

Assessment of Banks Asset and Liability Management: Problems and Perspectives (Case of Morocco)

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Abstract: ALM is the one of major problem in banking. it plays a very important role bringing together the different activities of the bank. Appropriate liquidity and balance sheet management is a key factor in ensuring the bank's business and its continuity also it's the most important tool for managers to make decisions and risk management to increase stakeholder value, to enhance profitability, to increase capital, to serve customer and community needs and to protect the bank and insurance from disastrous financial increase of interest rate. Banking sector analysis could be the instrument to measure the sustainability of the country's financial sector. This paper showed Moroccan banking sector asset and liability management activity and make assumptions of how sustainable the sector are during the different business cycle stages and how banks can manage their risks according to business cycles. The analysis revealed that banks not affected by international financial crisis because of non integration in the international financial and because of strict respect of bale policy.

Keywords: asset and liability management (ALM); banks; Morocco, business cycle, risk management; interest rate risk; balance sheet management.

1. Introduction

ALM is not a recent practice in banking risk management D.DUPRE & M.EL BABSIRI 1997 have highlighted the ALM's development origin as the bankruptcy of "SAVING AND LOANS" and to the detection of a negative equity value for more than 500 savings funds in 1985 in USA Because of the gap between resources and assets fixed-rate not covered included in their balance sheets (see APPENDIX 1) so ALM was developed in order to limit maturity gaps between assets and liabilities; Since several scientific works have been published in this context (Abbott et al. 2003; Alhumaidah 2015; Babbel; Ballotta et al. 2006; Birge; Birge and Jádice 2013; Bogentoft et al. 2001; Bosch-princep et al. 2002; Broga et al. 2016; Chaffai and Dietsch 2014; Chang 2015; Chen et al. 2008; Chiu and Li 2006; Chiu and Wong 2012; Choi and Ying 2014; Claessens and van Horen 2012; Company et al. 1994; Consigli and Dempster; Consiglio et al. 2015; Consiglio et al. 2008; Corsaro et al. 2010; Cousin et al. 2016; Daher et al. 2015; Dahl and Møller 2006; Dan and Stavros A. 2015; Decamps et al. 2009; Decamps et al. 2006; Dempster 1997; Dow and Han 2015; Drijver and Haneveld 2000; Economics 2003; Faleh and Universit 2008; Ferstl and Weissensteiner 2011; Frauendorfer and Sch; Gerstner et al. 2009; Gerstner et al. 2008; Giokas 1991; Grebeck and Rachev 2005; Gulpinar and Pachamanova 2013; Hilli et al. 2007; Hoevenaars et al. 2008; Hryckiewicz and Scribner Associates 2017; Høyland and Wallace 2001; Jager 2014; de Jong 2008; Klaassen 1997; Kleynen; Kosmidou and Zopounidis 2000; Kusy and Ziembra 1986; Lange et al. 2004; Li and Li 2012; Liang and Ma 2015; Moerman and van der Laan 2015; Novickytė and Petraitytė 2014; Onyiriuba; Pan and Xiao 2016; Papi and Sbaraglia 2006; R.Kouwenberg 1998; Raubenheimer 2010; Rinaldi and Shin 2008; Sissy et al. 2016; Sodhi and Tang 2009; Statistics; T et al. 2012; T et al. 2011; Treasury 2014; Update 2008; Wei et al. 2013; Xiao and Zhang 2016; Xiong et al. 2010; Yang and Grothey 2009; Yao et al. 2016; Yao et

al. 2013; Yao 2011; Yu et al. 2003; Zanghirati et al. 2000; ZIEMBA 2006; 1992;) recently MOORAD Choudhry (2007) has consider that the [ALM is the key aspect of risk management in the financial services industry]. So ALM is the one of major problem in banking. it plays a very important role bringing together the different activities of the bank. Appropriate liquidity and balance sheet management is a key factor in ensuring the bank's business and its continuity. More recently, even the major international financial institutions have been faced with serious liquidity problems and even took some outside help. This shows that the importance of APV(Adjusted Present Value) was not evaluated or it was not properly executed. This has led to the financial market supervisory authorities around the world have taken action to ensure that financial institutions should have an effective ALM mechanism.

The aim of this paper is to analyze Moroccan banking sector ALM activity and studying the sustainability of the sector during crisis and different business cycle stages and managing risks.

The article consists of five sections. The first section introduce the problem of ALM in banking sector ,the second section presents the literature review of ALM. Third section gives a brief of Data and empirical methodology. Results of the study are presented in section four, and section five concludes the article.

2. Literature Review

Asset and liability management is a process of how minimizing risks of an institution by optimizing assets and cash flows to meet financial goals due to the ability to pay a liability on time. The balance sheet of a financial institution have two sides the left side or assets and the right side or liabilities so if the cash flows or assets streams are greater than outflows or liabilities there is a surplus and there is a

deficit in the opposite case. The concept of timing in ALM is a key because managers need to know at what time the liability will be paid and to insure about availability of assets to pay this liability. Mehndi Pirbhai in (2008). ALM deals with the optimal investment of assets in view of meeting current goals and future liabilities. Choudhry (2007) said.

To arrive at these goals the ALM model deterministic or stochastic (Kosmidou and Zopounidis, 2001) was developed. S.A. Zenios & W.T. Ziemba (2006) confirm that ALM has a history dates back to Markowitz contributions in the 1950s (Markowitz, 1952, 1991) for asset allocation, and extensions to include liabilities (Sharpe and Tint, 1990). The ALM is an integrated model aims to find the optimal strategy investment considering assets and liabilities in the same time.

