
Supervisory Risk Assessment in a Basel Environment: The Stress Testing of Banks in Botswana

By

THOBO MATHAME



Submitted to the Department of Finance and Tax, Faculty of
Commerce, UNIVERSITY OF CAPE TOWN in partial fulfilment
of the requirements for the degree of

MASTER OF COMMERCE,

specialising in

FINANCIAL AND RISK MANAGEMENT

Supervised By

PROFESSOR PHILLIP DE JAGER

The copyright of this thesis vests in the author. No quotation from it or information derived from it is to be published without full acknowledgement of the source. The thesis is to be used for private study or non-commercial research purposes only.

Published by the University of Cape Town (UCT) in terms of the non-exclusive license granted to UCT by the author.

DECLARATION

I, Thobo Mathame, hereby declare that the work on which this thesis is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university. I authorise the University to reproduce for the purpose of research either the whole or any portion of the contents in any manner whatsoever

SIGNED: DATE:

DEDICATION

To my family:

I dedicate this research to my beloved mother for being my very first teacher. Your love, humility and constant support make me strong and have seen me through each and every day. To my sister Esi, for you have always believed in me and continuously offer your full support in all my endeavours. I remain forever indebted to the both of you. To my nephews Thabang and Karabo, our phone chats always stiched up a bad day.

ACKNOWLEDGEMENTS

First and foremost, I would like to give thanks to the Almighty God for the protection, guidance and strength which have brought me such a long way. I have also been privileged to work with Professor Phillip de Jager, whose continuous support and counsel through comments and suggestions, were invaluable at every stage of this research. I wish to also express a word of acknowledgement to my sponsor, Bank of Botswana, for the opportunity to further my studies. I send my profound gratitude to my family for their constant love and encouragement throughout this journey. A special mention goes to my friends Kagiso Modise and Morebodi Modise, who I highly appreciate for taking time out to offer technical assistance.

Thank you Professor Gary van Vuuren for the insightful comments at the workshop on bank stress testing held in Sandton, Johannesburg.

ABSTRACT

The study uses stress testing to determine the need, if any, for additional capital and/or provisioning for commercial banks in Botswana. The aim is to probe the use of supervisory stress testing as a mitigating factor to some concerns that have been raised with the Basel capital adequacy ratio (CAR) following the 2007-9 global financial crisis. During the crisis, some financial institutions failed or required some form of government assistance, amid having met the minimum CAR requirements prior to the crisis. This led to increased public scrutiny and a loss of confidence in financial regulation. As a result, some scholars have argued that the Basel capital framework is not sufficient as a measure of capital adequacy and as such advocate for the adoption of stress testing to overcome the shortcomings. Specific reference is often made to the success of the subsequent SCAP (US) and CEBS (EU) stress tests that are conceived to have helped restore public confidence as they revealed several oversight loopholes in the existing Basel methodology for the determination of adequate capital for financial institutions. In this regard, this paper considers the context of Botswana, where, even though banks withstood the financial crisis with a relatively strong stance, the economy remains concentrated with heavy dependence on the mining sector. This increases macroeconomic vulnerability and banking sector risks and hence intensifies the need to ensure that banks have sufficient capital holdings at all times. The study adopts an accounting-based approach to stress testing by applying shocks for credit, interest rate, foreign exchange and liquidity risks with the CAR as the main metric. A combined scenario stress test revealed that a collective change in provisions, NPLs, interest rate and exchange rate, that resulted in a decline in CAR from 19.4 to 18.6 post-shock. The available capital remains adequate even following assumed stress conditions. However, the stress test has revealed weaknesses in credit risk and foreign exchange risk as some banks' capital adequacy fell below the 15 percent minimum. Furthermore, the scenario analysis showed the need for a P22 million capital injection into the banking system, should the tested scenarios occur. As far as can be reasonably established, this kind of study has not been published before for Botswana. As such, this paper lays groundwork for future studies particularly relating to the formulation of scenarios that can better reflect the risk profile of the Botswana banking system.

KEYWORDS: stress testing, Basel capital accord, capital adequacy ratio

TABLE OF CONTENTS

	Page
List of Tables	viii
List of Figures	ix
List of Abbreviations	x
1 Introduction	1
1.1 Background	1
1.2 Overview of the Basel Accords	2
1.3 Overview of Supervisory Stress Testing	3
1.4 Research Problem	4
1.5 Research Objective	5
1.6 Research Questions	5
1.7 Contribution	5
1.8 Limitations of the Study	6
1.9 Organisation	6
2 Background and Related Work	8
2.1 Introduction	8
2.2 The Evolution of the Basel Capital Framework	9
2.3 The Role of Supervisory Stress Testing	11
2.4 Are the Basel Standards Enough? - Wall (2014)	12
2.5 Supervisory Risk Assessment in Africa	14
2.6 Stress Testing Insights from the Global Financial Crisis	14
2.7 Building Blocks of Stress Testing Models	15
2.7.1 Objectives	16
2.7.2 Elements	16
2.7.3 Exposures and Scope	16
2.7.4 Measures of Risk	17
2.8 Stress Testing Techniques	19
2.9 Limitations and Challenges	19
2.9.1 Technical (Modular) Limitations	19
2.9.2 Contextual Limitations	19
2.9.3 Other Limitations	20
2.10 Methodological Approaches to Stress Testing	21

2.10.1	Bottom-up vs. Top-Down Approach	21
2.10.2	Scenario Design	21
2.11	Conclusion	23
3	The Botswana Context	25
3.1	Introduction	25
3.2	Banking Sector Risk Profile	25
3.3	Macroeconomic Risk and the Banking System	27
3.4	Conclusion	29
4	Research Approach	30
4.1	Research Design	30
4.2	Population and Sampling	30
4.3	Data	31
5	Stress Testing Model	32
5.1	Introduction	32
5.2	Calibration of Shocks	33
5.2.1	Credit Risk Shocks	33
5.2.2	Interest Rate Risk	34
5.2.3	Foreign Exchange Rate Risk	34
5.2.4	Liquidity Tests	35
5.2.5	Scenario Analysis	36
5.3	Identification of Vulnerabilities	36
5.4	Formulation of Assumptions and Shocks	37
5.4.1	Credit Risk	37
5.4.2	Interest Rate Risk	38
5.4.3	Exchange Rate Risk	38
5.5	Conclusion	39
6	Stress Testing Results	40
6.1	Introduction	40
6.2	Sensitivity Tests	40
6.2.1	Stress Testing for Credit Risk	40
6.2.2	Stress Testing for Interest Rate Risk	41
6.2.3	Stress Testing for Exchange Rate Risk	41
6.3	Additional Tests	42
6.3.1	Liquidity Tests	42
6.3.2	Scenario Analysis	42
6.4	Model Validation	46

7 Discussion	48
7.1 Introduction	48
7.2 Implication of the Results on the Capital Adequacy of the Banking System	48
7.3 Research Questions	50
8 Conclusion	52
8.1 Introduction	52
8.2 Review of Research Background	52
8.3 Recommendation for Future Work	53
9 Reference List	54

LIST OF TABLES

TABLE	Page
2.1 Some common risks assessed in the stress testing process	17
2.2 List of FSIs relating to the banking sector	18
3.1 Key FSIs and prudential standards for commercial banks 2012-2016	26
3.2 Mineral and non-mineral revenue in Botswana	28
3.3 Botswana Exports for 2015/16(in BWP mil)	29
6.1 Summary of liquidity tests over a five-day period for the banking system	43
6.2 Changes in solvency and liquidity under adverse scenario conditions	44
6.3 Summary of the post-shock capital needs of the system	45
6.4 A comparison of pre-shock and post-shock banking system FSIs and ratings	45
6.5 Risk indicator levels per bank size under baseline and stress conditions	46
6.6 Bottom-up Stress Test	47

LIST OF FIGURES

FIGURE	Page
3.1 Banking sector quarterly performance 2012-2016	27
3.2 Summary of CAMELS ratings for commercial banks in Botswana	27
5.1 The stress testing framework	32
6.1 Proportional daily withdrawals and contagion over a 5-day period	43
6.2 Comparison between pre-shock and post-shock CAR	44
6.3 The z-score, ratings and probability of default according to bank size	46
6.4 Comparison between top-down and bottom-up adverse CAR	47

LIST OF ABBREVIATIONS

AIRB	Advanced Internal Ratings-Based Approach
BCBS	Basel Committee on Banking Supervision
BIS	Bank for International Settlements
BOB	Bank of Botswana
CAMEL	Capital Adequacy, Asset Quality, Market Sensitivity, Earnings, Liquidity
CAR	Capital Adequacy Ratio
CEBS	Committee of European Bank Supervisors
CGFS	Committee on the Global Financial System
EU	European Union
FIRB	Foundation Internal Ratings-Based Approach
FSAP	Financial Sector Assessment Program
FSI	Financial Soundness Indicators
GDP	Gross Domestic Product
IMF	International Monetary Fund
NPL	Non-performing Loans
PD	Probability of Default
SCAP	Supervisory Capital Assessment Program
US	United States of America

INTRODUCTION

1.1 Background

The role of financial intermediation establishes banks as facilitators of spending and investment in an economy and, as such, vital to the stability of the financial system. Despite this, banks remain susceptible to risks and possible failure. A bank failure can have far reaching and detrimental effects. This has created the need for regulators to strive to maintain stable financial systems at all times. It is through the use of banking regulation that regulators are able to respond to the increased risk that comes with financial institutions' growth and progression with the times.

For a long time, banking regulation has been dominated by the use of the Basel rules developed by the Basel Committee on Banking Supervision (BCBS) of the Bank for International Settlements. Amid their success in many respects, the regulations have had to undergo several revisions over the years as it often emerged that some critical regulatory aspects had been overlooked. Schuermann (2014:718) postulates that neither a firm's internal economic capital nor regulatory capital models can guarantee failure prevention especially because it is the responsibility of any firm to gauge its probability of failure through its risk appetite. Some scholars, including Caprio, Demirgüç-Kunt and Kane (2010), have criticised the Basel stipulated capital adequacy measures following several defaults or near defaults by institutions¹ that were considered adequately capitalised prior to the 2007-2009 financial crisis. The institutions consistently reported Tier 1 capital adequacy ratio (CAR) at an average of 8 percent, relative to Basel I's 4 percent minimum threshold (Furlong, 2011:2). This resulted in a loss of confidence in many large banking organisations by depositors and investors alike, with banking regulation losing some credibility in the process.

¹Bear Stearns and Lehman Brothers under the Securities and Exchange Commission and Basel II capital rules; Wachovia under the Federal Reserve and using Basel I rules; Washington Mutual under the Office of Thrift Supervision and Fannie Mae and Freddie Mac under the Office of Federal Housing Enterprise Oversight

The Basel Committee on Banking Supervision [BCBS] (2010:4) also acknowledged weaknesses of the existing framework at the time, attributing the crisis to excessive on and off-balance sheet leverage, a gradual erosion of the quality of capital as well as insufficient liquidity which hampered the system from absorbing systemic trading and credit losses. Regulators have since sought other ways of improving the assessment of capital adequacy in financial institutions. One such way is the adoption of periodic stress tests as part of the supervisory process (Schuermann, 2014:718). One scholar, Wall (2014:266) argues that the supervisory stress tests carried out following the financial crisis, through the Supervisory Capital Assessment Program (SCAP) in the US and by the Committee of European Bank Supervisors (CEBS) in the EU, helped restore confidence in financial regulation. As such, Wall (2014:275) advocates for the adoption of stress testing over the reliance on Basel capital ratios mainly due to the latter's inability to capture a deterioration in asset values, which leads to overstated regulatory capital that does not reflect the economic condition of a financial institution.

Supervisory stress tests are used by policy makers and researchers to not only understand vulnerabilities in the financial system, but quantify them as well (Čihák, 2007:4). By recognizing the inadequacies of the universal Basel capital ratios and taking into account Wall (2014)'s advocacy for the active adoption of stress testing in the determination of capital adequacy for financial institutions, this paper seeks to explore the value of stress testing through a comparison of bank capitalisation before and after stress testing, with a focus on the banking system of Botswana.

1.2 Overview of the Basel Accords

The formal implementation of the regulations in 1988 introduced the Basel I Accord, which adopted the use of a capital ratio to measure banks' capital holdings against their assets adjusted for credit risk (risk-weighted assets). The ratio had to equal at least 8 percent and comprised two components; Tier 1 and Tier 2 capital. Tier 1 (core) capital, regarded as having the highest quality and ability to absorb losses, includes common equity and retained earnings while Tier 2 capital represents the supplementary capital with relatively lesser quality such as subordinated debt and reserves. The risk-weighted assets were computed by allocating risk weightings using a categorisation based on the counterparty involved. Larson (2011: 26) describes such a mechanism as arbitrary, overly broad, and not sensitive enough to the unique risks associated with individual assets held by a bank. Basel I was updated in 1996 to include capital provisioning for market risk in addition to credit risk.

Due to concerns raised over the efficacy of the Basel I rules, the Basel II² rules were introduced

²...also referred to as the International Convergence of Capital Measurement and Capital Standards: A Revised Framework; available at <http://www.bis.org/publ/bcbs128.pdf>

in 2004. One outstanding feature of Basel II is the introduction of a three-pillar system of minimum capital requirements, supervisory oversight and market discipline. However, Basel II also faced objections particularly during the financial crisis relating to its lapses in reliability and objectivity in the determination of asset risk. Larson (2011:30) cited another problem as lack of consistency particularly in credit risk assessment thus allowing banks to maintain lower capital amounts during economic peaks which resulted in insufficient cushion during economic downturns. Such problems led to the subsequent adoption of Basel III³ which was released in 2010 for full implementation by 2019. Basel III ushered in a new definition of regulatory capital which is more restrictive and emphasised quality of capital. With Basel III, overall minimum capital requirement becomes 10.5 percent, which includes the original 8 percent plus a capital conservation buffer equal to at least 2.5 percent of risk-weighted assets (BCBS, 2010:64). As with the first two installments of the Basel accord, Basel III's higher capital requirements and complexity has prompted prospects of another Basel installation, Basel IV.

1.3 Overview of Supervisory Stress Testing

Supervisory stress testing is a risk management technique aimed at assessing the vulnerability and resilience of individual banks or a financial system to severe but plausible events or shocks (Blaschke *et al.*, 2001:4; Oura & Schumacher, 2012:8; Schuermann, 2014:718). The use of stress testing often complements other analytical tools such as early warning systems and Financial Soundness Indicators (FSIs). Early warning systems are often used for prediction of banking crises according to Davis & Karim (2008:89) while FSIs are macroprudential indicators used to assess the financial health and soundness of financial institutions including their corporate and household counterparts (International Monetary Fund [IMF], 2006:1). The BCBS (2009:7) considers stress tests necessary for a forward-looking assessment of risk, overcoming limitations of models and historical data; supporting internal and external communication; feeding into capital and liquidity planning procedures; informing the setting of banks' risk tolerance and facilitating the development of risk mitigation plans across a range of stressed conditions. Further, they are considered especially important after periods of benign economic and financial conditions when complacency and underpricing of risk may be prevalent.

A supervisory authority may employ the bottom-up approach which involves the aggregation of the results of banks, own portfolio stress tests using internal data and models. Alternatively, they may adopt the top-down approach which involves using sample data of some or all the financial institutions in the system and common assumptions (Čihák, 2007:12). Most of the authorities conduct stress tests using both approaches as they may be used to cross-examine each other. Nonetheless, for this paper, only the top down approach will be used as it is regarded

³..also referred to as Basel III: A Global Regulatory Framework for More Resilient Banks and Banking Systems; available at http://www.bis.org/publ/bcbs189_dec2010.htm

as relatively quicker to implement with less analytical complexity (Oura & Schumacher, 2012:14). Moreover, following the financial crisis, several financial regulation reforms published including (Turner Report, 2009; The Geneva Report on the World Economy, 2009; de Larosiere Report, 2009; US Treasury White Paper, 2009), have recommended the use of the top down approach going forward. Macro stress tests also form a critical part of the Financial Sector Assessment Program (FSAP) instituted by the IMF and the World Bank. In macro stress testing, financial system stability is measured by the extent to which a portfolio, individual institution or group of institutions is capable of withstanding external shocks from the macroeconomy (Gadanez & Jayaram, 2008:366). Since 1999, the FSAP has carried out stress tests in several countries around the world and a few large economies in Africa such as South Africa which was included for the first time in 2008 (Havrylchyk, 2010:2). The FSAP stress tests have not reached Botswana, however, the IMF Article IV mission has previously made a recommendation ⁴ for the stress testing of banks' lending, particularly to the household sector.

1.4 Research Problem

The objective of banking regulation is centred around the need for banks to hold capital consistent with the level of risk undertaken. The Basel accord has been established as the standard for determining capital adequacy for banks mainly because of its standardised approach using a CAR that fosters easier comparability of financial institutions and systems. However, the 2007-2009 global financial crisis saw some institutions which were classified as adequately capitalised as per the Basel standards, undergo failure or near failure, which led scholars to question the ability of the Basel accord to ensure that banks hold the sufficient capital buffers even in periods of economic distress (Čih'ak, 2007:53; Haldane, 2009:4; Wall, 2014:266). Notably is the criticism by Wall (2014:274), who also discounts the Basel accord's ability to determine the necessary capitalisation for banks and advocates for the adoption of supervisory stress tests as they were able to identify undercapitalised banks in the US following the crisis. Haldane (2009:4) also laments the complexity of the Basel III standards which he argues have shifted focus from simplicity to increased risk sensitivity making them complex. The constant evolution of the Basel accord provides an indication that regulators are faced with an impasse of having to strike a balance between simplicity and complexity which diminishes comparability among financial institutions.

