the maturity transformation of short-term deposits into long-term loans makes banks inherently vulnerable to liquidity risk, both of an institution-specific nature and that which affects markets as a whole. Every financial transaction has implications for bank's liquidity. Effective liquidity risk management helps ensure a bank's ability to meet cash flow obligations, which are uncertain as they are affected by external events and other agents' behaviour. Liquidity risk management is important because a liquidity shortfall at a single institution can have system-wide repercussions.

Strong positive correlations between liquid assets and short-term deposits stipulate that banks with large amounts of transactions accounts need to hold higher balances of cash as a precaution against a large volume of payments presentments on any given day.

Positive correlations between long-term loans and deposits suppose that banks match long-term credits with long-term deposits. Banks with large amounts of core deposits are better able to hold large portions of their portfolios in long-term loans without incurring large amounts of interest rate risk.

Positive relationships between borrowings and long-term loans indicate a poor matching of maturity structure of assets and liabilities and strong relationships between net worth and fixed assets from one side and between borrowings and liquid assets from another indicate a judicious matching of assets and liabilities in terms of their explicit cost and revenue as well as maturity and liquidity.

Table 2 shows the redundant factors which indicate how redundant one set of variables is, given the other set of variables. This gives an idea of independent and dependent sets and also identifies whether the bank is asset managed or liability managed. The cause and effect relationship for different bank groups is shown.

Table 2. Cause-effect relationship

Banks	*Independent Set*	*Dependent Set*
Overall	Asset	Liability
Public banks	Asset	Liability
Private banks	Asset	Liability
Banks controlled by foreign institutions	Liability	Asset

As presented, public and private Tunisian banks have assets as their independent set. We can conclude that these banks were actively managing assets and liabilities and were dependent on how well the assets are managed. Foreign banks have liability as an independent set.

5. CONCLUSION

In this paper we analyzed the correlation between Tunisian bank assets and liabilities using the canonical correlation method: a multivariate statistical model that studies interrelationships among sets of multiple dependent variables and multiple independent variables. The asset group we analyzed is subdivided into fixed assets, liquid assets, short-term loans, long-term loans, short-term securities and long-term securities; and liabilities into net worth, borrowings, short-term deposits and long-term deposits.

From the analysis, it is found that different banks have a different degree of association among constituents of assets and liabilities. For most of cases, there have been strongly positive relationships between fixed assets, liquid assets, loans (short and long-term) and short-term securities from asset side and net worth and short-term deposits. For most of cases, there has been a poor matching of the maturity structure of assets and liabilities and a judicious matching of assets and liabilities in terms of their explicit cost and revenue as well as maturity and liquidity.

It is further observed that most of Tunisian are asset-managed banks: these banks were actively managing assets and liabilities and were dependent on how well the assets are managed.

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