Lina Novickytė & Indrė Petraitytė (2013) "ALM is a tool that combines several bank portfolios - asset, liabilities, and the difference between the banks received and interest paid The main ALM purpose is to connect different bank activities into a single unit, facilitating liquidity and balance sheet management"

For an integrated ALM model we need inputs both economic and market data, forecasting the liabilities and assets using Monte Carlo simulation see APPENDIX 2

3. Data and Empirical Methodology

Seasonality is excluded from series by ARIMA model and The cyclical by Hodric-Prescot filter with Eviews software. The trend will not be analyzed because the financial crisis of 2008 because of the absence of assumptions. The choice of the indicators (Table 1) was based on other scientific research (Lakštutienė, 2008; Levine, 2000; Lina Novickytė & Indrė Petraitytė, 2013) and because they often used in scientific articles and can adequately describe the relationship between ALM and business cycle.

Table 1: Indicators used in the paper and Hypothesis

Indicator	Hypothesis
Leverage - equity and liabilities ratio	H1: Seasonality affects the leverage;
	H2: Cyclical affects the leverage.
The share of loans in total assets	H3: Seasonality affects the loan component of bank total assets ;
	H4: Cyclical affects the loan component of bank total assets.
The share of deposits in total assets	H5: Seasonality affects the share of deposits in total assets;
	H6: Cyclical affects the share of deposits in total assets.
GDP	H7: Cyclical affects GDP;
	H8: Cyclical affects GDP.
	H9: There is a close link between the share of loans in total assets, the share of deposits in total assets, leverage and GDP ($R^2 > 0,5$).

Leverage - equity and liabilities ratio and The share of loans in total assets indicators gives us the level of risk in the Moroccan financial sector because they concerned the major asset and liability items show how assets are funded by deposits and how the resources are allocated.

Other indicators was included: Receivable due (Fig 2) , Moroccan trade balance (FIG 3) but not analyzed in correlation (see Table 2)

Leverage is The most well known financial ratio. A high leverage generally indicates that a bank has been aggressive in financing its growth with debt. Shows the amount of equity owned by Moroccan banks and shows the part of the assets held by the shareholders.

GDP is defined in Investopedia as the monetary value of all the finished goods and services produced within a country's borders in a specific time period. it is used in many researches as the market indicator. Presents the health of the country, it is very significant to determine economic cycle.

To conclude the relationship between indicators we will analyze correlation coefficient assessment and Granger causality determination. The data is taken from BAM -Bank AL Maghreb- Central bank of Morocco period from December 2001 to November 2015 also from The World Bank exactly from <http://data.worldbank.org/country/morocco> for GDP.

4. Empirical Results

4.1 Moroccan banks ALM during 2001–2015

The period from 2001 to 2015 includes various phases of the economic cycle, which reflects both the internal and the external shock effects. to review the basic ALM performance changes over the time (Fig. 1).

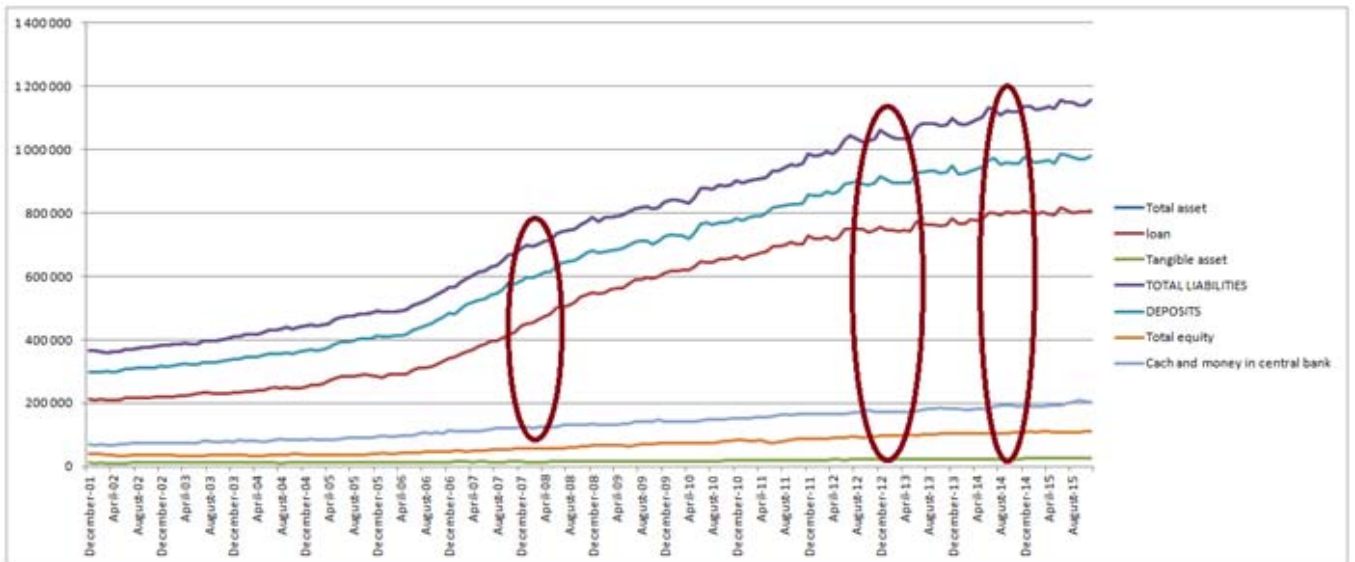


Figure 1: Moroccan banks main asset and liability indicators during 2001–2015 (primary axis: loans, deposits, total liabilities, total assets; secondary axis: cash and money in central bank, tangible assets, total equity) (Source: compiled by the authors based on BAM (central bank of Morocco)..., 2001–2015)

From the graph it is difficult to delineate economic cycles. Everything appears normal and evolves in a tendentious way :total assets, loans, deposits and total liabilities.