As the Basel accords continue to undergo changes and improvements, their ability to prevent another financial crisis remains unascertainable. Having always played less of a role in prudential supervision (Wall, 2013:1), stress testing is being presented as an alternative approach towards ensuring that banks hold sufficient capital at all times. This study presents an opportunity to

⁴see in IMF (2016:21); available at <https://www.imf.org/external/pubs/ft/scr/2016/cr16103.pdf>

analyse the dynamics and value of stress testing as a tool to ensure that the banking system holds sufficient capital resources that would avert the likelihood of a bank failure and enough to alleviate future crises. This is a legitimate interrogation as stress testing programs often tend to require a substantial investment in resources, monetary and otherwise. By placing focus on Botswana, the aim is to bring more understanding to the process of stress testing financial systems, especially given the concentrated nature of the developing economy, which can elusively harbour potential risks for the banking system. The study has been motivated by the need to ascertain the resilience and the ability of the banks in Botswana to withstand an economic deterioration as purported by the current strong Basel-based CARs of most banks.

1.5 Research Objective

The aim of the study is to determine whether supervisory stress tests can mitigate the shortcomings of the Basel accord in establishing adequate capital levels for banks in Botswana. The study is guided by the following objectives;

- To determine the system's capital needs using stress testing;
- To explore, comparatively, capital adequacy determination under stress testing as well as the Basel approaches.

1.6 Research Questions

Some of the ideas the study intends to probe include;

- Are the current CARs as determined using the Basel standards sufficient?
- Would a stress test reveal the need for additional capital in the system?
- Would supervisory stress tests mitigate Basel accord shortcomings in establishing bank capital adequacy in Botswana?

1.7 Contribution

This paper seeks to contribute to the limited literature on approaches to supervisory risk assessment in less developed economies, to ensure that financial stability is attained through proper capitalisation of banks in order to improve the resilience of banking systems to unforeseen macroeconomic shocks. The study is relevant for policy relating to bank supervision in Botswana, which is a middle-income country with a concentrated economy, a state of affairs which can translate to increased macroeconomic risk. Simple mechanical exercises are often adopted for stress testing less advanced financial systems and usually involve directly shocking balance sheet

and income statement items using macro-economic factors (Havrylchyk, 2010:4). The study uses a stress testing model developed by Čihák (2014) for less complex banking systems and is, as such, regarded as ideal for Botswana.

1.8 Limitations of the Study

The major limitation of the study is data availability, which is a common problem for developing and transition economies (Havrylchyk, 2010:4). Of all the 10 commercial banks studied, only three are listed and hence some of the data necessary to carry out the stress testing exercise is not publicly available for most of the banks. The stress test, nonetheless, adopted an aggregate focus, where only collective commercial banks' data was used. This, however, means the results are deprived of the more detailed bank by bank analysis which would provide more insight into the system's vulnerabilities. An analysis involving individual banks is deemed necessary because, even though the system has shown to be adequately capitalised and resilient, some banks could possess considerable unique weaknesses and as such remain prone to increased risk should there be a deterioration of macroeconomic conditions. The model also uses simplified assumptions to accommodate the relatively less developed nature of the financial system, however, this tends to take away robustness in the processing of shocks. Lastly, there is limited past research on stress testing of financial systems for less developed countries, hence benchmarking, such as on assumption formulation, often refers to cases of developed markets, which are structurally different.

Furthermore, the interpretation of stress testing results also takes into consideration the various theoretical and practical limits. Firstly, the use of a system-wide stress test means that the assessment does not cover idiosyncratic institutional risks in terms of asset quality and even operational issues. Secondly, aggregate-level stress testing only provides approximate results as it does not take into account the responses, of both the individual banks and supervisors, to shocks in the financial system (Čihák & Heřmánek, 2005:4). Finally, the choice of risks selected for modelling is largely dependent on the availability of required data. For instance, due to the unavailability of sufficient data, only simple liquidity tests have been carried out.

1.9 Organisation

The rest of the paper is organised as follows; Chapter 2 discusses the general theoretical background relating to approaches to supervisory risk assessment in terms of the Basel capital accord and application of stress tests, while making references to the 2007-9 global financial crisis. Chapter 3 describes the economic climate of Botswana and its interaction with the banking system to provide justification as to why the banking system in Botswana needs to be stress tested. Chapter 4 outlines the research approach including the method and data adopted for this study. Chapter 5 describes the stress testing model employed in carrying out the process of stress

testing the banking system. Chapter 6 presents the results of the stress testing exercise followed by an analysis in Chapter 7 where a comparison between the pre-stress and post-stress CAR is the focal point. Chapter 8 summarises the outcome in the conclusion and makes recommendation for future studies.

BACKGROUND AND RELATED WORK

2.1 Introduction

This chapter analyses the theoretical background of supervisory risk assessment with a focus on stress testing as a regulatory tool that can be used to overcome the shortcomings of the Basel capital framework in ensuring that banks continuously hold adequate capital. The section discusses the background of both stress testing and the Basel accord by comparing the two in terms of strengths and shortfalls as well as why the Basel accord is considered inadequate by some scholars. Finally, this review will narrow the discussion to supervisory risk assessment in Africa in order to relate it to the context of Botswana, whose banking system will be the subject of the study.

As a result of globalisation, financial innovation and financial sector deregulation, banking business has become more complex and especially risky. It is for this reason that various initiatives have been geared towards the development of more structured and quantified assessments of the risks faced by financial institutions. These efforts are collectively termed supervisory risk assessment and entail the identification, measurement and control of risk exposures existing in the financial system (Sahajwala & van den Bergh, 2000:1). When the balance sheets of banks are affected by a common asset shock, a crisis occurs (Acharya, Engle & Pierret, 2014:37). Bank failure comes at a cost owing to government bailouts and in some instances depositors' insurance. In addition, when the financial system is undercapitalised it becomes susceptible to externalities that spill over to the rest of the economy (Acharya *et al.*, 2017:3). For a long time, bank regulation has placed emphasis on the positive aspects of banks' capital (Barth, Caprio & Levine, 2004:215; Demirgüç-Kunt, Detragiache & Merrouche, 2013:1147). This is because capital serves as a cushion against losses and ultimately bank failure. Bank supervisors largely rely on ratios to evaluate the capital adequacy of financial institutions.

2.2 The Evolution of the Basel Capital Framework

After World War II, many regulatory agencies used a variety of ratios, however, without any specific requirements (Kim & Santomero, 1988:1220). The ratios helped supervisors to compare institutions against each other while keeping the individual banks from reducing their capital ratios below their peers. However, this system could not prevent widespread declines in capital ratios which eventually became a problem (Wall, 2014:267). Furthermore, the regulatory standards varied from one country to the other, which resulted in similar exposures receiving different treatments depending on the jurisdiction. This capital regulation form of assigning numeric requirements based on a leverage ratio was denounced by Kapstein (1991:16) as "hopelessly simplistic". In the late 80s, bank supervisors began investing substantial resources in the development and implementation of capital adequacy requirements as a primary prudential regulatory tool (Kim & Santomero, 1988:1220). These efforts have led to the development of regulatory capital framework of the BCBS, which had a threefold objective; (a) to ensure that the amount of capital buffers that banks hold is congruent to their respective risk levels; (b) to standardise capital measures across jurisdictions and (c) to foster comparability of capital levels between different banks (Goodhart, 2011:147). The BCBS' work on developing regulation aimed at combating banking risk can be broken down in to five regulatory waves.

The first wave involved the publication of the 1975 Basel Concordat⁵, which provided guidance on cross border regulation relating to banks' foreign establishments with a focus on supervisory cooperation, liquidity and solvency management (BCBS, 1975:1-5). The Concordat ran its course until 1986 amid several bank failures⁶, the 1973 oil shock as well as the Iran-Iraq war of 1982 (Penikas, 2015:15). In December 1987, the second regulatory wave began with the publication of a consultative document on the Basel I Accord which was adopted in 1988. Basel I established a formal basis for banking risk regulation using a CAR. Between 1988 and 1996, Basel I was periodically amended to address changes in banks' activities. The most notable change is the introduction of capital provisioning for market risk, in addition to credit risk, through the Market Risk Amendment of 1996 (Amendment). The Amendment also included a revision of countries to be allocated a zero-risk weighting (BCBS, 2005a:9). The third regulatory wave commenced with the announcement of the revision of Basel I to create Basel II. According to Penikas (2015:16), the third wave experienced the most turbulent economic environment owing to the 1997 Asian crisis, the 1998 Russian sovereign debt default, 2001 dotcom bubble breach as well as the 2007 subprime mortgage plunge.

The Basel II framework's main objectives were to increase the scope, flexibility and risk sensitivity of capital charges by providing approaches that determine requirements for major banking

⁵see in <http://www.bis.org/publ/bcbs00a.pdf>

⁶Notably, Herstatt Bank in 1974 which was overcome by settlement risk.

risks regardless of size and sophistication levels (BCBS, 2006:2). A three-pillar system was also introduced comprising minimum capital requirements as Pillar 1, which relates to the minimum regulatory capital that a bank must hold to cover its exposure to credit, market and operational risk (BCBS, 2006:12). Pillar 2 complemented Pillar 1 by outlining a supervisory review process which allows for capital requirements to be tailored to each bank's risk profile including the calculation of any further regulatory capital that may be needed. Public disclosures that enhance market discipline are covered under Pillar 3. The supervisory expectation is that banks which the market judges to have increased their risk profiles without adequate capital backing will have their securities unattractive in debt and equity markets and as such compel them to modify either their risk profile or capital base (BCBS, 2006:3). However, the financial crisis revealed several problems with the Basel II standard including condemnation of the rating agencies' flawed allocation of ratings to securitised products using faulty methodologies, apparent bribery and in some cases, conflict of interest (Wojtowicz, 2011:4). This left some banks undercapitalised relative to their true exposures. Between 2004 and 2009, the BCBS published several documents⁷ providing Basel II implementation guidance as well as setting up the Standards Implementation Group to support the implementation process in different countries.

This paved way to the fourth regulatory wave which was short-lived and started with the introduction of the Basel III accord that was created in response to the financial crisis. Revisions⁸ to the Basel II accord began in December 2009 with a Basel III consultative paper, which included inter alia; additional capital requirements, a proposal for quantification for liquidity as well as the introduction of a leverage ratio of 3 percent (BCBS, 2010:63). As per the BCBS (2010:5), the objectives of Basel III include strengthening the quality and consistency of regulatory capital, improving transparency and risk coverage as well as ensuring that capital requirements are able to dampen financial shocks. The Basel III capital requirements include a minimum common equity, Tier 1 and total capital requirements of at least 4.5 percent, 6 percent and 8 percent of risk-weighted assets, respectively; the elimination of capital instruments that no longer qualify as regulatory capital plus a capital conservation buffer, expected to reach 2.5 percent of risk-weighted assets by January 2019. A counter-cyclical capital buffer of between 0 percent and 2.5 percent of risk-weighted assets will also be implemented as per national circumstances (BCBS, 2010:7).

Criticism of Basel III has ignited prospects of Basel IV. According to Amorello (2016:24), the four main weaknesses of the Basel III framework are; (a) extreme complexity of the requirements; (b) the use of capital adequacy computations based on banks' internal models; (c) failure to capture

⁷See documents available at http://www.bis.org/list/bcbs/tid_23/index.htm

⁸Two documents published in July 2009: see Enhancements to the Basel II Framework (available at <http://www.bis.org/publ/bcbs157.htm>) and Revisions the Basel II market risk framework (available at <http://www.bis.org/publ/bcbs158.htm>)

all off-balance sheet risks and (d) incomprehensive market disclosure requirements. Amorello (2016:29) further asserts that due to several publications⁹ of reforms post Basel III, there is reasonable ground for the anticipation of a Basel IV package aimed at enhancing the inadequacies of Basel III. According to Dormans & Pit (2014:16), Basel IV would help reduce reliance on complex internal models, standardise comprehensive data collection and reporting, increase transparency in risk reporting, make credit rating agencies less fundamental to regulatory credit risk assessment as well as a possible increase of capital requirements for banks. Penikas (2015:17) posits that all the post-Basel III regulation qualifies to be regarded as the fifth regulatory wave as it consists of regulatory proposals that are not consistent with Basel III.

2.3 The Role of Supervisory Stress Testing

Originally an engineering concept, supervisory stress testing is used to describe various techniques and procedures that gauge financial institutions' potential vulnerability to exceptional but plausible events (Committee on the Global Financial System [CGFS], 2000:6; Borio, Drehmann & Tsatsaronis, 2014:4). Exceptionality indicates that they should be low probability events, however, not too farfetched as to exceed the confines of plausibility as this can limit the importance given to the results of the tests. Hilbers, Jones and Slack (2004:4) also describe stress testing as a rough estimate of how the value of a portfolio changes when large shocks are effected to its risk factors. The inclusion of the term "rough estimate" here, is said to dilute the perception that stress testing is a precise tool that can be used with scientific accuracy. Schuermann (2014:722) indicates that stress testing was traditionally performed on the trading book and not necessarily the banking book mainly because the latter is dominated by credit risk and quantitative credit risk modelling is itself a newer discipline. Similarly, Dovern, Meier and Vilsmeier (2010:1844) point out that macroeconomic stress testing is also a relatively new research area, however, following the 2007-9 global financial crisis, stress tests are fast becoming standard tools used by regulators to assess the resilience of the financial system (Acharya, Engle & Pierret, 2014:37).

According to Blaschke *et al.* (2001:6), internationally active banks began applying stress tests in the early 90s but were officially sanctioned for use with the Amendment of 1996. The Amendment permits banks to use their own internal models to measure their capital requirements for market risk, subject to certain conditions, inter alia; the requirement to have a rigorous stress testing program (BCBS, 2005a:35). A major impediment with this requirement as noted by Wall (2014:270) is that most banks only conducted stress tests that were largely limited to their trading books. On the supervisory front, Trapanese (2009:7) puts forward that there is yet

⁹Revisions to the Standardised Approach for credit risk - Second consultative document (Dec 2015) (available at <http://www.bis.org/bcbs/publ/d347.htm>); Minimum Capital Requirements for Market Risk (Jan 2016) (available at <http://www.bis.org/bcbs/publ/d352.htm>); Standardised Measurement Approach for operational risk - consultative document (March 2016) (available at <http://www.bis.org/bcbs/publ/d355.htm>)

to be a widely-accepted analytical risk assessment framework to measure financial stability. In measuring macroeconomic vulnerability, stress tests can also be used to simulate portfolios of individual financial institutions in what is referred to as micro stress testing (Borio, Drehmann & Tsatsaronis, 2014:4). According to Hilbers, Jones and Slack (2004:1), macro- and micro- stress tests complement each other as they allow for a broader analysis while leveraging the existing expertise found in different financial institutions.

Stress testing programs can be resource intensive and as such it is only reasonable that the adoption of such a process be justified. One of the main benefits of system-wide stress tests is that they provide policymakers with insights on the financial system vulnerabilities, and implications thereof (Hilbers, Jones & Slack, 2004:3). As indicated by IMF (2003:4), system stress tests often involve a series of consultations between banks and regulators as well as effect a standard approach to risk assessment while taking into account macroeconomic activity. Hilbers, Jones and Slack (2004:3) further explain that the stress testing process can help supervisors identify weaknesses in data collection and reporting, cross-check the performance of individual firms' risk models as well as improve their expertise of risk, based on the relationship between the financial sector and the macroeconomy. Borio, Drehmann and Tsatsaronis (2014:12) posit that macro stress tests help discipline thinking about financial stability for all stakeholders involved. As also noted by Acharya, Engle and Pierret (2014:38), stress tests can help to align the market's perception of risk with the likelihood of bank failure. Finally, Borio, Drehmann and Tsatsaronis (2014:4) propose that for stress tests to be effective, they have to be tailor made for a specific purpose.

2.4 Are the Basel Standards Enough? - Wall (2014)

Prior to and during the financial crisis several institutions¹⁰ failed or needed some form of government assistance albeit meeting the minimum capital adequacy requirements (Demirgüç-Kunt, Detragiache & Merrouche, 2013:1149; Schuermann, 2014:717). This cast aspersions on the efficacy of the Basel capital regulations in place at the time. In his critique of the performance of the Basel ratios in the financial crisis, Wall (2014:266) argues that the problem was not that banks were reporting low Basel CARs, but that the regulation that had been entrusted with ensuring that banks maintained sufficient capital at all times, was unable to do so. Wall (2014:266) further contends that it is for this reason that regulators resorted to stress tests as a way of addressing stakeholders' concerns about financial institutions' capital adequacy. Wall (2014:274) has advocated for the adoption of stress testing in banking risk regulation, a case argued from the perspective of what it is that stress tests can do that the Basel ratios do not.

¹⁰including Bear Sterns, Lehman Brothers, American International Group, Royal Bank of Scotland, Dexia, Lloyds and Fortis

Wall (2014:266) asserts that stress testing uses forward looking scenarios whereas the Basel capital ratios rely on historical risk distributions and data to estimate bank specific distribution of losses. Moreover, the Basel measures are based on the supposition that for bank capital to be regarded as adequate, it should on average, be able to cover unexpected losses of a bank in excess of available total capital "once in a thousand years"¹¹, with a 99.9 percent confidence level (BCBS, 2005b:11). Wall (2014:266) argues that this assumption increases the risk of using prevailing benign economic conditions as a yardstick which is likely to lead to an underestimation of potential losses. In contrast, however, supervisory stress tests allow supervisors to specify conditions against which banks' capital positions will be tested. This provides allowance for construction of even random scenarios that may not necessarily be based on economic activity of the recent past (Wall, 2014:275). Wall (2014:275) further indicates that Basel ratios use capital figures computed as per accounting standards which may harbour unrecognised losses in asset values as compared to stress tests which allow for capital to be adjusted against a specified stress scenario. Moreover, even though they use accounting measures of capital as well, stress tests can use a longer time horizon to allow for the eventual recognition of losses by banks. Wall (2014:266) further indicates that for these reasons, bank asset values were criticised for not reflecting security valuations in full during the financial crisis. This is also supported by the results of a study by Furlong (2011:3), in which a comparison between banks' book value and market values of capital during the crisis, revealed that the Basel ratios were calculated based on inflated estimates of capital.

