ASSETS LIABILITIES MODELS - A LITERATURE REVIEW

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Abstract: *The main objective of this paper is to offer a review of assets-liabilities management models. The use of assets and liabilities management models has been rapidly developing since financial institutions require specific tools in order to minimize their risk exposure while maintaining a high level of profitability. Asset and liabilities management models were applied initially for companies and financial institutions but there are also models which can be applies within central banks or even at countries. Asset-liability management models are classified according to the period and variables specification in: single period static models, multi-period static models, single period stochastic models, multi-period stochastic models. Static models are deterministic models in which the variables are well defined and the links between the variables do not change during time. Dynamic models capture much better the financial market volatility, the correlations between assets classes and/or liabilities classes can change, also the variables used in these models can be described as probability functions with different values. The limits of static models are due to their inability to capture the dynamics of financial markets, the changes in the correlations between the various types of assets, also the treatment of the financial system is done in a purely deterministic system. The main disadvantage of dynamic models is their increasing complexity. There is a trade-off between model complexity and ease of use in the case of assets-liabilities models.*

Keywords: *bank assets-liabilities; literature review; financial crises; balance sheet.*

JEL classification: *C31; G21; G01.*

1. Introduction
Assets-liabilities management models (ALM) are used both within companies and financial institutions, lately assets-liabilities models where developed for countries (Animante, 2013), while (Alhumaidah, 2015) propose two ALM models for the central bank of Saudi Arabia. In the case of financial institutions the main objective of assets-liabilities management is the management of interest rate and liquidity risk (Novickytė & Petraitytė, 2014). ALM is a strategic planning tool that unifies various banking activities under a single department (ALCO) in order to identify and minimize the risks that may arise as a result of the activity or external shocks; the utility of ALM models for banks derive from the identification of potential problems and risk that effect the balance sheet and income (Novickytė & Petraitytė, 2014, p. 1084).
The type of models used in ALM can be classified according to the incorporation of random variables into stochastic or deterministic models (Zopounidis, Doumpos, &

Pardalos, 2010, p. 284), while another clasifficationcan be made according to the analyzed time period and the influence of the random variables in which case we have four categories (Stavros A Zenios & Ziemba, 2007):

- Single period static models;
- Multi-period static models;
- Single period stochastic models;
- Multi-period stochastic models.

By static models we understand the deterministic models in which the variables are well defined and the links between the variables do not change during the analyzed period. Dynamic models, on the other hand, capture the aspect of financial market variability, for e.g. changes in the correlations between assets / liabilities, and variables are described as probability functions and may have distinct values depending on market developments.

2. Literature review

2.1. Single period static models

Single period deterministic models are structured so that the portfolio's evolution is predictable for the investor, these models are focused (Romanyuk, 2010, p. 11) mainly on the use of duration and convexity risk measures. The duration ($D = -\frac{\partial P}{P \partial r}$) of a portfolio measures the time period in which the initial investment is being recovered, and at the same time the sensitivity of the portfolio P to changes in the interest rates r. While the convexity of a portfolio captures the changes in duration as a result of changes in interest rate.

The main methods based on the use of duration and sensitivity are (Romanyuk, 2010, p. 12):

- immunization strategy proposed by (Redington, 1952), the main advantage of this method is given by its simplicity, the main disadvantage of the immunization strategy is due to the fact that analyzing a single period does not capture the volatility existing in the financial markets;
- dedication method assumes that asset-generated cash flows are fully matched with liabilities cash-flows.
- GAP analysis, which involves the classification of resources and placements by maturity, aiming at correlating the maturity between assets/ liabilities.

Immunization (Redington, 1952) involves matching assets and liabilities depending on different maturities of interest rates, (De La Grandville, 2006) shows that the impact of portfolio duration and immunization differs from investor to investor according to the time horizon for which the investment is made.

Ventura and Pereira (Ventura Bravo & Pereira da Silva, 2006) uses an immunization technique augmented with a stochastic-process and found that immunization minimizes the interest rate risk, but the cost associated with this strategy are high due to the transaction cost.

Dedication as an ALM method involves the correlation of cash flows between assets and liabilities, while GAP analysis addresses the differences between maturities of assets and liabilities. The GAP analysis is applied to Indian banks by (Dash & Pathak, 2011) which notes that the level of liquidity and profitability is influenced by the shareholder structure, with state-owned banks being more conservative in liquidity risk management, while private owned banks are more profitable.

While single period static models provide protection of the portfolio against minor fluctuations of financial markets (Rosen & Zenios, 2008, p. 21) the limits of portfolios building through these methods are:

- not using probabilities in specifying models, variables are considered static with predefined behavior ,
- single period static methods do not take into account the possibility of surpluses or deficits that can lead to the rebalancing of the portfolios.