In 2008 the four quantities continue to grow in parallel but from the 3rd quarter of 2012 the four ALM indicators begin to move away from each other

This is due to the fact that loans to Moroccan banks are financed largely by deposits.

Cash and money is less than other ALM's indicator in Moroccan banks because it is the least profitable (FIG1). The aim of correlation matrix (Table 2) is to confirm or infirm the use of indicators for analyzing ALM indicator and business cycle in Moroccan banks. Regarding the correlation coefficients table there is a strong positive relationship between all variables that's mean a close and direct relation (all values are > 0.9)

Table 2: Correlation coefficients of main ALM indicators in Moroccan banks

	Cach And Money Bam	Deposits	Loans	Tangible Asset	Total Asset	Total Equity	Total Liabilities
CACH AND MONEY IN BAM	1						
DEPOSITS	0.9940	1					
LOANS	0.9877	0.9967	1				
TANGIBLE ASSET	0.9744	0.9616	0.9404	1			
TOTAL ASSET	0.9953	0.9995	0.9945	0.9681	1		
TOTAL EQUITY	0.9851	0.9850	0.9710	0.9831	0.9884	1	
TOTAL LIABILITIES	0.9953	0.9995	0.9945	0.9681	0.9999	0.9884	1

(Source: compiled by the authors based on BAM data December 2001 to November 2015)

2008 represent the most important date between 2001 and 2013 because the international financial system was shocked by the financial crisis but it's not viewed in FIG1 all indicators continue the rising trend.

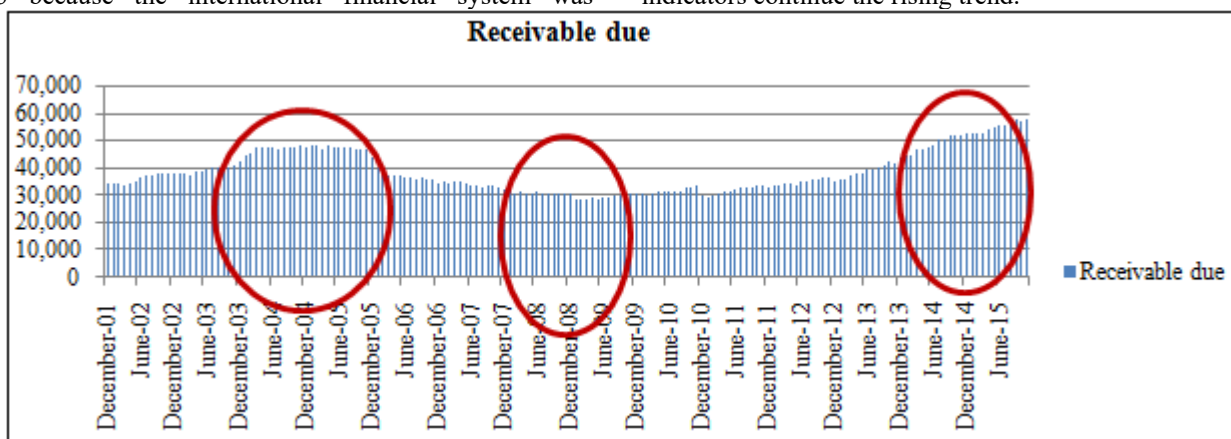


Figure 2: Receivable due (Source: compiled by the authors based on BAM data December 2001 to November 2015) Source :"-Central Bank of Morocco- Ventilation du crédit bancaire par objet économique BAM"

The graph shows that receivable due knows high and low values (FIG2) but the three periods encircle extreme values between December 2003 and December 2005, in 2008 and during the international financial crisis the receivable due are at the minimum values which pushes to hypothesize that there is no strong relationship between the international financial system and Moroccan banks; The thing that was confirmed by the HCP in its article "IMPACT DE LA CRISE MONDIALE SUR L'ECONOMIE MAROCAINE"

(2010) For two reasons: strict compliance with Moroccan banking regulations. The second is linked to its weak integration into global finance; The share of foreign assets in the total assets of Moroccan banks is less than 4% [Source : Bank Al-Maghrib (BAM central bank of Morocco)] and the share of non-residents in market capitalization, excluding shareholdings was less than 1,8% [Source : Statistics of Moroccan Securities Ethics Council (CDVM)] at the end of 2007