Finally, Wall (2014:274) describes Basel ratios as static and unconditional because they measure capital adequacy at a single point in time without consideration for possible future economic developments. The scholar maintains that although the Basel ratios provide definitions for items necessary for capital adjustments, these values are deduced directly from individual banks' financial statements and as such have been measured through "a process that is totally independent from the one used to calculate Basel ratios". Financial statements are prepared following a set of accounting standards, a process which is independent of the determination of regulatory capital as stipulated by the Basel capital standards. By contrast, Wall (2014:274) describes stress tests as dynamic because the adjustment for risk takes place in the capital itself. In line with Wall (2014)'s arguments, Blum (1999:768) discounts capital requirements as inducing risky behaviours in banks. Because supervisors use regulatory capital as one of the tools to reduce insolvency risk in financial institutions, Blum (1999:768) argues that this may not necessarily be the case due to the inverse relationship between a regulatory capital and profitability. Therefore, if expected future profitability is lower, a bank may have a lesser incentive to avoid default. Moreover, because capital regulation increases the value of equity, a bank may find it optimal to increase its risk appetite in order to boost returns.

¹¹see in An explanatory note on the Basel II IRB Risk Weight Functions available at <http://www.bis.org/bcbs/irbriskweight.pdf> (BCBS 2005b:11).

2.5 Supervisory Risk Assessment in Africa

This paper studies the impact of stress tests on the banking system of Botswana, a middle-income economy in Africa. According to Barth, Caprio and Levine (2004:215), there is limited evidence that the international best practices in banking regulation will succeed in countries with different institutional and political environments. In developing quantitative risk management models, most studies have placed focus on developed economies (Barrell *et al.*, 2010:2256). This means most low-income countries, including those in Africa tend to receive little specific attention related to building of early warning systems and stress testing frameworks that are tailored for their economies (Caggiano, Calice & Leonida, 2014:258; Triki *et al.*, 2017:184). This, perhaps, is the case because most of the financial distress of the past two decades took place outside Africa.

According to Nyantakyi and Sy (2015:14), between 1970 and 2012, Africa experienced, on average, one systemic banking crisis per year while the equivalent figure for the rest of the world is 2.4. As a consequence, relevant empirical literature seems to have devoted less attention to middle and low-income countries, albeit history showing that these countries' episodes of crises take much longer to be resolved (Caggiano, Calice & Leonida, 2014:258). It is important to note that during the 2007-9 global financial crisis, banking systems in many African countries have, on average, been able to remain stable. The resilience has been attributed to improved macroeconomic policies (Caggiano, Calice & Leonida, 2014:258), as well as stringent regulatory frameworks which have bolstered prudential requirements (Triki *et al.*, 2017:187). Nyantakyi and Sy (2015:1), however, indicate that vulnerabilities are likely to become more pronounced in developing countries as financial deepening increases and financial transactions become more sophisticated. Nyantakyi and Sy (2015:15) have also observed that African countries seem reluctant in the implementation of the recent Basel III rules, attributing the position to underrepresentation in the BCBS as well as the notion that the rules are less relevant for Africa. Another factor suggested is the low integration of Africa with global financial markets which makes Basel II and III rules too complex for most of the banking systems. Lastly, Beck *et al.* (2011:242) and Triki *et al.* (2017:184) conclude that due to the uniqueness of its financial system, it is up to Africa to define its priorities in terms of banking regulation and supervision.

2.6 Stress Testing Insights from the Global Financial Crisis

Undoubtedly, the 2008 global financial crisis will remain a future standard for an extended period of time (Borio, Drehmann & Tsatsaronis, 2014:5). Blundell-Wignall and Atkinson (2010:21) contend that every financial crisis is unique and that there are probably flaws in the current financial system that regulators have not yet identified. The value of stress tests is often related to the success of SCAP after the crisis, however, the ability of the tests to remain valuable in the next crisis cannot be ascertained. Wall (2014:275) expounds two possible reasons for this asser-

tion. Firstly that, Basel ratios may become improved and a better measure of capital before the next crisis. Secondly, the problem of Basel's reliance on accounting measures of capital could be resolved as the major accounting standard setting bodies, the International Accounting Standards Board and Financial Accounting Standards Board, have been engaged to devise ways of averting some accounting problems from the crisis (Wall, 2014:278). However, there is no guarantee that banks themselves will address their own problems relating to timely deterioration of their assets' values. Wall (2014:279) nonetheless, acknowledges that should the necessary changes be effected to the Basel regulations, the value added of stress testing may greatly diminish.

Another important lesson is that the motive and level of risk appetite should also be clearly reflected in scenario design. For instance, the need to recognise or avoid recognising potential economic losses should be clearly indicated as was the case in the SCAP and CEBS, respectively (Schuermann, 2014:722). Wall (2014:280) describes a problem such as a possible reluctance by supervisors to use scenarios that may reveal severe systemic problems, banking on the expectation that financial institutions would be able to rebuild capital adequacy on their own. For instance, for the CEBS test, it was revealed that a severely stressful scenario may reveal weakness which supervisors would need to take prompt action on, however, that may well be a false alarm that would undermine stakeholder confidence in the banking system. This was particularly necessary because, given the financial difficulties by some EU member states, there was no provision to cover capital shortfalls or even resolve systemically important banks, should they fail the test. Stress testing, as such, requires supervisory caution because it has a bearing on one of the core role of supervisors: to ensure confidence in the financial system.

2.7 Building Blocks of Stress Testing Models

The process of macro stress testing commences with an assumed shock to the system. The shock is then related to macroeconomic variables such as the Gross Domestic Product (GDP), interest rates and inflation using a macroeconomic model. Thereafter, the shocked variables are linked to banks financial statement data using the model. The effect of the shock on the banks' financial performance is estimated in terms of minimum capital adequacy (Henry & Kok, 2013:14). Generally, macro stress testing models can be represented as follows;

$$\Omega\left(\frac{\check{Y}_{t+1}}{\check{X}_{t+1}} \geq \check{x}\right) = f(X^t, z^t) \quad (1)$$

Source:(Sorge, 2004:3-4; Vukelić, 2011:8)

where \check{X}^t is the set of past realisations of the macroeconomic variable X; Z^t is the set of past realisations of the other relevant factors; \check{Y}_{t+1} is the measure of distress for the financial system; \check{X}_{t+1} ; \check{X} is the condition for stress test scenario to occur; $\Omega\left(\frac{\check{Y}_{t+1}}{\check{X}_{t+1}} \geq \check{x}\right)$ is the uncertain future realisation of a measure of distress in the event of the shock; $\Omega(.)$ is the risk metric used to

compare financial system vulnerability across institutions and scenarios and; $f(.)$ is the loss function that maps the initial set of shocks to the final impact measured on the financial sector,s portfolio.

2.7.1 Objectives

The main goal of macro stress tests is for bank supervisors to identify system vulnerabilities and overall risk exposures that may affect financial stability. Drehmann (2008:60) outlines the three main objectives of stress testing as (a) to provide validation for perceived risk and vulnerabilities; (b) to aid decision making as the results are used to inform business decisions and future plans; and (c) through the results, to communicate the overall positions of the financial institutions to the target audience. Vukelić (2011:10) also writes that the financial institutions to be analysed should also be clearly defined with a possible distinction drawn in terms of ownership, size and performance as seen in (Čihák, 2007).

2.7.2 Elements

According to Borio, Drehmann and Tsatsaronis (2014:5), a stress test consists of four elements, viz; (a) the set of risk exposures subjected to stress; (b) the scenario that defines the exogenous shocks that stress those exposures (c) the model that maps those shocks onto an outcome (or impact) as well as (d) a measure of the outcome. For instance, if a macro stress test assesses solvency as measured by capital (outcome), the financial statements of a group of financial institutions (risk exposures) may be subjected to a recession (the scenario defining the shock) using specified structural relationships (the model). Stress test modelling requires a clear definition of the scope of the analysis in terms of objectives, institution coverage, exposures and risk measures (Vukelić, 2011:8).

2.7.3 Exposures and Scope

Although inclusion of the whole financial system is more comprehensive, it runs the risk of complexity. Therefore, due to data and model limitations, it is common that only a section of the financial system can be assessed. This approach is supported by Drehmann (2008:67), who highlights banks' role of financial intermediation as pivotal to the economy and as such makes them likely to transfer financial system shocks into the real economy. However, other sectors of the financial system such as insurance and other financial corporations may also be included (Čihák, 2007:20). Moreover, stress testing is usually limited to domestic financial system more especially due to data availability, however, studies, such as Pesaran *et al.* (2006), have carried out international macro stress testing by linking asset values in the domestic credit portfolio to a dynamic global macro model. Exposures to be tested are developed from the objectives of the stress test. Table 2.1 summarises some common risks which banking institutions can be exposed

to. Most stress testing studies focus on the credit risk exposure (Schuermann, 2014:722). Some studies, nonetheless, do account for other exposures such as (Drehmann, 2008) who considered interest rate risk and (Čihák, 2007) who created a hypothetical banking system to analyse several risk exposures including credit, liquidity, market and contagion risks. Contagion risk can also be found in studies such as (Barnhill, Papapanagiotou & Schumacher, 2002; van den End, Hoerberichts & Tabbae, 2006).

Table 2.1: Some common risks assessed in the stress testing process

Credit Risk	The risk of losses arising from a counterparty's failure to meet his contractual obligations.
Liquidity Risk	The risk that an institution will be unable to meet its obligations as and when they fall due without incurring any significant losses.
Market Risk	The risk of losses in both on- and off-balance sheet exposures due to changes in market prices inter alia; interest rate, foreign exchange rate and commodity prices).
Contagion Risk	The risk that the failure of one or more institutions will negatively affect financial performance of other institutions.
Concentration Risk	The risk of losses as a result of uneven distribution of exposures to an institution's debtors, sectoral or product-wise.

Source: (Čihák, 2007:26-42; Committee of European Bank Supervisors [CEBS], 2010:31-47)

2.7.4 Measures of Risk

The choice of the risk measures is determined by the objectives of the stress testing and the considered exposures. Vukelić (2011:13) and Čihák (2007:14) indicate that a risk measure should fit two requirements; produce a variable to measure the financial system's health and create a credible linkage between the financial system and macroeconomic risk factors. For example, FSIs designed to measure the health of the financial sector, corporations as well as household sector of a given country (Sundararajan *et al.*, 2002:2). Using data obtained from financial statements, the ratios provide an indication of financial health in terms of capital adequacy, profitability, asset quality, liquidity and sensitivity to market risk (IMF, 2006:155). Table 2.2 shows the core set of FSIs, which should be computed by all IMF member countries as well as the encouraged set which includes supplementary, non-compulsory indicators that extend beyond deposit takers to cover other economic sectors such as households, financial and non-financial corporations as well as the real estate market.

Čihák (2007:14) also provides an overview of other risk measures commonly used in stress testing as follows;

TABLE 2.2. List of FSIs relating to the banking sector

FSI Code	Core FSIs for Deposit Takers
I01	Regulatory capital to risk-weighted assets
I02	Regulatory Tier 1 capital to risk-weighted assets
I03	Common equity Tier 1 to risk-weighted assets (Solvency Ratio)
I04	Capital to assets
I05	Non-performing loans net of provisions to capital
I06	Non-performing loans to total gross loans
I07	Provisions to non-performing loans
I08	Sectoral distribution of loans to total loans
I09	Return on assets
I10	Return on equity
I11	Interest margin to gross income
I12	Non-interest expenses to gross income
I13	Liquid assets to total assets
I14	liquid assets to short term liabilities (liquidity coverage ratio will replace this measure when Basel 3 is fully adopted)
I15	Available amount of stable funding to required amount of stable funding (Net stable funding ratio)
I16	Net open position in foreign exchange to capital
	Additional FSIs for Deposit Takers
I18	Large exposures to capital
I19	Geographical distribution of loans to total loans
I20	Gross asset position in financial derivatives to capital
I21	Gross liability position in financial derivatives to capital
I22	Trading income to total income
I23	Personnel expenses to non-interest expenses
I24	Spread between references lending and deposit rate (base points)
I25	Spread between highest and lowest interbank rates (base points)
I26	Customer deposits to total (non-interbank) loans
I27	Foreign-currency-denominated loans to total loans
I28	Foreign-currency-denominated liabilities to total liabilities
I29	Credit growth to private sector

Source: (International Monetary Fund, 2006:155)

- Capital, capitalisation and capital injection - The impact of a shock on solvency usually results in changes in capital. Using capital as a risk measure is advantageous because the variable is easily accessible and publicly available;
- Profits and profitability - During periods of financial distress, a bank's profit can be considered as the first line of defence against losses and before capital is engaged. Accordingly, it is useful to express the impact of a shock based on a bank's profits in addition to capital. The main difficulty with this approach is that information on the distribution of profits, for instance, pertaining to treatment of retained earnings may not be publicly disclosed resulting in estimation using historical values;
- Ratings and probabilities of default (PDs)- These allow for a combination of solvency and the liquidity risks into a single measure. The indicators are useful as they translate the changes in variables into the changes in ratings allowing for the impact on PDs to be estimated by linking ratings with a bank's chances of going bust.

2.8 Stress Testing Techniques

There are two main stress-testing techniques, sensitivity testing and scenario analysis. Sensitivity tests assess the impact of a short-term change in a specified risk factor without necessarily indicating the reasons for such movements (CGFS, 2000:6; CEBS, 2010:11). Despite being relatively quick and easily applicable, sensitivity tests may lack historical and economic content, and this can limit their usefulness in longer term risk management decisions. Scenario analysis on the other hand, carries out a "what-if" analysis by specifying the shocks that might affect, simultaneously, a number of market risk factors (Dowd, 2002:4). Scenarios may be historical or hypothetical. This is discussed further under scenario design.

2.9 Limitations and Challenges

The shortcomings of the current stress testing methodologies have been extensively discussed in the studies by, among others; (Sorge & Virolainen, 2006; Čihák, 2007; Drehmann, 2008; Borio & Drehmann, 2010; Borio, Drehmann & Tsatsaronis, 2014). Two main sets of limitations stand out; the technical and contextual aspects as elaborated below. Other shortcomings are also discussed.

2.9.1 Technical (Modular) Limitations

Borio, Drehmann and Tsatsaronis (2014:9) contend that models tend to perform worst precisely during conditions of financial distress especially given that these episodes are rare and data availability is poor, which limits the degree of statistical confidence. As shown by Alfaro and Drehmann (2009:34), and contrary to popular belief, financial crises do not begin after output has collapsed, but rather before it contracts significantly. Similarly, work by Drehmann, Borio and Tsatsaronis (2012:2) also suggests that crises tend to begin at the peak of the medium-term financial cycle, not during the depth of the bust. This highlights the need for regular stress testing and not necessarily during periods of financial distress. Breuer and Summer (2013:77) also posit that most model structures do not incorporate the effect of feedbacks, such as credit tightening by banks following a recession, even though they are the root cause of financial instability. This may result in econometric errors and model risk which may provide a false sense of security and an underestimation of risk. Finally, Borio and Drehmann, (2010:22) do point out that sometimes the size of a stress test shock must be very large to get any action in a model for identifying serious vulnerabilities.

2.9.2 Contextual Limitations

Borio and Drehmann (2010:9) discuss an unusual observation where the system tends to look strongest at its most vulnerable stage thereby inducing aggressive risk taking by banks and reluctance by supervisors. Likewise, Reinhart and Rogoff (2009:3) found that booms are also

associated with a proliferation of financial innovation, however, because of lack of historical data on new products and their performance, there tends to be an underestimation of their potential resultant risk. These are possible reasons why macro stress tests are often incapable of capturing vulnerabilities before they manifest into a crisis, as similar observations were made by Ong and Čihák (2010:21) in their analysis of the failed stress tests of the Icelandic banking system before the global financial crisis. In terms of behavior, Borio, Drehmann and Tsatsaronis (2014:12) posit that even if stress tests were successful in identifying potential vulnerabilities, policymakers would find it hard to take them seriously especially given that market confidence is usually at its highest and prudence at its lowest in pre-crisis periods. Furthermore, there is extensive reliance on the judgement and experience of risk managers without any guarantee that they will interpret the results effectively (Dowd, 2002:165). Lastly, Drehmann, Borio and Tsatsaronis (2014:14) consider stress tests as better tools for crisis resolution and not for prediction purposes, arguing that once the crisis has already emerged sources of vulnerability become apparent and as such can be easily stressed.

2.9.3 Other Limitations

2.9.3.1 Data Availability

Severe historical events are rare which often makes the use of available historical data not entirely relevant. This means that the model needs to be adjusted with additional assumptions that rely on expert judgement or a data generating process (Drehmann, Borio & Tsatsaronis, 2012:7). Moreover, necessary data may not be available for public consumption, for example, some client information may be regarded as confidential (Drehmann, Sorensen & Stringa, 2010:726). Other data may not be comparable among firms. Unavailability of data often leads to aggregation, which also presents a methodological challenge and introduces aggregation bias where parameters estimated at a macro-level deviate from the true underlying micro parameters (Hale, Krainer & McCarthy, 2015:3). Furthermore, measuring the capital adequacy of a financial system with data that is combined, may not reveal vulnerabilities that are bank-specific from the perspective of individual banks who understand their exposures in greater detail. Finally, because big, insolvent institutions are more likely to cause systemic disruptions due to the contagion effect, size weighted averages may then be employed to account for the systemic importance of banks (Tabak, Fazio & Cajueiro, 2013:3856).

2.9.3.2 Endogeneity of Risk

The endogeneity of risk can result in a disproportionate response to exogenous shocks. Drehmann (2008:77) found three sources of endogenous risk in stress tests. Firstly, is the endogenous behaviour of market agents, for instance, banks make an effort to control losses from a crisis through hedging or realigning portfolios. Secondly, liquidity risk may result in a bank run,

particularly for weak banks, due to panic in the market as a result of shocks. Finally, macro feedbacks -how the macro economy affects the financial system and the second-round effects - how the financial system affects the economy, should also be considered. Because market agents respond differently to shocks, it often becomes complex to determine all the feedback costs in addition to the amount necessary to restore banks to minimum capital adequacy.