In order to increase the efficiency of single period models a range of techniques have been proposed in order to overcome the limitations of the short time horizon analyzed and the deterministic aspect, (S A Zenios, 1995) discusses the positive impact of the immunization strategies of the balance sheet observing that the limitations of these methods became apparent with the increase of interest rate volatility. The author proposes the use of Monte Carlo simulations to augment the methods of immunization and portfolio dedication. (Monfort, 2009) proposes a model which uses risk measures, for e.g. by using Value of Risk in assets and liabilities management.

The limits of these static models are due to their inability to capture the dynamics of financial markets, the changes in the correlations between the various types of assets, also the treatment of the financial system is done in a purely deterministic system. The use of these short-term static methods should be complementary to the use of dynamic models.

2.2. Multi-period static models

Multi-period static models offer the possibility of making changes to the structure of assets and liabilities without, these changing can be of the structure/correlation of different types of assets/liabilities(Rosen & Zenios, 2008). Multi-period static models uses the same tools as annual static models (immunization, GAP analysis, dedication), plus the possibility to make changes in the structure of assets and liabilities at the end of each period, and they can incorporate changes in the variables used (Stavros A Zenios & Ziemba, 2007).

Since the 1960s linear programming models have been used for asset allocation decisions (Cohen & Hammer, 1967), the objectives of the functions being used were: maximizing the long-term value of the company, NPV of net income and the NPV of the liquidation value of the financial institution.

In the multi-period static models the most common algorithm is based on the linear programming, the canonical form of the linear programming model (Zopounidis et al., 2010) is:

$$\max \text{z} = \sum r_i X_i - \sum c_j Y_j \qquad (1)$$

where:

r_i – represent the income from the asset X_i,

c_i – represents the cost of liability Y_i ,

and z (profit) is the maximized function expressed as the difference between income and expense, the objective function being maximized taking into account some restrictions.

Due to the fact that linear programming cannot incorporate more than one objective, if the financial institutions have, besides the main objective for e.g. maximization of

revenues, other secondary objectives such as (Zopounidis et al., 2010, p. 285): risk minimization, market share, deposit rates, the level of loans granted, exposure to a particular sector, then the multi-objective programming can be used.
The linear multi-objective model developed by (Zopounidis et al., 2010, p. 296) for financial institutions seeks to minimize deviations from the main objectives provided that the imposed restrictions are respected:

$$\min \text{ z} = f(d_i^+ + d_i^-) \tag{2}$$

So that

$$\sum_{j=1}^{n} c_{mj} x_j \leq \Theta_m, \forall m = 1, \cdots, M(\text{constraint}) \tag{3}$$

$$\sum_{j=1}^{n} a_{ij} x_j = b_i + d_i^+ - d_i^-, \forall i = 1, \cdots, I(\text{objective}) \tag{4}$$

$$x_j, d_i^+, d_i^- \geq 0 \tag{5}$$

In this case the objective function (Zopounidis et al., 2010, p. 297) is:

$$\left\{ \begin{array}{l} \{P_1 \left[\sum_{m=1}^{M} W_{1m}(d_m^+, d_m^-)\right], \quad P_2 \left[\sum_{i=1}^{I} W_{2i}(d_i^+, d_i^-)\right] \quad , \ldots \\ P_\varphi \left[\sum_{i=1}^{I} W_{\varphi i}(d_i^+, d_i^-)\right] \end{array} \right\} \tag{6}$$

Where P_φ are the priority levels with $P_1 > P_2 > \cdots > P_\varphi$, and $W_{\varphi i}$ is a weighted linear function of the constraints' deviation and theirr priority level.
(Kosmidou & Zopounidis, 2004) propose a model with a main objective and various secondary objectives like: liquidity, profitability and risk level. Due to the fact that the various objectives can yield contradictory results, the authors suggest the use of a single main objective, and for the other objectives they should be classified according to their importance.
(Tektas, Nur Ozkan-Gunay, & Gunay, 2005) applies the linear multi-objective model to two banks in Turkey, the objectives being maximizing: liquidity, revenue, capital adequacy or market share; while the constraints of the equation's system are legal and regulatory framework.