Balance commerciale (US\$ courant), Maroc

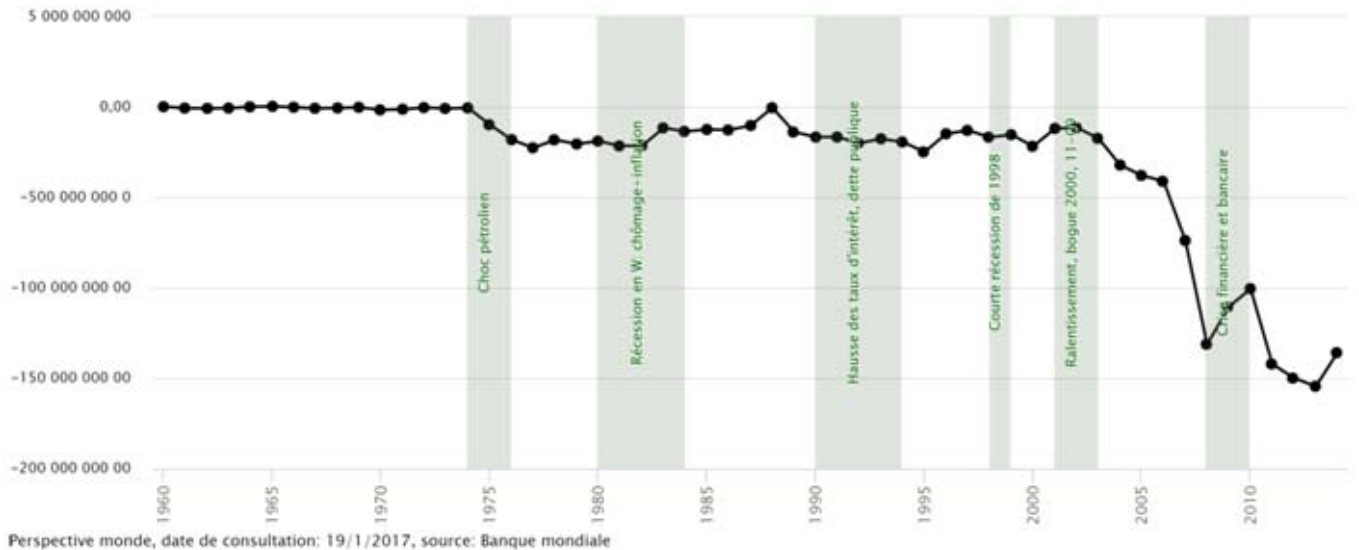


Figure 3: Moroccan trade balance source the World Bank

Even if the ALM indicator was not affected by financial crisis the Moroccan trade balance was largely negatively affected as it clearly in Fig3 because of it's integration in the

international system and the impact of financial crisis specially in Europe first partner of Morocco.

Table 3: Granger causality test results

No. of Granger causality test	Cause → result	F statistic	probability	Result
1.	GDP → SHARE OF DEPOSITS	0.91601	0.4022	Reject H0
2.	SHAREDEPOSIT → GDP	2.48151	0.0868	Accept H0
3.	SHARELOAN → GDP	3.80627	0.0243	Accept H0
4.	GDP → SHARELOAN	3.86118	0.0230	Accept H0
5.	GDP → LEVERAGE	11.5651	0,00002	Accept H0
6.	LEVERAGE → GDP	0.42865	0.6521	Reject H0

Source: compiled by the authors based on BAM data

The Granger causality test or vector auto regression shows that the changes in deposits share in total assets is determined by the changes in GDP and the GDP is determined by Leverage this method enables to ascertain

that Moroccan financial sector conform their ALM policy according the policy developments or anticipated changes.