Other common administrative limitations include; time or resource constraints, a high computational cost for structural models as well as a lack of expertise (CGFS, 2000:3). Nevertheless, even with these limitations, historical experience has shown that macro stress tests are useful, because they provide a quantitative measure of the vulnerability of the financial system to different shocks, which can be used with other analyses to draw conclusions about the overall stability of the financial system (Blaschke *et al.*, 2001:44).

2.10 Methodological Approaches to Stress Testing

2.10.1 Bottom-up vs. Top-Down Approach

Bottom-up stress testing is when a supervisory authority provides assumptions about possible future economic conditions and allows banks to use their own internal models to carry out stress tests and report the results to the supervisor. The top down approach, on the other hand, entails supervisors designing scenarios and actually conducting the stress tests (Čihák, 2007:12; Borio, Drehmann & Tsatsaronis, 2014:7). Often times, authorities combine the two approaches by comparing bottom-up exercises with top-down evaluations. The combination approach was applied in both the SCAP and the CEBS stress testing programs in the US and Europe, respectively (Borio, Drehmann & Tsatsaronis, 2014:7). Haldane (2009:15) distinguishes between the two approaches by indicating that the top-down approach provides information on the overall impact of shocks as well as their distribution throughout the system which aids in understanding the potential contagion effects on financial stability. It also uses same assumptions and procedures across board making comparisons easier. The major disadvantage of the top-down approach is that it can lead to the loss of some relevant information such as overlooking data which may be confidential or too complex. Contrastingly, the bottom-up approach can capture such information better as it would be the banks themselves who provide the detailed information. The main disadvantage is, however, that banks do not necessarily use the same models which hampers comparability and benchmarking (Vukelić, 2011:9).

2.10.2 Scenario Design

Berkowitz (1999:8) outlines four types of scenarios as follows; (a) those that simulate the shocks that are likely to happen than historical data suggests; (b) those that work with shocks which have never occurred; (c) those that simulate shocks which may result in defiance of statistical patterns due to structural differences of financial systems and (d) those that simulate the shocks

that express possible future structural breaks such as a change in the exchange rate regime. A scenario can be formulated by relying directly on historical episodes of financial crises or alternatively, using judgement (Dowd, 2002:168). Historical scenarios are easier to articulate and reasonable and as such appear more credible because the hypothesised event actually happened in the past. The downside to using historical scenarios is that scenario selection is usually based on past developments in the market and/or business segment. This creates a tendency to focus on past events and not future dangers. As such, there is an increased chance that a firm may adopt risk management that is based on past shocks rather than future risks that do not have an exact historical parallel (CGFS, 2000:3). Moreover, the number of usable historical scenarios is limited as stress events are rare by definition. Further, scenarios may be difficult to apply to products that did not exist at the time of the historical event in question (James, 2012:173). By contrast, (Borio, Drehmann and Tsatsaronis (2014:5) suggest that hypothetical scenarios avert the tendency to pay more attention to past events than potential future occurrences. However, the major problem with the latter is the difficulty in formulating sensible and easily apprehensible scenarios.

As discussed in Čihák (2007:48), scenario design can adopt two approaches, the worst-case approach and the threshold approach. The worst-case approach formulates a scenario with the worst likely impact whereas the threshold approach identifies the most plausible scenario that would lead to a specified impact. Historical experience is often used to judge plausibility of the scenario. Scenarios may also be developed through a data generating process of which Drehmann (2008:73) has identified four main methods namely; (a) the calibrated distributions of the unobserved factors; (b) the autoregressive processes for each underlying macro variable; (c) the reduced form vector autoregressive macro models and (d) the structural macro models. Borio, Drehmann and Tsatsaronis, (2014:3) do note an observation that scenario design becomes a difficult exercise particularly when used to uncover vulnerabilities during tranquil times.

Caggiano, Calice and Leonida (2014:262) also provide three groups of explanatory variables that may be used in scenario design for stress testing as follows;

- Banking system characteristics such as foreign exchange net open position, liquidity position and leverage should be taken into consideration. A negative foreign exchange net open position signals substantial potential losses should the domestic currency fall in value. Further, a high deposit turnover increases liquidity risk especially in cases where sources of funding for banks are limited (IMF, 2012:8). Lastly, the ratio of aggregate equity to total assets can be used to assess the ability of a bank, with a deteriorating capital position, to absorb unexpected losses (Caggiano, Calice & Leonida, 2014:262).
- Macroeconomic fundamentals including real GDP growth, inflation and nominal exchange rate depreciation. Economic performance has an effect on the ability of borrowers to meet their obligations and thus affects the quality of credit in the banking system. This is

especially the case for developing countries, as the relatively low economic diversification leads to a concentration of banks' exposures such that a shock to the dominant sector of the economy may become of systemic importance (Narain, Rabanal & Byskov, 2003:17). Further, a nominal depreciation of the exchange rate is likely to destabilise the banking sector especially if it is heavily exposed to foreign exchange risk.

- Monetary conditions including growth of the credit-to-GDP ratio and broad money cover of international reserves. Moreover, excessive credit growth can result in high credit risk in instances where there is a decline in asset quality, and thereby increasing the likelihood of a banking crisis. Finally, the credit-to-GDP ratio was adopted as a common reference point under Basel III to guide the build-up of countercyclical capital buffers (Drehmann & Tsatsaronis, 2014:55).

2.11 Conclusion

The negative events that financial sector supervisors seek to guard against are difficult to predict. For instance, the global financial crisis which exposed the weaknesses in the Basel capital framework. This study draws motivation from Wall (2014), as the author strongly contends that macro stress testing helped restore confidence in the financial sector following the failure or close calls for several financial institutions in the crisis. Stress testing itself is not without criticism, stemming particularly from its extensive use of personal judgement and to some extent, complexity (Dowd, 2002:165). However, the positive outcomes of macro stress testing have been observed, for instance Bernanke (2013:1) described the SCAP as a "critical turning point" in the financial crisis which helped restore confidence and enabled recapitalisation in banks in the US.

The literature also indicates that the African banking system generally remained resilient during the financial crisis, with most banks holding strong CARs. However, the literature is limited in terms of the use of stress tests in supervisory risk assessment in Africa except for the IMF FSAP stress testing program, which is also only being carried out only in select African countries. This is despite Jakubík and Schmieder (2008:3) having established that stress events tend to leave a significant impact in less developed economies. Moreover, the suboptimal performance of the Basel regulations during the financial crisis may be regarded as an indication that they are not entirely a reliable measure of financial institutions' health, especially when considered on their own. With a focus on Botswana, this study will apply stress testing to the banking system and compare capital adequacy as determined by the stress test, with the Basel-based capital adequacy. The main postulation is that the financial system vulnerabilities of African countries are unique and possibly vaster to be only determined by the Basel ratios. The nature of most economies is such that they are resource dependent and concentrated thus increasing the perceived fragility. According to Quagliariello (2009:6), the more fragile the system, the more severe the effects

of exogenous shocks. This study will help improve understanding of the Botswana financial system vulnerabilities and fragility as well as contribute to the literature on the stress testing experiences of less developed financial systems.

THE BOTSWANA CONTEXT

3.1 Introduction

As with several other countries, the Botswana banking system constitutes a significant portion of the financial system. Botswana has never had a severe banking crisis and instances of problems have been handled without compromising the integrity of the banking system (Jefferies & Tacheba, 2010:10). As part of prudential supervision, the central bank, Bank of Botswana (BOB) subscribes to the Basel Standards. Basel II was implemented in January 2016, and prior to that, Basel I had always been the basis for determination of adequate capital for banks. Botswana currently has 10 privately owned commercial banks. In addition, there is government owned development bank, building society and savings bank. The study, however, is restricted to commercial banks only. This is because of their private ownership and the associated higher default risk relative to the government owned institutions which have an implicit government protection (Iannotta, Nocerra & Sironni, 2013:154). Furthermore, the banking system is dominated commercial banks with 91 percent of total banking industry assets (Bank of Botswana [BOB], 2016:4).

3.2 Banking Sector Risk Profile

The Botswana economy, like the rest of the world economy, was negatively affected by the global financial crisis, whose effects can be regarded as a form of stress test on the banking sector. Although it was overall described as resilient and sound during the period (BOB 2010:1), the banking system did experience some indirect effects in two ways. Firstly, Botswana banks are subsidiaries of international banking groups which, subsequent to the crisis, tightened their credit criteria and reduced risk appetite which affected new credit approval (Jefferis & Tacheba, 2010:32). Secondly, the economy faced rationalisation and even closure of some mining projects, postponement of other key economic projects as well as a general slack in the real economy of 4.6 percent in 2009 (Ntsosa, 2011:60). The resultant government cutback on fiscal spending had a bearing on businesses that rely on government-supported activities and ultimately banks, as

could be seen in the substantial increase in non-performing loans (NPLs) at the time.

Table 3.1 provides a summary of banking performance in terms of key FSIs from which breaches of prudential standards have been highlighted to provide indication of risk prone aspects of the banking system.

TABLE 3.1. Key FSIs and prudential standards for commercial banks 2012-2016

KEY FINANCIAL SOUNDNESS INDICATORS & RANGE OF PRUDENTIAL STANDARDS FOR COMMERCIAL BANKS 2012-2016						
Financial Indicator	Prudential Standard (percent)	Range for Commercial Banks				
		2012	2013	2014	2015	2016
Capital Adequacy	≥15	17.3-24.2	16.2-24.3	16.1-23.1	16.4-31.0	16.3-20.8
Liquid Asset Ratio	≥10	12.4-51.4	12-36	10.5-19.6	2.9-28.6	10.3-36.5
Profitability (ROA)	Positive	0.9-4.5	0.7-4.0	0.2-3.8	(1.0)-2.7	0.2-3.3
Profitability (ROE)	Positive	9.2-39.1	6-32	2.1-27.7	(6.4)-21.4	2.7-29.2
Asset Quality (NPL/TL)	≤2.5	1.7-4.4	0.6-1.6	0.6-1.8	0.6-8.4	0.8-5.9

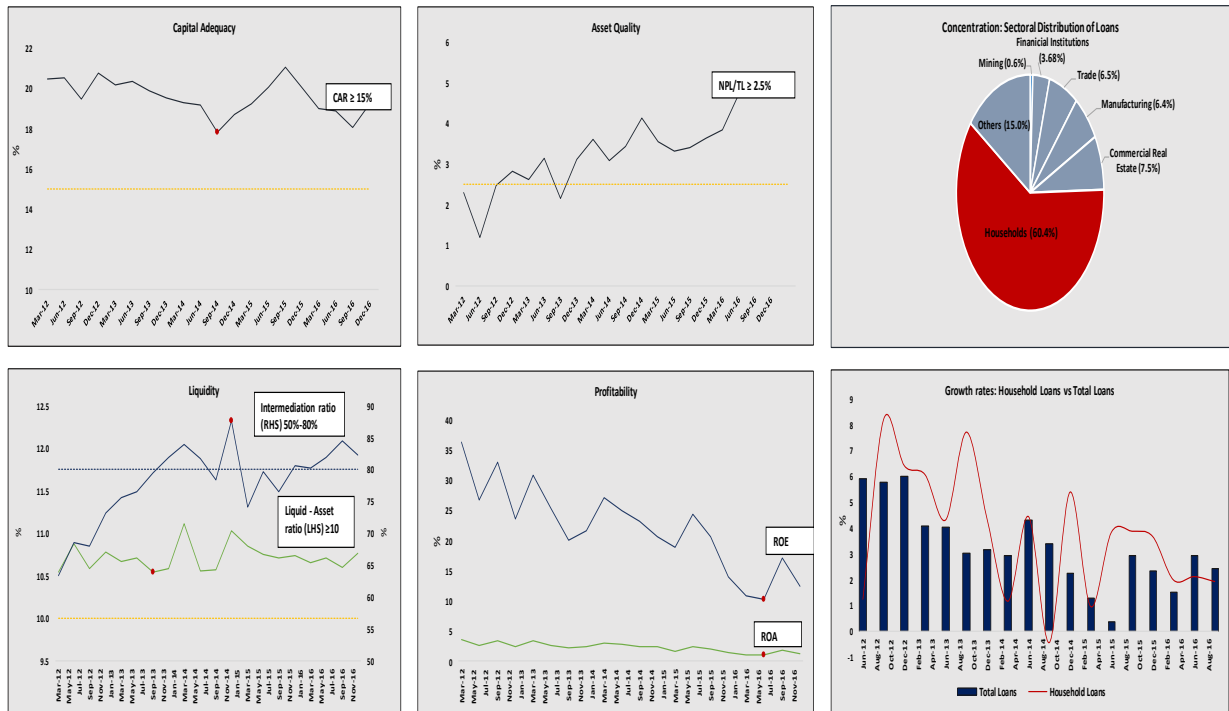
Source: (Bank of Botswana, 2017: 26)

In the last five years, the banks remained adequately capitalised, however with some threats visible in liquidity and asset quality. As at December 2016, all banks were able to meet the 15 percent and 4.5 percent minimum capital requirements for total and common equity Tier 1 capital ratios, respectively, even following the introduction of the Basel II regulatory capital requirements in 2016. The CAR averaged 19.4 percent in December 2016 with a 12 percent growth in risk-weighted assets to P52.3 billion under the new standard. The banking sector assets have increased steadily over the years to P80.7 billion in December 2016, signalling improved financial strength. Total loans also increased to P51.3 billion in December 2016, even though accompanied by an increase in the NPL/Total loans ratio from 3.9 percent in 2015 to 4.9 percent in 2016. The household sector accounted for 52 percent of total NPLs, showing increased vulnerability in terms of credit risk concentration. The heavy exposure to unsecured household debt in the local financial system poses a threat to asset quality particularly in periods of tightened monetary policy (Delis & Karavias, 2015:15). Figure 3.1 provides a graphical analysis of the performance of the commercial banks based on key indicators.

Profitability also improved in December 2016 with after-tax income increasing by 22.9 percent to P1.4 billion in December 2016. Overall, the banking sector met all the minimum statutory requirements in December 2016. However, asset quality, earnings and liquidity are observed to be partially inadequate as per the CAMELS ratings¹² in Figure 3.2.

¹²Generated using an off-site supervisory rating system that assesses banks' performance based on capital adequacy, asset quality, management, earnings, liquidity and sensitivity to market risk.

FIGURE 3.1. Banking sector quarterly performance 2012-2016



Source: (Author's computations based on data from Bank of Botswana)

FIGURE 3.2. Summary of CAMELS ratings for commercial banks in Botswana

CAMELS	Capital Adequacy	Asset Quality	Management	Earnings	Liquidity	Market Sensitivity	OVERALL
BANKS AVERAGE							

RATING	Strong		Adequate		Partially Adequate		Weak	
CATEGORY	Band 1		Band 2		Band 3		Band 4	
SUB-CATEGORY	B1- Upper	B1- Lower	B2- Upper	B2- Lower	B3- Upper	B3- Lower	B4- Upper	B4- Lower
SCORE	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
RISK RATING	Low		Medium		Medium High		High	

Source: (Bank of Botswana, 2016: 30)

3.3 Macroeconomic Risk and the Banking System

The discovery of diamond mining, following independence in 1966, catapulted the economy of Botswana to hold the record as the fastest growing economy in the world for over a decade in the 80s (Malema 2012:52). As the country thrived on having a democratically elected government, mining continued to contribute tremendously to the GDP, translating into high economic growth rates. To date, the Botswana economy is still dependent on diamond mining despite the long-standing efforts to diversify the economy, a matter that continues to be reiterated in the National Development Plan¹³. Considering the economic status, it can be postulated that the

¹³See in (Botswana Government, 2017)(available at: <https://drive.google.com/file/d/0BzYE5YZqKfVKQmZwbWZWTzZWR1E/view>)

economy harbours risks that can potentially spill over to the financial system. This is because economic concentration leaves the government budget and balance of payments largely dependent on commodity prices which are vulnerable to sustained fluctuations in international demand. According to Sekwati (2010:79), international experience indicates that economic diversification is a mammoth task as structural changes are usually slow to implement particularly for resource dependent countries like Botswana where the dominant resource is poorly linked to the rest of the economy. In this regard, lack of economic diversification poses as a threat to the stability of Botswana's financial system.

Between 2005 and 2015, mining constituted between 35 percent and 41 percent of GDP (BOB 2016:67). Table 3.2 draws a distinction between mineral and non-mineral revenue in Botswana. Although the latter only accounts for about a third of total revenue, the economy remains sluggish towards diversification (Sekwati, 2010:79). As observed in Table 3.3, in 2016, diamonds alone accounted for 86.4 percent of Botswana's total exports, up from 82.8 percent the previous year. These figures are an indication of the high dependence on diamonds for generation of foreign currency revenue (Harvey, 2015:830).

