Faculty of Economics and Business

The Cost Impact of Basel III across Banking Sectors of ASEAN-5 and Macro Stress Testing of Malaysia's Banking Sector

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DECLARATION

I hereby certify that the work embodied in this thesis is the result of original research and has not been submitted for a higher degree to any other University or Institution. The thesis has not been accepted for a degree and is not concurrently submitted in candidature of any other degree.

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DEDICATION

To my son John Kerem Taskinsoy: True meaning of my life;

I will love and stand by you forever, no matter what...

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ABSTRACT

The propagation of financial crises has made Basel III and stress testing a central focus across ASEAN-5. The primary objective of the thesis was twofold; to assess the cost impact of Basel III on bank capital, lending spreads, and steady state output across ASEAN-5; and to construct a macro stress testing framework to test the resilience of Malaysia's banking sector to extreme but plausible scenarios. Even though the capital impact analysis used a substantially high benchmark CAR of 10.5%, the main results demonstrated that ASEAN-5 banking sectors were comfortably capitalized and needed no recapitalization by 2019 when all the Basel III rules become fully effective. Higher capital and liquidity requirements put pressure on ASEAN-5 banks to increase lending spreads to pass down a portion of the relevant costs to bank customers. The impact of 1 pp rise in TCE ratio on lending spreads was analyzed; to meet the minimum capital requirement of 7% as of 2015, ASEAN-5 banks would have to increase their lending rates by 30.26 bps on average; to meet 10.5% fully effective as of 2019, ASEAN-5 banks would have to increase their lending rates by 68.22 bps on average. In the steady state output impact analysis, the results indicated that the estimated economic benefits outweighed economic costs across ASEAN-5. The main results of the macro stress testing exercise revealed only a modest change in capital ratios and bank profitability in the baseline scenario. The impact of all fundamental shocks under the adverse scenario reduced the average CAR by -3.40% and Tier 1 ratio by 3.64% from the baseline (no bank failed, or faced suspension of license).

Keywords: ASEAN-5, Basel III, stress testing, financial stability, Malaysia

Kesan Kos Basel III di seluruh ASEAN-5 dan Ujian Tekanan Makro bagi Sektor Perbankan Malaysia

ABSTRAK

Perambatan krisis kewangan telah menjadikan Basel III dan ujian tegasan tumpuan utama di seluruh ASEAN-5. Objektif utama tesis ini adalah binari; untuk menilai kesan kos Basel III ke atas modal bank, spread pinjaman, dan kemantapan output di seluruh ASEAN-5; dan untuk membina satu rangka kerja ujian tekanan makro untuk menguji daya tahan sektor perbankan Malaysia kepada senario tekanan melampau. Walaupun analisis impak modal menggunakan penanda aras CAR sebanyak 10.5%, penemuan menunjukkan bahawa sektor perbankan ASEAN-5 mempunyai kapital pada tahap selesa dan tidak memerlukan permodalan semula pada 2019 bilamana peraturan Basel III berkuat kuasa sepenuhnya. Kapital yang tinggi serta keperluan mudah tunai memberikan tekanan kepada bank ASEAN-5 untuk meningkatkan spread pinjaman dengan memindahkan sebahagian daripada kos berkaitan kepada pelanggan. Kesan kenaikan 1 pp dalam nisbah TCE ke atas spread pinjaman telah dianalisis; untuk memenuhi keperluan modal minimum sebanyak 7% pada 2015, bank ASEAN-5 perlu meningkatkan kadar pinjaman dengan 30.26 bps; untuk memenuhi 10.5% pada 2019, bank ASEAN-5 perlu meningkatkan kadar pinjaman dengan 68.22 bps secara purata. Keputusan analisis menunjukkan bahawa anggaran faedah ekonomi mengatasi kos ekonomi di seluruh ASEAN-5. Keputusan utama ujian tekanan makro mendedahkan bahawa perubahan nisbah modal adalah sederhana dan keuntungan bank dalam senario garis asas. Kesan kejutan asas di bawah senario meruncing, purata CAR kurang sebanyak -3,40% dan nisbah Tier 1 sebanyak 3.64% dari garis dasar (tiada bank gagal, atau menghadapi penggantungan lesen).

Kata kunci: *ASEAN-5, Basel III, ujian tekanan makro, kestabilan kewangan, Malaysia*

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SPECIAL DEFINITIONS

ASEAN	Association of Southeast Asian Nations: Indonesia, Malaysia, Philippines, Singapore, Thailand; the association was expanded to include; Brunei, Burma (Myanmar), Cambodia, Laos, and Vietnam.
ASEAN-3	China, Japan, and Korea
ASEAN-4	Indonesia, Malaysia, Philippines, and Thailand
ASEAN-5	Indonesia, Malaysia, Philippines, Singapore, and Thailand
Asia	Australia, China, Hong Kong SAR, India, Indonesia, Japan, Korea, Malaysia, New Zealand, Philippines, Singapore, Taiwan Province of China, Thailand, and Vietnam.
EA	Emerging Asia: China, Hong Kong SAR, India, Indonesia, Korea, Malaysia, the Philippines, Singapore, Taiwan Province of China, Thailand, and Vietnam.
EU-15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kingdom.
Euro Zone	Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Slovakia, Slovenia and Spain.
G-2	The euro zone and the United States
G-7	Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.
G-10	Belgium, Canada, France, Germany, Italy, Japan, Netherlands, Sweden, Switzerland, the UK, and the United States.
G-20	Argentina, Australia, Brazil, Canada, China, the European Union, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the United Kingdom, the United States.
IA	Industrial Asia: Australia, Japan, and New Zealand.
NIE	Newly industrialized economies: Hong Kong SAR, Korea, Singapore, and Taiwan (province of China).
OECD	It was formed in 1948 as OEEC (Organization for European Economic Co-operation); its name was changed to Organization for Economic Co-operation and Development in 1961, currently has 34 members.

LIST OF ABBREVIATIONS

AAOIFI	Accounting and Auditing Organization for Islamic Financial Institution
ABCP	Asset Backed Commercial Paper
AEC	ASEAN Economic Community
ADBI	Asian Development Bank Institute
AIG	American Insurance Group
A-IRB	Advanced Internal Ratings-Based Approach
AMA	Advanced Measurement Approaches
ANOVA	Analysis of Variance
AQR	Asset Quality Review
BCBS	Basel Committee on Banking Supervision
BHC	Bank Holding Company
BI	Bank Indonesia (central bank)
BIA	Basic Indicator Approach
BIS	Bank for International Settlements
BNM	Bank Negara Malaysia
BOT	Bank of Thailand
BRIC	Brazil, Russia, India, and China
BSP	Bangko Sentral ng Pilipinas
BU	Bottom-Up Stress Testing Approach
CA	Competent Authority

CAD	Current Account Deficit
CAP	Capital Assistance Program
CAPM	Capital Asset Pricing Model
CAR	Capital Adequacy Ratio
CBOE	Chicago Board Options Exchange
CBOT	Chicago Board of Trade
CBRC	Banking Regulatory Commission
CCAR	Comprehensive Capital Analysis and Review
CCP	Central Counter-Parties
CCQ	Core Capital Quota
CDIC	Canada Deposit Insurance Corporation
CDO	Collateralized Debt Obligation
CDS	Credit Default Swap
CEBS	Committee of European Banking Supervisors
CET1	Common Equity Tier 1
CGFS	Committee on the Global Financial System
CLO	Collateralized Loan Obligations
CME	Chicago Mercantile Exchange
CMBS	Commercial Mortgage-backed Securities
CPSS	Committee on Payments and Settlement Systems
CRO	Chief Risk Officer

CRMPG-III	Counterparty Risk Management Policy Group III
CVA	Credit Valuation Adjustment
DFAST	Dodd-Frank Act Stress Tests
DFI	Development finance institution
D-SIB	Domestic Systemically Important Bank
DSGE	Dynamic Stochastic General Equilibrium
DV	Dependent Variable
EBA	European Banking Authority
ECAI	External Credit Assessment Institution
ECOFIN	Economic and Financial Affairs Council
ECGB	European Cross-Border Banking Groups
EIOPA	European Insurance and Occupational Pensions Authority
EME	Emerging Market Economy
EMRC	Effective Minimum Required Risk-based Capital
ESA	European Supervisory Authorities
ESMA	European Securities and Markets Authority
ESRB	European Systemic Risk Board
ESS	Explained Sum of Squares
EU-QIS	EU-wide Quantitative Impact Study
EVT	Extreme Value Theory
FDI	Foreign Direct Investment

FDIC	Federal Deposit Insurance Corporation
Fed	US Federal Reserve
FI	Financial Institution
F-IRB	Foundational Internal Ratings-Based Approach
FOMC	Federal Open Market Committee
FPI	Foreign Portfolio Investment
FRB	Federal Reserve Board (USA)
FSAP	Financial Sector Assessment Program
FSB	Financial Stability Board
FSI	Financial Stability Institute
FSI	Financial Soundness Indicator
FSMP	Financial Sector Master Plan
FSOC	Financial Stability Oversight Council
FSSA	Financial System Stability Assessment
FWST	Firm-Wide Stress Test
GDP	Gross Domestic Product
GFC	Global Financial Crisis
GSE	Government-sponsored Enterprise
G-SIB	Global Systemically Important Bank
G-SIFI	Global Systemically Important Financial Institution
HIPC	Heavily Indebted Poor Country

IA	Industrial Asia (Australia, Japan, and New Zealand)
IBFC	International business and financial center
IFSB	Islamic Financial Services Board
IIF	Institute of International Finance
IM	Internal Model Approach
IMF	International Monetary Fund
IPO	Initial Public Offering
IRB	Internal Ratings-Based Approach
IOSCO	International Organization of Securities Commissions
IV	Independent Variable
IWST	Industry-Wide Stress Test
LCR	Liquidity Coverage Ratio
LFSA	Labuan Financial Services Authority
LR	Leverage Ratio
LSAP	Large-Scale Asset Purchase
LTCM	Long-Term Capital Management
MAS	Monetary Authority of Singapore (Central Bank)
MBS	Mortgage Backed Security
M&A	Mergers and Acquisitions
MAST	Malaysia-Wide Stress Test
MoU	Memorandum of Understanding

MPI	Macro-Prudential Indicator
MPT	Modern Portfolio Theory
MRC	Minimum Required Risk-based Capital
NCBA	New Central Banking Act
NIC	Newly Industrialized Country
NPL	Non-Performing Loans
NSFR	Net Stable Funding Ratio
OCC	Office of the Comptroller of the Currency
OLS	Ordinary Least Squares
OPEC	Organization of the Petroleum Exporting Countries
PCA	Prompt Corrective Action
PCSS	Payments Clearance and Settlement Systems
PDIC	Philippine Deposit Insurance Corporation
PPNR	Pre-Provision Net Revenue
PRA	Prudential Regulation Authority
QIS	Quantitative Impact Study
ROA	Return on Assets
ROE	Return on Equity
RPC	Reduced Probability of Crisis
RROE	Required Rate of Return on Equity
ROI	Return on Investment

RSS	Residual Sum of Squares
RWA	Risk Weighted Asset
SA	Standardized Approach
SAR	Special Administered Region
SBS	Shadow Banking System
SCAP	Supervisory Capital Assessment Program
SEC	Securities Exchange Commission
SIB	Systemically Important Bank
SIV	Structured Investment Vehicle
SME	Small-Medium Enterprises
SOE	State-Owned Enterprise
SPE	Special Purpose Entity
SPV	Special Purpose Vehicle
TCE	Tangible Common Equity
TD	Top-Down Stress Testing Approach
TSS	Total Sum of Squares
VaR	Value-At-Risk
VECM	Vector Error Correction Models
WWII	Second World War

CHAPTER 1
INTRODUCTION

1.0 Introduction

In the pre-Basel world (at least within G-10) dating back to the late 1980s, internationally active banks were believed to operate in an unsafe and unsound manner; furthermore, large banks had constant propensity to circumvent banking regulation and supervision via loopholes such as *skirting, race to the bottom, de facto versus de jure* and *cherry picking*.[1] Notwithstanding the augmented financial turmoil in the 1980s, large internationally active banks engaged in greater risk-taking which, as predicted by economists, caused massive regulatory arbitrage. Against this backdrop, overly leveraged banks across G-10 had inadequate quality capital plus insufficient levels of capital buffers to absorb potential losses in the event of financial distress.

The banking sector in any country is at the epicenter of financial intermediation; therefore, a prolonged disruption to its normal functioning could cause a severe dislocation to the entire financial system. To avoid disintermediation and to ensure global banking stability, *"International Convergence of Capital Measurement and Capital Standards"* (commonly known as Basel I) became absolutely necessary (BCBS, 1988). Before Basel I, capital adequacy measurements and capital standards of the G-10 banks were disparate which made it extremely challenging for regulators and supervisors to assess whether each bank as well as banking sectors had adequate capital. A decade prior to the recent global financial crisis (GFC), the onset

[1] Each of these methods involved expanding bank operations into countries where banking regulation/supervision is weak or relocating to countries where banks are subject to less rigorous capital and liquidity requirements.

of the homegrown Asian crisis of 1997-98, which was in systemic nature, unmistakably proved that the systematic assessment of both systemically important banks and banking sectors was imperative. The high-magnitude macro events in the late 1990s marked the birth of stress testing (BCBS, 1996a, 1996b), which prompted the Basel Committee on Banking Supervision ("the Basel Committee") to revise Basel I. The International Monetary Fund and the World Bank were also impelled to jointly launch the Financial Sector Assessment Program (FSAP) in 1999.

Financial deregulation in the 1980s and the subsequent fast-paced globalization throughout the 1990s resulted in ever more diversification and interconnectedness among banks. Although these developments were widely perceived as positive, unforeseen (or uncalculated) risks and vulnerabilities were unimaginable. Initially, Basel I had the objective of creating a level of playing field by requiring all G-10 banks to comply with the *one-size-fits-all* capital adequacy rules; in tandem with Basel I (1996 amendment), the earlier stress tests conducted by banks and supervisors had the objective of strengthening banks' capital to absorb losses in an acute stress.

Unfortunately simplistic and risk insensitive Basel I rules caused massive capital arbitrage, mainly fostered (or unintendedly incentivized) by intense use of securitization as a way to disperse risk; but quite the opposite, this technique enabled inherent risks from complex securitized products to be deeply entrenched in the financial system, making it nearly impossible for financial authorities to assess whether banks had adequate capital and banking sectors had sufficient liquidity capable of absorbing losses under extreme but plausible scenarios. Another drawback of Basel I was that it predominantly focused on credit risk, ignoring other important elements such as the supervisory review process and market discipline (Basel II).

No doubt Basel II – the revised framework, introduced by the Basel Committee in 2004, was made more risk-sensitive than Basel I, but it still failed to strengthen the resilience of the global banking system (BCBS, 2004). Although not implemented prior to the GFC, Basel II further raised procyclicality, turned *too-big-to-fail banks* into bigger-and harder-to-fail banks; on top of that, it has created shadow banking by giving banks incentives to move assets off their balance sheets (and the upshot was excessive leverage). Basel II also made banks overly rely on the external credit assessment institutions' (ECAIs) ratings for decisions on audit frequency, dividend payout, and deposit rates; this in turn made banks feel the least urgency to allocate funds to strengthen existing risk-management frameworks or develop far better ones.

In the aftermath of the GFC (2009 onward), the Basel Committee concluded that "...the current capital framework for market risk, based on the 1996 *Amendment to the Capital Accord to incorporate market risks*, does not capture some key risks" (BCBS, 2011a). Many economists share the view that both Basel I and Basel II standards ushered greater risk-taking which resulted in significant cross-border activity, capital arbitrage and procyclicality. The deficiencies of the Basel standards in conjunction with inadequately designed stress tests containing light scenarios (including the IMF's FSAPs) are believed to have contributed to the global financial instability (Asian crisis of 1997-98, subprime debacle in 2006, the 2008 GFC, the EU sovereign debt crisis in 2009-12, and now the 5th wave which is triggered by the May taper tantrum and August rout in 2013). The domineering lesson of the GFC revealed that banks gravely failed to differentiate different risk dynamics between structured products and bonds; further, micro stress tests by the banks and supervisory authorities failed to capture key risks such as pipeline, securitization, short-term funding liquidity, interbank contagion and counterparty default (BCBS, 2009a).

The Asian crisis and the GFC (worst crisis in human history) clearly proved that the use and the capacity of the earlier stress tests have been misunderstood. A universally agreed consensus shows that both micro and macro stress testing are not standalone tools nor they supplement other tools in the macroeconomic toolkit mainly available to central banks and the supervisory community. It is also clear by now that stress testing is not an early-warning device to calculate probability and timing of the next future crisis. Although various uses of stress tests are under close scrutiny since the GFC, the learned lessons in the aftermath have highlighted that stress testing is not a standalone tool but it can be indispensable when used as a complement to value-at-risk (VaR) models. The success of the Supervisory Capital Assessment Program (SCAP), undertaken for the first time by the U.S Federal Reserve (Fed) in 2009 (a similar program was taken in parallel by the CEBS in EU), spurred the use of macro stress testing as a crisis management tool, designed and conducted by central banks and supervisors to assess the resilience of the financial system as a whole plus to develop supervisory assessments of capital adequacy and adequate capital planning at systemically important banks (SIBs).

In the wake of nocuous developments, an ordinary-looking U.S. recession ensuing the subprime debacle of 2006 unexpectedly turned into a high-magnitude global financial meltdown. The GFC was so unprecedented that its farfetched financial and societal implications spared no nation based on size (i.e. small or large) or economic power (i.e. poor or rich). Virtually all countries across the globe were affected one way or another. Although there were protracted unresolved issues prior to the GFC (i.e. imbalances), the sudden crisis jolted societies from their roots, dislocated countless banking systems, displaced millions of people, and shook investor confidence in the resilience of the whole global financial system. In that regard, the GFC serves as a painful reminder how the advanced nations' governments (initially) and the industry participants have failed to prevent recurrence of banking crises, alleviate their costs to economies, and ultimately safeguard global financial stability.

One of the important lessons of the GFC was a realization that Basel I & II and the earlier stress testing practices were inadequate and insufficient to cope with risks related to securitization and over-the-counter (OTC) derivatives. The growing skepticism and bitter criticism towards stress tests arose from the flawed stress testing exercises which painted a rosy picture before and after the GFC; this caught banks unprepared to react properly to unfolding events. International Institute of Finance (IIF) argues that "during the market turbulence, the magnitude of losses at many firms made it clear that their stress testing methodologies needed refinement – stress testing was not consistently applied, too rigidly defined, or inadequately developed (IIF, 2008). Many suggest that stress tests with severe scenarios in the run up to the GFC would have mitigated financial losses and alleviated the crisis' farfetched implications across the world.

In the immediate aftermath of the GFC (since 2009), the adoption and implementation of Basel II and Basel III banking regulation has gained momentum, plus the regular design and conduct of micro/macro-prudential stress testing frameworks have become a central focus. Further, the severity of the losses arising from the GFC underpinned a universally agreed consensus that the Basel III and stress testing frameworks are vital to safeguarding financial stability. Stress testing and Basel III, integral components of a comprehensive risk management framework, therefore must be the primary objective of central banks, supervisors and banks to strengthen the global banking resilience as the foundation of sustainable economic growth.

In 2009, the Basel Committee incorporated the GFC's valuable lessons and published them in a document titled *The Principles for Sound Stress Testing Practices and Supervision* (BCBS, 2009a) which had a total of 21 principles; of which, 15 principles were for the banks and 6 of them were for the supervisors. Afterwards, stress testing has been used regularly as a supervisory and a crisis-management tool to ensure financial stability across the world's financial systems via higher capital ratios along with the new liquidity requirements, additional capital buffers, and limits on capital distributions (were subject to prior approval). Yellen (2014) has made the following remarks regarding the new and important role of stress testing; "at the Federal Reserve, we have devoted substantially increased resources to monitoring financial stability and have refocused the regulatory and supervisory efforts to limit the buildup of systemic risk".

Stress testing, despite numerous variations used in different disciplines, has been an arcane subject in the finance field. After its inception, stress testing in banking has evolved from its infancy in the late 1990s to become indispensable through its new assumed role by 2009. Stress testing as a crisis management tool (i.e. SCAP) has the ability to detect and quantify various risk exposures under extreme but plausible scenarios in a single number. In spite of a plethora of definitions found in the literature, no universally agreed definition constitutes what a good stress testing is. Nonetheless, the IMF defines stress testing as "…a range of techniques used to assess a vulnerability of a portfolio to major changes in the macroeconomic environment or to exceptional, but plausible events" (Blaschke et al., 2001).