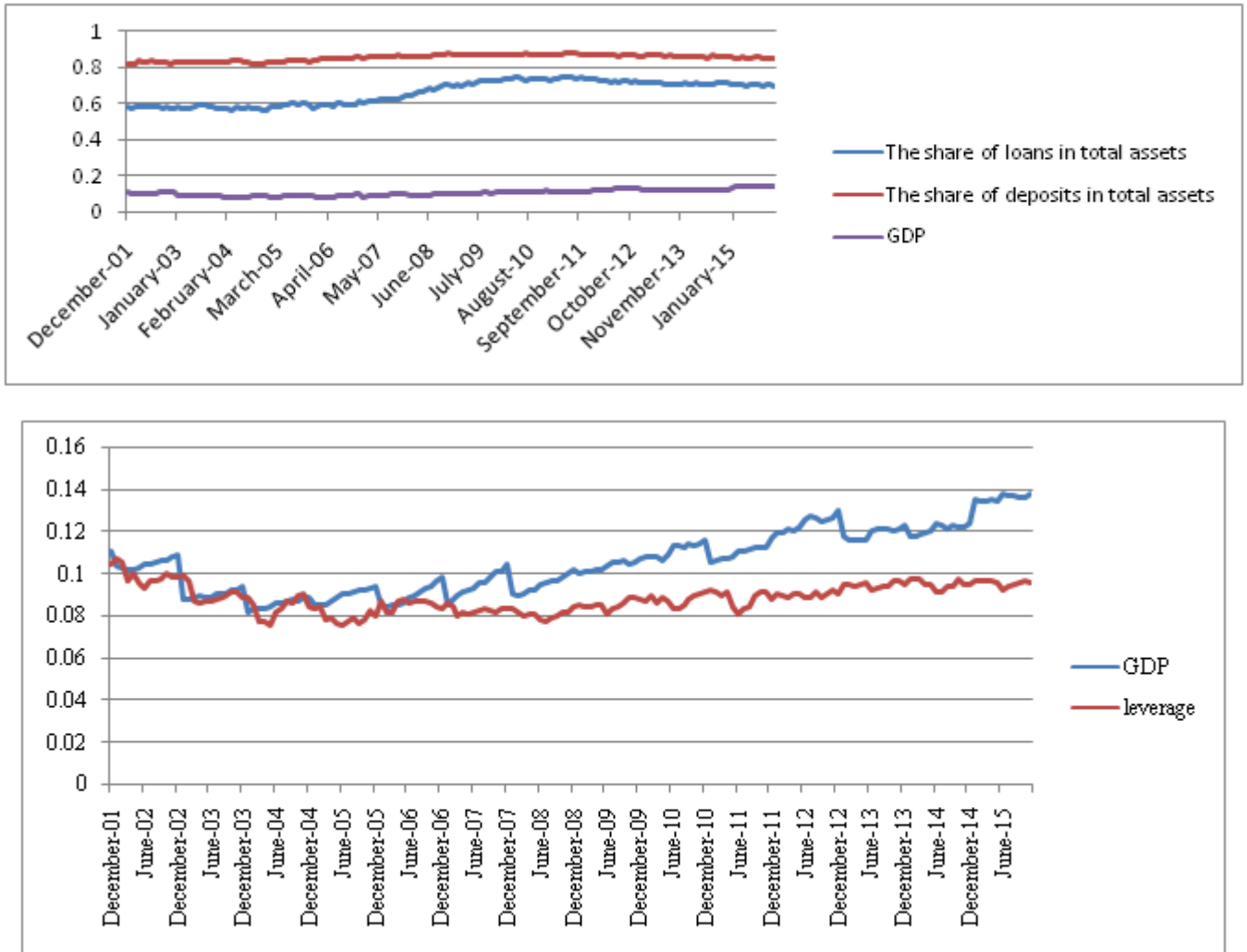


Figure 4: The cyclical component of the share of deposit and loans in total assets, leverage and GDP (primary axis: the share of loans in total assets, the share of deposits in total assets, leverage; secondary axis: GDP) (Source: compiled by the authors based on BAM data)

A small increase in share of loans in total assets due to finance mega project in Morocco since 2007.

Dependent Variable: GDP
 Method: Least Squares
 Date: 01/14/17 Time: 22:54
 Sample: 12/31/2001 6/16/2002
 Included observations: 168

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SHAREDEPOSIT	-0.707591	0.088886	-7.960679	0.0000
SHARELOAN	0.328330	0.022743	14.43633	0.0000
C	0.491329	0.062712	7.834748	0.0000
R-squared	0.663500	Mean dependent var		0.105477
Adjusted R-squared	0.659422	S.D. dependent var		0.015015
S.E. of regression	0.008763	Akaike info criterion		-6.618946
Sum squared resid	0.012669	Schwarz criterion		-6.563161
Log likelihood	558.9915	Hannan-Quinn criter.		-6.596306
F-statistic	162.6711	Durbin-Watson stat		0.274011
Prob(F-statistic)	0.000000			

Figure 5: Estimation of dependant variable GDP with exogenous variables (the share of deposits and the share of loans) Source: compiled by the authors based on central Bank of Morocco and the World Bank

From the Least Squares output estimation we can write the estimation equation of GDP as:

$$GDP = -0.707591 * \text{SHARE_OF_DEPOSITS} + 0.328330 * \text{SHARE_OF_LOANS} + 0.491329$$

5. Conclusion

Empirical study showed that there is extremely close relationship leverage in Moroccan banks and GDP, although the relationship between the cyclical components is moderate. The Granger causality test showed that the ALM policy volatility isn't caused by the variations or expectations of variation in the economic cycle in Morocco.

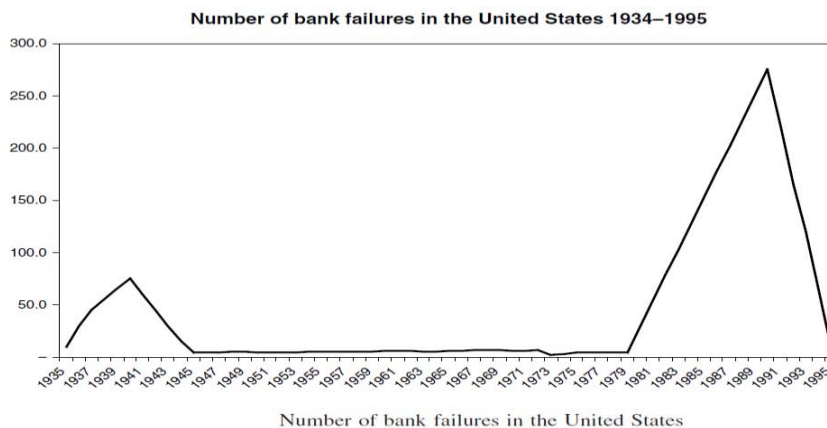
Moroccan's banks respect and apply the ALM policy so it's moderately affected by business cycle.

The event of non integration of Moroccan's financial system in the international financial system has limited the impact of international financial crisis on banking sector but the Moroccan trade balance has largely negatively affected.

The banking sector in Morocco it's not pro-cyclical.