TABLE 3.2. Mineral and non-mineral revenue in Botswana

	2015/16			2016/17		2017/18
	Budget	Revised	Final	Budget	Revised	Budget
Revenue	55,382	51,764	47,420	48,398	55,926	57,187
Mineral Revenue	20,144	18,299	14,438	17,033	20,854	16,334
Non-mineral Revenue	35,238	33,465	32,983	31,365	35,072	40,853
Expenditure	54,153	55,961	54,411	54,445	57,031	59,544
Recurrent Expenditure	41,296	41,719	40,413	39,669	39,663	43,071
Personal Emoluments	16,057	16,072	18,544	18,107	18,107	21,450
Grants & Subventions	10,864	10,969	11,269	10,986	11,100	12,496
Public Debt Interest	1,079	1,079	827	736	736	903
Other charges	13,296	13,600	9,774	9,871	9,720	8,222
Development Expenditure	12,933	14,318	12,773	14,821	16,277	16,520
Net lending	(76)	(76)	1,225	(76)	1,091	(47)
Balance	1,229	(4,197)	(6,991)	(6,046)	(1,106)	(2,357)

Source: (Bank of Botswana, 2017:80)

Moreover, with an unemployment rate of 20 percent, Botswana has one of the highest levels in the region (Statistics Botswana, 2013:36). The spate of job losses in recent years which resulted from the closure of several companies is also expected to cause strain for some individuals and companies and thus affecting their reimbursement potential (BOB 2017:92). Notably is the liquidation of the state-owned, BCL Limited and its subsidiary Tati Nickel Company in 2016, which were the country's biggest copper and nickel mines, respectively. These developments have raised credit risk concerns for banks, as they have 65 percent of their household exposures as unsecured loans. As Fei, Fuertes and Kalotychou (2012:231) have established, there is a strong

TABLE 3.3. Botswana Exports for 2015/16(in BWP mil)

	<i>BWP'millions</i>		<i>Percentage Share</i>	
	<i>2015</i>	<i>2016</i>	<i>2015</i>	<i>2016</i>
Total Exports	63,675	69,489		
<i>Of which:</i>				
Diamonds	52,730	60,052	82.8	86.4
Copper-Nickel	3,790	2,062	6.0	3.7
Beef	1,057	931	1.7	1.3
Soda As	924	939	1.5	1.4
Gold	283	344	0.4	0.5
Textiles	374	280	0.6	0.4
Vehicles & Transport Equipment	701	529	1.1	0.8
Other Goods	3,817	3,280	6.0	5.5

Source: (Bank of Botswana, 2017:86)

correlation between unemployment levels and default risk. In consideration of the high levels of unsecured lending, the IMF has made a recommendation¹⁴ for the stress testing of banks' lending to the household sector. The aggregate ratio of NPLs to total loans increased from 3.3 percent in December 2015 to 4.9 percent in December 2016 which is almost double the prudential limit of 2.5 percent.

3.4 Conclusion

Apart from evidence of asset quality deterioration after the crisis, the Botswana banks' financial positions were not significantly affected. However, risk in the financial system need not emanate from the system itself as it may be introduced by a deterioration of the economic conditions. Gyzicki (2001:18) has found macroeconomic variables to exert a strong influence on bank risk and profitability by affecting the share of interest payments and real credit growth. The financial crisis has been used as a reference point to show that because regulatory failures during the period were linked the serious liquidity and solvency problems that many banks faced (Moschella & Tsingou, 2013:407), authorities have since been pressured to advance efforts on risk mitigation, including embarking on the periodic stress testing of their financial systems (Schuermann, 2014:718).

¹⁴See in IMF (2016:21) (available at: <https://www.imf.org/external/pubs/ft/scr/2016/cr16103.pdf>)

RESEARCH APPROACH

4.1 Research Design

Stress testing is, by nature, a highly statistical exercise and hence the proclivity towards a quantitative research approach. The study is aimed at establishing the value of stress testing in the determination of adequate capital for the Botswana banking system. This is done through a comparison of the CAR for the banking system before and after the stress test. The result can be used to ascertain additional capital the system needs to stay properly capitalised. The study has been motivated by the criticism of the Basel capital framework in its determination of adequate capital for banks prior to and during the financial crisis. Among other critics is Wall (2014), who contends that by contrast, stress tests are better able to capture system vulnerabilities by observing performance of banks under downside scenarios, which are extreme but still plausible.

The model used in this study closely follows the one designed by Čihák (2014), which is described as suitable for use in less complex financial systems. The model, based on a hypothetical financial system, focuses on the application of macro stress testing from a supervisory perspective. Some real-life insight is drawn from Vukelić, (2011) who performed stress testing on the banking systems of Croatia and Serbia. The latter is important in adding realism to the stress testing exercise in this study as it was performed on actual financial systems. Any deviation from the two methodologies will be duly explained.

4.2 Population and Sampling

A population represents a group of people, companies, hospitals, stores, students or anything that share some set of characteristics (Zikmund, 2003:369). In Botswana, the banking sector constitutes a significant portion of the financial system. The population for this study is thus, banks licensed and operating in Botswana. The population sample, however, is restricted to commercial banks only, licensed in accordance with the Banking Act (CAP 46:04). The commercial

banks are all foreign owned private entities which are separately capitalised and account for 91 percent of total banking industry asset base in Botswana (BOB, 2016:4).

4.3 Data

The sources of data are the statistical reports from Bank of Botswana and Statistics Botswana, as at December 31, 2016. In some instances, data will be sourced from the banks' financial statements. Some important components of the data include regulatory capital and risk-weighted assets for computation of both the baseline and adverse CAR; loan book structure for assessing asset quality as well as sectoral distribution of loans; provisioning and collateral for credit risk calculation; bond portfolio structure for interest rate risk calculation, net open position in foreign exchange and foreign currency lending for foreign exchange risk as well as average profits and standard deviation of profits over time as a reference point for profitability (Čihák, 2014:26).

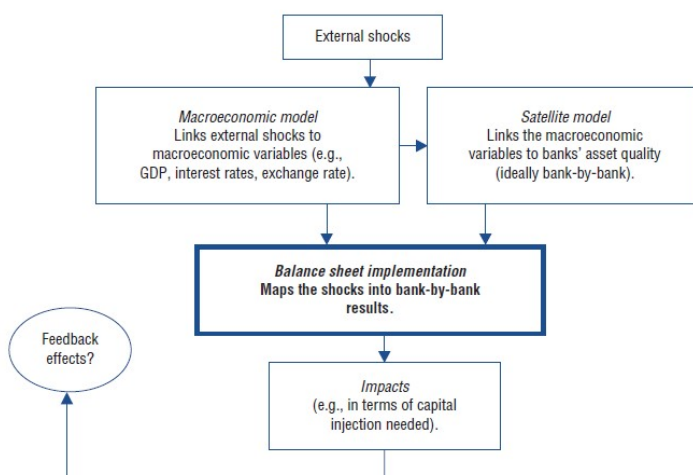
Using the *Microsoft Excel* based stress testing model, the parameters are shocked to determine the resilience of the banks' balance sheets to unexpected macroeconomic shocks as well as determine additional capital needed, if any. The financial data is also used to compute FSI ratios, which measure the operational health of financial institutions (IMF, 2006:1). By observing their trend over a period of time, FSIs can help to identify financial areas of weakness that require supervisory attention and as such play a complementary role to stress testing (Sorge, 2004:5).

STRESS TESTING MODEL

5.1 Introduction

The stress testing process follows the pattern of; identification of specific vulnerabilities, sensitivity and scenario construction, scenario testing and financial analysis and summary and interpretation of results (Čihák, 2014:18). The study illustrates this process for the Botswana banking system. However, it is worth noting that the steps need not be sequential allowing for necessary review to be carried out as required. The broader stress testing framework as illustrated in Figure 5.1, seeks to map macroeconomic variables such as GDP, interest rates and exchange rate into financial sector variables and expressing impact in terms of capital adequacy and capital injection as a percentage of GDP.

FIGURE 5.1. The stress testing framework



Source: (Čihák, 2014:19)

The model represents a centralised approach where all calculations are carried out at one centre, for instance, by a supervisory authority. This forms part of the top-down approach to stress

testing (Čihák, 2014:22). The first part of the model carries out sensitivity analysis on credit, interest rate, and foreign exchange risks. To augment the individual risk tests, simple liquidity tests and a scenario analysis are also performed. The impact of the shocks is shown in terms of a change in the CAR of the system, with interest drawn to incidences where post-stress CAR falls below the 15 percent statutory requirement for banks in Botswana. In addition, the changes in capital expressed as a percentage of the GDP represent the macroeconomic costs of the banking sector losses (Čihák, 2004:8).

5.2 Calibration of Shocks

The shocks used in the study are based on both historical and hypothetical assumptions. Čihák (2004:25) notes that the size of shocks can be based on past experience, a multiple of the standard deviation or even a theoretical estimation.

5.2.1 Credit Risk Shocks

The model uses data on asset quality to carry out credit stress tests based on two components; aggregate increase in NPLs and credit concentration using sectoral distribution of loans.

- Increase in Non-Performing Loans

With this shock, a general decline in asset quality is modelled with the assumption that all banks will be affected proportionately by an increase in the existing stock of NPLs. An increase in NPLs is often deducted from the risk-weighted assets (Čihák, 2014:29) with the additional NPLs represented by an assumed percentage increase on the existing stock of NPLs. An alternative may be to relate the increase in NPLs to total loans or to the new performing loans. However, as a rule of thumb, existing NPLs are often regarded as a good proxy for a bank's risk management and other future risks (Čihák, 2014:30). Performing loans can also be a good benchmark as they represent the same loans that may eventually become compromised. However, the latter may only be necessary for use when there has been a structural change such as a shift from household to corporate lending rendering past NPLs not very useful (Čihák, 2014: 29).

Credit assets in banks can be classified into five¹⁵ according to performance as pass, special mention, substandard, doubtful and loss loans. For this model, NPLs are as defined by

¹⁵The five classes comprise pass loans which are fully protected by the current sound worth and paying capacity of the creditor and are regarded as performing according to the contractual terms such as borrower's overall financial condition, resources and cash flow, credit history, and character, purpose of the loan and types of secondary sources of repayment; special mention loans which comprise loans in arrears beyond 30 days but less than 90 days; substandard loans represents loans past due by 90 days or more but less than 180 days; doubtful loans which exhibit all the characteristics of substandard loans. However, they possess weaknesses that make collection in full highly questionable and improbable, based on current existing facts, conditions, and value. Any asset which is past due 180 days or more will generally be classified doubtful. Loss loans are considered uncollectible that their continuance as bankable assets is not warranted (D'Hulster, Salomao-Garcia & Letelier, 2014: 8).

D'Hulster, Salomao-Garcia and Letelier, (2014: 8), to be loans in arrears by more than 90 days and as such comprise substandard, doubtful and loss loans. The impact of this shock on capital is represented by a decrease in both the initial capital and risk-weighted assets by the amount of provisioning required to cover the new NPLs.

- **Credit Concentration**

This shock targets the different economic sectors and seeks to establish how banks are likely to be affected by the sizes of their credit exposures to these sectors. The increase in NPLs is assumed to be proportional to a bank's credit exposure in a particular sector and the impact on existing capital is represented by the product of the stock of new NPLs from each sector and the provisioning rate assumed necessary to account for the new NPLs.

5.2.2 Interest Rate Risk

Financial institutions can be exposed to direct interest rate risk when there is a mismatch in the interest rate sensitivities between assets and liabilities. On the other hand, they can also face indirect interest rate risk when interest rate changes affect borrowers' ability to meet their contractual obligations in terms of creditworthiness and ability to repay the loans (Čihák, 2014:30). In the model, interest rate risk is assessed using duration analysis where banks' variable rate assets and liabilities are divided into buckets¹⁶ as per their time-to-repricing (Čihák, 2004:3).

The outcome consists of two components; the impact on capital due to the interest rate gap as well as the impact resulting from the repricing of bonds. The interest rate gap for each bucket is given by the difference between rate sensitive assets and rate sensitive liabilities (Blaschke *et al.*, 2001:12). The assumption is that as the bank rate increases this would affect interest rates on both loans and deposits of banks. The cumulative interest rate gap for one year or less contributes towards capital if positive or is deducted if negative. In terms of the impact of bond repricing on capital, the change in the value of banks' bond portfolio is deducted from capital. Theoretically, bond value on banks' portfolios are also expected to decline with an interest rate increase.

5.2.3 Foreign Exchange Rate Risk

Stress testing this type of risk seeks to capture how exchange rate changes would affect domestic currency value of assets, liabilities as well as off balance sheet items (Čihák, 2014:31). The effect can be direct or indirect. Direct foreign exchange risk comes as a result of a bank's exposure based on the net open position in foreign currency whereas the indirect risk represents the impact of foreign exchange positions taken by borrowers on their creditworthiness and repayment ability.

¹⁶...only buckets of one year or less have been considered.

- **Direct Exchange Rate Risk**

The model uses net open positions in foreign exchange to assess how a shock change in the exchange rate would affect the capital holdings of banks. To compute the effect on capital, the initial capital (pre-shock) is reduced (or increased) by the change in the net open position. The direction of the impact is determined by whether the net open position is negative or positive as well as whether the exchange rate change is a depreciation or an appreciation. According to Čihák (2014:32), a depreciation tends to benefit banks that have a long (positive) net open position in foreign currency than those with a short (negative) net open position in foreign currency. Further, the central bank imposes limits¹⁷ on foreign exchange exposures which are usually set as a percentage of capital and to some extent, are able to control the level of this risk in the system.

- **Indirect Exchange Rate Risk**

An exchange rate change has an effect on credit risk and as such, modelling this risk involves the assumption that an increase in NPLs is proportional to the amount of foreign currency loans (Čihák, 2014:32). This means a depreciation would increase the domestic currency value of the loans thus making it more difficult for borrowers to repay. In the model, the stress test involves shocking banks' foreign currency loans with the assumption that a proportion of them will become compromised and as a result, default. The impact on capital is represented by the decline in initial capital due to the deduction of the necessary provisions to cover the new NPLs.

5.2.4 Liquidity Tests

Liquidity stress tests are often used as indicators of the impact of liquidity shortage on banks particularly in the short run (Goodhart, 2006:112). In the model, this impact is shown in terms of number of days banks would be able to withstand a liquidity drain without resorting to external sources including the central bank or other banks. Although not fully comprehensive, the approach offers an opportunity to stress test liquidity at a preliminary level. This study carried out two basic liquidity tests; first, a liquidity run that affects all banks uniformly and relative to the proportion of demand and time deposits. The sizes of the shocks are based on the proportions of the deposits assumed to be withdrawn each day. Further, they reflect of percentage of a bank's liquid asset holdings that can be easily converted to cash each day. The second test considers the effect of a possible liquidity contagion among banks, with the assumption that the liquidity drain starts from the weakest banks to the strongest banks. (Čihák, 2014: 35) highlights difficulty in modelling liquidity risk as liquidity fluctuations are not easy to capture properly and the necessary detailed and high frequency data may not be as easily disposable, even to

¹⁷For banks in Botswana, the net open position per currency for the South African rand, British pound, euro and US dollar should not exceed 15 percent of its unimpaired capital, the net open position for any other currency should not exceed 5 percent of unimpaired capital and overall net open position should not exceed 30 percent of its capital.

regulators. It is also worth noting that the role of the central bank as "the lender of last resort", confers upon it, some level of control over large liquidity shocks in the market (Allen, Carletti & Gale, 2009:644).

5.2.5 Scenario Analysis

The use of scenarios in the stress testing exercise allows for the simultaneous application of shocks involving a combination of several risk factors in order to assess their effect on banks' capital. This is important in adding practicality to stress testing, as compared to only using single-factor shocks, because factors are interconnected in the macroeconomic space. For instance, a change in the nominal interest rate leads to a change in the real interest rate and this has an effect on NPLs. Therefore, banks would not only be affected directly by the interest rate changes, but by the subsequent indirect credit risk, although with a time lag. The effect of changes in solvency and liquidity risks combined in scenario analysis can also be observed through a change in the ratings and the implied probability of default of banks.

The outcome of the scenario analysis includes the cumulative impacts on capital, of the credit, interest rate, exchange rate and liquidity shocks that are added together to produce an aggregate impact. Furthermore, the impact of the scenario on risk-weighted assets comprises of the impact of increasing NPLs and the resultant provisions from the credit risk shock. Using the post-shock risk-weighted assets, the amount of capital necessary to satisfy the minimum CAR rule, is computed as 15 percent of the post-shock risk-weighted assets. Banks that have their actual post shock capital less than this capital amount necessary to meet the minimum capital requirement, are regarded as under-capitalised. It cannot be ascertained whether the government would bail out failing private-owned institutions. However, if it becomes necessary for the government to intervene, Čihák (2014:24) estimates the amount of capital injection needed using the formula;

$$I = \frac{\rho * RWA - C}{1 - q\rho} \quad \text{if } C < \rho * RWA \quad (2)$$

$$= 0, \text{ otherwise}$$

where C is the bank's existing total regulatory capital, RWA are its existing risk-weighted assets, I is the capital injection, q is the percentage of the capital injection that is immediately used to increase risk-weighted assets, and ρ is the regulatory minimum CAR ($\rho = 15$ percent in the case of Botswana).

5.3 Identification of Vulnerabilities

In addition to the determination of adequate capital for the system through a stress testing process, Čihák (2014:26) also highlights the importance of other risk measures in locating

weaknesses and risk in the financial system. For instance, the model uses z-scores as a measure of the probability of becoming insolvent as has also been discussed by (Boyd & Runkle, 1993; Hesse & Čihák, 2007). (Čihák, 2014:26) defines the z-score as;

$$z = (k + \mu)/\sigma \quad (3)$$

where k is the equity capital as a percentage of assets, μ is the average after-tax return as a percentage of assets, σ represents the standard deviation of the after-tax return on assets as a proxy for return volatility.

Furthermore, a supervisory early warning system can be used to generate FSIs and rankings to be used to identify institutions that require increased supervisory attention (Sahajwala & van der Bergh, 2000:7). The ranking system also helps in creating a link to the probability of default or technical insolvency, when a bank's capital adequacy falls below the regulatory minimum requirement (Čihák, 2014:27). (Jones, Hilbers & Slack, 2004: 6) posit that for a more efficient use of resources and time, it is important to tailor the exercise to identified weak points in the financial system. Narrowing the focus allows for a more advanced and comprehensive analysis of identified inherent vulnerabilities in the system.