Two dimensions of stress testing are micro-prudential and macro-prudential; the former is usually a bottom-up (BU) approach, often employed by banks for internal risk management purposes and by supervisors for "*Pillar II Solvency"* under Basel II and III. The latter is a top-down (TD) stress test that involves incorporating some elements of BU, designed and conducted by central banks and regulatory supervisors to assess financial stability. Since the GFC, a new dimension of stress testing is born, that is liquidity stress testing which is less advanced and not linked to banking solvency, but it is of critical importance in the financial stability assessment. Stress testing results provide informative data for risk managers of banks, regulators, and supervisory authorities. By focusing on tail risks, stress tests quantify banks' vulnerabilities to risk exposures and the resultant financial losses under extreme but plausible scenarios. The utmost objective of stress tests is to assess banks' positions in terms of capital and high liquid assets to withstand shocks in an acute stress for at least a period of 30 days. Stress testing results can also be inputs in the decision making process within the bank.

The evolution of stress testing has gone through different stages and versions in industrialized economies (the U.S. and the EU in particular) since the late 1990s, however stress testing was fairly a new phenomenon for ASEAN-5 countries where most banks despite significant strides are still increasingly vulnerable to exogenous shocks resulting from credit risk, interest rate risk, foreign exchange risk and liquidity risk. Although ASEAN-5 countries have been designing and conducting own micro (bank-run) and macro (supervisory) stress tests since 2006 (Singapore is at the forefront implementing Basel III and stress testing), they underwent their first macro stress testing experience via FSAP. However, ASEAN-5 as a group is underrepresented among the IMF member-countries in terms of the number of FSAPs either requested or completed.

The recurrence of high-magnitude crises in the new millennium has triggered a surge in the use of stress tests and implementation of Basel III across ASEAN-5. Each of the five founding members at varying degrees has made remarkable strides in bringing respective domestic banking standards in line with Basel III. The GFC is now in the past, but the taper tantrum in May followed by the August rout in 2013 proved that the banking sectors and currencies of ASEAN-5 were not at all immune to exogenous shocks. During the past two decades, ASEAN-5 countries have become ever more susceptible to macro shocks arising from rapid boom-and-bust cycles, excessive private and household leverage, further U.S. monetary tightening (the end of cheap dollar or the global dollar glut), reversal in capital flows, volatility in asset price movements, and policy divergences between the U.S. and Europe. As the new periphery, all ASEAN-5 countries rely heavily on capital inflow consequence of the elongated addiction to the US dollar, which is viewed as an essential gateway to sustain economic growth to leap into higher levels of GDP growth to catch up to the levels of G-7 nations.

Despite country-specific differences and varying development levels (i.e. Singapore is the only advanced mature economy within the group) in the region, ASEAN-5 central banks are fully committed to the timely adoption and implementation of the Basel III rules with minor modifications before they become fully effective as of January 2019. Because some of the Basel III rules are too general and not designed for financial sectors of developing and emerging market economies (EMEs) in mind, the central banks of few ASEAN-5 countries (i.e. Thailand) have conducted quantitative impact studies (QIS) to determine whether some elements of Basel III (i.e. G-SIB surcharge or LR) need to be modified, partially implemented or cancelled as required by the nature and needs of their financial systems. Going forward, banks across ASEAN-5 are mandated by central banks, regulators, and supervisors to conduct micro stress tests using own internal models and to undergo regular macro stress tests designed and conducted by the central bank/supervisory body in each member-country.

1.1 Background of the Study

In the post Second War (WWII) era, financial markets were relatively small and the coverage for the pure financial risk was in infancy stages. Insurance policy was used predominantly as a protection against physical losses resulting from accidents or environmental disasters such as an earthquake. The five seminal papers have instigated the evolution of finance to accelerate at a remarkable pace. For instance, Markowitz's (1952, 1959) *mean-variance criterion* reduced risk via the ultimate portfolio selection, which primarily focused on portfolio risk; Modigliani-Miller (1958) introduced unconventional then the *irrelevance* and *arbitrage-reasoning,* arguing that a firm's market value is irrelevant to its cost of capital; Sharpe's (1964) Capital Asset Pricing Model (CAPM) was a paradigm-shifting; but most importantly, Black and Scholes' (1973) option pricing formula and the Merton's (1974) pricing of corporate debt created a shift from *risk-based pricing* (i.e. CAPM) to *arbitrage-based pricing* models.

The risk of financial stability increased substantially in the 1970s and a series of high-magnitude events resulted in a strong demand for effective option-based hedging instruments (Schwartz & Smith, 1990). The sudden collapse of the Bretton Woods system of fixed exchange rate regime in the early 1970s, the Arab-Israeli conflict-Yom Kippur War in 1973 and the failure of Germany's Herstatt Bank in 1974 prompted the central bank Governors of the G-10 to engage in cooperation and financial collaboration, which later gave birth to the creation of the Basel Committee in 1974 (BCBS, 2001a). Over a decade of relentless work, the Basel Committee released Basel I in 1988 (BCBS, 1988) "...to strengthen the soundness and stability of the international banking system" and "...to reduce competitive inequalities" (BCBS, 1999a).

Although the Basel Committee envisaged that the Basel I standard in the long-run would make the global banking system more resilient, internationally active banks with propensity invented loopholes to circumvent banking regulation and supervision. Basel I faced skepticism and was subject to considerable criticism due to its arbitrary risk categories (OECD and non-OECD origination) and arbitrary risk buckets (0%, 10%, 20%, 50%, and 100%); based on this, Turkey (developing) and the U.S. (advanced) received a 0% risk weight. Ferguson (2003), the Federal Reserve's Vice Chairman, elaborated in a speech that "Basel I Accord is too simplistic to adequately address the activities of the most complex banking institutions".

The Basel Committee observed that insensitiveness of Basel I to credit risk caused distortions in cross-border lending and market risk (BCBS, 2004a, b). Rodríguez (2002) suggests that Basel I not only allowed banks to engage in excessive risk-taking but enabled them to accumulate more capital than through disintermediation. Blundell-Wignall et al. (2014) suggest that Basel I created incentives for gaming the system, enabling banks to move higher-risk assets between on-balance and off-balance sheets via securitization; this in turn created *shadow banking*.

End of the Cold War and taking down of the Berlin wall as reminiscence of the isolationist policies set the stage for collaboration among the countries/regions that were once isolated. In that regard, the gradual integration of ASEAN-5 into the world's major trading hubs and financial centers has provided widespread benefits, while the spinoff Asian crisis of 1997-98 was bitter and unsettling for ASEAN-5 (Bekaert & Harvey, 1998; Obstfeld & Taylor, 1998; Wang, 2004). For the past three decades, trading accounts at SIBs have grown significantly in complexity and risk exposures largely fostered by fast-pace globalization, banking deregulation, and financial and technological innovations; the latter led to booms in real estate and stock markets in the 1990s in advanced and ASEAN-5 economies. The asset boom mania in these countries was sufficient enough to turn ordinary people into avid buyers, mainly facilitated by the global savings glut and the resultant easy-credit environment (e.g. Bernanke, 2005). In turn, the intensified competition among large banks persuaded them to expand credit into riskier sub-prime segment via lax and predatory lending (Schwartz, 2009).

The Basel Committee conducted a study to determine whether Basel I contributed negatively to the financial sectors of ASEAN-5, the results of its empirical analysis state that "...risk weighting of short-term interbank exposure was an important contributing factor to the crisis" (BCBS, 1999b). However, Baig and Goldfajn (1999) and Berg (1999) argue that fundamental causes of the Asian crisis are widespread. Prior to the crisis in the late 1990s, a good number of banking sectors of ASEAN-5 had common weaknesses (which are usually seen in developing countries) such as unsustainable current account deficits, heavy reliance on short-term funds, poor banking regulation and supervision, asset price bubbles, and fixed exchange rates (BIS, 1997; 1998). Glick (1998) argues that the financial liberalization since the 1980s in the absence of both fiscal and structural reforms made ASEAN-5 become increasingly susceptible to macroeconomic shocks. Subsequently, the prolongation of the stable exchange rates and the liquidity glut enticed the risk appetite of ASEAN-5 banks to borrow short-term foreign-denominated funds which in turn were loaned back domestically in national currency for long-term projects (i.e. causing maturity mismatches). Bursting of the bubbles, falling banking stocks, and changing investors' sentiment ahead of the crisis triggered a sudden reversal in capital flows which did precipitate a capital flight to quality (Burnside et al., 1998).

Interest rates, in nominal and inflation-adjusted terms, have been historically low globally. As a result, the easy-credit environment created a malaise in most advanced economies, and the side effect of which was an illusory perception that unconventional risks related to structured products, securitization, and derivatives were *the new normal"*. Interconnectedness spread this malaise in advanced countries to ASEAN-5 economies in ways of exchange rate and capital flows (Bluedorn et al., 2013). Schwartz (2009) argues that the easy monetary conditions via the Federal Reserve's expansive policies have been utilized far too long for the short-term gain ignoring the unthinkable cost of the long-term agony as observed during and after the GFC.

Economic growth among ASEAN-5 has been unbalanced and disparate. The private corporate and household indebtedness have been noticeably high, this placed strain on banking sectors and unbearable burden on households. Since the GFC, the GDP growth has moderated in most ASEAN-5 nations suggesting that short-term policy fine-tuning instead of structural policies is not sufficient anymore to address systemic financial crises. Because equity and currency markets in East and Asia Pacific have been historically more volatile than those in the United States and Europe, the respective central bank of ASEAN-5 is highly committed to the timely adoption of Basel III and the development of enhanced micro/macro stress testing programs. Albeit the steady progress of the Basel III implementation is on track, the Basel Committee's report to G20 leaders reveals that the progress has been a slow-moving process (BCBS, 2014a).

The monetary policy decisions taken by ASEAN-5 central banks are quite accommodative despite the danger of upward spikes in inflation. Because ASEAN-5 countries have substantial credit in the U.S. dollar, their monetary policies tend to be influenced by the imported monetary conditions of the U.S. and the EU to mitigate the adverse impact arising from interest rate differentials and exchange rate movements. The former Fed Chairman Bernanke (2013) covered some of the monetary policy issues in the global economy, while Disyatat (2008) warned about consequences of misaligned monetary policies, and later the GFC clearly revealed adverse effects of narrow-focused domestic measures and the prolonged use of accommodative monetary policies to stimulate debt-fueled growth in the near-term.

Basel I, the first installment of the Basel standards released to banks in July 1988 and adopted by over 100 countries, failed to safeguard "the soundness and stability of the international banking system" (BCBS, 1988). The shortcomings of Basel I coupled with mounting pressures from industry participants prompted the Basel Committee to revise Basel I. The Basel II was introduced in June 2004; under Basel II, two profound changes are noticed; company ratings are provided by the external credit assessment institutions (ECAIs); large banks are allowed to use a foundational (F-IRB) or advanced internal ratings-based approach (A-IRB) to calculate their capital adequacy ratios (BCBS, 2004). The procyclical aspect of the Basel II rules was criticized by many including Blundell-Wignall & Atkinson (2010), and the Basel Committee observed that banks' overreliance on the ECAIs resulted in *"cliff"* effect in the capital requirements. Regulatory distortions under Basel II also provided *too-big-to-fail* banks incentives to move risky assets off their balance sheets, the practice of which created a new form of intermediation referred to as *shadow banking* (Blundell-Wignall et al., 2014).

The breakout of the GFC sent clear signals that a new installment of the Basel standards was in the works. Basel III, unlike Basel II, is not a revision; it is an overhauling of the banking regulation and supervision. A set of proposals were adopted in September 2010 and the first draft of the rules was released to banks in mid-2011. The Basel Committee strongly emphasizes that higher capital along with liquidity requirements has the objective of strengthening the global banking resilience and reducing the probability of a crisis occurring in the long-run (BCBS, 2010a). This view is empirically supported by Modigliani-Miller (1958) who argue that switching to a higher cost of debt (i.e. higher capital ratios) offset by a lower cost of equity reduces risk (i.e. the likelihood of bankruptcy). Along the same line, Carmassi and Micossi (2012) suggest that banks have become a lot more susceptible to macro shocks due to insufficient capital and excessive leverage. Regardless of improvements, Haldane (2011) points out that the regulatory framework is still open to gaming, therefore it would be unable to prevent systemic shocks. Basel III requires banks to put in place enhanced stress testing approaches as part of a comprehensive framework to assess stability for internal risk-management purposes.

Although stress testing is not new, its use in finance and banking however began in the 1990s as several private banks at the time began developing proprietary risk assessment capabilities for internal risk management purposes. Hirtle and Lehnert (2014) infer that "...stress testing began at the same time as financial risk modeling, when analysts had contemplated pessimistic or worst-case outcomes before investing". The Basel Committee developed a framework just prior to the Asian crisis for "...incorporating backtesting into the internal models approach to market risk capital requirements" (BCBS, 1996b). On account of deficiencies and imperfect signals generated by backtesting (Campbell, 2005), stress testing became a mainstay when the Basel Committee required banks with substantial trading to use stress testing to confirm the accuracy of Value-at-risk (VaR) outputs. Studies such as CGFS (2000, 2001, and 2005) surveyed major and large financial institutions for their uses of stress testing.

The typology of stress testing is categorized along two dimensions: micro-prudential and macro-prudential. Microprudential stress testing (BU: bottom-up) is employed by banks for internal risk management purposes and by supervisors for p*illar II solvency*. Macroprudential stress testing (both BU and TD: top-down) is employed by central banks and supervisors for assessing the entire financial system and by the IMF for country-level surveillance (IMF, 2013a). Starting with the US SCAP in 2009, macroprudential stress tests (BU) are used as a crisis management tool. There is also liquidity stress testing but it is still in infancy and not linked to solvency. The earlier stress tests failed to detect risks, plus the flaws and deficiencies of stress tests caused banks to react insufficiently to the GFC's unfolding events (BCBS, 2009a; b). International Institute of Finance argues that "during the market turbulence, the magnitude of losses at many firms made it clear that their stress testing methodologies needed refinement – stress testing was not consistently applied, too rigidly defined, or inadequately developed (IIF, 2008).

The successful stress testing exercise by the Federal Reserve (Fed) in the U.S. (the SCAP) was informative, which provided credible and market-demanded information regarding the projected post-stress losses (Bernanke, 2013). In contrast to the SCAP experience, the Committee of European Banking Supervisors (CEBS) and its successor the European Banking Authority (EBA) bungled on their two EU-wide stress test attempts (CEBS, 2010a, b; EBA, 2011), the results of which were not sufficiently granular. Tarullo (2010) contends that stress tests can stand a chance of succeeding if the rigor is absent in the design of exceptional but plausible scenarios that must be consistent and comparable. Wall (2013) argues that one of the success attributes of the SCAP was a *backstop* (i.e. temporary financial relief) provided by the U.S. Treasury that enabled supervisors to identify the tail risks better. According to Ellahie (2012), the stress test conducted by the CEBS (2010a) in most part was uninformative and its partial disclosure caused a decline in equity values. Conversely, Beltratti (2011) believes that the EBA (2011) stress test was informative in terms of methodologies and scenarios used.

Although central banks of ASEAN-5 have been designing and conducting own stress tests since 2006 (e.g. Siregar, 2011), they were introduced to stress testing for the first time through the IMF's FSAP in response to the Asian crisis of 1997-98 (Blaschke et al. (2001) studied the early examples of stress tests). The IMF's FSAP, as part of its surveillance program known as *Article IV Consultation*, was primarily established "...to help countries enhance their resilience to crises and foster growth by promoting financial stability and financial sector diversity" (IEO, 2004). Although the FSAP has been initially praised as a forward-looking process for making stress testing systematic and consistently applied in the IMF-member countries, but the misleading results of Iceland FSAP (IMF, 2008) caused not only loss of credibility but left a long lasting scuff on the unblemished reputation of the IMF and the World Bank (see IMF & World Bank, 2003 for tools used and 2005a; b for lessons learned).

Indonesia's recovery from the GFC was quick without a major dent in its economy, attributable to a decade of sound policies and structural reforms. In the face of some unresolved prolonged issues related to the law enforcement, transparency, governance, and political risk to a lesser degree; the Financial System Stability Assessment (FSSA) as part of the FSAP (during October 2009 and March 2010) concludes that Indonesia's banking system is still comparatively robust (IMF, 2010a). Malaysia's FSSA, completed in January 2013, shows that the banking system is relatively resilient (i.e. strong capital position and strengthened banking regulation/supervision), nevertheless banks in Malaysia are still vulnerable to the overexpansion of credit, ballooning house prices, increased household leverage, and overreliance on demand deposits (IMF, 2013b). The banking sector in Philippines, compared to its peers, is less developed. The FSSA (completed in January 2010), an update mission to the initial FSAP in 2002, indicates that the development of capital markets is necessary to diversify risks and both regulatory and supervision frameworks need to be further strengthened (IMF, 2010b).

Singapore is the only highly-developed and high-income country within ASEAN-5, where the financial system is transparent underpinned by the superior banking regulation and supervision. The FSSA (completed in October 2013) of Singapore clearly proves that even best systems are vulnerable to spillover effects due to a high degree of interconnectedness; as such, Singapore's economy directly or indirectly is exposed to slow-growth trend (*the new normal*) in China, further monetary tightening by the U.S., and reemerged risks in Europe (IMF, 2013c). Thailand, similar to peers, has made remarkable strides in bringing its financial system in line with the international standards. Yet, Thai banks are still vulnerable to a major contraction in domestic consumption; plus, a few banks may face liquidity issues (IMF, 2009). In overall, ASEAN-5 are not immune to a wide range of shocks; therefore, they need to continue making progress on policy and structural reforms to increase their resilience to shocks.

1.2 Statement Problem of the Study

Contemporaneous financial crises and their massive spillover effects have proved that ASEAN-5 economies are still not immune to macroeconomic shocks. Therefore, external factors remain a challenge and risks are tilted to the downside as ASEAN-5 countries have been trying hard to cope with the GFC's prevalent economic and societal implications as well as post-crisis adjustments. Consequently, export-dependent ASEAN-5 saw widening contraction in trade mainly arose from soft oil and commodity prices, rising household debt, and excessive private leverage. Bouts of shocks since 2013 (triggered by the U.S. monetary tightening) rattled markets worldwide and caused fast depreciation in currencies across ASEAN-5 in recent memory.

Against the backdrop of amplified financial turmoil arose from farfetched impacts of the GFC, Basel III implementation and ongoing micro and macro stress tests have become a central focus, however not without enormous costs and numerous challenges. Some smaller banks (i.e. Islamic) within ASEAN-5 are projected to face capital shortfalls by the January 2019 deadline when all of the Basel III standard become fully effective. Although the minimum required capital level (CET1) in 2015 is markedly higher in Asia (at least 2% higher) than Basel III (4.5%), some of ASEAN-5 banks are expected to raise fresh capital before 2019. The new elements under Basel III as follow: capital buffers (2.5%), liquidity standards (LCR – Liquidity Coverage Ratio and NSFR – Net Stable Funding Ratio > 100), countercyclical buffer (2.5%), leverage ratio (2.5%), and global systemically important bank (G-SIB) surcharge (2.5%).

Banking sectors of ASEAN-5 and their respective economies are varied and disparate[2], largely influenced by country-specific imperatives and differing economic development stages. Therefore, a great majority of ASEAN-5 banks are at disadvantage compared with fully-developed mature economies (i.e. Singapore) where large internationally active banks use Advanced Measurement Approaches – AMA such as foundation or advanced Internal Ratings-Based Approach (IRB) to calculate capital ratios. Using AMAs allows large banks to assign

[2] According to *The Global Competitiveness Index 2015-2016 Rankings*, Philippines (ranked 66 in the world) is in transition from Stage 1 (factor driven) to Stage 2 (efficiency driven), Indonesia (ranked 49) and Thailand (ranked 42) are in Stage 2, Malaysia (ranked 22) is in transition from Stage 2 to Stage 3 (innovation driven), and Singapore (ranked 2 behind Switzerland) is in Stage 3 (WEF (2015) explains how rankings are computed).

lower risk weights (subject to supervisory approval); doing so can reduce regulatory capital charge and improve bank profitability (i.e. higher ROI, ROA, and ROE). Within ASEAN-5, only Singapore is a mature economy where the AMAs are utilized by all banks, the remaining four of ASEAN-5 are considered as the emerging implementation countries. In the former, large banks use the AMA, however smaller banks initially adopted the Standardized Approach (SA); in the latter, the majority of banks are less sophisticated, using either the Basic Indicator Approach (BIA) or the SA which give higher risk weights.