2.3. Single period stochastic models

The starting point of the single period dynamic models is Markowitz's seminal work (Markowitz, 1952) "Portfolio Selection". In this paper he proposed how to determine efficient portfolios so that for a given profitability to offer lower risk or at a predetermined risk level how to provide the highest return.
(Markowitz, 1952) uses a vector that includes the portfolio of assets $w = [w_1, w_2, \ldots, w_N]'$, $\mu = [\mu_1, \mu_2, \ldots, \mu_N]'$ represent the expected return on asset returns, $\mu_p = w'\mu$ the expected return on portfolio profitability, $\Sigma : N \times N$ the covariance matrix of returns and $\sigma_p^2 = w'\Sigma w$ portfolio variance. In this case the return of portfolio is maximized μ_p given a σ_p^2 some level of risk.
Within the mean-variance model we can combine the profitability and the variance in order to obtain a single objective function:

$$\max \text{ f(w)} = c\mu_p - \frac{\sigma_p^2}{2} \tag{7}$$

Based on the mean-variance analysis for asset portfolios (Sharpe & Tint, 1990) extend the analysis of liabilities using the criterion of the correlation between assets

and liabilities and (S A Zenios, 1995) extends the mean-variance analysis from portfolios that follow normal distribution to portofolios governed by asymmetric/non-normal distribution laws.
Stochastic ALM models take into account the notion of risk, the risk in this case influencing investors' decision at the beginning and at the end of the period for most of the annual stochastic models. The most used (Romanyuk, 2010, p. 12) measures of risk are:

- absolute deviation, $|w - E(w)|$, where w represents the value of the investment and E(*w*) the expected value of the investment;
- semi-variance, $(min\,[(w - E(w)); 0])^2$, which takes into account the lower than average returns, is a measure of asymmetric risk;
- downside formula, $(min\,[(w - w^*), 0])^2$, in this case the threshold w^* is the minimum return of the investor;
- CVaR, $CVaR_\alpha = \frac{1}{1-\alpha}\int_0^{1-\alpha} VaR_\gamma(X)d_\gamma$, which measures average losses that are greater than or equal to VaR.

2.4. Multi period stochastic models

The most widespread models of assets-liabilities management are the multi-period stochastic models, which model the dynamic evolution of resources and liabilities over time, following different distribution functions. (Rosen & Zenios, 2008) argue that these models best capture the need to re-evaluate the position of the portfolio and make new decisions on the most appropriate allocation due to changes in the initial conditions.
Within the multi-period stochastic models we find the following types of methods used (Romanyuk, 2010, p. 13):

- decision rules, this method involves portfolios allocation strategies for each period, between the periods there is no change in the portfolio; these types of strategies imply that at the end of the period the portfolio manager will make the necessary adjustments, this strategy is optimal for long-term investors and when there are a reduced number of decision variables.
- Scenario analysis/simulation, including Basel III, focuses on the analysis of scenarios in stress tests. The practical difficulty of this method is given by the large number of possible scenarios and by the probabilities associated with each scenario;
- Stochastic optimal control involves the use of Markov processes in defining state variables and the transition from one state to the next. It is similar to scenario analysis, but because it uses numerous variables the complexity of modeling increases exponentially which raises serious problems in solving them.
- Stochastic programming, in this case the states are described as discrete; it's one of the most popular technique used in ALM modeling due to the fact that can encompass many decision variables that capture various goals and constraints, can also incorporate scenarios with low probabilities that can have a strong impact and the investment decisions may be reversible and the analysis extends over long periods of time.

Sometimes in practice a combination of these methods are used, (Boender, 1997) employ a scenario analysis and after the identification of the best strategy an optimization method is used; (Consigli & Dempster, 1998) propose the use of the CALM asset-liabilities management model, which is an a multi-period dynamic model using stochastic programming

(Chiu & Li, 2006) uses a stochastic optimal control to achieve the assets-liabilities management over long periods of time, the authors note that in markets without transaction costs the optimal behavior is to rebalance the portfolio as often as necessary, also the discrepancy between the variance in assets and liabilities has a big influence on portfolios managers behavior.

The Russell-Yasuda Kasai model (Carino et al., 1994) is a model specifically developed for the Japanese market involving the use of multi-period stochastic programming, the objective of the model is to increase the portfolio's profitability without affecting the long-term development of the portfolio; the Russel-Yasuda Kasai model includes multiple objectives of the financial institution and takes into account the restrictions imposed by regulators. The results of this model were extraordinary, in the first two years of the Russel-Yasuda Kasai implementation the profitability was 4.2% higher than in the previous period.

The Russel-Yasuda Kasai model uses the scenario tree method, which assumes that decisions are taken at each stage and each moment of each scenario is associated with a probability. The Russell-Yasuda Kasai model (Carino et al., 1994, p. 48) maximizes the expected portfolio value at the end of the T planning period, taking into account the penalties accumulated as a result of non-compliance, Russell-Yasuda Kasai model is defined as:

$$\max \mathrm{E}\left[V_t - \sum_{t=1}^{T} c_t(w_t)\right] \tag{8}$$

Where $\sum_n X_{nt} - V_t = 0$ are the budgetary constraints, $t = 0, 1, \ldots, T$ represent time periods , V_t value of the asset portfolio, c_t is the cost function, w_t captures the decrease in revenue and X_{nt} represents the market value of asset *n* at time *t.*