5.4 Formulation of Assumptions and Shocks

5.4.1 Credit Risk

Loan impairments in the financial sector increases the possibility financial difficulty and unprofitability. Banks usually have a high level of impaired loans before the bankruptcy. Therefore, a large amount of bad loans in the banking system generally results in a bank failure. (Ahlem & Messai, 2013: 852). FSAP stress tests often assume a growth in NPLs of between 5 percent and 30 percent. According to BOB (2009:5), NPL growth for Botswana banks reached 53 percent in 2009 following the global financial crisis. This is well above the maximum for the FSAP range. As such, using the crisis figure as a yardstick, an increase of 60 percent in NPLs is assumed. Čihák (2014:30) indicates that a high growth rate can be used to reflect the indirect credit risk that comes as a result of interest rate and exchange rate shocks which affect credit quality. A high growth rate in NPLs may also reflect the increased credit risk relating to household loan concentration which was 60.4 percent of total loans in December 2016. In order to test the system's ability to withstand any shock that may result from concentrated household lending, a 30 percent shock is used to represent a one-time increase in NPLs of the household sector.

Further, to accommodate the possible default of other key sectors of the economy such as mining and trade, an assumed increase in NPLs of 5 percent is used across board. This is because the 40 percent remainder of the loan book is regarded as reasonably diversified among the rest of the

sectoral counterparties. For credit risk, the ratio of NPLs to total loans is used as proxy to signify the relationship between a deterioration in credit quality and overall credit.

5.4.2 Interest Rate Risk

Some prudential propositions previously made include; a parallel up and down change in interest rates by 100 basis points, an adjustment of the slope of the yield curve by 25 basis points or parallel changes in the volatilities of the three-month yield by 20 percent of the current levels (Derivatives Policy Group, 1995); a standardised interest shock of 200 basis points (BCBS, 2004); a 200 basis point parallel shift in the yield curve, based on 1974-1994 data (U.S. Federal Reserve Bank examination manual); and an interest rate shock range of between 50 and 300 basis points has been used for the FSAP stress tests (IMF, 2003). On account of insufficient data, particularly on asset and liabilities maturities, a shock of 150 basis points increase in interest rates is considered reasonable against these general guidelines. Moreover, it is important to note that between 2007 and 2016, changes in the bank rate in Botswana have not exceeded 100 basis points at any single time, hence, an increase of 150 basis points seems extreme enough yet realistic.

5.4.3 Exchange Rate Risk

In terms of prudential recommendations, the FSAP uses a range between 10 and 50 percent for exchange rate shocks while the Derivatives Policy Group (1995) recommends at least 6 percent shock for main world currencies and 20 percent for all the others. In May 2005, the exchange rate system in Botswana was changed from an adjustable peg to a crawling peg coupled with a Pula depreciation of 12.5 percent to improve export competitiveness (Motlaleng, 2009:105). The adjustable peg allowed for officials to make discrete changes in the exchange rate as deemed necessary. In contrast, the crawling peg ensures small and continuous adjustments of the exchange rate. Motlaleng (2009:110) found that since the adoption of the crawling peg mechanism, the Pula has been depreciating with minimal variations making it favourable for an economy which depends, to a significant extent, on export revenue.

The risk in the depreciations has, however, been noted by Taye (2011:11) who theorises that the constant depreciation of the Pula should be carefully monitored to avoid the problem of elasticity pessimism, where low elasticity between imports and exports results in a depreciation not sufficiently increasing exports or decreasing imports. This may result in a falling trade balance and no significant increase in export revenue whereas the import bill is rising. Taye (2011)'s postulation is important as it presents an angle of indirect exchange rate risk that may not be obvious. However, because the crawling peg mechanism makes it unlikely that an exchange rate shock may occur, the assumed shock is a sudden depreciation of the Pula against the US dollar by 10 percent which corresponds to the lower bound of the FSAP approach.

5.5 Conclusion

The model's main inputs are the financial statistics from the balance sheets and income statements of banks. The main output of the model is the specification of the impact of shocks on the CAR as well as the amount of capital necessary to meet the minimum capital adequacy requirement of 15 percent. The major strength of the model is that it is relatively comprehensible and flexible with assumptions and shocks easily adjustable. Further, it also covers more than one risk exposure. Nonetheless, the model requires numerous assumptions and the mechanism for generation of shocks is left unspecified. This leaves the reliability of stress test results largely dependent on the quality of input data.

STRESS TESTING RESULTS

6.1 Introduction

This section presents the outcome of the stress test of the Botswana banking system using credit, interest rate and foreign exchange risk sensitivities. The aim is to determine whether the banking system holds sufficient capital through a comparison of CAR under baseline conditions (as at December 2016) and after the system undergoes some form of stress owing to a sudden change in certain macroeconomic variables. The outcome helps determine whether the amount of regulatory capital available in the system would be enough to absorb the assumed shocks and still be able to meet the stipulated regulatory capital requirement of 15 percent. Over and above the aforementioned tests, a simple liquidity test and scenario analysis have been carried out to further observe the resilience of the banking system to unexpected changes in macroeconomic factors.

6.2 Sensitivity Tests

6.2.1 Stress Testing for Credit Risk

6.2.1.1 Increase in Non-performing Loans

This shock helps project the consequences of an event such as an economic recession on banks' impaired loans. An assumed blanket increase of 60 percent in NPLs can reduce the average system CAR by 0.6 percent to 18.8 percent, with no bank breaching the 15 percent threshold. The sensitivity of the CAR to an increase in NPLs was further tested with a 100 percent increase in the NPLs which still produced a slight decrease in the average CAR to 18.3 percent. This provides an indication that banks may have their NPLs sufficiently provided for as observed by Bushman and Williams (2015:511), that high loan loss provisions offer a safety net for both present and future losses. Moreover, another explanation could be that using a standard increase in NPLs across banks and economic sectors ignores individual banks' loan profiles as well as sectoral credit concentration. Even though the outcome shows that the NPL/total loans ratio

would increase from 4.9 percent to 8.0 percent post-stress, the available capital for all banks would be able to absorb the shock as none of the banks have their CAR fall below the minimum 15 percent.

6.2.1.2 Credit Concentration

As total household credit accounts for at least 60 percent of commercial banks' loan book in Botswana, this is a sign of credit concentration. A sudden increase in household NPLs, alone, by as little as 15 percent is likely to result in at least one bank breaching the minimum 15 percent CAR mark. For this shock, however, a 30 percent increase in household NPLs is assumed and the results show that the system CAR would fall to 15.4 percent, with at least three banks likely to default the 15 percent threshold. Furthermore, when accounting for other important economic sectors, also holding relatively large shares of the loan book such as mining, construction, trade and manufacturing, the CAR drops further to 15.2 percent. For the latter shock, a 5 percent increase in each sector's NPLs is assumed. It can then follow that the distribution of loans and NPLs in the banks' loan book matters in terms of projection of specific system vulnerabilities.

6.2.2 Stress Testing for Interest Rate Risk

A sudden increase in the nominal interest rate by 1.5 percentage points would affect the systems' capital in two ways. First, is the repricing effect where the increase in interest rates would result in a decrease of P96 million in the value of bonds held by banks. This would lead to a fall in the system CAR of 0.2 percent to 19.2 percent. Second, the results show that the impact on capital due to the change in net interest income is negligible. As such the CAR would remain unchanged for the latter shock. Under both components, none of the commercial banks is likely to have their individual CAR fall below the 15 percent minimum regulatory requirement. It is important to note that the shock has been applied to all net asset positions including foreign currency assets since there was no separate data on maturity distribution of domestic and foreign currency assets. This, by implication, means the shock affects both domestic currency and foreign currency assets the same way while exchange rates are held constant (Čihák, 2004:3). If this is the case and assuming only Botswana interest rates change, the interest rate risk is likely to be less.

6.2.3 Stress Testing for Exchange Rate Risk

6.2.3.1 Direct Exchange Rate Risk

For this shock, the Pula is assumed to depreciate unexpectedly by 10 percentage points against the US dollar at once. The direct effect is measured using banks' net open positions in foreign currency which would result a 2.1 percent decline in the CAR to an average of 17.3 percent.

6.2.3.2 Indirect Exchange Rate Risk

Although conditions where the local currency falls in value are favourable for Botswana's export revenue, mining in particular, the fall should not be too drastic to cripple importing industries thus affecting their reimbursement potential. In assessing the possible indirect effect of the 10 percent depreciation of the Pula on the creditworthiness of borrowers, a 5 percent increase in both NPLs and the corresponding provisions is also assumed. The result shows that the average CAR also declines by 2.1 percent to 17.3 percent. For both instances, although the system CAR remains above the 15 percent minimum capital requirement, the results further show that at least three banks would breach this minimum requirement. Nonetheless, the crawling peg exchange rate system in Botswana is likely to shield the currency from abrupt changes. The limited impact of an exchange rate shock is shown by the banking system capital adequacy remaining above the 15 percent threshold even under adverse conditions. This, however, does not hold true for individual banks, the difference owing to the size and direction of their net foreign currency exposures.

6.3 Additional Tests

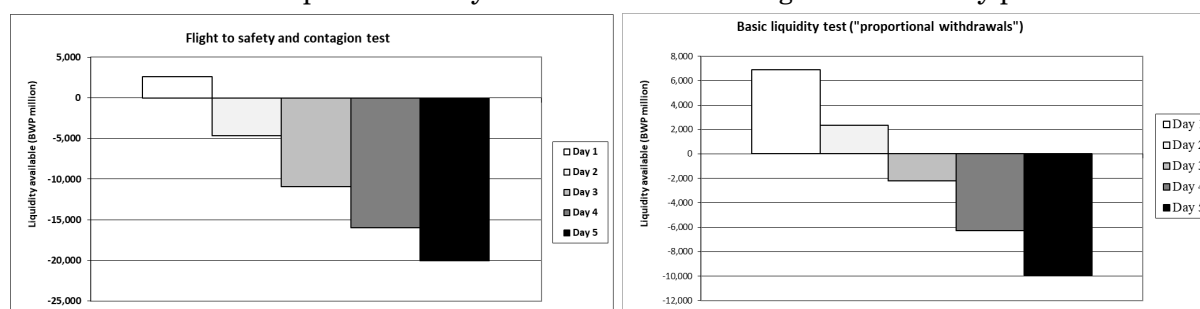
6.3.1 Liquidity Tests

For the liquidity tests, the assumptions for the proportions of withdrawals are a maximum of 10 and 5 percent for domestic and foreign demand deposits, respectively, as well as a maximum of 3 and 1 percent for domestic and foreign time deposits, respectively. Figure 6.1 indicates that for the first test relating to a liquidity drain, the system liquidity would remain positive, on average, for the first two days only. From days 3-5, the system liquidity turns negative, which automatically translates into a breach of the 10 percent statutory liquidity requirement by some banks. As can be seen in Table 6.1, not all the banks would survive a liquidity run on their own in all of the five days. On the first day, all the 10 banks would be able to maintain positive liquidity. However, on days 2-5 only eight, four, three and one, respectively, would stay liquid. The second test which considers the effect of the contagion and the potential "flight to safety" that may result from the assumed bank run, the available liquid assets can sustain eight banks on the first day only, with the other two having negative liquidity. Thereafter, from day 2 onwards, six banks would fail the liquidity test with only four staying afloat.

6.3.2 Scenario Analysis

This section of the model has combined the overall impact of the different shocks, in an instance where the occurrence of one shock could lead to the occurrence of others. This would be as a result of inter-linkages found between macroeconomic factors. The use of the adverse scenario is important in showing the perceived vulnerability of the banking system using a combined risk

FIGURE 6.1. Proportional daily withdrawals and contagion over a 5-day period



Source: Author's computations based on model output

TABLE 6.1. Summary of liquidity tests over a five-day period for the banking system

Proportional withdrawals (BWP 'mil)	Day 1	Day 2	Day 3	Day 4	Day 5
New cash outflow (during day ...)	6,494	5,850	5,269	4,747	4,276
Liquid assets (after day ...)	669	33	2	0	0
Non-liquid assets (after day ...)	67,640	66,963	66,294	65,631	64,974
New cash inflow (during day ...)	13,390	1,312	701	665	656
Net cash inflow since beginning of run	6,896	2,358	-2,210	-6,292	-9,912
No. of liquid banks (after day ...)	10	8	4	3	1

Flight to safety (BWP 'mil)	Day 1	Day 2	Day 3	Day 4	Day 5
New cash outflow (during day ...)	10,602	8,590	6,994	5,724	4,708
Liquid assets (after day ...)	780	153	121	120	120
Non-liquid assets (after day ...)	67,643	66,970	66,304	65,644	64,991
New cash inflow (during day ...)	13,231	1,301	698	661	653
Net cash inflow since beginning of run	2,629	-4,660	-10,956	-16,018	-20,073
No. of liquid banks (after day ...)	8	4	4	4	4

Source: Author's computations based on model output

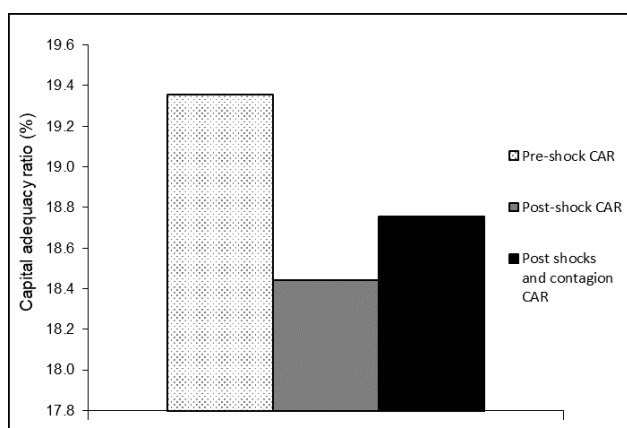
approach relative to the individual risk shocks. The pre-shock CAR is 19.4 percent, but would fall to 18.6 percent following the combined shock as shown in Figure 6.2.

Table 6.2 provides a summary of results of the scenario stress test divided into effects on solvency and liquidity. The table shows the effect of a collective change in provisions, NPLs, interest rate as well as exchange rate, that resulted in a decline in CAR from 19.4 to 18.6 post-shock.

Although the adverse scenario shows that the system capital remains adequate after being shocked, there is indication that not all banks would be able to meet the 15 percent benchmark. As such using the post stress risk weighted assets, the amount of capital needed to meet the minimum CAR, can be computed by multiplying the post shock risk-weighted assets by the 15 percent. This amount is then compared against the existing post shock capital holdings, with a shortfall representing the amount of capital injection needed. As per Table 6.3, this amount is P22 million, which represents 0.014 percent of the domestic GDP.

Finally, a comparison of risk indicators under baseline (pre-shock) and stress (post-shock) conditions is presented in Table 6.4. The changes in the indicators reveal increased risk in the system

FIGURE 6.2. Comparison between pre-shock and post-shock CAR



Source: Author's computations based on model output

TABLE 6.2. Changes in solvency and liquidity under adverse scenario conditions

Solvency	%
Pre-shock CAR	19.4
Impact of (percentage points of the original RWA)	
Increase in provisioning	-0.4
Increase in NPLs	-0.3
Increase in interest rates	-0.2
Exchange rate change (+ depreciation, - appreciation)	0.0
Post-shock CAR	18.6
Change in CAR (all fundamental shocks)	-0.8
Liquidity	%
Liquid assets/total assets	
Pre-shock	16.4
Post-shock	2.9
Liquid assets/short-term liabilities	
Pre-shock	20.0
Post-shock	4.5
Post-shock CAR (if profits used for defence)	19.7

Source: Author's computations based on model output

under the stressed environment. Some notable indicators include the NPLs to total loans ratio, which increases from 4.9 percent to 7.8 percent, after the shock. The liquidity ratio also shows a substantial fall from 20 percent to just 4.5 percent, reflecting the possible effects of a liquidity run over five consecutive days. For the liquidity test, consideration is only given to liquid assets available at banks as at December 2016, with the main assumption being that during the five-day period, banks do not have access to any external source of liquid assets. The adverse scenario would also affect average bank profitability in terms of after-tax return on assets and return on equity which slumped from 1.9 percent and 17 percent to 0.6 percent and 5.2 percent, respectively.

Ratings¹⁸ based on the different financial indicators are also observed to worsen under the stress scenario. The CAR maintains a rating of 1 under both baseline and adverse conditions, which is

¹⁸Ratings: 1 - low risk, 2 - increased risk, 3 - high risk, 4 - very high risk

TABLE 6.3. Summary of the post-shock capital needs of the system

Summary	BWP million
Total post-shock capital	9,739
Total post-shock RWA	51,927
Capital needed to satisfy the minimum CAR rule for all banks	7,789
Capital injection needed	22
Capital injection needed (% of GDP)	0.0144

Source: Author's computations based on model output

an indicator that, on average, the banking system is well capitalised. The system, however, shows signs of distress in asset quality, profitability as well as liquidity as all the indicators' ratings show a negative change from pre-shock conditions as per Table 6.4.

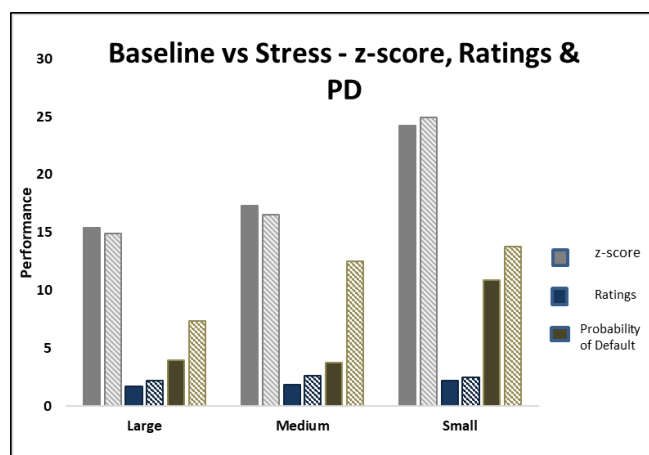
TABLE 6.4. A comparison of pre-shock and post-shock banking system FSIs and ratings

Indicator	FSIs		Ratings	
	Baseline	Stress	Baseline	Stress
<i>Capital Adequacy</i>				
Total capital / RWA (CAR)	19.4	18.6	1.0	1.0
<i>Asset Quality</i>				
NPLs (gross)/ total loans	5.0	7.8	1.4	2.0
Provisions/NPLs	66.2	45.1	1.8	2.5
(NPLs-provisions)/capital	9.3	21.6	1.0	1.3
FX loans/total loans	10.2	10.2	1.1	1.1
RWA/total assets	64.0	63.9	3.0	3.0
<i>Profitability</i>				
ROA (after-tax)	1.9	0.6	1.5	2.9
ROE (after-tax)	17.0	5.2	2.0	2.9
<i>Liquidity</i>				
Liquid assets/total assets	16.4	2.9	2.8	3.9
Liquid assets/short-term liabilities	20.0	4.5	1.5	4.0
<i>Sensitivity to Market Risk</i>				
Net FX exposure / capital	-2.6	-2.6	1.1	1.1

Source: Author's computations based on model output

To show the distribution of risk in the system, banks have been divided according to size as per Table 6.5, where a comparison of the z-score, ratings and probability of default has been carried out. Figure 6.3 provides a graphical depiction of the change in the indicators under adverse conditions across different bank sizes. Under pre-stress conditions, large banks have an average z-score of 15, medium banks 17 and small banks 24. Even though the aftershock average z-score remains the same for large and medium sized banks it increases slightly to 25, for smaller banks. The risk ratings for the three bank sizes only show a slight increase, signalling increased risk should the banking system undergo stressful conditions.