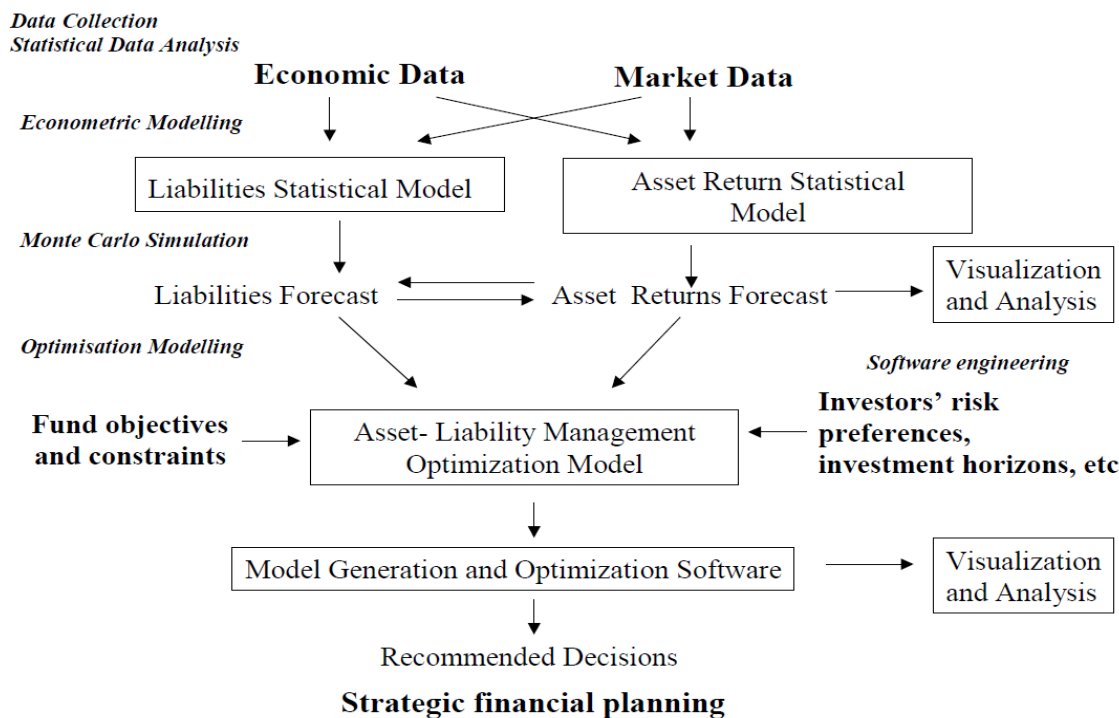
ALM policy deploys conservative measures. Bank's managers must stay vigilant in future to reduce expected high losses in their balance sheets

Appendix 1



Source: Handbook of Asset and Liability Management From models to optimal return strategies Alexandre Adam (2007)

Appendix 2



Source: Global Asset Liability Management M. A. H. Dempster, M. Germano, E.A. Medova and M.Villaverde 2002

References

- [1] Abbott, M.C., Backus, J.E., Benedetti, S., Bergman, D., Cox, S.H., Feldblum, S., Gilbert, C.L., Liu, X.L., Lui, V.Y., Pedersen, H.W., Rudolph, M.J., Shiu, E.S., Smith, P.L.: Society of Actuaries Professional Actuarial Specialty Guide Asset-Liability Management. Soc. Actuar. (2003).
- [2] Alhumaidah, F.: Asset-liability Management for Reserves under Liquidity Constraints: The Case of Saudi Arabia. *Procedia Econ. Financ.* 29, 17–40 (2015).
- [3] Babbel, D.F.: Asset / Liability Management for Insurers in the New Era : Focus on Value. 7770, 1–30.
- [4] Ballotta, L., Esposito, G., Haberman, S.: The IASB Insurance Project for life insurance contracts : Impact on reserving methods and solvency requirements. 39, 356–375 (2006).
- [5] Birge, J.R.: Stochastic Programming Models in Asset-Liability Management Overview of Approaches. 1–15.
- [6] Birge, J.R., Júdice, P.: Long-term bank balance sheet management : Estimation and simulation of risk-factors. *J. Bank. Financ.* 37, 4711–4720 (2013).
- [7] Bogentoft, E., Romeijn, H.E., Uryasev, S.: Asset/Liability Management for Pension Funds Using CVaR Constraints. *J. Risk Financ.* 3, 57–71 (2001).
- [8] Bosch-princep, M., Devolder, P., Domínguez-fabián, I.: Risk analysis in asset-liability management for pension fund. 2, (2002).
- [9] Broga, K.M., Viegas, E., Jensen, H.J.: Model analysis of the link between interest rates and crashes. *Physica A.* 457, 225–238 (2016).
- [10] Chaffai, M., Dietsch, M.: Modelling and measuring business risk and the resiliency of retail banks. *J. Financ. Stab.* (2014).
- [11] Chang, H.: Dynamic mean-variance portfolio selection with liability and stochastic interest rate. *Econ. Model.* 51, 172–182 (2015).
- [12] Chen, P., Yang, H., Yin, G.: Insurance : Mathematics and Economics Markowitz ' s mean-variance asset-liability management with regime switching: A continuous-time model. 43, 456–465 (2008).
- [13] Chiu, M.C., Li, D.: Asset and liability management under a continuous-time mean-variance optimization framework. *Insur. Math. Econ.* 39, 330–355 (2006).
- [14] Chiu, M.C., Wong, H.Y.: Mean-variance asset-liability management: Cointegrated assets and insurance liability. *Eur. J. Oper. Res.* 223, 785–793 (2012).
- [15] Choi, M., Ying, H.: Insurance : Mathematics and Economics Mean - variance asset - liability management with asset correlation risk and insurance liabilities. *Insur. Math. Econ.* 59, 300–310 (2014).
- [16] Claessens, S., van Horen, N.: Being a foreigner among domestic banks: Asset or liability? *J. Bank. Financ.* 36, 1276–1290 (2012).
- [17] Company, F.R., Street, A., Turner, A.L.: The Russell-Yasuda Kasai Model: An Asset/ Liability Model for a Japanese Insurance Company Using Multistage Stochastic Programming. 1994, 29–49 (1994).
- [18] Consigli, G., Dempster, M.A.H.: To appear in *Annals of OR DYNAMIC STOCHASTIC PROGRAMMING FOR ASSET-LIABILITY MANAGEMENT*.