The central banks of ASEAN-5 have voiced concerns regarding some elements under Basel III that must be met with only common equity Tier 1 (CET1) and question their appropriateness in their respective financial systems. Albeit the risk-based capital has been implemented across ASEAN-5 before the January 2015 deadline; Indonesia, Philippines, Malaysia, and Thailand have lagged behind the advanced economies in terms of adoption and implementation of the Basel III capital and liquidity rules (not yet drafted liquidity rules as of 2015). Moreover, a majority of banks within ASEAN-5 lack of sophisticated risk measurement and management techniques, which often lead to inaccurate assessments of vulnerabilities to risk exposures.

Already several years passed since the unprecedented GFC, the panic receded in the U.S. and euro zone but the global economy is still in rebalancing mode and is due for bouts of new financial shock. On that note, the recent macroeconomic signs such as the new slower growth-path in China, further US monetary tightening, and renewed risks in Europe rattled markets abruptly leading to the taper tantrum in May and the August rout (2013). Continued structural and policy reforms are more critical for ASEAN-5 now than have been in the past because the current global financial conditions are not expected to improve anytime soon; quite the opposite, economic downturns in advanced countries may turn into deeper and prolonged recessions, the spillover effects of which could easily spread to ASEAN-5 countries.

During the menacing time of global instability resulting from repeated shocks, sustainable growth of ASEAN-5 still depends on the ability of each domestic banking sector to provide unconstrained access to credit for private corporations and households. Disintermediation due to capital hoarding by banks and the ensuing contraction in credit markets may cause a cascade of defaults as well as a domino effect in the region. ASEAN-5 rely on net capital flow to continue on investing in government-sponsored projects, and the continued flow of foreign capital is seen as a gateway to leap into higher economic output to catch up to the G-7 (namely Canada, France, Germany, Italy, Japan, United Kingdom, and United States). Because the export-depended ASEAN-5 countries have substantial trade ties and close financial linkages with the U.S., Japan, Europe, and China; the renewed risks in Japan, a slower growth path of China, reemerged sovereign debt concerns in Europe and a prolonged recovery in the U.S. may lead to a downgrade in the currently favorable outlook of ASEAN-5. Aside from a number of economic issues, the global economy is facing downside risks coupled with the relevant uncertainties due to geopolitical challenges and risen conflicts in many parts of the world.

Recurrence of high-magnitude financial instability-imposing events mainly originated in advanced nations[3] coupled with the post-GFC adjustments prompted a surge in the use of stress tests among ASEAN-5. Banks began conducting microprudential stress tests to detect and gauge a wide range of risks for internal risk-management purposes as well as to calculate capital

[3] The burst of the US dot.com (Internet) bubble in 2000-2001, the US mortgage debacle in 2006, the US originated GFC in 2007-08, the Icelandic financial crisis in 2008-11, Irish banking crisis in 2008-10, Greek sovereign-debt crisis in 2008-12, Russian financial crisis in 2014, and China's stock market crash in 2015. Although it is not termed as a crisis, the currencies of ASEAN-5 have depreciated as much as 40% since the US rate hike in 2015.

adequacy and make proper capital allocations. Stress testing as a supervisory tool is employed to assess the soundness of banks and the resilience of banking sectors to ensure that both banks and banking sectors have sufficient capital plus buffers to absorb financial losses in an acute stress. As a crisis-management tool, central banks have the objective of integrating stress testing into the on-going supervision to ensure that banks have a strong position of capital base.

Different types of stress tests have been used in advanced economies since mid-1990s, but stress testing (as supervisory and crisis management tools) is fairly a new phenomenon for ASEAN-5 countries where banks, despite remarkable strides, still remain vulnerable to credit, interest rate, and liquidity risks. Even though BU and TD stress tests have been developed and employed by the central banks of ASEAN-5 since 2006 (particularly Malaysia and Singapore), ASEAN-5 countries underwent their first macro stress testing experience through the IMF's FSAP, which publishes the results along with the methodology and stress testing approaches used. However, ASEAN-5 as a group is underrepresented among the IMF's 189 member countries in terms of the number of FSAPs have been either requested or completed (28 EU states top the list).

Although the FSAP's primary objective is "the identification and mitigation of financial sector vulnerabilities and their macroeconomic stability implications" and "fostering development of the financial sector and its contribution to economic growth" (World Bank, 2006), both micro and macro stress testing programs prior to the GFC failed to ensure global financial stability. Despite growing concerns, the majority of staffs both from the IMF and the World Bank proclaim that FSAPs have led to positive changes in financial and non-financial sectors (IMF & World Bank 2003). Nevertheless, repeated misleading results (IMF, 2008) not only caused loss of credibility and trust, but left a long-lasting scuff on the unblemished reputation of the IMF and World Bank. An extensive review of the program's processes (IMF & World Bank, 2005a; b) was initiated after overhauling of banking systems (i.e. Irish bank system) and collapsing banks (i.e. Dexia) shortly after passing FSAPs and EU-wide stress tests in 2010 and 2011.

The fast paste globalization and the resultant gradual integration of ASEAN-5 economies into financial markets and trade hubs has made ASEAN-5 more vulnerable to exogenous shocks.

1.3 Objective of the Study

General objectives

The general objective of this thesis is to estimate the cost impact of Basel III on banking sectors of ASEAN-5 and construct a macro stress testing framework to stress test Malaysia's banking sector; also to determine their potential effect on financial stability across ASEAN-5.

Specific objectives

The specific objectives set for the achievement of this research purpose are to:

1. Estimate the cost impact of Basel III on bank capital, lending spreads, and GDP;
2. Analyze the effects of micro and macro stress testing on financial stability;
3. Investigate the impact of Basel III and stress testing on financial stability;
4. Stress test the resilience of Malaysia's banking sector to shocks.

1.4 Research Model and Hypotheses

The main objective of this thesis is twofold; to estimate the cost impact of Basel III on bank capital, lending spreads and GDP growth across ASEAN-5; construct a macro stress testing framework from publicly available accounting and market-based information. The analysis of Basel III impact is based on Slovik & Cournède (2011) who use a very simple banking model to take into account two categories of assets such as lending assets (AL) held on banking books and other assets (AO) held on trading books. The macro stress testing framework is adopted from Čihák (2007a); a TD stress testing approach is carried out on aggregated actual bank data to address two critically important questions: (1) is Malaysia's banking sector as a whole (56 entities, controlling over 60% of financial assets) able to withstand the assumed adverse shocks under the two adverse scenarios in each quarter of the stress testing horizon? (2) What is the potential cost to Malaysia's government arising from failed banks? The Malaysia-wide stress test (herein: "MAST") mainly examines the credit risk, interest rate risk, and foreign exchange rate risk. The 2016 MAST exercise predominantly measures the impact on Malaysia's banking sector in one baseline and two adverse scenarios; the results are expressed in capital adequacy or government intervention (i.e. capital injection) as a percent of GDP.

The theoretical and scientific foundation of the thesis, empirical support, as well as the basis of research can be found in the macroprudential regulation and supervision of the banking system and the stress testing literature published by the industry participants and experts. More specific studies related to each of ASEAN-5 have been published by the respective central bank, the Federal Reserve, the CEBS (succeeded by EBA), the Financial Services Authority of the UK, and the multilateral organizations such as the IMF, World Bank, and the Basel Committee as well as national and international authorities for banking regulation and supervision.

As part of the research aim, in the first three chapters, some of the main research methods have been utilized such as the analysis and synthesis methods, induction, deduction, and analogy. In the methodology chapter, the research methods such as the factorial and comparative analysis, statistical and mathematical methods have been employed. For the purpose of an econometric study, specific macroprudential banking data and macroeconomic data for each banking sector of ASEAN-5 was compiled from a number of sources including but not limited to bankscope, central bank databases, World Bank, the IMF FSAPs, Eurostat, the Basel Committee, and individual banks' official websites. The research's postulated hypotheses are listed below:

H_1 Basel III capital ratios result in a higher cost impact on bank capital across ASEAN-5.

H_2 Basel III capital ratios result in a higher cost impact on lending spreads across ASEAN-5.

H_3 Basel III capital ratios result in a higher economic cost across ASEAN-5.

H_4 Basel III capital ratios result in a higher economic benefit across ASEAN-5.

Operational Hypotheses

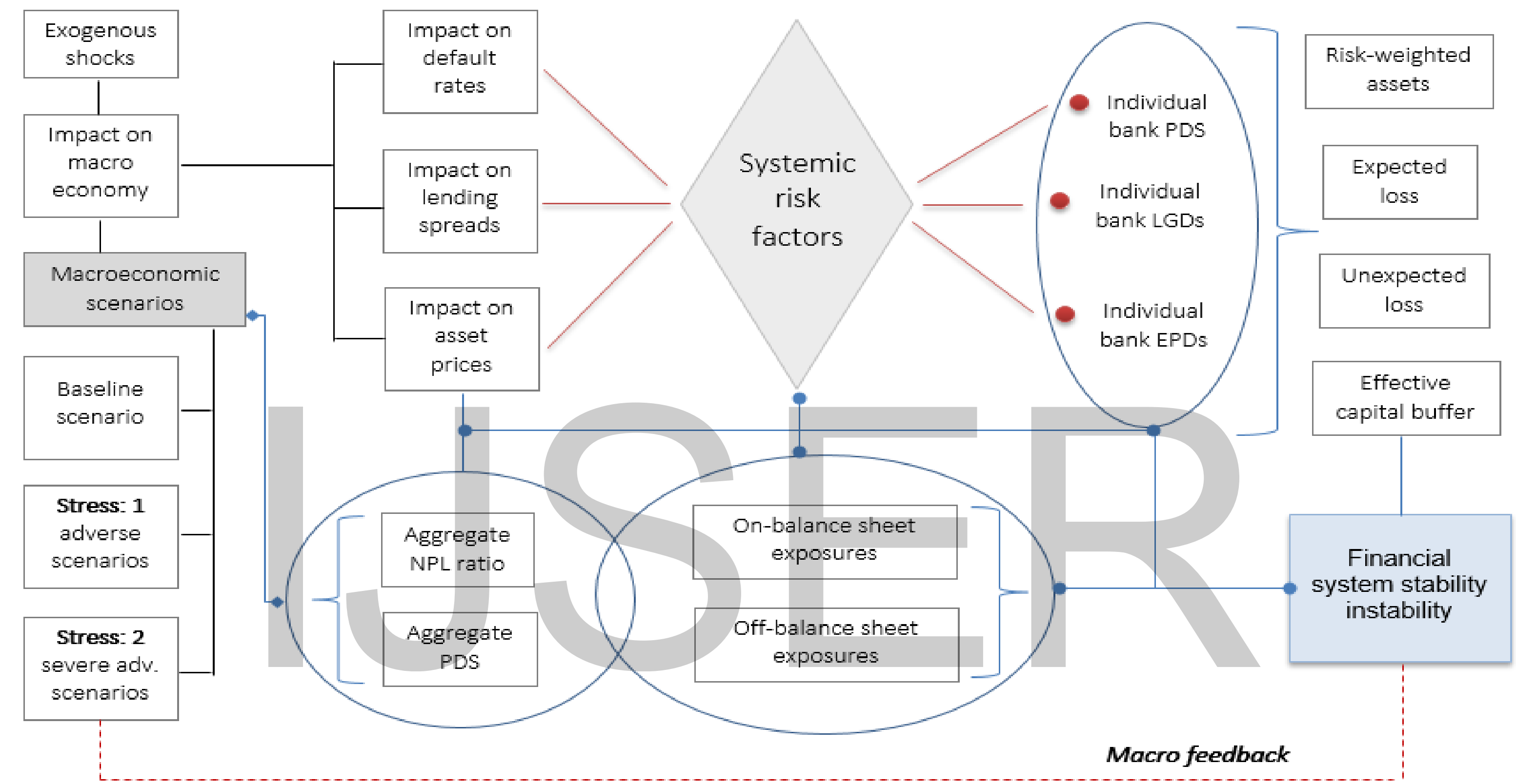
H_5 There is a positive relationship between higher capital ratios and banking stability.

H_6 There is a negative relationship between higher lending spreads and banking stability.

H_7 There is a positive relationship between sufficient liquidity and banking stability.

H_8 There is a negative relationship between financial crisis and GDP growth.

It is critically important that all specific independent and dependent variables used in this thesis are clearly defined. In the stress testing analysis, IVs are interest rate risk, foreign exchange risk, and liquidity risk; and the DV is banking stability measured in terms of CAR and Tier 1 ratio as well as the amount of capital injection requested by banks from the government. Rejecting the null hypotheses would mean that higher capital ratios and liquidity tightening would result in a higher cost on bank capital, lending spreads, and steady state output.



Source: Adapted from Borio et al. (2012); Buncic and Melecky (2012)

Notes: The proposed macro stress testing framework shows a sequence of developments and the steps were considered in the pre-design of the macro stress test undertaken in this thesis. Because any banking operation revolves around a constant inventory of risks, in order to choose an appropriate model (i.e. a sensitivity test or a scenario analysis), all pertinent risks must be clearly specified (i.e. micro factors, macro factors, or systemic factors). Stress tests can focus on the impact of individual risk types (i.e. PDs, LGDs, and EPDs; as well as credit, interest rate, and liquidity risks) or systemic (i.e. on-balance and off-balance sheet exposures) risk on bank capital, lending spreads and steady state output. Once the nature of impact and its spillover effects on banks and the broader economy are determined, these can be used as inputs in specifications of stress tests scenarios.

Figure 1.1: Overview of macroprudential stress testing framework

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1.5 Significance of the Study

ASEAN-5 as a group of five founding members is considerably a large economy with the 2014 GDP of little over $2 trillion dollars (about 12% of the U.S. 2016 GDP of $18 trillion). Besides minor restrictions here and there, it is an open as well as a highly-integrated economy with significant cross-border linkages. Gradual integration through fast-pace globalization along with internationalization of finance, aside from generalized benefits, made ASEAN-5 highly vulnerable to macro events and developments elsewhere (the U.S., Japan, Europe, and China in particular). Further, the creation of ASEAN Economic Community (AEC) exposes ASEAN-5 to additional common risks seen in regional integration facilitated by a free flow of goods and capital between member states. Financial sectors of ASEAN-5 face global exposure due to foreign and regional banks operating in each member-state where banks are still the dominant source of intermediation accounting for over 60% of total financial assets.

ASEAN-5 has been selected as the thesis' subject for a number of reasons; first, the group contains high-ranked emerging market economies in the world that are subject to somewhat similar shocks faced by the advanced countries while still hindered by financial and infrastructural issues that are common to many developing/emerging economies; second, recently published academic, sectoral, and professional papers brusquely chose to address the cost impact of Basel III and significant effects of macro stress testing on financial sectors of developed countries and ignored EMEs; third, goals of a common market with a monetary union, similar to that of the EU, may potentially create a number of unanticipated challenges across the banking sectors of ASEAN-5; fourth, although the combined economic output of ASEAN-5 represents over $2 trillion, the practice of stress tests in the region not only has been limited but also underrepresented among the total number of IMF's FSAPs; this thesis attempts to address this gap. Last but not the least, gradual integration of ASEAN-5 into global affairs as well as the world's major trading hubs and financial centers has made them ever more susceptible to shocks and economic downturns across G-2 plus China.

The results of this thesis are intended to contribute to the literature that examines the cost impact of Basel III capital and liquidity regulation on banks' activities and the importance of stress testing. The analysis shows that Basel III rules may initially cause cost impact on bank capital, lending spreads and GDP growth, but the consensus is that the new Basel standard in the long-run will be better at safeguarding financial stability and strengthening the resilience of the global banking system. The thesis reports that although banks vary in their risk appetites plus being under the scrutiny of heavy banking regulation and supervision, the strengthened global capital base together with enhanced risk coverage are seen as significant determinants of financial stability. The results provide insights regarding the resilience of Malaysia's banking sector and place the spotlight on the probable macroeconomic impact of Basel III and significance of macro stress testing as a central mechanism to assess financial stability. The results of this thesis should be of significant interest to numerous parties including regulatory bodies, policy makers, the supervisory community, practitioners, risk managers, bank executives, and the general public.

1.6 Definition of Terms

Asset risk is the value of the firm's asset at risk due to uncertainty arising from domestic and /or external factors. Due to many multidimensional aspects and complex linkages, the value of the firm's assets cannot be calculated with 100 percent accuracy.

Bank refers to conventional banks, non-banks, financial and nonfinancial intermediaries including but not limited to Federal Reserve banks, private and public commercial banks, thrifts, savings banks, savings and loan associations, credit unions, insurance companies, investment banks, brokerage firms, venture capitalists, and other lending institutions.

Basel I, II & III are broad banking regulation and supervision standards, guidelines and best practice recommendations. Implementation is in voluntary basis and they do not carry a legal force. The objective of Basel standards is to improve banking supervision and set standards.

Bottom-up (BU) stress testing is employed by banks for risk management purposes using internal models and by supervisors for "*Pillar II Solvency"* under Basel II and III.

Cost impact is an additional cost incurred by banks as a result of Basel III implementation plus the cost of the higher capital and liquidity regulation imposed on banks by the Basel Committee.

Default correlation is the degree of relations showing how default risks of borrowers and counterparties in portfolios are correlated, important for calculating default probabilities.

Default probability is a statistical term that gives the likelihood (the probability) of borrowers or counterparties who will fail to service short-term and long-term debt obligations.

Developed economy is the country that enjoys certain high standards. Such country generally has a good infrastructure, stable economy, and high per capita income. The degree of development, industrialization and general standard of living for its citizens is very.

Deleveraging is a necessary process often used by banks to improve imperatives such as imbalances built during benign economic times and strengthen business models; when it is done in a disorderly fashion (as observed during the GFC), it could pose substantial threats to the global stability and massive costs to economies across the world.

Derivatives, whose values are derived from an underlying asset (a publicly traded company stock), are common features of the modern finance. Derivatives are used to disperse risks and provide an important source of funding and market liquidity; without them, pricing and reallocation of riskier assets (foreign exchange and interest rate) may have been difficult.

Distance-to-default (DtD) measures how many standard deviation a firm is away from default risk. The distance to default models may be less informative and misleading for both regulators and supervisors to determine a set of corrective actions for weak banks facing insolvency.

Diversification, in simple terms, means not putting all eggs in one basket; in financial terms, reducing risk of a portfolio or investment by selecting securities that will not increase the aggregate variance of the portfolio. Diversification is the key to portfolio selection.

Financial stability can be defined as the presence of stable banks and stable markets.

Financial Sector Assessment Program (FSAP) is jointly established in 1999 by the IMF and World Bank, which is a comprehensive and in-depth analysis of a country's financial sector. The focus of FSAP assessments is twofold: to assess the resilience of the financial sector to endogenous and exogenous shocks and to measure the financial sector's potential contribution to growth and development of non-financial sectors of the economy.

Financial soundness indicators (FSIs) are created to measure particular risk exposures (vulnerabilities) of the financial system to macroeconomic risk factors as well as to unique products (e.g., derivatives). Each FSI may not produce meaningful results, but collectively, they capture the financial system's sensitivity to risks including credit, market, or liquidity.

Flight home occurs when banks either reduce exposures or get out of positions in foreign markets in favor of domestic borrowers. Deteriorating external factors prompt banks to rebalance their loan portfolios, from riskier to low-risk investment options.

Flight-to-quality usually takes place before, during, or after a financial crisis when investors lose confidence in the macroeconomic outlook and are increasingly concerned about asset payoffs. Flight-to-quality can be substantially disruptive if orchestrated in a herd mentality.

Forward contracts give the holder the right to trade the underlying asset at expiration at a strike price. Investors normally use forward contracts to neutralize risk by fixing the price.

Futures are forward contracts but traded on exchanges. Unlike forward contracts, investors use futures to hedge the price movement risk of the underlying asset and therefore investors offset their positions before maturity by entering into an opposite futures contract.

Hedging is a financial transaction (activity) to protect (i.e., insurance) an asset or liability against adverse price movements in the future.

Interest rate swap is an exchange where interest rate is swapped for the equal amount of cash flows; between two parties, one agrees to pay cash flows equal to fixed interest rate on a notional principle with an expiration date; the other agrees to receive interest at a floating rate.