FIGURE 6.3. The z-score, ratings and probability of default according to bank size



Source: Author's computations based on model output

Of all the three indicators of risk used in this study, the change in the probability of default under the baseline and adverse conditions is most notable for all the bank size categories. Under pre-shock conditions, the probability of default is, on average, 5.3 percent, 7.1 percent and 12.3 percent for large, medium and small sized banks, in that order. However, average probability of default substantially increases to 7.3 percent, 14.5 percent and 15.1 percent for large, medium and small banks, respectively, following the stress test.

TABLE 6.5. Risk indicator levels per bank size under baseline and stress conditions

BASELINE	z-score		Rating		Probability of Default (%)	
	Average	Range	Average	Range	Average	Range
Large	15	5.6 - 22.0	1.7	1.6 - 2.1	3.9	3.6 - 6.3
Medium	17	5.0 - 22.2	1.9	1.8 - 2.3	3.7	6.2 - 8.1
Small	24	9.3 - 39.2	2.2	2.1 - 2.5	10.9	9.6 - 15.1
STRESS	z-score		Rating		Probability of Default (%)	
	Average	Range	Average	Range	Average	Range
Large	15	8.7 - 18.5	2.2	2.0 - 2.4	7.3	6.4 - 7.7
Medium	17	3.3 - 25.8	2.6	2.3 - 3.3	12.5	7.6 - 19.9
Small	25	9.0 - 41.0	2.5	2.5 - 2.5	13.8	15.1 - 15.1

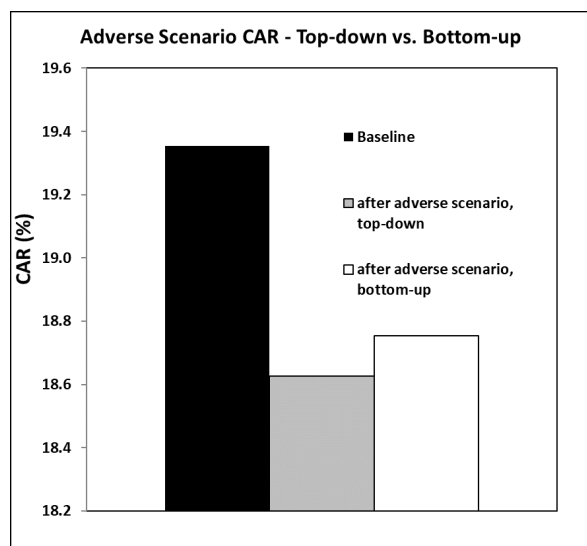
Source: Author's computations based on model output

6.4 Model Validation

To ensure consistency of the results, a bottom-up stress test has been carried out and the results have been compared to those of the top-down test. The comparison is specifically of the CAR under adverse conditions, which is 18.6 percent and 18.8 percent for the top-down and bottom-up

tests, respectively. The difference is negligible and hence the stress test results are regarded as consistent.

FIGURE 6.4. Comparison between top-down and bottom-up adverse CAR



Source: Author's computations based on model output

TABLE 6.6. Bottom-up Stress Test (numbers are in BWP millions, ratios are in percent)

	All Banks	A	B	C	D	E	F	G	H	I	J
<i>Bottom Up Stress Test - Reported Results</i>											
Capital (after adverse scenario)	9,739	1,969	1,451	2,921	1,377	205	477	1,068	129	39	104
RWA (after adverse scenario)	51,927	9,594	7,438	16,056	7,992	776	2,996	5,636	1,007	110	323
CAR (after adverse scenario)	18.8	20.5	19.5	18.2	17.2	26.4	15.9	18.9	12.9	35.1	32.2
<i>Cross-Checking Bottom Up and Top-Down Stress Test - CAR</i>											
Baseline	19.4	20.8	20.3	18.4	18.0	26.7	16.3	20.0	18.1	35.9	32.8
after adverse scenario, top-down	18.6	20.5	19.3	18.1	17.1	26.3	15.8	18.7	12.5	34.7	32.0
after adverse scenario, bottom-up	18.8	20.5	19.5	18.2	17.2	26.4	15.9	18.9	12.9	35.1	32.2
Difference	0.1	0.1	0.2	0.0	0.2	0.1	0.1	0.2	0.4	0.4	0.3

Source: Author's computations based on model output

DISCUSSION

7.1 Introduction

This study carries out a system-wide stress test to assess adequacy of the amount of regulatory capital available in the Botswana banking system as at December 2016. Capital in banks helps provide a cushion and readily available support during periods of unexpected adverse conditions. The standard convention in determining adequate capital for banks has, for a long time, been the Basel capital framework using a CAR. Even though the international prudential standard for this measure is 8 percent, a 15 percent requirement has been set for banks in Botswana. The main objective of the study is to assess whether the capital holdings of banks in Botswana, as determined using Basel ratio, is sufficient enough to withstand an economic downturn, by subjecting it to a series of stress shocks. The expectation is that the stress test would reveal system vulnerabilities that may result in shortfalls in the amount of capital that has been reported as ideal using the Basel capital measure. A decline in post-shock CAR is regarded as an indication of a knock in the amount of capital available in the system.

7.2 Implication of the Results on the Capital Adequacy of the Banking System

As at December 2016, the system has, on average, enough capital resources as shown by the 19.4 percent baseline CAR, which is well above the 15 percent requirement. Several scholars, such as Čihák, (2007:53) and Wall (2014:266) have argued that CAR alone does not capture all possible macro effects that arise from shocks in the macroeconomy. As a result, this study uses a stress test to model a potential deterioration of the economy and to observe whether the available capital would be enough to absorb all the shocks and still meet the required threshold. This is because past experience, such as in the US during the 2007-9 financial crisis, has shown that it is possible for banks to meet the minimum Basel capital requirements and still not be able to withstand certain macroeconomic conditions, counter expectation.

The stress test results indicate that under most shocks, the system CAR declined but still remained above the 15 percent benchmark. Although this is a positive sign, there were several occurrences where not all banks were able to meet the benchmark. This can be attributed to the high loan impairments or low collateral and loan loss provisioning levels as well as a high credit exposure in one particular industry, relative to others. Nonetheless, the literature (Hilbers, Jones & Slack, 2004:1; Borio, Drehmann & Tsatsaronis, 2014:4; Čihák, 2014:18) indicates that if done well, stress test exercises help to identify specific weaknesses in the financial system. Having been identified, supervisory resources can be focused on specific areas of concern.

Furthermore, the use of FSIs, ratings and probabilities of default as part of the stress testing process is also considered necessary as the measures help to direct focus to the weak aspects of banks performance. The stress tests also confirm that the most vulnerable area for the banks relates to their credit exposures, particularly to the household sector. This is evidenced by high non-performing loans against potentially insufficient loan loss provisioning. In terms of interest rate risk, the low bank rate, which is the benchmark rate, has greatly reduced interest income for banks, especially when compared to past periods. In terms of foreign exchange risk, the exposures have been relatively low due to the generally low foreign market activity and plain vanilla products available in most banks in Botswana. Although liquidity is often contained and properly managed in the banking system of Botswana, should banks undergo severe stress, public perception could trigger a bank run that may result in liquidity contagion. This may be particularly true if a large bank could be affected first. Therefore, the Botswana banking system, as per expectation, is more exposed to credit risk than either the interest rate or exchange rate risk. However, Čihák (2012:15) states that because of a large number of individual exposures for the household sector, it becomes highly unlikely that the majority of loans in the sector could default on account of a single shock.

Under the adverse scenario, the stress test results also revealed the amount of capital that may need to be injected into the system to cover the capital deficit. The results show that an amount of P22 million would be required to ensure that all banks are able to meet the minimum CAR. In terms of fiscal costs, this amount is equivalent to 0.014 percent of the GDP. The amount can be raised by the affected bank, failing which, the government may have to step in to prevent a bank failure. However, government intervention, to a large extent, depends on bank ownership with state owned banks most likely to be bailed out. For privately owned institutions, the decision may depend on the importance of a bank in the system. If the failure of a bank is likely to cause serious contagion effect, the government may be compelled to bail it out (Iannotta, Nocerra & Sironni, 2013:154).

7.3 Research Questions

This study, using the CAR as a metric, sought to establish the value of stress testing in the determination of sufficient capital for banks in comparison to the Basel capital methodology. Three research questions were posed to address this quest:

a) Are the current CARs for all the 10 commercial banks as determined using the Basel capital measure sufficient?

The results of the stress test indicate that some banks' CARs do fall below the 15 percent minimum requirement when some of their parameters are subjected plausible economic shocks. For instance, a 30 percent increase in the household sector NPLs is likely to result in at least three banks defaulting the 15 percent benchmark, while a sudden 10 percent depreciation of the Pula, would also lead to at least three banks' CARs falling below the 15 percent requirement. By deduction, it can be drawn that the available capital for some banks may be insufficient to withstand a sudden macroeconomic shock, particularly one that results in increasing NPLs.

b) Would stress tests reveal the need for any additional capital in the system?

The shocks adopted under the scenario analysis indicate that the banking system would not be able to absorb all the shocks with the currently available bank capital and as such, an injection of P22 million may have to be injected into the system to avoid bank failure.

c) Would supervisory stress tests mitigate the shortcomings of the Basel capital framework in establishing bank capital adequacy in Botswana?

The question aims to highlight what it is that stress tests can do that the Basel CAR cannot. It can be answered from the viewpoint of the two measures' ability to account for the level of risk in a financial institution or the entire financial system. This is because for bank capital to be regarded as adequate, it should be consistent with the level of risk a bank undertakes or is faced with. Therefore, as the level of riskiness increases, expectation is that the available bank capital should be enough to absorb any shock to its balance sheet. However, while the CAR measures risk based on the credit, market as well as operational risk exposures, macro stress testing considers the external sources of risk emanating from the economy. This means stress testing contributes to the comprehensiveness of the process of determining adequate capital for banks by incorporating macroeconomic shocks that can potentially affect banks' performance as well as the subsequent survival of a bank. In this regard, the Basel capital framework helps set the minimum standard for capital holdings, whereas stress testing identifies specific problem areas, thus both processes can be regarded as necessary and complementary. For instance, the results show that the capital holdings of the banking system as at December 2016 are not sufficient as additional capital of P22 million would be needed for all banks to be able meet the minimum 15

percent under adverse conditions. This is amid all the banks being able to meet the minimum 15 percent CAR threshold and hence considered adequately capitalised under Basel. In this manner, since history has shown that meeting the minimum capital requirement is not always enough, stress tests can help to reveal information that may not be readily availed by a Basel CAR.

CONCLUSION

8.1 Introduction

The study investigated the use of stress tests in supervisory risk assessment to overcome the weaknesses of the Basel capital adequacy measure. The goal of the study has been to observe the inadequacies of the Basel CAR that can be mitigated using stress testing. The use of the Basel capital adequacy framework has become the prevailing standard for bank regulators globally. Understandably so, as it standardises the amount of capital that banks need to set aside as a readily available buffer for periods of financial distress. However, following the financial crisis, many flaws have been highlighted in both the Basel II and III capital standards resulting in investors and the public losing confidence in financial regulation. Wall (2014) argues that the subsequent use of stress tests in the US and EU helped restore market confidence.

8.2 Review of Research Background

The results of the stress test in this study show that the available capital in the Botswana banking system, (aggregate 19.4 percent CAR, relative to the 15 percent regulatory minimum), is adequate as it has been able to withstand and absorb macroeconomic shocks as per the assumed stress conditions. However, this supposition does not discount the value of stress testing in the determination of adequate capital for banks. This is because unlike the Basel CAR which despite being specific and accounting for risk through the risk-weighted assets, stress testing assesses risk by incorporating the effect on capital of possible unexpected changes in the macroeconomic environment. For instance, the Botswana economy is likely to possess immense risk owing to its concentrated nature. The use of stress tests, therefore, allows for the explicit linkage of macroeconomic factors to the amount of capital that banks should hold. Furthermore, stress tests are also able to estimate additional capital that may have to be injected into the system for it to be sufficiently capitalised. In light of this, both approaches are necessary and complement each other in measuring capital adequacy. This complementary role becomes clearer in the aspects of

the results that show that not all banks would be able to withstand an assumed shock despite meeting the minimum 15 percent CAR requirement. This reveals the value of stress testing over the solitary use of the Basel CAR. The latter results support Wall (2014)'s contention that stress testing can be used to mitigate the shortcomings of the Basel CAR. According to Wall (2014:266), this is due to the ability of stress tests to capture a deterioration in asset values which the Basel CAR does not account for and as such tends to produce overstated capital figures.

8.3 Recommendation for Future Work

It remains imperative, nevertheless, that stress testing results be interpreted with caution due to challenges relating to model construction. In this study, the model that has been used is relatively basic and intuitive and can be developed further by including more time periods in order to improve the robustness. Possible future research could consider increasing the range of shocks covered to include a variation of minor, moderate and major shocks. Furthermore, the study could be expanded by carrying out a bank by bank analysis, taking into account systemic importance, which would aid regulators to identify potential problem banks and specific areas of weakness. The time horizon into the future may also be extended to allow for a full manifestation of shocks into the deterioration of financial performance of banks. In terms of the Basel Accord, future research work could consider the implication of Basel III on stress testing. Finally, this study contributes to the current stress testing literature by testing the resilience of capital as determined in terms of the Basel capital requirements, under stressful macroeconomic conditions. This is considered particularly important for a country (Botswana) that is not frequently considered in international bank stress tests. This makes the framework available for use in other countries with similar economic structures and where stress testing modelling is still at a developing stage.

REFERENCE LIST

1. Acharya, V., Engle, R. & Pierret, D. 2014. Testing macroprudential stress tests: the risk of regulatory risk weights. *Journal of Monetary Economics*. 65:36-53.
2. Acharya, V., Pedersen, L., Philippon, T. & Richardson, M. 2017. Measuring systemic risk. *Review of Financial Studies*. 30(1):2-47.
3. Ahlem, S. & Messai, F. J. 2013. Micro and macro determinants of non-performing loans. *International Journal of Economics and Financial Issues*. 3(4):852-860.
4. Alfaro, R.A. & Drehmann, M. 2009. Macro stress tests and crises: what can we learn? *BIS Quarterly Review*. Fourth quarter. Basel: Bank for International Settlements. Available: http://www.bis.org/publ/qtrpdf/r_qt0912e.pdf [2017, August 3].
5. Allen, F., Carletti, E. & Gale, D. 2009. Interbank market liquidity and central bank intervention. *Journal of Monetary Economics*. 56(5):639-652.
6. Amorello, L. 2016. Beyond the horizon of banking regulation: what to expect from Basel IV. *Harvard International Law Journal*. 58(1):21-38.
7. Bank of Botswana. 2010. *Banking Supervision Annual Report 2009*. Gaborone: Bank of Botswana.
8. Bank of Botswana. 2016. *Banking Supervision Annual Report 2015*. Gaborone: Bank of Botswana.
9. Bank of Botswana. 2017. *Annual Report 2016*. Gaborone: Bank of Botswana.
10. Barnhill, T.M., Papapanagiotou, P. & Schumacher, L. 2002. Measuring integrated market and credit risk in bank portfolios: application to a set of hypothetical banks operating in South Africa. *Financial Markets, Institutions and Instruments*. 11(5):401-443.

11. Barrell, R., Davis, E.P., Karim, D. & Liadze, I. 2010. Bank regulation, property prices and early warning systems for banking crises in OECD countries. *Journal of Banking and Finance*. 34(9):2255-2264.
12. Barth, J.R., Caprio, G. & Levine, R. 2004. Bank regulation and supervision: what works best? *Journal of Financial Intermediation*. 13(2):205-248.
13. Basel Committee on Banking Regulations and Supervisory Practices. 1975. *Report to the governors on the supervision of banks' foreign establishments*. Basel: Bank for International Settlements.
14. Basel Committee on Banking Supervision. 2005a. *Amendment to the capital accord to incorporate market risks*. Basel: Bank for International Settlements.
15. Basel Committee on Banking Supervision. 2005b. *Explanatory note on the Basel II IRB risk weight functions*. Basel: Bank for International Settlements.
16. Basel Committee on Banking Supervision. 2006. *International convergence of capital measurement and capital standards: revised framework comprehensive version*. Basel: Bank for International Settlements.
17. Basel Committee on Banking Supervision. 2009. *Principles for sound stress testing practices and supervision*. Basel: Bank for International Settlements.
18. Basel Committee on Banking Supervision. 2010. *Basel III: Global regulatory framework for more resilient banks and banking systems*. Basel: Bank for International Settlements.
19. Beck, T., Maimbo, S.M., Faye, I. & Triki, T. 2011. *Financing Africa: through the crisis and beyond*. Washington DC: World Bank.
20. Berkowitz, J. 1999. A coherent framework for stress testing. *Journal of Risk*. 2(2):5-15.
21. Bernanke, B.S. 2013. Stress testing banks: what have we learned? Speech given at the Maintaining Financial Stability: Holding a Tiger by the Tail Conference. Georgia, 8 April 2013. Available: <https://www.federalreserve.gov/newsevents/speech/bernanke20130408a.pdf> [2017, August 3].
22. Blaschke, W., Majnoni, G., Peria, M.S.M. & Jones, M.T. 2001. Stress testing of financial systems: an overview of issues, methodologies, and FSAP experiences. (IMF working paper; no. 01/88). Washington DC: International Monetary Fund. Available: <https://www.imf.org/external/pubs/ft/wp/2001/wp0188.pdf> [2017, August 3].
23. Blum, J. 1999. Do capital adequacy requirements reduce risks in banking? *Journal of Banking and Finance*. 23(5):755-771.