- [19] Consiglio, A., Cocco, F., Zenios, S.A.: Asset and liability modelling for participating policies with guarantees. *Eur. J. Oper. Res.* 186, 380–404 (2008).
- [20] Consiglio, A., Tumminello, M., Zenios, S.A.: Insurance : Mathematics and Economics Designing and pricing guarantee options in defined contribution pension plans. *Insur. Math. Econ.* 65, 267–279 (2015).
- [21] Corsaro, S., De Angelis, P.L., Marino, Z., Perla, F., Zanetti, P.: On parallel asset-liability management in life insurance: a forward risk-neutral approach. *Parallel Comput.* 36, 390–402 (2010).
- [22] Cousin, A., Jiao, Y., Robert, C.Y., Zerbib, O.D.: Asset allocation strategies in the presence of liability constraints. *Insur. Math. Econ.* 70, 327–338 (2016).
- [23] Daher, H., Masih, M., Ibrahim, M.: Ac ce p te d us t. "Journal Int. Financ. Mark. Institutions Money." (2015).
- [24] Dahl, M., Møller, T.: Valuation and hedging of life insurance liabilities with systematic mortality risk. 39, 193–217 (2006).
- [25] Dan, R., Stavros A., Z.: Handbook of Asset Liability Management Volume1. Br. Columbia. 1, 1689–1699 (2015).
- [26] Decamps, M., Schepper, A. De, Goovaerts, M.: A path integral approach to asset-liability management. 363, 404–416 (2006).
- [27] Decamps, M., De Schepper, A., Goovaerts, M.: Spectral decomposition of optimal asset-liability management. *J. Econ. Dyn. Control.* 33, 710–724 (2009).
- [28] Dempster, G.C. and M.A.: Dynamic Stochastic Programming for Asset-Liability Management. (1997).
- [29] Dow, J., Han, J.: Contractual incompleteness, limited liability and asset price bubbles. *J. financ. econ.* 116, 383–409 (2015).
- [30] Drijver, S.J., Haneveld, W.K.K.: Asset Liability Management modeling using multi- stage mixed-integer Stochastic Programming. 1–18 (2000).
- [31] Economics, P.H.M.K.T.P.De. of management S.H.S. of: a stochastic programming model for asset liability management of a finich pansion company. (2003).
- [32] Faleh, A., Universit, I.-: Un modèle de programmation stochastique pour l ' allocation stratégique d ' actifs d ' un régime de retraite partiellement. 1–38 (2008).
- [33] Ferstl, R., Weissensteiner, A.: Asset-liability management under time-varying investment opportunities. *J. Bank. Financ.* 35, 182–192 (2011).
- [34] Frauendorfer, K., Sch, M.: Stochastic Optimization in Asset & Liability Management: A Model for Non-Maturing Accounts 1. 67–100.
- [35] Gerstner, T., Griebel, M., Holtz, M.: Insurance : Mathematics and Economics Efficient deterministic numerical simulation of stochastic asset-liability management models in life insurance. *Insur. Math. Econ.* 44, 434–446 (2009).
- [36] Gerstner, T., Griebel, M., Holtz, M., Goschnick, R., Haep, M.: A general asset-liability management model for the efficient simulation of portfolios of life insurance policies. *Insur. Math. Econ.* 42, 704–716 (2008).
- [37] Giokas, D.: Case Study A goal pro . gramming model for bank assets and liabllitms management. *Eur. J. Oper. Res.* 50, 48–60 (1991).
- [38] Grebeck, M., Rachev, S.: Stochastic Programming Methods in Asset-Liability Management. 82–90 (2005).
- [39] Gulpinar, N., Pachamanova, D.: A robust optimization approach to asset-liability management under time-