Leverage is the extent of the firm's short-term and long-term contractually binding liabilities. The net market value of a firm is calculated by subtracting liabilities from the value of its assets.

Loss given default is the amount (extent) of losses incurred in the event of the borrowers or counterparties default.

Maximum loss approach, similar to VaR, forecasts the largest potential loss on a portfolio arising from changes in market conditions should a high-magnitude shock occur.

Macroprudential stress testing measures the resilience of the financial system as a whole, and it is not particularly concerned about the health of individual banks; however, micro aspects of macro stress testing require banks to take care of certain deficiencies such as capital shortfalls.

Microprudential stress testing (bank-wide, used by individual banks) gauges risk exposures for internal purposes to calculate capital adequacy and determine capital allocation; and used by supervisors to assess the health of banks and the resilience of banking sectors.

Migration risk is associated with changes made to portfolios and the resultant probability (increase or decrease) and value impact of changes in default probability.

Monetary stability can be defined as price stability in the general sense; in other words, no inflationary or deflationary pressures on prices.

Option contracts give holders the right to buy or sell securities at maturity at a strike price without the obligation to own them. The most commonly used ones are *call* (the right to buy) and *put* (right to sell) options. Frequently used option contracts are *"plain vanilla"* and *"exotic"*.

Risk exposure (many different types exist) is the size, or proportion, of the portfolio exposed to the default risk of each counterparty and borrower. Businesses, governments, and individuals mainly have exposures to credit risk, interest rate risk, exchange rate risk, and liquidity risk.

Scenario analysis attempts to measure risk exposures due to extreme but plausible market events triggered by simultaneously moving endogenous and exogenous risk factors, which has two branches; *a historical scenario analysis* where past events are used and *a hypothetical scenario analysis* (future is the focus) which takes into account events that have not yet occurred.

Securitization enables the issuance and re-issuance of liabilities in the form of special purpose vehicles (SPVs) and special purpose entities (SPEs). Banks use securitization to move assets between on-balance and off-balance sheet.

Sensitivity test measures the adverse impact (sensitivities) of hypothetical changes of a single risk factor (i.e., interest rate) on a portfolio, business unit, or the entire bank.

Stress testing is a risk management tool applied by individual banks, supervisors, and central banks to assess vulnerabilities of banks and financial systems to extreme but plausible scenarios. Two dimensions of stress testing are microprudential and macroprudential.

Swap is a contract that gives a pair of holders the right to exchange cash flows from one underlying asset for cash flows for another. Notional amounts are hardly exchanged, rather they are used to calculate the cash flow of each underlying asset.

Top-down (TD) stress testing is designed to stress test the entire financial system to see how it is able to withstand the shocks of adverse and severely adverse scenarios during the stress testing horizon. Top-down stress tests are conducted by using the data supplied by individual banks and then aggregated or using already aggregated data; but in both approaches, common scenarios and standardized assumptions along with all other technical or procedural rules are supplied by central banks or supervisory authorities to each bank undergoing the test.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

At the heart of financial stability lies credit risk, which is the primary risk of default. Growing market risk has induced the development of large-scale risk assessment tools (i.e. stress testing), and the adequate measurement of credit risk became a central focus. Before the 1950s, financial markets were in infancy stages and insurance was used predominantly as a protection against financial losses owing to accidents or environmental catastrophes, but pure risk was not covered by an insurance policy. Over the years, a large menu of models and theories has been developed, but particularly five of those are the foundation-building blocks (pillars) of the modern finance and this dissertation. Markowitz (1952) attacked risks relevant to portfolio selection problem via the *mean-variance criterion*, assuming that investors are risk-averse who always consider minimizing variance and maximizing expected returns of their portfolios. Modigliani-Miller (1958) shocked the world with their then unconventional concepts of *"irrelevance"* and *"arbitrage-reasoning"*, arguing that a firm's capital structure is irrelevant to its market value.

The Sharpe (1964) capital asset pricing model (CAPM) is a paradigm-shifting development as its impact on financial and non-financial sectors of the economy as well as on academic research has been quite significant. In the wake of increasing financial turmoil in the early 1970s (e.g. the Arab-Israeli war in 1973 and the subsequent oil crisis, plus the liquidation of Germany's Bankhaus Herstatt in 1974), pricing and hedging of derivatives (e.g. options) seemed like a good solution to mitigate macro events' adverse impact. Black and Scholes (1973) Robert Merton (1974) marked the birth of option pricing, the seed of which originally was planted in 1900 by the French mathematician Louis Bachelier (Cootner, 1964). Although these seminal papers are extraordinary contributions, and certainly without them economies of the industrialized nations would have not progressed as they have. Since the inception of derivatives and securitization of structured finance products, financial markets have become progressively more complex and increasingly vulnerable; as a result, crises have become more disruptive, prolonged, and costly.

Estimating default probabilities is an integral part of any financial stability assessment, it is also essential in the measurement of systemic risk. The normal-functioning of the financial system is usually impaired when the financial stability is threatened by a confluence of micro and macro factors fostered by imbalances, distorted incentives, and accommodative policies (the last is reactionary rather than being proactive). Financial system stability is dynamic in nature and revolves around a constant inventory of risks which also tend to be dynamic and continually evolve in response to various driving and contributing forces such as cyclical, secular, and regulatory. Financial stability is adversely affected when these forces create misaligned incentives for prolonged periods, and the upshot is a financial or economic crisis. The Financial Stability Oversight Council (FSOC) emphasizes that financial instability is instigated via transmission of three key sources: "(i) failure to honor a contractual obligation; (ii) deterioration in market functioning; (iii) and disruptions in financial infrastructure" (FSOC, 2011).

The view that securitization enhanced financial stability by means of dispersing credit risk was tarnished by the GFC's severe losses related to securitization. The newly formed view ensuing the GFC underpins the fact that the securitization of structured products contributed to financial instability by passing bad loans *("hot potato"*) to unwary investors. Securitization is also criticized for enabling issuances and re-issuances of liabilities in the form of SPVs and SPEs, through which risks are deeply entrenched in the financial system. Gorton (2008), among many others, contends that financial intermediaries (as a lender or a borrower) were able to disperse credit risk through securitization and mortgage-backed securities because they evidently suffered significant losses. Nevertheless, both views ignore the endogeneity aspects of risk associated with the aggregate credit supply. Shin (2009) argues that securitization is vital since it creates opportunities for new funding sources and needed liquidity in the financial system, facilitated by financial and technological innovations such as mortgage-backed securities (MBSs), collateralized debt obligations (CDOs), and asset-backed commercial paper (ABCP).

Preceding the GFC, microprudential (narrow and bank-focused) and macroprudential (broader and system-focused) stress testing, the IMF's FSAP, and the Basel standards (Basel I & II) failed to safeguard the global financial stability. According to Crockett (1997a; b), stable banks and stable markets are both prerequisites as well as two integral components of financial stability. But since the GFC, systemic risk and systemic stability have become a central focus for financial authorities (Adrian & Shin, 2008). A widespread consensus in the Basel literature shows that the risk-insensitiveness of Basel I has ushered greater risk-taking across internationally active banks that had never-ending propensity to invent loopholes or take advantage of the existing ones to escape banking regulation and supervision. The GFC revealed that banks' earlier stress tests were not fail-safe, their narrow bank-focused approach was inadequate as it failed to detect new risk types that were deeply embedded in securitized derivatives and structured finance products such as SIVs and SPEs. This turn of events contributed to financial instability and induced the development of enhanced new-generation stress tests (Jobst et al., 2013).

2.1 Measures of Financial Stability

Despite the plethora measures of financial stability, there is no single universally accepted risk measurement approach. However, the severity of the GFC underpinned a consensus that stress testing and Basel III (integral components of risk management) must be the primary objective of central banks and the supervisory community to strengthen the global banking resilience, which is the foundation for sustainable economic growth. The Federal Reserve and the European Banking Authority (EBA) have been at the fore designing and conducting stress tests with the objective of developing supervisory assessments of capital adequacy and capital planning at SIBs. Following the failure of banks' micro stress tests, the widely perceived success of the U.S. Federal Reserve's first macro stress test (SCAP) spurred worldwide implementations, but the success rate was varied and disparate across countries. In stark contrast to the US, Europe bungled with its first two macro stress tests designed and conducted by the CEBS (2010) and EBA (2011) which contributed to financial instability rather than restoring investor confidence.

The evolution of stress testing and Basel standards have two distinct phases; first is the pre-GFC period spanning from 1997 to 2007, which was marked by the homegrown systemic Asian crisis. During this period, the Market Risk Amendment (BCBS, 1996a) to Basel I required large banks to use value-at-risk (VaR) and confirm results by internally conducted microprudential stress tests (BCBS, 1996b) while calculating capital adequacy and assessing appropriate capital allocation. Increasing financial turmoil in the 1990s also prompted the IMF and the World Bank to jointly establish the Financial Sector Assessment Program (FSAP) in 1999 to assess the financial sector stability in the IMF member-countries (IMF & World Bank, 2003). Individual banks' micro stress tests had serious deficiencies; they were both inadequate (not bank-wide) and insufficient (light scenarios producing results by design) to prevent a high-magnitude financial crisis similar to the GFC. Another shortcoming was that micro stress tests were entirely portfolio focused and narrow in scope; further, the health of the financial system as a whole or the buildup of systemic risk was never a concern. In addition to micro (by banks) and macro (by supervisors and central banks) stress tests in the post-GFC period (since 2009), stress testing as a crisis management tool has been used (initially by the Federal Reserve in the U.S. and the EBA in Europe) by central banks to assess financial stability and systemic risk.

Prior to the seminal papers by Black-Scholes-Merton (before 1970), financial ratios along with univariate and multivariate statistical models (e.g. Z-score) were used to assess predominantly credit risk and predict the likelihood of bankruptcy by private corporations (Altman, 1968; Clark et al., 1997; and Hill et al., 1996). Altman (1968) asserts that financial ratios alone are insufficient to predict defaults since they are subject to manipulation and misinterpretation. Financial ratios do not follow a normal distribution compared to those based on it (e.g. VaR, option pricing, regression and multiple discriminant). Due to the popularity of financial ratios (Beaver, 1968), models not following a normal distribution and mean-variance criterion have been developed. The literature reveals that iterative learning systems such as neural networks and inductive learning provide better PD forecasts than multiple discriminant analysis (see Tam & Kiang, 1992 for bank-failure predictions via neural networks; Bhattacharyya & Pendharkar, 1998 for inductive learning; and Kane et al., 1998 for rank transformation).

Credit risk and probabilities of default are commonly measured by the distance-to- default, the reduced-form, and credit ratings. Campbell et al. (2011) argue that reduced-form models provide robust default forecasts because they incorporate market-based information with accounting-based data (Duffie & Singleton, 1999).The use of credit ratings either as an early indication of a firm's financial soundness or as a prediction of distressed firms has been quite popular, but at the same time, an utterly distorted component of the investment process. Unregulated external credit assessment institutions (ECAI) misused their power, causing agency conflict as they issued inconsistent and artificially improved ratings to clients from whom ECAIs earned fees. The Basel Committee observed that excessive reliance on ECAI ratings gave banks incentive not to develop internal risk-assessment models, causing *"cliff"* effect in capital (BCBS, 2004a).

2.1.1 Portfolio Selection Theory

Risk measurement models saw a fast-paced evolution enabled by the groundbreaking work of Markowitz (1952) on portfolio selection, subsequently the seminal papers by Modigliani-Miller (1958) on capital structure (the M&M theorem), Sharpe (1964) on capital asset pricing (Merton, 1973a), Black and Scholes (1973) and Merton (1973b) on option pricing theory, and Merton (1974) on probability of default. Markowitz argues that portfolio risk can be diversified away, but not entirely. The latter remark is irrelevant because one of the underlying assumptions of his portfolio theory states that risk inherent in each security is not a concern to optimizing investors *("efficient frontier"*) who consider maximizing expected return while minimizing variance of returns of the portfolio. Portfolio selection is based on mean-variance criterion, its optimization is calculated by an algorithm through expected return, standard deviation, and correlation.

Although criticized by Merton (1972), the Markowitz's (1952) portfolio theory starts with two rules; (i) the investor maximizes discounted expected returns; (ii) the investor prefers expected return over variance of the return. These two assumptions make risk-averse investors be efficient, and the upshot is a portfolio choice "...with the greatest discount values". Markowitz claims that his theory differs from other theories; (i) the investor behavior (utility functions) is a central focus as opposed to theories based on consumers or production firms; (ii) agents of the economy act under uncertainty, and; (iii) the portfolio theory can be used by practitioners in real-world applications (Markowitz, 1959). Tobin (1958), extending on Markowitz (1952), shows that investors can create different portfolio combinations based on their risk thresholds.

Diversification is the key to portfolio selection, which promotes the concept that the risk inherent in each security is irrelevant as long as each security's contribution to the entire portfolio's variance (σ_P^2) is acceptable; therefore, understanding of the variance of return of a portfolio and its covariance is important (σ_P^2 for security $j = 1,2,\ldots,m$);

$$\sigma_P^2 = \sum\nolimits_j x_j^2 \sigma_j^2 + \sum\nolimits_j \sum\nolimits_{k\#j} x_j x_k p_{jk} \sigma_j \sigma_k$$

Where j and k denote securities and ρ_{jk} represents the correlation between the securities, x_j is the fraction value of the portfolio's total value (Rubinstein, 2002).

Although the path-breaking Markowitz (1952) portfolio theory earned him the Nobel Prize in 1990 plus he has been called "...the father of modern portfolio theory (MPT)..." (Rubinstein, 2002), unfortunately for practitioners to use the theory in real-world applications, "...it has been generalized and refined in innumerable ways..." The theory is also criticized for its arduous data requirements, which has been markedly simplified by the Sharpe (1964) CAPM that simply focuses on two types of risks; systematic and systemic (market risk and the residual) and idiosyncratic risk (company-specific). Over the years, Markowitz's (1952, 1959) portfolio theory has been subject to many empirical and theoretical objections; Merton (1973a) says that this was inevitable, attributable to the theory's single-period (discrete time) nature, it also assumes that investors have homogeneous expectations rather than "myopic utility functions" and conform to the mean-variance criterion (Rubinstein, 2002).

2.1.2 Modigliani & Miller (MM) Theorem

The seminal Modigliani-Miller (1958), commonly referred to as the M&M theorem, is based on *irrelevance* and *arbitrage reasoning*, which assume that under certain conditions a firm's market value is irrelevant to its capital structure; in other words, the average cost of capital to the firm is not determined by its capital structure. Modigliani-Miller argue that switching to a lower cost of debt is offset by a higher cost of equity as a consequence of the increased risk. The M&M theorem is structured around the following key assumptions: (i) taxes neutrality; (ii) capital markets are free of frictions and costs related to transactional and bankruptcy; (iii) easy access to credit markets; (iv) changes in capital structure are irrelevant to the firm's market value.

Since the Basel Committee has introduced Basel III in December 2010, banks have strongly opposed higher capital requirements, claiming that the Basel III capital and liquidity rules will reduce bank profitability; however, a proponent of the M&M theorem would point out that the reduced leverage as a result of increased equity capital would benefit banks in terms of the lower cost of equity. It is not clear whether the M&M theorem applies to the banking same way as it does to nonfinancial sectors, even Miller (1991) was not able to give a definitive "yes" or "no" answer, instead he replied as "Yes and No" (this was also the abstract of his article). On the contrary to nonfinancial sectors, the banking sector has very high leverage and relies considerably less on debt financing (Berlin, 2011). High leverage normally indicates distress, and this is exactly why financial firms were excluded from Fama and French (1992) analysis of equity returns. DeAngelo and Stulz (2013) plainly label banks as *"different"* and conclude that the M&M theorem is inapplicable to banking sectors (i.e. higher leverage without the cost).

The key argument of the much celebrated M&M theorem states that a firm's market value is determined by profitability, not by its capital structure (*the cost of capital*). Modigliani-Miller (1958) attempt to prove this through three propositions in "static, partial equilibrium", the upshot is the cost of capital definition in the operational sense, and they believe that the concept can be a guide for the management in the investment decision-making process. Several key assumptions are made and the theory describes the general environment as one of uncertainty, but with "...a state of atomistic competition in the capital markets". Another assumption is that money is neutral and capital is easily accessible through various funding sources. Although both bond holders and equity holders own the firm (proportional to their investments), the risks are varied and not equally shared; for example, bond holders have a fixed claim ("yielding known") whereas equity holders have a "...pro-rata share in the uncertain venture".

Modigliani-Miller (1958) formulate their *Propositions* analytically:

$\mathrm{X_i}(1), \mathrm{X_i}(2), \dots, \mathrm{X_i}\ (\mathrm{T})$	, assets of the ith firm generate a stream
$\mathrm{X_i} = (\mathrm{Xi_1}(1), \mathrm{X_i}(2), \dots, \mathrm{X_i}(\mathrm{T}))$	, random variables are subject to the joint probability distribution.
$\mathrm{X_i} = \lim\limits_{\mathrm{T}\to\infty} \frac{1}{\mathrm{T}} \sum_{\mathrm{t}=1}^{\mathrm{T}} \mathrm{X_i}(\mathrm{t})$	, the return of the ith firm with a random variable X_i and a probability distribution $\emptyset_i(X_i)$.

The celebrated (much criticized) Modigliani-Miller (1958) propositions were certainly viewed as unorthodox with many controversies when they were first introduced (e.g., Durand, 1959). In response to this, Miller (1988) says that the M&M theorem was "departing substantially from the then-conventional views about capital structure". On the contrary to a nearly perfect world (e.g., tax, bankruptcy, and transaction) created by the theorem's assumptions of *"irrelevance"*, the opponents argue that the world is imperfect with costs and frictions; and just because of that, the *gearing* matters; moreover, in the real world, investors with varying risk tolerance have asymmetry of information and do not have an equal access to capital markets. Also, there is a stark contrast between theoretical framework and empirical results, the latter are poor.

After three decades of skepticism and bitter controversy, Miller (1988) feels that "some of these controversies can now be regarded as settled", but he, nonetheless, infers that "Our hopes of settling the empirical issues by that route, however, have largely been disappointed". Despite theoretical and empirical objections and unresolved controversies, the modern corporate finance starts with the capital structure irrelevance. Some important impediments of the M&M theorem have been addressed by numerous extensions as well as those by the authors; Miller and Modigliani (1961) address dividend irrelevance and Modigliani and Miller (1963) re-calculate the cost of capital, but this time the cost of corporate income taxes are considered.

2.1.3 Capital Asset Pricing Model

Before the advent of the "mean-variance equilibrium model of exchange" (Merton, 1973a) or commonly referred to as the capital asset pricing model (CAPM), conditions of risk and the relationship between risk and expected return were not well-understood; nonetheless, capital markets have operated in the absence of empirically proven microeconomic theories. Extending on Markowitz (1952, 1959), the Sharpe (1964) and Lintner (1965) papers marked the birth of the CAPM (also exceptional contributions were provided by Mossin, 1966; and Treynor, 1962).

Despite many theoretical and empirical issues, Merton (1973a) feels that the CAPM is one of the most important developments in modern finance, earning William Sharpe along with Harry Markowitz, Franco Modigliani and Merton Miller the Nobel Prize in 1990. Although the CAPM is used both in financial and non-financial firms, and in spite of its revolutionary impact on financial innovations and academic research, it has been subject to theoretical objections mainly caused by empirical failures. The proponents defend the CAPM by arguing that the normal-functioning of the capital markets is indicative that the CAPM's assumptions were satisfied.

Prior to the development of the CAPM, the old view presupposed that the expected return on an asset was relevant to the asset's financing (risk was not factored in the cost of capital calculation using the weighted average of debt and equity costs). According to Merton (1973a), the CAPM deduces that investors conform to the Markowitz (1952, 1959) mean-variance criterion, this is the centerpiece of the criticism. Fama and French (2004) conclude that the empirical test failures of the model suggest that most of its applications may be invalid. Black et al. (1972) empirically invalidated the CAPM's key assumption that the higher return from an asset is proportional to the variance/covariance of the return. Their results indicated that CAPM under-or over-predicts; low market beta (β) assets earn a higher yield and high β assets earn a lower yield than what CAPM predicted. Sharpe (1964) and Lintner (1965) extend on the Markowitz (1952) by adding two new assumptions; *"complete agreement"* and *"borrowing and lending at a risk-free rate"*.