24. Blundell-Wignall, A. & Atkinson, P. 2011. Thinking beyond Basel III: necessary solutions for capital and liquidity. *OECD Journal: Financial Market Trends*. 2010(1):9-33.
25. Borio, C.E. & Drehmann, M. 2010. Towards an operational framework for financial stability: fuzzy measurement and its consequences. In *Financial stability, monetary policy, and central banking*. R. A. Alfaro, Ed. Santiago: Central Bank of Chile.
26. Borio, C., Drehmann, M. & Tsatsaronis, K. 2014. Stress-testing macro stress testing: does it live up to expectations? *Journal of Financial Stability*. 12(1):3-15.
27. Boyd, J.H. & Runkle, D.E. 1993. Size and performance of banking firms. testing the predictions of theory. *Journal of Monetary Economics*. 31(1):47-67.
28. Breuer, T. & Summer, M. 2013. Stress test robustness: recent advances and open problems. *Financial Stability Report*. (25):74-86. Vienna: Austrian Central Bank.
29. Bushman, R.M. & Williams, C.D. 2015. Delayed expected loss recognition and the risk profile of banks. *Journal of Accounting Research*. 53(3):511-553.
30. Caggiano, G., Calice, P. & Leonida, L. 2014. Early warning systems and systemic banking crises in low income countries: multinomial logit approach. *Journal of Banking and Finance*. 47:258-269.
31. Caprio, G., Demirgüç-Kunt, A. & Kane, E.J. 2010. The 2007 meltdown in structured securitization: searching for lessons, not scapegoats. *The World Bank Research Observer*. 25(1):125-155. Available: <http://documents.worldbank.org/curated/en/759851468327562018/pdf/767980JRNOWBR000Box374387B00PUBLIC0.pdf> [2017, August 3].
32. Čihák, M. 2004. Designing stress tests for the Czech banking system. (CNB internal research and policy notes; no. 3). Praha: Czech National Bank. Available: https://www.cnb.cz/en/research/research_publications/irpn/2004/irpn_3_2004.html [2017, August 3].
33. Čihák, M. 2007. Introduction to applied stress testing. (IMF working paper; no. 07/59). Washington DC: International Monetary Fund. Available: http://www.elibrary.imf.org/abstract/IMF001/03800-9781451866230/03800-9781451866230/03800-9781451866230_A001.xml?redirect=true [2017, August 3].
34. Čihák, M. 2014. Stress tester: a toolkit for bank- by- bank analysis with accounting data. In *A guide to IMF stress testing: methods and models*. L. Ong, Ed. Washington DC: International Monetary Fund. 17-43.
35. Čihák, M. & Heřmánek, J. 2005. Stress testing the Czech banking system: where are we? where are we going? (CNB internal research and policy notes; no. 2). Praha: Czech National Bank.

36. Committee of European Bank Supervisors. 2010. *CEBS guidelines on stress testing*. London: European Banking Authority.
37. Committee on the Global Financial System. 2000. *Stress testing by large financial institutions: current practice and aggregation issues*. Basel: Bank for International Settlements.
38. D'Hulster, K., Salomao-Garcia, V. & Letelier, R. 2014. Loan classification and provisioning: current practices in 26 ECA countries. (FinSAC working paper series; no. 92831). Vienna: Financial Sector Advisory Center. Available: <https://openknowledge.worldbank.org/handle/10986/21109> [2017, August 3].
39. Daumont, R., Le Gall, F. & Leroux, F. 2004. Banking in sub-Saharan Africa: what went wrong? (IMF working paper; no. 04/55). Washington DC: International Monetary Fund. Available: <https://www.imf.org/en/Publications/WP/Issues/2016/12/30/Banking-in-Sub-Saharan-Africa-What-Went-Wrong-17289> [2017, August 3].
40. Davis, E.P. & Karim, D. 2008. Comparing early warning systems for banking crises. *Journal of Financial Stability*. 4(2):89-120.
41. Delis, M.D. & Karavias, Y. 2015. Optimal versus realized bank credit risk and monetary policy. *Journal of Financial Stability*. 16:13-30.
42. Demirgüç-Kunt, A., Detragiache, E. & Merrouche, O. 2013. Bank capital: lessons from the financial crisis. *Journal of Money, Credit and Banking*. 45(6):1147-1164.
43. Dormans, B. & Pit, V. 2014. Basel IV, Changing the regulatory landscape of banks. Paris:Capgemini Consulting Worldwide. Available: https://www.nl.capgemini-consulting.com/resource-file-access/resource/pdf/02-014.15_report_road_to_basel_iv_webpdf.pdf [2017, August 3].
44. Dovern, J., Meier, C. & Vilsmeier, J. 2010. How resilient is the German banking system to macroeconomic shocks? *Journal of Banking and Finance*. 34(8):1839-1848.
45. Dowd, K. 2002. *An introduction to market risk measurement*. West Sussex: John Wiley and Sons.
46. Drehmann, M. 2008. Stress tests: objectives, challenges and modelling choices. *Sveriges Riksbank Economic Review*. 2:60-92. Available: <http://www.riksbank.se/en/Financial-stability/Published-about-financial-stability/Selected-articles-from-Sveriges-Riksbank-Economic-Review1/20082-Stress-tests-Objectives-challenges-and-modelling-choices-by-Mathias-Drehmann/> [2017, July 23].
47. Drehmann, M., Borio, C.E. & Tsatsaronis, K. 2012. Characterising the financial cycle: don't lose sight of the medium term! (BIS working paper; no. 380). Basel: Bank for International Settlements. Available: <http://www.bis.org/publ/work380.htm> [2017, August 1].

48. Drehmann, M., Sorensen, S. & Stringa, M. 2010. The integrated impact of credit and interest rate risk on banks: dynamic framework and stress testing application. *Journal of Banking and Finance*. 34(4):713-729.
49. Drehmann, M. & Tsatsaronis, K. 2014. The credit-to-GDP gap and countercyclical capital buffers: questions and answers. *BIS Quarterly Review*. First quarter. Basel: Bank for International Settlements. Available: http://www.bis.org/publ/qtrpdf/r_qt1403g.htm [2017, August 3].
50. Fei, F., Fuertes, A. M. & Kalotychou, E. (2012). Credit rating migration risk and business cycles. *Journal of Business Finance and Accounting*. 39:229-263.
51. Furlong, F. 2011. Stress testing and bank capital supervision. (FRBSF economic letter; no 2011-20) San Francisco: Federal Reserve Bank of San Francisco. Available: <http://www.frbsf.org/economic-research/publications/economic-letter/2011/june/stress-testing-bank-capital-supervision/> [2017, July 29].
52. Gadanez, B. & Jayaram, K. 2008. Measures of financial stability: a review. Proceedings of the Irving Fisher Committee Conference on *Measuring Financial Innovation and its Impact*. 26-27 August 2008. 31:365-383.
53. Goodhart, C. 2011. *The Basel Committee on Banking Supervision: a history of the early years 1974-1997*. New York: Cambridge University Press.
54. Gizycki, M. 2001. The effect of macroeconomic conditions on banks' risk and profitability. (RBA discussion paper; no. 2001-06). Sydney: Reserve Bank of Australia.
55. Haldane, A.G. 2009. Why banks failed the stress test. Speech given at the Marcus-Evans Conference on stress testing. London, 9-10 February 2009. Available: <http://www.bis.org/review/r090219d.pdf> [2017, August 3].
56. Hale, G., Krainer, J. & McCarthy, E. 2015. Aggregation level in stress testing models. (FRBSF economic letter; no 2016-14) San Francisco: Federal Reserve Bank of San Francisco. Available: <http://www.frbsf.org/economic-research/publications/economic-letter/2016/may/aggregating-data-in-bank-stress-test-models/> [2017, April 15].
57. Harvey, R.G. 2015. From diamonds to coal? critical reflections on Botswana's economic future. *The Extractive Industries and Society*. 2(4):827-839.
58. Havrylchuk, O. 2010. A macroeconomic credit risk model for stress testing the South African banking sector. (SARB working paper; no. 10/03). Pretoria: South African Reserve Bank. Available: <https://www.resbank.co.za/Lists/News%20and%20Publications/Attachments/3579/wp1002.pdf> [2017, June 29].

59. Henry, J. & Kok, C. 2013. A macro stress testing framework for assessing systemic risks in the banking sector. (ECB Occasional Paper Series; no. 152) Frankfurt: European Central Bank. Available: <https://www.ecb.europa.eu/pub/pdf/scpops/ecbocp152.pdf> [2017, August 3].
60. Hesse, H. & Čihák, M. 2007. Cooperative banks and financial stability.(IMF working paper; no. 07/02). Washington DC: International Monetary Fund. Available: <https://www.imf.org/external/pubs/ft/wp/2007/wp0702.pdf> [2017, June 29].
61. Hilbers, P., Jones, M.T. & Slack, G 2004. Stress testing financial systems: what to do when the governor calls. (IMF working paper; no. 04/127). Washington DC: International Monetary Fund. Available:<http://www.elibrary.imf.org/imf/viewnlmarticlecontents/IMF001/06526-9781451855012/06526-9781451855012/06526-9781451855012.xml> [2017, February 10].
62. Honohan, P. & Beck, T. 2007. Making finance work for Africa. Washington DC: World Bank.
63. Huss, W.R. 1988. A move toward scenario analysis. *International Journal of Forecasting*. 4(3):377-388.
64. Iannotta, G., Nocera, G. & Sironi, A. 2013. The impact of government ownership on bank risk. *Journal of Financial Intermediation*. 22(2):152-1766.
65. International Monetary Fund. 2003. Analytical tools of the FSAP. Washington DC: International Monetary Fund. Available: <https://www.imf.org/external/np/fsap/2003/022403a.pdf> [2017, August 3].
66. International Monetary Fund. 2006. *Financial soundness indicators: compilation guide*. Washington DC: International Monetary Fund.
67. International Monetary Fund. 2012. Enhancing financial sector surveillance in low-income countries: financial deepening and macrostability. (IMF policy paper; April 2012) Washington DC: International Monetary Fund. Available: <https://www.imf.org/en/Publications/Policy-Papers/Issues/2016/12/31/Enhancing-Financial-Sector-Surveillance-in-Low-Income-Countries-Financial-Deepening-and-PP4649> [2017, July 29].
68. Jakubík, P. & Schmieder, C. 2008. Stress testing credit risk: comparison of the Czech Republic and Germany. Basel: Bank for International Settlements. Available: <http://www.bis.org/fsi/awp2008.pdf> [2017, August 3].
69. James, T. 2012. *Energy markets: price risk management and trading*. New Jersey: John Wiley and Sons.

70. Jefferies, K. & Tacheba, A. 2010. *Botswana financial sector overview 2009/10*. Gaborone: Capital Resources (Proprietary) Limited.
71. Kapstein, E.B. 1991. Supervising international Banks: origins and implications of Basle Accord. *Princeton Studies in International Economics*. 185(1):1-38.
72. Kim, D. & Santomero, A.M. 1988. Risk in banking and capital regulation. *The Journal of Finance*. 43(5):1219-1233.
73. Larson, J. 2011. *The Basel accords*. (discussion paper - College of Law: Center for International Finance and Development) Iowa City: University of Iowa.
74. Malema, B. 2012. Botswana's formal economic structure as a possible source of poverty: are there policies out of this economic impasse? *Pula: Botswana Journal of African Studies*. 26(46):51-70.
75. Moschella, M. & Tsingou, E. 2013. Regulating finance after the crisis: unveiling the different dynamics of the regulatory process. *Regulation and Governance*. 7(4):407-416.
76. Motlaleng, G.R. 2009. Botswana's crawling-peg exchange rate system: trends and variations in the pula exchange rate. *Botswana Notes and Records*. 41:104-111.
77. Narain, A., Rabanal, P. & Byskov, S. 2003. Prudential issues in less diversified economies. (IMF working paper; no. 03/198). Washington DC: International Monetary Fund. Available: <https://www.imf.org/en/Publications/WP/Issues/2016/12/30/Prudential-Issues-in-Less-Diversified-Economies-16858> [2017, March 12].
78. Ntsosa, M. 2011. The impact of 2007 global financial crisis on Botswana economy. *Asian-African Journal of Economics and Econometrics*. 11(1):45-63.
79. Nyantakyi, E.B. & Sy, M. 2015. The banking system in Africa: main facts and challenges. *Africa Economic Brief*. 6(5):1-16.
80. Ong, L.L. & Čihák, M. 2010. Of runes and sagas: perspectives on liquidity stress testing using an Iceland example. (IMF working paper; no. 10/156). Washington DC: International Monetary Fund. Available: <https://www.imf.org/en/Publications/WP/Issues/2016/12/31/Of-Runes-and-Sagas-Perspectives-on-Liquidity-Stress-Testing-Using-an-Iceland-Example-24019> [2014, July 29].
81. Oura, H. & Schumacher, L. 2012. Macrofinancial stress testing: principles and practices. (IMF policy paper; August 2012) Washington DC: International Monetary Fund. Available: <https://www.imf.org/en/Publications/Policy-Papers/Issues/2016/12/31/Macrofinancial-Stress-Testing-Principles-and-Practices-PP4702> [2017, August 3].

82. Penikas, H. 2015. History of banking regulation as developed by the Basel Committee on Banking Supervision in 1974-2014 (brief overview). *Financial Stability Journal of Bank of Spain*. 28(1):9-48.
83. Pesaran, M.H., Schuermann, T., Treutler, B. & Weiner, S.M. 2006. Macroeconomic dynamics and credit risk: a global perspective. *Journal of Money, Credit, and Banking*. 38(5):1211-1261.
84. Quagliariello, M. 2009. *Stress-testing the banking system: methodologies and applications*. New York: Cambridge University Press.
85. Reinhart, C.M. & Rogoff, K.S. 2009. *This time is different: eight centuries of financial folly*. New Jersey: Princeton University Press.
86. Sahajwala, R. & van den Bergh, P. 2000. Supervisory risk assessment and early warning systems. (BCBS working paper; no. 4). Basel: Bank for International Settlements. Available: http://www.bis.org/publ/bcbs_wp4.pdf [2017, May 2].
87. Schuermann, T. 2014. Stress testing banks. *International Journal of Forecasting*. 30(3):717-728.
88. Sekwati, L. 2010. Botswana: note on economic diversification. *Botswana Journal of Economics*. 7(11):79-85.
89. Sorge, M. 2004. Stress-testing financial systems: overview of current methodologies. (BIS working paper; no. 165). Basel: Bank for International Settlements. Available: <http://www.bis.org/publ/work165.htm> [2017, August 3].
90. Sorge, M. & Virolainen, K. 2006. A comparative analysis of macro stress-testing methodologies with application to Finland. *Journal of Financial Stability*. 2(2):113-151.
91. Statistics Botswana. 2013. *Botswana AIDS Impact Survey IV Statistical Report*. Gaborone: Statistics Botswana.
92. Sundararajan, V., Enoch, C., San Jos, A., Hilbers, P., Krueger, R., Moretti, M. & Slack, G. 2002. *Financial soundness indicators: analytical aspects and country practices*. Washington DC: International Monetary Fund.
93. Tabak, B.M., Fazio, D.M. & Cajueiro, D.O. 2013. Systemically important banks and financial stability: the case of Latin America. *Journal of Banking and Finance*. 37(10):3855-3866.
94. Taye, H. 2013. Is the Botswana Pula misaligned? (BIDPA working paper; no. 33). Gaborone: Botswana Institute for Development Policy Analysis. Available: <http://www.bidpa.bw/publication/details.php?id=38> [2017, August 3].

95. Trapanese, M. 2009. Fundamentals: framework for assessing financial stability. In *Stress-testing the banking system: methodologies and applications*. M. Quagliariello, Ed. Cambridge: Cambridge University Press. 7-17.
96. Triki, T., Kouki, I., Dhaou, M.B. & Calice, P. 2017. Bank regulation and efficiency: what works for Africa? *Research in International Business and Finance*. 39(Part A):183-205.
97. van den End, J., Hoerberichts, M. & Tabbae, M. 2006. Modelling scenario analysis and macro stress-testing. (DNB working paper; no. 119) Amsterdam: De Nederlandse Bank. Available: https://www.dnb.nl/binaries/Working%20Paper%20119_tcm46-146776.pdf [2017, August 3].
98. Vukelić, T. 2011. Stress testing of the banking sector in emerging markets: case of the selected Balkan countries. Ph.D. Thesis. Charles University in Prague.
99. Wall, L.D., 2013. Measuring capital adequacy supervisory stress tests in a Basel world. (FRBA working paper; no. 2013/15). Atlanta: Federal Reserve Bank of Atlanta. Available: <https://www.frbatlanta.org/research/publications/wp/2013/15.aspx> [2017, August 3].
100. Wall, L.D. 2014. The adoption of stress testing: why the Basel capital measures were not enough. *Journal of Banking Regulation*. 15(3-4):266-276.
101. Wojtowicz, M. 2011. CDOs and the financial crisis: credit ratings and fair premia. *Journal of Banking and Finance*. 39(1):1-13.
102. Zikmund, W.G. 2003. *Business research methods*. Rev. 7th ed. Mason: Thomson/South-Western.