- varying investment opportunities. *J. Bank. Financ.* 37, 2031–2041 (2013).
- [40] Hilli, P., Koivu, M., Pennanen, T.: A stochastic programming model for asset liability management of a Finnish pension company. 115–139 (2007).
- [41] Hoevenaars, R.P.M.M., Molenaar, R.D.J., Schotman, P.C., Steenkamp, T.B.M.: Strategic asset allocation with liabilities: Beyond stocks and bonds. *J. Econ. Dyn. Control.* 32, 2939–2970 (2008).
- [42] Hryckiewicz, A., Scribner Associates, ??ukasz: Banking business models and the nature of financial crisis. *J. Int. Money Financ.* 71, 1–24 (2017).
- [43] Høyland, K., Wallace, S.W.: Analyzing legal regulations in the Norwegian life insurance business using a multistage asset ± liability management model. 134, (2001).
- [44] Jager, P. De: Accounting , Organizations and Society Fair value accounting , fragile bank balance sheets and crisis : A model. *Accounting, Organ. Soc.* 39, 97–116 (2014).
- [45] de Jong, F.: Pension fund investments and the valuation of liabilities under conditional indexation. *Insur. Math. Econ.* 42, 1–13 (2008).
- [46] Klaassen, P.: Solving Stochastic Programming Models for Asset / Liability Management using Iterative Disaggregation. (1997).
- [47] Kleynen, R.: Asset-Liability Management for Pension Funds: A Case Study.
- [48] Kosmidou, K., Zopounidis, C.: A multicriteria methodology for bank asset liability management. 1–26 (2000).
- [49] Kusy, M.I., Ziemba, W.T.: A Bank Asset and Liability Management Model. *Oper. Res.* 34, 356–376 (1986).
- [50] Lange, P.E. De, Fleten, S., Gaivoronski, A.A.: Modeling financial reinsurance in the casualty insurance business via stochastic programming. 28, 991–1012 (2004).
- [51] Li, C., Li, Z.: Multi-period portfolio optimization for asset-liability management with bankrupt control. *Appl. Math. Comput.* 218, 11196–11208 (2012).
- [52] Liang, Z., Ma, M.: Optimal dynamic asset allocation of pension fund in mortality and salary risks framework. *Insur. Math. Econ.* 64, 151–161 (2015).
- [53] Moerman, L.C., van der Laan, S.L.: Silencing the noise: Asbestos liabilities, accounting and strategic bankruptcy. *Crit. Perspect. Account.* 27, 118–128 (2015).
- [54] Novickytė, L., Petraitytė, I.: Assessment of Banks Asset and Liability Management: Problems and Perspectives (Case of Lithuania). *Procedia - Soc. Behav. Sci.* 110, 1082–1093 (2014).
- [55] Onyiriuba, L.: Bank Risk Management in Developing Economies.
- [56] Pan, J., Xiao, Q.: Optimal asset–liability management with liquidity constraints and stochastic interest rates in the expected utility framework. *J. Comput. Appl. Math.* (2016).
- [57] Papi, M., Sbaraglia, S.: Optimal asset-liability management with constraints: A dynamic programming approach. *Appl. Math. Comput.* 173, 306–349 (2006).
- [58] R.Kouwenberg: Scenario Generation and Stochastic Programming Models for Asset Liability Management 1 Introduction 2 Generating scenarios. (1998).
- [59] Raubenheimer, B.H.: A STOCHASTIC-PROGRAMMING APPROACH TO INTEGRATED ASSET AND LIABILITY MANAGEMENT OF INSURANCE PRODUCTS. 10, 43–70 (2010).
- [60] Rinaldi, E., Shin, A.: Asset protection. *J. Am. Dent. Assoc.* 139, 185–189 (2008).
- [61] Sissy, A.M., Amidu, M., Abor, J.Y.: The effects of revenue diversification and cross border banking on risk and return of banks in Africa. *Res. Int. Bus. Financ.* (2016).
- [62] Sodhi, M.S., Tang, C.S.: Modeling supply-chain planning under demand uncertainty using stochastic programming: A survey motivated by asset-liability management. *Int. J. Prod. Econ.* 121, 728–738 (2009).
- [63] Statistics, M.: ALM models for pension funds. 1–31.
- [64] T, O.N., Planchet, F., Lyon, U. De, Claude, U., Lyon, B.: Insurance : Mathematics and Economics Stochastic evaluation of life insurance contracts : Model point on asset trajectories and measurement of the error related to aggregation. *Insur. Math. Econ.* 51, 624–631 (2012).
- [65] T, O.N., Planchet, F., Thérond, P.: Insurance : Mathematics and Economics Optimal strategies for hedging portfolios of unit-linked life insurance contracts with minimum death guarantee. *Insur. Math. Econ.* 48, 161–175 (2011).
- [66] Treasury, N.: Asset and liability management. (2014).
- [67] Update, L.: ASSET LIABILITY MANAGEMENT USING STOCHASTIC Asset-Liability Management (ALM) using Stochastic Programming (SP). (2008).
- [68] Wei, J., Wong, K.C., Yam, S.C.P., Yung, S.P.: Markowitz’s mean-variance asset-liability management with regime switching: A time-consistent approach. *Insur. Math. Econ.* 53, 281–291 (2013).
- [69] Xiao, W., Zhang, X.: Pricing equity warrants with a promised lowest price in Merton ’ s jump – diffusion model. *Physica A.* 458, 219–238 (2016).
- [70] Xiong, X., Cui, G.U.O., Wei, Z., Yong-jie, Z.: Loan Rate Pricing of SME Financing based on Agent-based Computational Finance Approach. *Syst. Eng. - Theory Pract.* 29, 9–14 (2010).
- [71] Yang, X., Grothey, A.: Asset-Liability Management Modelling with Risk Control by Stochastic Dominance. 1–26 (2009).
- [72] Yao, H., Lai, Y., Hao, Z.: Uncertain exit time multi-period mean-variance portfolio selection with endogenous liabilities and Markov jumps. *Automatica.* 49, 3258–3269 (2013).
- [73] Yao, H., Li, Z., Li, D.: PT US CR. *Eur. J. Oper. Res.* (2016).
- [74] Yao, H.X.: A simple method for solving multiperiod mean-variance asset-liability management problem. *Procedia Eng.* 23, 387–391 (2011).
- [75] Yu, L.-Y., Yu, L.-Y., Ji, X.-D., Ji, X.-D., Wang, S.-Y., Wang, S.-Y.: Stochastic Programming Models in Financial Optimization: A Survey. *Adv. Model. Optim.* 5, 1–26 (2003).
- [76] Zanghirati, G., Cocco, F., Paruolo, G., Taddei, F.: Cray T3E implementation of a parallel stochastic dynamic assets and liabilities management model. *Parallel Comput.* 26, 539–567 (2000).
- [77] ZIEMBA, S.. Z.& W.Z.: HANDBOOK OF ASSET AND LIABILITY MANAGEMENT VOLUME 1: THEORY AND METHODOLOGY. (2006).

- [78] Stavros A. Zenios, William T. Ziemba-Handbook of Asset and Liability Management - Set, Volume 1 & 2- North Holland (2007)
- [79] D.DUPRE & M.EL BABSIRI ALM TECHNIQUES POUR LA GESTION ACTIF/PASSIF edition ESKA (1997)
- [80] MOORAD Choudhry BANK ASSET AND LIABILITY MANAGEMENT Strategy, Trading, Analysis published by John Wiley & sons (Asia) Pte Ltd (2007)
- [81] M. A. H. Dempster, M. Germano, E.A. Medova and M.Villaverde Global Asset Liability Management (2002).
- [82] Alexandre Adam Handbook of Asset and Liability Management From Models to Optimal return strategies (2007)