In market equilibrium, Sharpe (1964) says investors can choose between two prices provided by markets; the *"price of time"* Modigliani-Miller (1958) call it "yielding known, sure streams" and the *"price of risk"* for optimizing investors who are willing to take additional risk for higher expected returns. Markowitz's (1952) mean-variance portfolio theory, classified as *"normative (prescriptive)"* by Sharpe, provides a clear prescription as to how risk can be alleviated via diversification on the basis of mean-variance analysis, which results in an optimum portfolio choice for investors conforming to the utility functions. Sharpe infers that CAPM falls into *"positive (descriptive)"* theories (Sharpe, 1990), which assumes that all economic agents operate by the rules of Markowitz' portfolio theory and make investment decisions accordingly.

The CAPM starts with *"the investors' preference function"*, which assumes that outcomes of future investment opportunities are viewed with the use of probability distribution, and an investor is willing and able to take an action on the basis of desired investment's "expected value and standard deviation" which are expressed by a total utility function (p. 428):

$\mathrm{U} = \mathrm{f}(\mathrm{E_w}, \sigma_\mathrm{w})$, utility function.

$\mathrm{dU} \,/\, \mathrm{dE_w} > 0$, a higher $\mathrm{E_w}$ to a lower value is preferred.

$\mathrm{dU} \,/\, \mathrm{d}\sigma_\mathrm{w} < 0$, a lower value to a higher $\mathrm{E_w}$ is preferred.

Where E_w denotes the expected future wealth, σ_w is the standard deviation. In the last two assumptions, "...indifference curves relating E_w and σ_w will be upward-sloping". Next an investor decides to commit a given fund ($\mathrm{W_i}$) from his existing wealth to investment; where $\mathrm{W_t}$ is his *"terminal wealth"*, and R is the rate of return on investment (Sharpe, 1990):

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$\mathrm{R} \equiv (\mathrm{W_t} - \mathrm{W_i})/\mathrm{W_i}$, this formula can also be expressed as: $\mathrm{W_t} = \mathrm{RW_i} + \mathrm{W_i}$

Similar to the M&M theorem and predicament it has faced, the CAPM failed to validate its measure of risk as well as linkages between risk and expected return, ally due to simplistic assumptions, theoretical issues, and implementation challenges in testing the model (Fama & French, 2004). In the last 50 years, theorists have attempted to reduce certain impediments of the CAPM by incorporating some of the missing real-world elements such as; transaction costs (Levy, 1978), arbitrage pricing (Ross, 1976), market segmentation (Merton, 1987), and taxation effects (Brennan, 1970). The Black and Scholes (1973) option pricing formula and the Merton (1973b) *Theory of Rational Option Pricing* not only caused a paradigm change, but a shift from risk-based pricing (e.g. the CAPM) to arbitrage-based pricing. Due this shift, Sharpe (1990) acknowledged that his initial CAPM was *"extremely parsimonious"* and his model's impediment to new risk types (e.g. asset prices with negative holdings) needed to be improved.

Sharpe (1990) assumes an economy that consists of K investors and the investor (k) invests a portion of his wealth which is a proportion of the total wealth invested by all investors (W_k) where E_k denotes the expected return on investor k's portfolio, V_k is the variance, τ_k is the risk tolerance, and the expected return is maximized: $U_k = E_k - (V_k/\tau_k)$

Sharpe (1990) addresses one of the impediments related to the negative holding constraint in the initial CAPM (1964) which excluded short sales (a negative position in an asset can occur via borrowing for the riskless asset or a short sale for a risky asset). As a major exodus from the original CAPM (1964), Sharpe introduces a new condition that investors can hold positions in one or more assets with negative values. Sharpe's model assumes that every optimizing investor, under *"a full investment constraint"*, wishes to maximize U_k; to do that, the investor must select a portfolio where every security's *"marginal utility"* is homogeneous; if a different situation exists where this is not achieved, then the investor can do shifting from a lower marginal utility security to a security with higher marginal utility (p. 316).

Merton (1973a) develops his own version of the capital asset pricing model and calls it *"An Intertemporal Capital Asset Pricing Model"*, and he emphasizes that the assumptions must be *"intertemporal"* because "...the intertemporal nature of the model allows it to capture effects which would never appear in a static model" such as the single-period CAPM. The extracted assumptions that form the capital market as follow (p. 868):

1) All assets have limited liability.
2) No transaction costs, taxes, or problems with indivisibilities of assets.
3) There are a sufficient number of investors with comparable wealth levels so that each investor believes that he can buy and sell as much of an asset at the market price.
4) The capital market is always in equilibrium (e.g. no trading at non-equilibrium prices).
5) There exists an exchange market for borrowing and lending at the same rate of interest.
6) Short-sales of all assets, with full use of the proceeds, is allowed.
7) Trading in assets takes place continually in time.
8) The vector set of stochastic processes describing the opportunity set and its changes, is a time-homogeneous (Markov process).
9) Only local changes in the state variables of the process are allowed.
10) For each asset in the opportunity set at each point in time t, the expected rate of return per unit time, defined by

$$\alpha \equiv E_t((P(t+h) - P(t))/P(t))/h$$

The variance of the return per unit time is defined as:

$$\sigma^2 = E_t((P(t+h) - P(t))/P(t) - ah)^2)/h$$

Where $P(t)$ represents the price of share, h is the return on the asset over a horizon of time, E_t is the conditional expectation operator, α is the instantaneous expected return, and σ^2 ($\sigma^2 > 0$) is the instantaneous variance of the return (Merton, 1973a).

2.1.4 Option Pricing Theory

Even though the paradigm-changing option pricing formula was first published by Black and Scholes (1973), the resultant contingent-claim option pricing theory is a product of a network of brilliant economists who happened to be associated at different points in their academic or professional careers. Everything began when Fisher Black (working at Arthur D. Little) was introduced to the CAPM by his colleague Treynor (1965) who derived the model separately from Sharpe (1964); in 1969, Black and Myron Scholes teamed up to empirically test the CAPM. Though the use of the CAPM gave Black (1989) the *"differential equation"*, nonetheless Black was unable to solve the equation, causing him frustration which he describes as "I spent many, many days trying to find the solution to the equation. ... But I was still unable to come up with the formula" (p. 5). During this time, prominent economists such as Samuelson (1965) had published an article on warrant pricing, and before him, there was Sprenkle (1961) whose option pricing formula can be written as follows (Black & Scholes, 1973):

$$kxN(b_1) - k * cN(b_2)$$

$$b_1 = \frac{\ln kx/c + \frac{1}{2}v^2(t^* - t)}{v\sqrt{(t^* - t)}} \qquad b_2 = \frac{\ln kx/c - \frac{1}{2}v^2(t^* - t)}{v\sqrt{(t^* - t)}}$$

Where x represents the stock price, c is the exercise price, t^* is the maturity date, t is the current date, v^2 is the variance rate of the return on the stock, $N(b)$ is the cumulative normal density function, k is the ratio (expected value/stock value at maturity), and k^* is the discount factor relevant to the stock's risk.

For the past four decades, many economists and theorists have contributed to the option pricing theory, and the topic has been extensively covered in both the academic and financial literature. Among all studies attacking the option pricing problem, two formulations particularly are the most influential; Black and Scholes (1973) and Merton (1973b). In his breakthrough paper *"Theory of Rational Option Pricing"*, Merton has said that "...options are specialized and relatively unimportant financial securities, the amount of time and space devoted to the development of a pricing theory might be questioned"; Merton must have not envisaged the growth potential of options (over 20% per annum since 1995 compared with equity – 11% and bond – 9%) because the global derivatives market in 2007 surpassed €450 trillion of notional amount outstanding, five times larger than equity (€40 trillion) and bond (€55 trillion) markets (BIS, 2008), but the exponential growth of derivatives is blamed for causing the GFC.

The Black-Scholes option pricing theory should have been called the Black-Merton-Scholes option pricing theory, provided that Black-Scholes may have never worked out a solution to their famous theory without the seminal contributions of Merton who himself published his derivation of the formula titled *"Theory of Rational Option Pricing"* (Merton, 1973a). Black's testimony to this fact as follows: "A key part of the option paper I wrote with Myron Scholes was the arbitrage argument for deriving the formula. Bob gave us that argument. It should probably be called the Black-Merton-Scholes paper" (Bernstein, 1992). Merton says, "I am also responsible for naming the model *the Black-Scholes Option Pricing Model*..." the use of which first appeared in his 1970 working paper (Merton, 1998). Certainly a good level of competition has existed among these three paradigm-changing economists, but the competition was pleasing in nature, not a destructive one; Black's remark solidifies this view; "We were both working on papers about the formula, so it was a mixture of rivalry and cooperation" (Black, 1989). Everyone has benefitted from this wonderful rivalry; over the years, their exceptional papers have been cited the most and extended immensely, but Merton's contributions in this field is unmatched. He has developed a pricing theory for more important contingent-claims such as corporate liabilities (Merton, 1974), deposit insurance and loan guarantees (e.g. Merton, 1977a).

Prior to Black and Scholes (1973) who developed the option pricing formula to calculate the prices of European options, the earlier attempts of options valuations were based on warrants rather than stocks (Samuelson, 1965; Sprenkle, 1961). European options can only be exercised at maturity, whereas the American option by Merton (1973b) can be exercised at any time before expiration. Merton empirically proves that this gives an advantage to American put option over European put option, and the value of the former will be greater than the value of the latter. An option gives the holder the right to buy or sell an asset at a fixed price called the *"strike price"*. An option contract is subject to pre-set terms and conditions within a specified time schedule.

An option that gives the holder the right to buy is termed as a *"call option"* and the one that gives the right to sell is referred to as a *"put option"*. Stock prices and option values are positively correlated, and when to exercise a call or put option is a simple mathematics. A call option is most likely exercised when the strike price is substantially lower than the stock price; and it is definitely left to expire if an opposite situation occurs (i.e. the strike price is higher than the price of the stock. A put option is exercised if the stock price depreciates more than the strike price; and a put option is sure to expire if the stock price appreciates exceeding the strike price. Prior to driving the formula, Black and Scholes (1973) created a capital market environment with some *"ideal conditions"* for the stock and for the option, extracted from p. 640.

a) The short-term interest rate is known and is constant through time.

b) The stock price follows a random walk in continuous time with a variance rate proportional to the square root of the stock price.

c) The stock pays no dividends or other distributions.

d) The option is "European", it can only be exercised at maturity.

e) There are no transaction costs buying or selling the stock or the option.

f) It is possible to borrow any fraction of the price of a security to buy it or hold it, at the short-term interest rate.

g) There are no penalties to short selling.

Under these ideal conditions (assumptions), Black-Scholes say that "...the value of the option will depend only on the price of the stock and time and on variables that are taken to be known constants". Their formula of the European options as follows:

$$W(x, t) = xN(d_1) - ce^{r(t-t^*)}N(d_2)$$

$$d_1 = \frac{\ln x/c + (r + \frac{1}{2}v^2)(t^* - t)}{v\sqrt{(t^* - t)}}$$

$$d_2 = \frac{\ln x/c + (r - \frac{1}{2}v^2)(t^* - t)}{v\sqrt{(t^* - t)}} \qquad d_2 = d_1 - \sigma_v\sqrt{T}$$

Where $w(x,t)$ denotes the value of the option as a function of the stock price x at time t, t^* is the maturity date, r is the interest rate, c is the strike price, v^2 is the variance rate of the return on the stock, and $N(d)$ is the cumulative normal density function (Black & Scholes, 1973).

Option pricing theories, including Black-Scholes and Merton, are based on restrictions which are necessary assumptions or conditions to achieve consistency. Merton (1973b) says that his assumed standard restrictions are insufficient to extend the Black and Scholes (1973) option pricing theory, so he has introduced new assumptions to deal with specifically the effects of dividend payouts since the European option is dividend protected. Also using the option pricing approach, Merton (1974) develops a pricing theory for corporate bonds which are riskier with a higher default probability. The value of corporate debt depends on provisions and restrictions imposed on them, but Merton (1974) suggests that three of those are particularly important; (i) the riskless rate of return on government bonds or high-rated corporate bonds; (ii) the indenture imposing provisions or restrictions; (iii) the firm's probability of default on its debt.

To develop his pricing theory of corporate liabilities, Merton makes several assumptions (the first five is previously listed on p. 44), extracted from Merton (1974).

6. The Modigliani-Miller theorem states that the market value of a firm is invariant to its capital structure options (whether financed via debt, equity, or hybrid).

7. The Term-Structure is "flat" and known with certainty ($P(\tau) = \exp(-r\tau)$);

Where r is the riskless rate of interest (constant), and the price of a riskless bond which promises a payment of one dollar at time τ in the future.

8. The dynamics for the value of the firm, V, through time can be described by a diffusion-type stochastic process with stochastic differential equation (p. 450).

$$dV = (\alpha V - C)dt + \alpha V dz$$

Where α (and α_y) denotes the instantaneous expected rate of return on the firm per unit time, C (and C_y) is the total dollar payouts to its either shareholders or liabilities-holders, σ^2 (and σ_y^2) is the instantaneous variance of return, and dz (and dz_y) is a standard Gauss-Wiener process.

The Black and Scholes (1973) model is subject to criticism due to its theoretical and empirical weaknesses. Short-term interest rate may not be constant through the horizon of the investment period; stock price follows a *"random walk"*, but the confluence of many macro and financial factors contribute to changes in stock prices; the dividend-protected nature of the European options creates a disadvantage because most public companies pay dividends; no costs to buying or selling stocks or options is an immature assumption and it does not hold today because there is a cost for each transaction which could be high in some instances; lastly, an investor may technically buy or sell an option containing a single stock, but options are traded by institutional investors usually in large blocks. Merton (1973b) concludes that the Black and Scholes (1973) "...model has been applied with some success to empirical investigations of the option market", but he nevertheless describes it as "...a significant break-through" (p. 142).

Merton (1972) corrects the flaw of CAPM (risk-return tradeoff, in other words, investors select their portfolios based on the relation between risk and expected return) by focusing on "risk-neutral valuation" where the relation between risk and expected return is irrelevant, as Merton's derivation of the Black-Scholes formula is based on the arbitrage-based pricing instead of calculating the present value of the option through the discounting method. Merton points out that, in continuous trading (as opposed to intertemporal trading) involving no transaction costs and restrictions to short sales, "...the existence of a dominated security would be equivalent to the existence of an arbitrage situation", termed as *"symmetric market rationality"*.

Merton assumes that, under the above assumption, investors who would buy a particular security (say "A") would also buy another security (say "B) because of the risk-neutral aspect (Merton, 1973b). Next, Merton brilliantly thought that "A hedged portfolio containing the common stock, the option, and a short-term, riskless security..." could be constructed "...where the portfolio weights are chosen to eliminate all 'market risk" (p. 160); in other words, Merton's derivation of the Black-Scholes formula was through a duplication portfolio where Itô-Calculus was applied with the dynamics of the value of the firm by a stochastic process. Merton asserts that Black and Scholes (1973) makes "...use of the Samuelson application to warrant pricing of the Bachelier-Einstein-Dynkin derivation of the Fokker-Planck equation, to express the expected return on the option in terms of the option price function and its partial derivative" (p. 160).

2.1.5 Value-at-Risk (VaR) Model

A new portfolio risk measurement approach called value-at-risk (VaR) became popular In the 1990s among financial and non-financial firms. VaR is not a new model, at least in theory; it has been around for half a century since Baumol (1963) first introduced the concept in the early 1960s. The reemergence of VaR models in the 1990s as a promising tool to mitigate financial crisis related losses attracted enormous interest from everyone who had been subject to extreme volatility and the resultant losses in the 1980s. Despite VaR's deficiency to measure risk under highly adverse market conditions and the resultant volatility, VaR nonetheless still became a universally accepted standard measure to quantify market risk in a single number. However two key decisions were pivotal in VaR's widespread adoption; first, JP Morgan created a benchmark open architecture called *"RiskMetrics"* and provided public access to its compiled massive database on the variances and covariance across different asset classes (JP Morgan, 1996); second, VaR became the mainstay when the Basel Committee required banks to employ VaR (at 99% confidence interval for 10 days) internally while computing the capital adequacy and the minimum capital requirements (BCBS, 1996a). VaR is calculated as shown below;

$$\mathrm{VaR} = \mathrm{portfolio\ Value} * \sigma * \alpha * \sqrt{\delta_t}$$ (e.g. Jorion, 1996;2001)

Where, σ denotes the daily volatility of the portfolio value, α is the confidence level at which the possibility of a loss is measured, δ is the time interval measured in days.

Fallon (1996) defines VaR as a "one-sided confidence interval on portfolio losses" which is calculated by the formula illustrated below;

$$\mathrm{Prob}(\Delta\overline{\mathrm{P}}\ (\Delta \mathrm{t}, \Delta\overline{\mathrm{x}}) > -\mathrm{VaR}) = 1 - \alpha$$

Where, $\Delta\overline{\mathrm{P}}(\Delta \mathrm{t}, \Delta\overline{\mathrm{x}})$ is the change in the value of the portfolio, Δt is the time horizon, $\Delta\overline{\mathrm{x}}$ is the vector of changes in the random state variables (p. 2).

Benninga and Wiener (1998) believe that VaR is rather a simple concept, but estimating asset return distribution parameters and calculating position sizes of portfolios during its implementation pose challenges. Thus, they claim that the lognormal distribution is better for many asset prices (subject to the *non-negativity requirement*) than the normal distribution required by VaR. The value of the portfolio denoted by v, T is the time indicating the logarithm of the portfolio value with annual mean μ and standard deviation σ;

$$\log(V_T) \sim \mathrm{Normal}\left(\log(v) + \mu - \frac{\sigma^2}{2}\,T, \sigma T\right)$$

It is extensively covered in the finance literature that the tractability of VaR calculations depends on several statistical assumptions; first is the common *stationarity requirement*, which states that the possibility of 1% fluctuation in returns is the same for bond, equity, and commodity at any point in time; second is the *non-negativity requirement;* with the exception of forwards, futures, and swaps, financial assets cannot attain negative values; third and probably the most important one is the *distributional assumption*, which stipulates that rates of returns follow a normal distribution with a mean $(\mu = 0)$ and standard deviation $(\sigma = 1)$. For a longer perspective, see Jorion (2001), Kupiec (1995), and Lopez and Walter (2000).

Aside from the statistical assumptions, VaR calculations also require additional assumptions regarding the values of assets or portfolios in the future. A number of ways are exemplified in the literature to calculate a rate of return from period t to t + 1, but following three methods are commonly practiced (e.g., Hull & White, 1998; Lintner, 1965; and Merton, 1972).

$\Delta S_{t,t+1} = S_{t+1} - S_t$ (absolute change method)

$R_{t,t+1} = (S_{t+1} - S_t)/S_t$ (simple return method)

$r_{t,t+1} = \ln(S_{t+1}/S_t)$ (continuously compounded return method)

From an analysis perspective and owing to its proprietary nature, finding empirical studies on VaR using actual bank data is rare. Due to its limitations and constraints, VaR is not a standalone tool to measure risk; however, it compliments RAROC developed by Bankers Trust in the 1970s and micro stress testing used since the Asian crisis of 1997. VaR results are less reliable under extreme but plausible scenarios, thus VaR outputs must be confirmed by a statistical tool such as stress testing. Although banks' VaRs vary (see Jorion, 2001 for a survey), virtually all VaR models (e.g. variance-covariance, historical and Monte Carlo simulations) focus on the tail-risk which is the lower quantile of the distribution of the P&Ls and answer the question of the largest potential loss over a specified time horizon *t* at a given confidence interval *p*. One advantage of VaR is that it aggregates portfolio related losses in a single number, arising from volatility triggered by changes in interest rates, equity prices, or commodity prices. The largest value at risk can be written as *1 - p*; meaning, the VaR on an asset is $1 million for a day at 99% confidence. there is only 1% probability that the portfolio's asset value will drop more than $1 million in any given day (99% of the times the portfolio's value will drop less than $1 million).

Benninga and Wiener (1998) suggest that the three VaR approaches mentioned earlier produce similar results; however, each has strengths and weaknesses; as such, historical simulation takes much longer time to process and it is only good with a moderate data size; however, the distinctive advantage of this approach is its ability to time market crashes. The variance covariance method is the fastest of the three, but its quick results are less reliable involving options and bonds; the major weakness here is the heavy reliance on assumptions. The Monte Carlo simulation is the slowest compared to its peers, but has the capability of processing both private and historical data; as a result, it is a popular tool among banks and supervisors.