In order to establish the financial planning strategies within the banks (Kosmidou & Zopounidis, 2004) propose the use a stochastic model, the proposed model uses the information available in the financial reports of the year $t-1$ to propose strategies for the management of resources and placements during $t+1$. The specific objectives that can be incorporated into this model are: liquidity, profitability, risk level, model proposed by (Kosmidou & Zopounidis, 2004, p. 90) taking the following form:

$$\min \mathrm{z} = \sum_P p_k(d_k^+ + d_k^-) \tag{9}$$

with the following restrictions:

$$LB_X' \leq X' \leq UB_{X'} \tag{10}$$

$$LB_Y' \leq Y' \leq UB_{Y'} \tag{11}$$

$$\sum_{i=1}^{n} X_i = \sum_{j=1}^{m} Y_j \tag{12}$$

$$\sum_{j\in\Pi_{Y''}} Y_j - a\sum_{i\in E_{X''}} X_i = 0 \tag{13}$$

$$\sum_{j\in\Pi_1} Y_j - \sum_{i\in E} w_i X_i - d_s^+ + d_s^- = k_1 \tag{14}$$

$$\sum_{i\in E_x} X_i - k_2\sum_{j\in\Pi_k} Y_j + d_l^- - d_l^+ = 0 \tag{15}$$

$$\sum_{i=1}^{n} R_i^X X_i - \sum_{j=1}^{m} R_j^Y Y_j - d_r^+ + d_r^- = k_3 \tag{16}$$

$$\sum_{i\in E_p} X_i + d_p^- - d_p^+ = l_p, \forall p \quad (17)$$

$$\sum_{i\in \Pi_p} Y_j + d_p^- - d_p^+ = l_p, \forall p \quad (18)$$

$$X_i, Y_i, d_k^+, d_k^- \geq 0, \quad \forall i = 1, \ldots, n, j = 1, \ldots, m, k \in P \quad (19)$$

With X_i representing the assets *i*, Y_j liabilities, $\mathrm{LB}_{X'}(LB_{Y'})$ is the minimum level of asset X (liability Y), $\mathrm{UB}_{X'}(UB_{Y'})$ is the maximum level of asset X (liability Y), $E_{X''}$ $(E_{Y''})$ represents the specific category of assets (liabilities), k_1 (k_2) capital adequacy (respectively liquidity adequacy), k_3 is the expected value of return, P is the set of all objectives.

By using an objective driven model (Kosmidou & Zopounidis, 2004) show that we can quantify: the constraints imposed by supervisor authority, the structural constraints imposed by the equality of assets on the one hand and the liabilities / capital on the other, the specific objectives of the financial institution (structure of assets and liabilities, solvency, liquidity, efficiency, deposit / credit level); The model also incorporates credit risk, market risk, interest rate risk, liquidity risk, country risk.

The Prometeia model, developed by (Consiglio et al., 2007) which is based on the use of dynamic models with scenarios, is applied on an Italian insurance company, the authors note that using dynamic models with multiple objective can eliminate some inefficiencies and improve the insurer's financial situation. When analyzing the strategic allocation of assets with high risk liabilities (Hoevenaars, Molenaar, Schotman, & Steenkamp, 2008) notes that the investment horizon, the diversification of risk, the evolution of inflation and interest rates, the covariance between assets and liabilities have a significant impact on profitability.

In order to capture the relationship between assets and liabilities (Decamps, De Schepper, & Goovaerts, 2009) uses a Brownian geometric movement and the variability of cash-flows is modeled using spectral decomposition. (Geyer, Hanke, & Weissensteiner, 2010) show that scenario tree models can quickly become intractabile, using methods for reducing scenarios is not feasible for financial variables, concluding that the level of complexity of these models cannot be substantially reduced.

The ALM models are used not only on companies and financial institution but even for countries, (Das, Lu, Papaioannou, & Petrova, 2012) discusses the application of sovereign asset liability management (SALM) which has as the main objective the economic sustainability of the countries by increasing the economic diversification, the export level, the reduction of the import dependence. The model's constraints are: the degree of indebtedness, the structure and level of assets held, the inflation and interest rate, market development, institutional efficiency, exchange rate, price of prices, risk appetite.

3. Conclusion

The assumptions underlying the quantification of the relationships between variables used in assets-liabilities management can undergo sudden changes, especially in the context of shocks such as financial crises (Bae, Kim, & Mulvey, 2014), so the correct specification of models is particularly important. The optimization models presented provide the optimal solutions depending on the variables chosen and in which way we quantify their evolution, but it is often possible that the assumptions are not formulated correctly. However, we may be in a situation where the assumptions we have built optimization models are wrong, poorly specified, or do not include important variables. The large number of models developed by researchers offer the possibility of reducing the risk of model misspecification and can mitigate the main risk which effect financial institutions.

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