Dominguez and Alfonso (2004) apply stress tests to the quantitative risk estimates obtained from Parametric VaR, historical, and Monte Carlo simulations. Where, ω_i is the initial stock value, $\sigma_{i,daily}$ is the daily volatility responding to the stress scenario, and 1.6449 is the z value at 95% confidence, P_t is the simulated price, P_{1-t} is the current price, ε is a random variable, σ is the daily volatility, and $\sqrt{t}$ is an adjusted factor, and R_i is the historical return.

$\mathrm{VaR(stressed)} = \omega_i * 1.6449 * \sigma_{i,\mathrm{daily}}$ Parametric VaR

$P_t = P_{1-t} * e^{\sigma*\varepsilon*\sqrt{t}}$ Monte Carlo Simulation

$P_i = P_t * e^{R_i}$ Historical Non-Parametric Simulation

The family of parametric models of volatility, starting with ARCH – autoregressive conditional heteroscedasticity was introduced by Engle (1982); variations appeared later that include GARCH, EGARCH, and IGARCH. Generalized ARCH (GARCH), proposed by Bollerslev (1986), assumes the portfolio volatility as $\sigma_t^2 = \alpha + \beta(R_t - \mu)^2 + \gamma\sigma_{t-1}^2$, where α, β, γ are constants and γ is the confidence interval, usually set to 0.94 or 0.97. Exponential Garch (EGARCH) was proposed by Nelson (1991), which is formulated as;

$$\log\sigma_t^2 = \alpha + \gamma\log\sigma_{t-1}^2 + \beta_1\left(\frac{R_t - \mu}{\sigma_{t-1}}\right) + \beta_2\left[\left|\frac{R_t - \mu}{\sigma_{t-1}}\right| - \sqrt{\frac{2}{\pi}}\right]$$

$\overline{V}_{t,T} = \sqrt{\sum_{k=0}^{T-t-1} C_k \sigma_t^{2y^k}}$: structure of volatility implied by EGARCH.

Hendricks (1996) applies VaR models to randomly selected 1,000 portfolios (1983-94) at 95% and 99% confidence intervals. In his analysis, twelve approaches are employed from three commonly used categories of VaR models; namely, equally weighted moving average, exponentially moving average, and historical simulation approaches. Hendricks concludes that nearly all approaches perform well covering the intended risks, but the risk measures generated at 99% confidence level are less reliable (98.2% and 98.5% of the outcomes are covered). Probably the most striking conclusion of his analysis is that VaR models "even at the 99th percentile—do not "bound possible losses". It is asserted in the VaR literature that, due to extreme complexity and multifaceted nature of the modern financial system, it is impossible for structural models such as VaR to measure all risks as well as linkages among them. Hendricks (1996) calculates portfolio standard deviation by equally weighted moving average formula;

$$\sigma_t = \sqrt{\frac{1}{(k-1)} \sum_{s=t-k}^{t-1} (x_s - \mu)^2}$$

Where, σ_t denotes the estimated standard deviation of the portfolio at the beginning of day t, k is the number of days included in the moving average (the "observation period"), x_s is the change in portfolio value on day s, and μ is the mean change in portfolio value. The formula for the portfolio standard deviation under exponentially weighted moving average is (p. 42);

$$\sigma_t = \sqrt{(1-\lambda) \sum_{s=t-k}^{1-t} \lambda^{t-s-1} (x_s - \mu)^2}$$

Where the parameter λ refers to the "decay factor," more distant observations receive smaller (decayed) weights as more weights are assigned to the most recent observations.

Dominguez and Alfonso (2004) evaluate how well VaR methodologies respond to stress testing exercise based on historical scenarios (9/11 attack of 2001 in New York and Brazilian crisis of July 2002). The data set consists of 651 trading days (from 28 January 2000 to 30 August 2002), which amounts to 650 historical daily returns for the five Spanish stocks.

$$\mathrm{R_t} = \ln\left(\frac{\mathrm{P_t}}{\mathrm{P_{t-1}}}\right)$$

Daily price series are transformed into logarithmic return series by the formula on the left.

Once the logarithmic return series are obtained, Dominguez and Alfonso (2004) calculate historical volatility for each return series of the five stocks by the following formula; where, σ is the sample standard deviation, T is the total number of observations, μ is medium return of the series, and R_i is the return of individual asset (p. 64).

$$\sigma = \sqrt{\frac{\sum_{\mathrm{i}=1}^{\mathrm{T}}(\mathrm{R_i} - \mu)^2}{\mathrm{T}-1}}, \qquad \mathrm{i} = 1,2 \ldots 650$$

The GFC is a constant reminder that there is no model including value-at-risk approaches that performs well by every measure; in that regard, VaR models are no exception; they also have inherent advantages and disadvantages as well as certain limitations. Manganelli and Engle (2001) suggest that the common structures of all VaR models are generally designed to do three key things; (i) mark to market the portfolio, (ii) estimate the distribution of portfolio returns, and (iii) calculate the VaR of a portfolio or the entire bank. It is evident from the above tasks that VaR's primary focus is the measurement of value-at-risk of assets or portfolios attributable to fluctuations in volatility. Fallon (1996) argues that earlier studies lack of error analyses as they "...tradeoff accuracy for computational speed" (p. 5).

Berkowitz and O'Brien (2001) analyzed six large U.S. banks in terms of the distribution of historical trading P&Ls and daily VaR estimates. Their results indicate that banks' VaR forecasts were less robust compared to the reduced-form forecasts based on the GARCH model which is noticeably better than the bank VaRs for detecting and capturing banks' P&L volatility. They conclude that the reduced-form approach and the P&L time series models when used as a complement may improve VaR forecasting. Hendricks (1996) argues that one of the key weaknesses of VaR approaches is that "...extreme outcomes occur more often and are larger than predicted by the normal distribution (fat tails)" and "...the size of market movements is not constant over time (conditional volatility)" (p. 56).

Flexibility and easy-to-understand aspects of VaR made its adoption climax and be favored by practitioners as a measurement of market risk, but deficiencies of various VaR approaches have invoked concerns, which led to a consensus to form among the industry participants that VaR as a standalone tool of risk measurement is neither completely adequate nor sufficient to prevent recurrence of financial crises similar to the GFC. It would be informative to list some of the key weaknesses of VaR models extensively covered in the literature.

The accuracy of VaR outputs depends on the pre-set assumptions and parameters; wrong variances and covariance will result in inaccurate forecasts; the focus of virtually all VaR models are on downside risks, ignoring liquidity and systemic risks; the conditional normal distribution of returns is a prerequisite (ineffective in heterogeneous distributions with many outliers or negative returns); linearity is a requirement, but the payoff of an option is not linear; another requirement of VaR is stationarity, and non-stationarity may cause a breakdown in VaR computations; even though many variations of VaR models exist, none of the currently used VaR models are a universally agreed best approach to measure market risk or bank-wide risks. Therefore, it is suggested in the literature that either VaR models are incorporated with stress testing or further research should be done on GARCH, IGARCH, EGARCH, and the quasi-maximum likelihood GARCH (or QML GARCH) as alternative models.

2.1.6 Distance-to-Default Model

Structural (e.g. Merton, 1974) and reduced form (e.g. Hull & White, 2000) models, derived from Merton's model on the pricing of corporate debt (bonds), are widely used to forecast probabilities of default (PD) and distance-to-default (DtD). The DtD measures how many standard deviation a non-financial firm is away from (distance to) a default risk (Black & Cox, 1976). The default point is when the book-value of the debt exceeds the market value of assets, causing the firm a failure to service a portion or all of its debt obligations; in this situation, the firm is considered to be in default. However, it is not clear or well-understood what influences the DtD because the determinants of the DtD are varied and multifaceted with linkages to the real economy. The list of Blundell-Wignall and Roulet (2013) includes macro level and bank level factors (i.e. leverage and funding). Since the original Altman (1968) Z-score and the enhanced ZETA (1977), some option pricing and default prediction models have been extended on the Black-Scholes-Merton models (Wang & Campbell, 2010; Crosbie & Bohn, 2003).

The valuation of equity (stocks) and debt (bonds) is the underlying task in the Merton (1974) model and Black and Scholes (1973) option pricing theory, which are subject to assumptions and certain conditions concerning the nature of capital markets, the firm capital structure, equilibrium, continuous time (not single-period), unrestricted short sales, and default point. Prior to the seminal papers by Black-Scholes-Merton, financial ratios along with univariate and multivariate statistical models were used to assess credit risk and predict the likelihood of bankruptcy (Altman, 1968; Clark et al., 1997; Hill et al., 1996). Altman (1968) points out that a majority of financial ratios is rather ambiguous and open to manipulation.

Financial ratios hardly follow a normal distribution as opposed to those based on it (e.g. VaR, option pricing, regression and multiple discriminant analyses). Therefore, models less sensitive to non-normal distribution and mean-variance criterion have been developed (Beaver, 1968). The literature reveals that iterative learning systems such as neural networks and inductive learning provide better bankruptcy forecasts than multiple discriminant analysis. To predict bank failures, Tam and Kiang (1992) used neural networks, Bhattacharyya and Pendharkar (1998) employed inductive learning, and Kane et al. (1998) utilized rank transformation.

Altman (1968) developed the Z-score using six accounting and one market-based out of 22 variables which are combined to produce five key ratios; a statistical technique known as the multiple discriminant analysis (MDA) is used to classify or make default predictions. Although Altman's model predicts bankruptcy up to three years prior to the actual default, the prediction accuracy of his model drops from 95% (one year) to 72% (two years), and the prediction accuracy deteriorates as the lead time goes beyond two years (52% three years). Nevertheless, Altman (1968) considers his Z-score as a very useful measure of risk with the ability of predicting defaults of distressed companies (Altman & Hotchkiss, 2005). The Z-score was refined when Altman co-developed the *"second generation ZETA"* (Altman et al., 1977). The

ZETA model is more comprehensive than the Z-score and offers advantages over a univariate study, but regression analysis nonetheless is more popular. Through the discriminant coefficient function, individual variables are transformed into a single Z value (overall index)

$$Z = V_1X_1 + V_2X_2 + \cdots + V_nX_n,$$

$$V_1, X_2, \dots V_n = \text{discriminant coefficients, and}$$

$$V_1, X_2, \dots X_n = \text{independent variables}$$

$$Z = 0.012X_1 + 0.014X_2 + 0.033X_3 + 0.006X_4 + 0.999X_5$$

Where V_i represents the discriminant coefficient and the X_i values are independent, actual values (p. 592). The five variables (ratios) used in the study are: X_1 = working capital / total assets; X_2 = retained earnings / total assets; X_3 = earnings before interest and taxes / total assets; X_4 = market value equity / book value of total debt; and X_5 = sales / total assets. To determine the discriminating power of the model, Altman (1968) applies the F-value test, the output is a ratio describing the sums-of-squares between groups and within groups, mathematically;

$$\lambda = \frac{\sum_{g=1}^{G} N_g(\bar{y}_g - \bar{y})^2}{\sum_{g=1}^{G}\sum_{p=1}^{N_g}(y_{pg} - \bar{y}_g)^2} \qquad \text{, where } \bar{y}_g = \frac{1}{N_g}\sum_{p=1}^{N_g} y_{pg}$$

Where G represents the number of groups, g is the group g, g = 1....G, N_g is the number of firms in group g, y_{pg} is the firm p in group g, p = 1.... N_g, $\dot{y}_g$ is the group mean, and ẏ is the overall sample mean. Altman (1968) concludes that a firm with a Z-score > 2.99 is non-bankrupt (insignificant PD), a Z-score < 1.81 is considered bankrupt (or default is certain), and 1.81 < Z-score < 2.99 is in the *"zone of ignorance"* or *"gray area"* (p. 606).

The original Z-score needed refinements as risk has evolved considerably via fast-paced globalization, financial innovations, and gradual integration (interconnectedness); this turn of events gave birth to new risk types, triggering large corporate failures. As a result, Altman, Haldeman, and Narayanan (1977) developed the new ZETA model which predicts defaults up to five years prior to the actual bankruptcy event. Another improvement over the original Z-score is that the ZETA was tested on a sample of manufacturing and retail firms, whereas the Z-score was developed for predicting bankruptcies by manufacturers. The results of both Z-score and ZETA are similar for one year prior to default; 93.9% and 96.2% respectively, but the accurate bankruptcy prediction of ZETA is noticeably higher as the lead-time goes beyond two years (2.5 to 5 years); while the ZETA model achieves around 70% accuracy at fifth year, the performance of Z-score for the same period is only half of the ZETA (36%).

$$\mathrm{ZETA_c} = \ln \frac{q_1 c_1}{q_2 c_{11}}$$

The cost of misclassification is avoided by setting the cutoff score ZETA at zero, and calculated by the formula on the left (Altman et al., 1977).

Where q_1 denotes the prior probability of the bankrupt, q_2 is the non-bankrupt, c_1 is the cost of type I and c_{11}type II errors. The efficiency of the ZETA bankruptcy classification can be compared with other models through the use of the expected cost of ZETA shown below:

$$\mathrm{EC_{ZETA}} = q_1 \left(\frac{M_{12}}{N_1}\right) C_1 + q_2 \left(\frac{M_{21}}{N_2}\right) C_{11}$$

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Where M_{12}, M_{21} represent bankruptcy classification misses (type I and II errors), N_1, N_2 are the number of observations in the bankrupt (N_1) and non-bankrupt (N_2) groups.

Albeit criticism and statistical objections (e.g. narrow scope, old data, and absent of extreme events), the Altman (1968) Z-score model has been used extensively to predict firms facing distress and the resultant bankruptcies. However, one of the shortcomings of the Z-score is that it only focused on some manufacturers and did not factor in asset volatility. Bemmann (2005) asserts that although the Z-score's bankruptcy prediction is strong for the first year, the accuracy drops significantly in the long-term attributable to bias coefficients. More recent applications of the Z-score include Wang and Campbell (2010) who investigate the failure (default) rates of public companies in China; Lugovskaya (2010) forecasts defaults of SMEs in Russia using financial and market-based information. More criticism is found in the literature, the Z-score is not based on a theoretical foundation, and ratios obtained from financial statements are not real-time data. Methodological issues exist as well, the selection of data for analysis has bias aspects; this produces bias and inconsistent coefficients adversely affecting the end-result.

Čihák (2007a) sees weaknesses in the earlier default-prediction measures and argues that a good framework of financial stability needs to incorporate probabilities of default (PD) and loss given default (LGD) of individual banks, and correlations of defaults (CD) across the entire financial system. He also infers that the distribution of aggregate (systemic) loss as an early indicator provides a much clearer picture of financial stability or instability compared to other only accounting-based measures of risk (e.g., ratio analysis and Z-score). In his proposed systemic loss analysis, Čihák (2007a) uses both market-based information and accounting-based data which includes the daily equity prices for 29 banks in industrialized economies and EMEs over the period of 1990-2004 that witnessed 12 systemic banking crises; furthermore, he proposes using the distribution of systemic loss as a key measure of risk, and treating the financial system "as a portfolio of counterparty risks" (p. 4) where banks are counterparties. In the formulation of his proposals, Čihák (2007a) uses elements of the credit portfolio risk theory (e.g. Saunders & Allen, 2002), where he computes the distribution of systemic loss as;

$$\mathrm{L_s} = \sum_{\mathrm{i}=1}^{\mathrm{n}} \mathrm{L_i}$$

Where the financial system consists n banks, $\mathrm{L_s}$ is the distribution of systemic loss, i is the default value of banks (when $\mathrm{i} = 0$, the bank is solvent; insolvent if $\mathrm{L_i} > 0$), and $\mathrm{L_i}$ is a random variable with a distribution from 0 to $\mathrm{X_i}$, and $\mathrm{X_i}$ is the maximum loss of a bank (p. 3). In the event of an acute financial stress triggered by domestic, macroeconomic, or the confluence of both factors, Čihák (2007a) concludes that bank i may be in default when;

$$\mathrm{m}\sqrt{\mathrm{P}} + \varepsilon_{\mathrm{i}}\sqrt{1-\mathrm{P}} \leq \Phi^{-1}\,(\mathrm{PD}), \qquad \text{where } \mathrm{P} = \sum_{\mathrm{j}=1}^{\mathrm{k}} \beta_{\mathrm{j}}^{2}$$

$$\varepsilon_{\mathrm{i}} \frac{\Phi^{-1}(\mathrm{PD}) - \mathrm{m}\sqrt{\mathrm{P}}}{\sqrt{1-\mathrm{P}}}$$

Where M (m_1, m_2 ...,m_k) is the systemic factors affecting all banks in the financial system (but each bank's vulnerability exposure is varied), $\mathcal{E}_{\mathrm{i}}$ is the idiosyncratic shock, Φ is the cumulative normal distribution of losses, PD is the probability of default. Next, for a given value of *m*, Čihák (2007a) formulates the probability of bank i to be in default:

$$\mathrm{PD_i}|\mathrm{m} \leq \Phi\left[\frac{\Phi^{-1}(\mathrm{PD_i}) - \mathrm{m}\sqrt{\mathrm{P}}}{\sqrt{1-\mathrm{P}}}\right]$$

To check whether the bank i defaults or not, a standard normal variable $\mathcal{E}_i$ is drawn and characterized by the following indicator function:

$$\mathrm{I}\left\{\varepsilon_i \leq \frac{\Phi^{-1}(\mathrm{PD_i}) - \mathrm{m}\sqrt{\mathrm{P}}}{\sqrt{1-\mathrm{P}}}\right\} = \begin{cases} 1 \text{ if true} \\ 0 \text{ if false} \end{cases}$$

Next, the loss to bank i is calculated for a given state draw m, m(r), and $\mathcal{E}_i$, $\mathcal{E}_i$(r);

$$\mathrm{Loss_i}\,\Big|\,\mathrm{m(r)} = \mathrm{I}\left\{\varepsilon_i \leq \frac{\Phi^{-1}(\mathrm{PD_i}) - \mathrm{m}\sqrt{\mathrm{P}}}{\sqrt{1-\mathrm{P}}}\right\} \mathrm{X_i S_i}$$

Finally, the expected loss is formulated as;

$$\mathrm{E}\,\Big|\,\mathrm{m}^{(\mathrm{LOSS})} = \frac{1}{\mathrm{R}}\sum_{i=1}^{\mathrm{R}}\left(\mathrm{I}\left\{\varepsilon_i(\mathrm{r}) \leq \frac{\Phi^{-1}(\mathrm{PD_i}) - \mathrm{m}\sqrt{\mathrm{P}}}{\sqrt{1-\mathrm{P}}}\right\} \mathrm{X_i S_i}\right)$$

There is plethora measures of default probability, but the structural model (e.g., Merton, 1974) and the reduced-form model are the most widely used.

Although credit valuation (as well as forecasting defaults) has changed dramatically with the insights of Black and Scholes (1973) and Merton (1974) which have caused a paradigm shift from risk-based pricing (e.g., the CAPM) to arbitrage-based pricing, these seminal models have been subject to skepticism and blamed for under-predicting spreads (Arora et al., 2005). The literature exemplifies that the VK model, extended on Merton (1974) by Oldrich Vasicek and Stephen Kealhofer (Kealhofer, 2003a; b; Vasicek, 1984), provides robust predictions of defaults and bond spreads compared to Merton's model, but the reduced-form Hull-White (HW) model tends to outperform both Merton and the VK models (Jarrow & Turnbull, 1992; 1995).

Though, the disquieting issue with the reduced-form models is that they are not based on theoretical foundation and because of this they are subject to empirical objections (e.g., Duffee, 1999). The VK model, first commercially marketed by the KMV's (a leading provider of risk management tools), is a modified structural model (a refinement over Merton's model) which employs an empirical distribution of distance to default (DtD) to produce the proprietary (trademark) "*Expected Default Frequency"* (EDF). Following the huge success of the VK model, Moody's acquired KMV in 2002 and since then it is called Moody's KMV or MKMV.

In Merton (1974), the firm's equity is a call option and the strike price is equal to the value of its liabilities; therefore, the firm is considered to be in default when the value of its liabilities exceeds the market value of its assets. Because the structural models assume that asset values are log-normally distributed and follow a geometric Brownian process with implied unlimited upside payoffs, it is therefore not suitable for banks because the upside payoffs of contingent claims on bank assets such as mortgages are limited (see Acharya et al., 2014 for the Merton model-based bank default risk). For this reason, the DtD is not used as a standalone model to assess bank default risk, it is however incorporated in the empirical bank default risk modeling. Campbell et al. (2011) deduce that the reduced-form models provide more accurate default forecasts by incorporating market and accounting-based data (Duffie & Singleton, 1999).

In the Merton (1974), "the use of the term *"risk"* is restricted to the possible gains or losses to bondholders as a result of (unanticipated) changes in the probability of default...", and the distance-to-default $\mathrm{DD_T}$ over a horizon of T periods is given as;

$$\mathrm{DD_T} = \frac{\ln\frac{V}{D} + \left(\mu - \frac{1}{2}\sigma^2\right)T}{\sigma\sqrt{T}}$$

The value of equity (E) can be written as:

E = max(0, V – D)

Where V denotes the value of the firm assets, D is the strike price (or default barrier), μ is the growth value of firm's assets, and σ is the asset volatility (Chan-Lau & Sy, 2006).

Bank defaults, as well as measures taken prior to defaults and consequences afterwards, greatly differ from corporate defaults in some aspects; first, because bank defaults result in enormous costs to economies with long-lasting societal implications, banks are regulated heavily and can be intervened as necessary by regulators and governments before a final default takes place (e.g. Hoelscher & Quintyn, 2003); second, the distance to default models may be less informative and misleading for both regulators and supervisors to determine a set of corrective actions for banks facing insolvency; the Basel Committee provided guidance for banks (BCBS, 2002).

Corporations are subject to less regulation and intervened voluntarily at request or through negotiations (e.g., AIG). After the savings and loan (S&L) crisis in the 1980s and 1987 stock market crash, the Federal Deposit Insurance Corporation Improvement Act (FDICIA) of 1991 added two new provisions; (i) regulators are granted additional power to close failing banks despite positive capital levels; (ii) prompt corrective action (PCA) became mandatory making early interventions possible. As market-based models are supplementing traditional accounting-based indicators such as financial ratios, the uses of the DtD and reduced-form models are encouraged by central banks, regulators, and the supervisor community (e.g. Chan-Lau, 2006).

Extending on the Black-Scholes (1973) and Merton (1974) models, Vasicek (1984) assumes that the total asset value (or value of the firm) follows a stochastic process;

$$dA = \mu A dt + A dz, t > 0$$

Where A represents the value of total assets, μ and σ^2 are the instantaneous mean and variance respectively, and dz is a standard Gauss-Wiener process. Vasicek (1984) says that a short-term

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loan will be in default if $A(T) < D_T + C_T$; where, T is the term to maturity of the loan, D_T is the value of the short-term debt, C_T is the amount due at maturity, and F is the combined dividend and interest payments (p. 11). Next, the probability of default (p) is formulated below; N denotes the cumulative normal distribution function (Vasicek, 1984).

$$p = P(A(T) < D_T + C_T \,|A(0)) = A$$

$$p = P(\log A(T) < \log(D_T + C_T) \mid A(0) = A)$$

$$p = N\left(\frac{\log(D_T + C_T) - \log(A - F) - \mu T + \frac{1}{2}\sigma^2 T}{\sigma\sqrt{T}}\right)$$

Knowing default probabilities is of importance to firms, lenders, and counterparties; however, computing the default rate of a firm is not an easy task; this is also evinced in the literature that the relationship between stock returns and default probability is a complex one (e.g. Duffie & Singleton, 2003). Although the default rate of a firm with a rating of AAA in advanced countries is less than 2% per annum, losses in the event of a default can be pretty significant. Crosbie and Bohn (2003) point out that spreads tend to be higher to compensate higher risk surrounding PDs of volatile firms with high leverage. Merton's model computes spreads (Arora et al., 2005);

$$s = -\frac{1}{T}\log(\Phi(d_2) + \frac{A}{x}\exp\ (rT)\ \Phi\ (-d_1)$$

Where s is the spread, T is the default point in time, Φ is the cumulative normal distribution function, A is the initial asset value (before default), X is the default threshold (or point of default), μ is the deterioration in asset return, and σ is the asset return volatility.

The VK (Vasicek – Kealhofer) model is widely perceived as an improvement over Merton's model which assumes that a firm would be in default if its asset value falls below a certain threshold not allowing the firm to meet its short-term debt obligations (Merton, 1974). Same as Čihák (2007a), the VK model takes into account PD, LGD, and CD and groups key elements of credit risk under *standalone risk* and *portfolio risk*; the former contains default probability, loss given default, and migration risk; the latter group includes risk exposure and default correlations (Crosbie & Bohn, 2003). The VK model states that a firm's net worth can be computed as (market value of assets, MVA) – (default point, DP); a firm will default when its MVA is zero;

$$\mathrm{P_t} = \mathrm{Pr}\;(\mathrm{V_A^t} \leq |\; \mathrm{X_t} = \mathrm{V_A}) = \mathrm{Pr}\left(\ln \mathrm{V_A^t} \leq \ln \mathrm{X_t} \,\middle|\, \mathrm{V_A^0} = \mathrm{V_A}\right)$$

Where, $\mathrm{P_t}$ is the probability of default by time t, $\mathrm{V_A^t}$ is the firm's market value of assets, and $\mathrm{X_t}$ is the firm's book value of liabilities due by time t (Crosbie & Bohn, 2003). In the VK model, DD_T denotes a firm's distance to default, $\mathrm{V_A^t}$ is the market value of assets, $\mathrm{X_T}$ is the book value of liabilities, and μ is the expected return on assets (Arora et al., 2005).

$$\mathrm{DD_T} = \frac{\ln \frac{\mathrm{V_A}}{\mathrm{X_T}} + \left(\mu - \frac{\sigma_A^2}{2}\right)\mathrm{T}}{\sigma\sqrt{\mathrm{T}}}$$

The VK model is a more realistic approach for practitioners to estimate PDs and DtDs of firms; this model is also a notable improvement over Merton's structural model based on the Gaussianity assumption (Moody's KMV uses a proprietary empirical function to overcome Merton's model weakness). Another strength of the VK model and MKMV is that PDs of distressed firms under adverse market conditions are calculated more accurately. EDFs (calculated monthly, weekly, or daily) can maintain a level of alertness that cannot be matched by the traditional credit valuation processes. The VK model has weaknesses too; the biggest weakness is its inability to distinguish among different types of long-term bonds. Also, private firms' EDFs (publicly traded or not) can be calculated based on accounting data since their market values are not determined by equity (stock) prices.

Liu et al. (2004) extend on the Merton (1977b) to develop the distance to default for banks using the Z-score. Except in 1982 (the top five Canadian banks had an average Z-score of 2.0 which means high risk, attributable to Latin American debt crisis), the findings of their study show that Canadian banks are resilient with very high Z-scores and not near a default risk. This is not to suggest that Canada's financial system has not faced any bank failure; conversely, in about four decades (since the establishment of the Canada Deposit Insurance Corporation (CDIC) in 1967 to 2001), a total of 43 bank failures cost the CDIC $7 billion (p. 1). Liu et al. (2004) argue that their Z-score is more appropriate for banks than the original Altman (1968) Z-score because it takes into account the interest rate risk;

$$\mathrm{Z_t} = \frac{(\mathrm{V_t} - \lambda \mathrm{L_t})/\mathrm{V_t}}{\sigma_\mathrm{V}} = \frac{1 - \lambda(1 - \mathrm{E_t}/\mathrm{V_t})}{\sigma_\mathrm{V}} \qquad \sigma_\mathrm{V}^2 = \Phi_\mathrm{V}^2 \mathrm{V}^2 + \psi^2$$

Where three variables such as $\lambda, \sigma_V, E_t/V_t$ determine the Z-Score, λ represents the deposit insurance program (CDIC), E_t/V_t is the risk-based capital measure, and σ_V contains both interest rate risk and non-interest rate risk (p. 5).

Gropp et al. (2006) empirically test a sample of EU banks to see if distance-to-default along with bond spreads can be used as measurements of financial stability; the study concludes that both properties are impartial and capable of detecting fragilities in financial systems and gauging systemic risk. Tudela and Young (2003) compute default probabilities of publicly traded UK firms and believe that models based on Merton's (1974) structural model not only provides useful information, but also predict better estimates. Chan-Lau et al. (2004) use the distance-to-default (a risk neutral) to measure bank fragility in 14 emerging markets involving 38 banks.

Hesse and Čihák (2007a) empirically analyze cooperative banks' role in financial stability and find that their impact is positive as cooperative banks (due to less competition and low volatility) are more resilient compared to commercial banks. Avesani et al. (2007) show that movements in covered bond prices can work as a supervisory early-warning signal for any adverse credit developments and a possible deterioration in quality of mortgage loans which could contribute to systemic risk. Chan-Lau and Gravelle (2005) used the expected number of defaults (END) to measure systemic risk in corporate, financial, and sovereign segments.

In the mentioned studies above, accounting-based and market-based data is used; in the market-based, bond and equity prices provide information about default probabilities. Chan-Lau (2006) calculates the probability of default of a zero-coupon (one unit value at maturity);

$$\mathrm{B} = \frac{(1 - \mathrm{p}) + \mathrm{pRR}}{1 + \mathrm{r}} \qquad\qquad \mathrm{p} = \frac{1 - (1 + \mathrm{r})\mathrm{B}}{1 - \mathrm{RR}}$$

Where B is the price of one unit zero-coupon bond, ρ is the default probability, RR is the recovery rate, and r is the risk-free discount rate.

Chan-Lau (2006) states that knowing the asset value and asset volatility of the firm are prerequisites to estimating the default probability of an equity in period t for a horizon of T years which is given by the following formulas:

$$E_t = V_t N(d_1) - e^{-rT} D N(d_2) \qquad \sigma_E = \frac{V_t}{E_t} N(d_1)$$

Where *N* is the cumulative normal distribution, V_t is the value of assets in period *t*, *r* is the risk-free rate, and σ_A is the asset volatility.

$$P_t = N\left(-\frac{\ln\frac{V_t}{D} + \left(r - \frac{\sigma_A^2}{2}\right)T}{\sigma_A\sqrt{T}}\right) \qquad d_2 = d_1 - \sigma_A\sqrt{T}$$

There are numerous approaches to modeling credit risk, but two classes of models have gained prominence; structural models (as previously explained, these are extended on Black and Scholes, 1973; and Merton, 1974) and reduced-form models (Jarrow & Turnbull, 1992, 1995; Duffie & Singleton, 2003). The most distinctive characteristic between the two approaches is that structural models measure PDs or DtDs through financial variables such as assets and liabilities priced exogenously by the actions of investors who have incomplete information as to when firms default; reduced form models eliminate incomplete information impediment of structural models by using only bond or credit default swap (CDS) information which is observed by all market participants, but the problem with this scenario is that the default point is not based on the firm's credit quality (see Jarrow & Protter, 2004 for a survey of models).

The probability of default prior to maturity is formulated as (Jarrow & Protter, 2004);

$$Q(\tau \leq T) = E^Q[\, E^Q(N(T) = 1 \,|\sigma(X_s\colon s \leq T))\,]$$

$$= E^Q\left[e^{-\int_0^T \lambda_s ds}\right]$$

, and the value of the firm is given as below (p. 4):

$$v(0.T) = E\left[(1_{\{\tau\leq T\}}\delta_\tau + 1_{\{\tau>T\}}1)e^{-\int_0^T r_s ds}\right]$$

Where Q is the martingale measure, T is the maturity, τ denotes the default time, X_t is a vector of state variables, γ_t is the intensity process, $N_t = 1_{r \leq t}$ is the Cox process, r_t is the interest rate, $\gamma_t(X_t)$ is the conditioned Poisson process, and δ_t is the stochastic process.

2.2 Stress Testing: A Measure of Financial Stability

Stress testing is not new, it has just evolved from infancy to become more sophisticated. In recent years, it has gained prominence as an indispensable tool in the macroeconomic tool kit available to central banks, regulators, and the supervisor community who are (or should be) responsible for safeguarding financial stability as their primary objective. By focusing on the tail risks, stress tests quantify the impact of extreme but plausible scenarios on risk exposures of a portfolio, business unit, banking sector, or the banking system as a whole; moreover, stress testing is not an early-warning device, which means that the manifest objective of stress tests is not to identify or signal the timing of the next big financial or economic crisis. The typology of stress testing is categorized along two dimensions; microprudential (BU: bottom-up, by banks for internal risk management and by supervisors for "*Pillar II Solvency"* under Basel II and III), macroprudential (both BU and TD, the IMF FSAPs for surveillance, central banks and supervisors for financial stability), and macroprudential (BU, used as a crisis management tool since 2009). There is also separate liquidity stress testing, which is less advanced and not linked to solvency, it determines whether banks and markets have sufficient liquidity.

Although the stress testing literature exemplifies a plethora of descriptions, an extensive survey is found in CGFS (2000, 2001), the Basel Committee emphasizes that "…what constitutes a good stress test is, however, not universally clear" (BCBS, 2013a). Fender et al. (2001) describe stress testing as "...a risk management tool that measures a firm's exposure to extreme movements in asset prices". The CGFS highlights that stress tests quantify banks' risks under highly adverse market conditions, but they do not determine the likelihood of their occurrences (CGFS, 2000). The IMF defines stress test as "…a range of techniques used to assess a vulnerability of a portfolio to major changes in the macroeconomic environment or to exceptional, but plausible events" (Blaschke et al., 2001). The Basel Committee states that the upshot of stress testing is "…the evaluation of a bank's financial position under a severe but plausible scenario to assist in decision making within the bank" (BCBS, 2009a). Borio et al. (2011) contend that treating stress testing as an early-warning device would be *"ill-suited"*.

Stress testing is important to assess bank stability for internal risk-management purposes and the financial system stability. According to the Basel Committee, the latter is "…the foundation for sustainable economic growth, as banks are at the center of the credit intermediation process between savers and investors" (BCBS, 2010a). Despite a wide range of definitions in the literature. Goodhart (2006) asserts that there is also no universally accepted definition of financial stability. Yellen (2014) elaborates that although "…the pursuit of financial stability is complementary to the goals of price stability and full employment"; nevertheless, "…monetary policy faces significant limitations as a tool to promote financial stability".

Čihák (2007a) argues that the analysis of price stability is preferred as opposed to financial stability which lacks of a universally accepted common measure, but the measure of inflation in the former constitutes a clear operational definition. Crockett (1997a) argues that monetary stability and financial stability (Borio (2003) calls them *"twin stability"*) are integral as well as inter-reliant elements of a normal-functioning financial system where both banks and markets are stable. Borio (2014) infers that monetary and financial stability, except a short period during the Bretton Woods, were not achieved together across regimes for over a century.

The GFC has shown that, besides generalized benefits, mismanaged financial innovations accompanied by distorted incentives can cause detrimental impact on financial and systemic stability. Nier et al. (2008) investigate four situations where systemic stability is affected unfavorably creating funding problems, causing contagion that results in a systemic banking crisis; (i) direct bilateral exposures between banks; (ii) correlated exposures of banks to a common source (concentration) of risk; (iii) feedback effects from endogenous fire-sale of assets by the distressed institutions; (iv) informational contagion. Against this background, policy makers (central banks), multilateral institutions, regulators, and supervisors have been prompted to strengthen regulations and banking supervision. This concerted effort gave birth to Basel III and since 2009, stress testing has evolved to become a crisis-management tool.

Many economists share the view that national and international standards along with the earlier stress tests failed to contribute to financial stability. On that note, the previous two Basel standards ushered greater risk taking which resulted in significant cross-border activity, capital arbitrage, and pro-cyclicality. There is also a widespread consensus that the earlier stress tests failed to detect the banking sector's risks related to securitization, counterparty, contingent, continual access to short-term funding, and structured products under stressed liquidity conditions (BCBS, 2009b) and to restrain excessive leverage that inevitably triggered the subprime debacle of 2006, then the breakout of the GFC. Therefore, it would be most informative to provide a brief history of the earlier (microprudential) stress testing conducted by individual banks and supervisors.

2.2.1 Microprudential Stress Testing for Risk Management

Ever since the 1999 Gramm-Leach Bliley Act repealed the Glass-Steagall Act of 1933 (which in the aftermath of the 1929 US stock market crash barred all commercial banks from engaging in investment banking activities), the U.S. financial system has been hit hard repeatedly, attributable to increased rivalry amongst banks with continual propensity to search for higher yields to beat the competition, which in turn led to overextension of credit into higher-risk lending segments such as sub-prime. Greed and the nocuous lending practices (e.g., predator lending) accelerated the buildup of systemic risk, promising large financial losses. To alleviate the level of systemic risk and ensuing systemic loss, G-10 countries have been prompted to develop enhanced risk assessment and early-warning systems; accordingly, individual banks began developing proprietary risk assessment capabilities for internal purposes.

For the past three decades (since the late 1970s), trading accounts at systemically important banks have grown substantially both in complexity and the size of risk exposures facilitated by the fast-pace globalization, financial deregulation, and technological and financial innovations; the latter resulted in booms in real estate and stock markets in the 1990s in advanced (the U.S. in particular) and emerging market economies (e.g. ASEAN-5), putting excessive strain on banks and making them more susceptible to exogenous shocks as they became unjustifiably leveraged arising from perverse credit exposures to the private and household sectors. The homegrown Asian crisis of 1997-98 systemic in nature, sudden collapse of the LTCM hedge fund and the Russian ruble crisis in 1998 prompted central banks, supervisory authorities, and multilateral institutions to take a leading role in the development of micro and macroprudential stress testing programs (e.g. the IMF and World Bank jointly established the FSAP in 1999).

Various types of stress tests have been used in different fields for decades, but its debut in the banking sector began when the Basel Committee introduced the 1996 market risk amendment to Basel I (BCBS, 1996a) requiring internationally active banks with substantial trading volumes to use backtesting (Campbell, 2005) to confirm the accuracy of VaR outputs as VaR models fail to detect vulnerabilities under extreme but plausible scenarios, and calculate capital adequacy in conjunction with internal rating-based (IRB) approaches (BCBS, 1996b). Backtesting was later replaced by stress testing due to deficiencies and imperfect signals generated. Hirtle and Lehnert (2014) suggest that "...stress testing began at the same time as financial risk modeling, when analysts had contemplated pessimistic or worst-case outcomes before investing".

At the back of ever more financial turmoil, large banks were required to put in place rigorous stress testing programs under Basel II (in June 2004). Besides stress testing market risk and credit risk (via using the advanced and foundation internal ratings-based (IRB) approaches), banks are regulator-mandated to stress test their credit portfolios in the banking and trading books as well as their liquidity positions (BCBS, 2004b). Adequately designed stress testing programs containing extreme but plausible scenarios are argued to provide a better decision-making process for banks and supervisors; "stress testing alerts the bank management to adverse unexpected outcomes related to a variety of risks and provides an indication of how much capital might be needed to absorb losses should large shocks occur" (BCBS, 2009a).

A newly formed consensus since the GFC suggests that banks should undergo regular stress tests (more popular following a crisis) during benign economic times as well to avoid underpricing of risk. Bernanke (2013) points out that "…stress tests complement standard capital ratios by adding a more forward-looking perspective and by being more oriented toward protection against so-called tail risks; by design, stress tests help ensure that banks will have enough capital to keep lending even under highly adverse circumstances".

Banking operations revolve around risks, it is therefore crucial for banks to know where they stand in terms of risk exposures, therefore "a stress test is commonly described as the evaluation of a bank's financial position under a severe but plausible scenario to assist in decision making within the bank" (BCBS, 2009a). The Basel Committee believes that adequately designed stress tests with vigorous adverse scenarios will "…improve banking sectors' ability to absorb shocks arising from an acute financial and economic stress" (BCBS, 2010a).

The evolution of stress testing is divided into two distinct periods; first is the pre-GFC covering the years of 1997-2007, during which stress testing was used by practitioners for internal risk-management purposes and by supervisors to assess banking solvency and financial stability to minimize burden on tax payers should closures of insolvent or weak banks occur. These stress tests were narrow in scope, portfolio-focused, and produced results by design. Second is the post-GFC (since 2009); besides regular stress tests (as a risk-management and a supervisory tool) required under Basel II (e.g., stress testing credit portfolios in the banking book), macro stress testing has assumed a new role as a crisis-management tool (broad, system focused, and keeps systemic risk in check) which is for the first time designed and conducted by central banks and supervisory agencies to assess financial system stability as a whole.

The Committee on the Global Financial System (CGFS) investigated the use of stress tests through 424 stress tests conducted by 43 large, internationally active, banks and securities firms from ten countries (CGFS, 2000). The CGFS is a central bank forum, established by the Governors of the G-10 central banks to monitor and examine broad issues relating to global financial markets. The overall conclusion of the survey is that stress testing is a valuable tool for gauging and managing risks and the interviewed risk managers said that they were highly committed to developing in-house stress tests. Most commonly used stress testing techniques in 2000 were; *a simple sensitivity test*, which measures the adverse impact of changes of a single risk factor on a portfolio or business unit; *a scenario analysis* attempts to measure risk exposures due to extreme but plausible market events triggered by a confluence of risk factors.

The scenario analysis has two branches; based on chosen events, it can be called *a historical scenario analysis* (easy to understand and create) where past events are used (e.g., 9/11 terrorist attack, the GFC), and *a hypothetical scenario analysis* (future is the focus) which takes into account events that have not yet occurred. Some of the firms participated at the CGFS survey indicated that they applied other less popular techniques such as *a maximum loss approach* (similar to VaR) that forecasts the largest potential loss on a portfolio arising from changes in market conditions, and *extreme value theory* which focuses on tail risks (CGFS, 2000).

As a follow-up of the April 2000 survey, the CGFS initiated an exercise on enterprise-wide stress tests in May 2004, to which 64 banks and securities firms from 16 different countries participated (50% better than the 2000 survey). The exercise had two main objectives; first was to understand how financial institutions perceived various risk scenarios at the time of the survey; and second was to monitor and discover the mechanics of stress testing. The overall strategic goal was to observe how stress testing practices have evolved since 2000 (CGFS, 2005). The results of the 2004 survey show that interest rate fluctuations and credit risk stress tests took the top two places respectively (60 firms ran 357 stress tests on interest rate movements compared with 174 stress tests on credit default risks by 52 firms). Stress tests on foreign exchange positions (116 stress tests by 45 firms) and equities (130 tests by 49 firms) were the next two highest applied categories. Only fewer tests were conducted on real-estate bubble risk (18 firms ran 32 stress tests). As far as the regions are concerned, North America had the highest number of stress tests (186 tests by 48 firms), 35 firms from emerging markets conducted 172 stress tests (second highest). Japan had the fewest stress tests, 15 firms conducted about 50 tests (Asia excluding Japan, 124 stress tests).

Microprudential stress testing programs designed and conducted by banks and supervisors, to a degree, have provided some benefits, but they were nonetheless subject to skepticism and bitter criticism owing to the severity and protracted nature of the GFC, which has invoked concerns that the earlier stress testing practices may have been inadequate and insufficient to deal with new risk types formed by innovations and their adverse impact on boom-bust cycles that triggered rapid changes in micro and macro conditions. The most nocuous effect of these stress tests was twofold; they provided misleading indications regarding the GFC's severity; and their flaws caused banks' inability to react sufficiently to the unfolding events (BCBS, 2009a).

International Institute of Finance (IIF) argues that "during the market turbulence, the magnitude of losses at many firms made it clear that their stress testing methodologies needed refinement – stress testing was not consistently applied, too rigidly defined, or inadequately developed (IIF, 2008). The stress testing literature vividly shows that micro stress tests prior to the GFC had weaknesses to cope with extreme market conditions as well as the subsequent unfolding events, this huge oversight on the part of financial authorities contributed to the intensity of the GFC (e.g. BCBS, 2009a). Both 2006 sub-prime debacle and the GFC invoked concerns among the industry participants who argue that rigorous stress tests would have mitigated the severity of financial losses and alleviated the extent of social dislocation and displacement of millions.

The Basel Committee has observed that some important risks were not covered sufficiently in most stress tests prior to the GFC, plus the scenarios used in these stress tests were not rigorous enough. To insure that stress testing programs are properly embedded in banks' more comprehensive risk-management frameworks, the Basel Committee has introduced the *"Principles for sound stress testing practices and supervision"* in May 2009. Out of twenty one principles, fifteen concern individual banks' stress testing programs and are divided into three focus areas: use of stress testing and integration in risk governance (6 principle); stress testing methodology and scenario selection (4 principles); and specific area of focus (5 principles). Principles for supervisors (6 principles): make regular and comprehensive assessments, enforce corrective actions if necessary, challenge the scope and severity of banks' stress test scenarios, examine banks' stress test results as part of the supervisory review process under Pillar 2 of Basel II, and identify systemic vulnerabilities (BCBS, 2009a).

2.2.2 Macroprudential Stress Testing for Crisis Management

After fairly stable U.S. financial system for 75 years (considered as the expansion periods since the Great Depression of the 1930s), three notable developments such as the US Federal Reserve's expansive monetary policy (for two decades since the late 1990s); flawed financial innovations (with distorted incentives); and the collapse of trading; all of which provoked the largest U.S. (and the world) credit crisis which easily qualifies as the worst crisis in human history (Schwartz, 2009; Beachy, 2012). Allison (2012) blames the FDIC as "…one of the main contributors to the 2008 financial crisis" (p. 2), it is argued that the FDIC's three key responsibilities as an insurer, supervisor, and receiver supposedly created *"too big to fail"* and *"moral hazard"* dilemmas; thus, the FDIC has failed to promote equity (Farhi & Tirole, 2012).

Differing from the preceding crises (i.e. the Asian crisis of 1997-98), the GFC's far-fetched implications have jolted societies from their roots, dislocated banking systems, and displaced millions of people globally; as a result, the GFC's projected aggregate cost to economies has ranged from $6 to 14 trillion (Atkinson et al., 2013; Boyd & Heitz, 2012), which forced about 0.5-1.0% of the world population to slip into poverty (Beachy, 2012). One of the key lessons drawn from the GFC is that financial system vulnerabilities stem from both endogenous and exogenous shocks which make the new strain of crises more disruptive, longer-lasting, and costly. The inescapable truth is that humans possess no special power to prevent crises from breaking out; bank supervision must therefore be complemented by adequately designed macro stress tests used as a crisis management tool under extreme but plausible scenarios. For a longer perspective, see Blinder (2013) for steps taken to restore confidence; FCIC (2011) for causes; Dewatripont et al. (2010) for lessons learned; and Nissanke (2010) for impact on EMEs.

As banking systems across the world have become increasingly intricate, the need for enhanced risk detection/measurement tools plus advanced supervision techniques have become necessary. In that regard, macro stress testing has become a central focus to address the crisis-perpetrating issues such as inadequate financial sector capitalization and constrained access to short-term funding; however, among many others, Greenlaw et al. (2012) point out that macroprudential stress testing programs still focus on microprudential aspects. Regardless of micro or macro, Borio et al. (2011) argue that stress testing must have four common elements; (1) risk exposures that are pertinent to stress; (2) parameters of the scenario (exogenous) that send plausible shocks to risk exposures; (3) a model that simulates shocks at different levels to analyze and monitor propagation of various stress points through the system; (4) measurement of the outcome.

Bernanke (2013) points out that macro stress tests provide three critical benefits; i) adds a *"forward-looking"* aspect to capital ratios; ii) takes care of *"tail risks"*; and iii) ensures adequate level of capital (quality and quantity) along with sufficient capital buffers at each SIB to absorb losses and keep lending under extreme but plausible market conditions. Macro stress testing as a crisis management tool is an attempt in the right direction to take care of the four broad weaknesses (impediments) highlighted by the Basel Committee: (i) use of stress testing and integration in risk governance; (ii) stress testing methodologies; (iii) scenario selection; and (iv) stress testing of specific risks and products (BCBS, 2009a).

The GFC has revealed that stress testing practices prior to the crisis by individual banks and supervisors had structural and methodological flaws. Because the purpose of stress testing is not to identify the probability and the timing of next future crisis; regardless of some preventative measures, the GFC might have still occurred. However, adequate stress testing programs in place using rigorous scenarios designed with the involvement of the bank board and senior management could have helped alleviate the severity of financial losses during the worst episode of the crisis. In response to criticized flaws of stress testing, the Basel Committee introduced the stress testing principles (BCBS, 2009a) and the implementation review of the principles

(BCBS, 2012a, b); most stress tests were not bank-wide (i.e. narrow in scope), conducted as an isolated event, thus widely perceived as less credible; stress testing results had no relevance to capital planning nor played a part in banks' risk governance; they were more mechanical as opposed to dynamic, as a result, they failed to cope with deteriorating conditions caused by exogenous and endogenous shocks; stress testing frameworks were not fully integrated, providing limited risk-assessment coverage, as such, credit risk in the banking books and liquidity (in infancy) were not stress tested; overall, nearly all banks' stress testing approaches were inflexible and less granular (BCBS, 2009a).

Due to country-specific discrepancies, there is no one-size-fits-all stress testing methodology. Based on risk types (credit, market, operational, and liquidity), the complexity of stress tests can range from simple (sensitivity test) to highly sophisticated stress testing such as liquidity. The level of aggregation also varies, from a portfolio to bank-wide, the entire financial system, or even at the global level. Macro stress testing as a crisis management tool uses vastly complex (and usually proprietary) software programs, models, and statistical applications run on very sophisticated computer systems; therefore, absence or limited availability of infrastructure can cause a failure to identify or misidentify banks' risk exposures.

Another disquieting issue is that stress tests' overreliance on correlations to assess risk proved to be detrimental in the run-up to the GFC because the historical data (statistical relationships) employed in most stress tests included benign conditions due to prolonged stability in the U.S. and the world. As stressed conditions triggered rapid changes in investor sentiments, stress tests failed to detect negative system-wide interactions, which were further amplified as stress tests were unable to capture extreme but plausible market events. As far as stress testing scenarios are concerned, light to moderate scenarios were used, and more severe scenarios always faced objections from banks' board and senior management (BCBS, 2009a).

During and in the immediate aftermath of the GFC, alleviating the heightened uncertainty and restoring confidence were at the heart of the central bank agenda (specifically the U.S. and the EU); therefore, adoption and implementation of Basel III together with regular micro and macro stress tests have become a central focus to safeguard global financial stability. The severity of the GFC has underpinned a widespread consensus that stress testing along with Basel III must be the two integral components of a comprehensive risk management framework. The Federal Reserve and European Banking Authority (EBA) have been at the forefront designing and conducting stress tests in order to develop supervisory assessments of regulatory capital adequacy and capital planning at systemically important banks (SIBs).

After failures of earlier micro stress tests, the widely perceived success of the Supervisory Capital Assessment Program (SCAP) undertaken by the U.S Federal Reserve in 2009 has spurred worldwide implementations (Fed, 2009a; b), but their success rates in developing and emerging markets were mixed due to the country-specific discrepancies or implementation errors; as such, the Committee of European Banking Supervisors (CEBS) bungled with its first two macro stress testing exercises conducted in 2009 and 2010; the European Banking Authority (EBA), as the successor, had a better stress testing experience in 2011, but still faced skepticism and was subject to criticism (CEBS, 2010a, b; EBA, 2011).

Since the use of macro stress testing (2009), banks in the U.S. have had an easier time achieving recapitalization because publishing the full results of the SCAP helped restore investor confidence, which in turn led to better equity returns. Industry participants point out that publishing the results of macroprudential stress tests along with methodologies and scenarios employed has provided generalized benefits.

Table 2.1: Supervisory capital assessment program

Federal Reserve estimates in the supervisory severely adverse scenario

	$ Billions	% of loans
At December 31, 2008		
Tier 1 capital	836.7	
Tier 1 common capital	412.5	
Risk-weighted assets	7,814.8	
Loan losses (projected for 2009 and 2010 under more adverse)	599.2	
First lien mortgages, domestic	102.3	8.8
Junior liens and HELOCs, domestic	83.2	13.8
Commercial and industrial	60.1	6.1
Commercial real estate, domestic	53.0	8.5
Credit cards	82.4	22.5
Securities (AFS and HTM)	35.2	-na-
Trading and counterparty	99.3	-na-
Other (1)	83.7	-na-
Memo: Purchasing accounting adjustments	64.3	
Resources other than capital to absorb losses (2)	362.9	
SCAP buffer added for more adverse scenario (SCAP buffer is defined as additional Tier 1 common/contingent common)		
Indicated SCAP buffer as of December 31, 2008	185.0	
Less: Capital actions and effects of Q1 2009 results (3) (4)	-110.4	
SCAP buffer (5)	74.6	

Source: The Federal Reserve (Fed, 2009b)

(1) Includes other consumer/non-consumer loans and miscellaneous commitments and obligations.
(2) Includes pre-provision net revenue less the change in the allowance for loan and lease losses.
(3) Capital actions include completed or contracted transactions since Q4 2008.
(4) Includes only capital actions and effects of Q1 2009 results for firms that need a SCAP buffer.
(5) There may be a need to establish an additional Tier 1 capital buffer, but this would be satisfied by the additional Tier 1 Common capital buffer unless otherwise specified for a particular BHC.

Notes: The SCAP (2009) and its results were particularly of great importance since this was the first macro stress testing used by the US Federal Reserve as a crisis management tool. The results were also significant to central banks, supervisory authorities, bank executives, risk managers, and academia to understand the main sources of financial losses, the majority of which resulted from mortgage-backed securities.

The Supervisory Capital Assessment Program (SCAP) as the Federal Reserve's first stress testing exercise in the U.S. (backed by the U.S. Treasury's Capital Assistance Program – CAP) was not only macroprudential in nature, but had microprudential aspects mainly due to its role in banks' recapitalization efforts. This role was solidified by the CAP providing contingent equity (referred to as a government *backstop*) to participating 19 large domicile bank holding companies (BHCs) in the event they fail to raise capital in private capital markets. The SCAP was launched at the time of extreme stress in the U.S. financial system, triggered by the sudden collapse of Lehman Brothers which in turn contributed to a cascade of corporate defaults.

Stress testing exercises before and after the GFC have proved that stress testing is not fail-safe, and it is certainly not an early-warning device to signal future crises arising from endogenous, exogenous, or hybrid factors (e.g., Borio et al., 2012). At the early stages, the EU-wide stress testing failures is a testimony to the above fact. In stark contrast to the U.S. SCAP and CCAR, first two EU-wide stress testing exercises by the CEBS (2010a) and the EBA (2011) largely contributed to financial instability rather than restoring confidence because they were perceived as uninformative, not trustworthy, and less credible since banks (i.e. Dexia in Belgium) and financial systems (i.e. Ireland and Greece) failed after the 2010 test results were published.

At the back of increased financial turbulence, the SCAP had two fundamental goals; (1) to reduce uncertainty by minimizing bank opacity via transparency (disclosing stress testing results); and (2) to restore confidence in the financial system as a whole by ensuring that each BHC had adequate capital with sufficient buffers to absorb stressed losses. The SCAP stress tested 19 BHCs, each of which with a combined total assets of $100 billion or more at year-end

2008. These 19 BHCs (SIBs) have controlled nearly 70% of all assets in US banking system and collectively owned over 50% of loan types generated in the banking sector. The duration of the SCAP was two years covering 2009 and 2010; the BHCs were also asked at the end of the program (Q4 2010) to estimate their required capital buffers for 2011 (Fed, 2009a, b).

The SCAP employed two stress testing scenarios; baseline and more adverse, the latter scenario involved a more severe and prolonged recession contributed by persistent declines in GDP and house prices, and a surge in unemployment. Capital ratios for each BHC were calculated based on these scenarios and compared with the threshold levels. Because the SCAP's ultimate goal was to ensure capital adequacy with sufficient capital buffers, BHCs with a projected capital shortfall were mandated to raise fresh capital to comply with the regulatory minimum target levels without improving their capital ratios through a contraction in lending activities or a reduction in balance sheet exposures. The SCAP's key results indicated a cumulative capital shortfall of $185 billion, but the net final figure was only $75 billion after taking into account asset sales, preferred shares-to-common stock conversions, and other measures (Table 2.1). Out of the ten BHCs with a capital deficit, only GMAC (changed to "Ally Financial" after the SCAP) used the backstop (Fed, 2009b). Full disclosure of the SCAP's results was certainly a radical departure from then the non-disclosure practice by both banks and the supervisory community.

Since the SCAP, which was received well in the U.S. for being informative and transparent; there is ever more concern that the Federal Reserve's Comprehensive Capital Analysis and Review (CCAR) and Dodd-Frank Act Stress Testing (DFAST) may be becoming increasingly predictable (e.g., Glasserman & Tangirala, 2015). Hirtle et al. (2014) study is in agreement with this presumption, and Acharya et al. (2013) propose alternate models using public data as standalone or complement to stress testing. Some things to be foreseeable is desirable, but predictable outcomes in supervisory stress testing can have serious consequences. If stress tests become more of a routine task for banks, their results will be less informative as future risk exposures may be undetected or captured insufficiently due to the dynamic nature of risks which constantly evolve triggered by fast-changing domestic and external conditions. The SCAP and other stress testing programs in the U.S. have promoted trust and credibility, but some downside risks exist as well; making stress testing models public may give incentives to banks to rely on them rather than developing their own risk assessment models. Also, publicly disclosed stress testing models may lead to an oversight on the part of each bank to perceive risks in the same way and be subject to flaws of the model (Bernanke, 2013; Schuermann, 2012).

The results of the 2009 SCAP conducted by the Federal Reserve indicate massive losses facing the 19 BHCs; majority of the projected losses is related to the first lien mortgage and consumer loans ($322 billion). The projected aggregate loss ($599.2) during the stress testing horizon is the highest (9.1% of total loans), this is even greater than the astounding loss years of the Great Depression (9% during 1933-34). The 9 BHCs have sufficient capital to meet or exceed the minimum requirements of 6% Tier 1 capital and 4% Tier 1 common capital; in other words, the needed capital buffers ($75 billion) belonged to 10 BHCs (Fed, 2009b).

As the most severe episode of the GFC has receded and markets have been progressively stabilizing thanks to the SCAP's ability to restore confidence and a series of measures (see Figure 2.1 for the framework used in the 2011 EBA Capital Exercise) taken in the EU to improve negative investor sentiment; the EU and the US, going forward, have shifted their utmost focus towards addressing systemic risk through the use of regular stress tests during benign market conditions. After the consecutive EU-wide stress testing disappointments (the CEBS in 2009 and 2010, and its successor, the EBA in 2011), an EU legislation created the European Systemic Risk Board (ESRB) and the European Supervisory Authorities (ESAs); the latter cooperates with three other key authorities; as such, the European Insurance and Occupational Pensions Authority (EIOPA), the European Banking Authority (EBA), and the European Securities and Markets Authority (ESMA); all of these began operations in 2011.

The US legislative initiatives enabled the developments of two new stress testing programs despite SCAP's success; Comprehensive Capital Analysis and Review (CCAR), the scope of which is microprudential in nature, and macro stress tests under the Dodd-Frank Wall Street Reform and Consumer Protection Act; both stress testing programs are under the responsibility of the Federal Reserve. With the CCAR, the U.S. authorities intend to ensure that bank holding companies have adequate capital via robust internal capital-planning processes put in place by banks; the DFA stress tests (DFAST) aim to safeguard the resilience of the entire financial system by ensuring that banks have sufficient capital as well as adequate buffers to absorb losses while continuing operations under highly adverse economic conditions (Fed, 2013a).

The Federal Reserve has labeled the CCAR, succeeding the SCAP, as a *"forward-looking"* exercise, through which the Federal Reserve ensures that 19 BHCs "...hold sufficient capital in order to maintain access to funding, to continue to serve as credit intermediaries, to meet their obligations to creditors and counterparties, and to continue operations, even under adverse economic conditions" (Fed, 2012). The CCAR has become a centerpiece in the development of supervisory assessments by the Federal Reserve, which believes that the program encourages BHCs to put in place robust capital planning processes to constitute risks relevant to each BHC.

The Comprehensive Capital Analysis and Review process begins with each BHC conducting own analysis as to where it stands in capital position under baseline and adverse scenarios, and then submitting their capital plans to the Federal Reserve, which in turn evaluates the plans to project revenues, losses, expenses, and capital ratios for each BHC under its own provided severely adverse scenario. Furthermore, the Federal Reserve's evaluation considers five specific areas of supervisory considerations; (1) capital assessment and planning processes; (2) capital distribution policy; (3) plans to repay any government investment; (4) ability to absorb losses under several scenarios; and (5) plans for addressing the expected impact of Basel III and the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 (Fed, 2011).

The CCAR differs in many critical aspects from the SCAP and the DFAST. The primary goal of the SCAP was to identify whether or not any of the 19 BHCs had capital shortfalls, and to ensure that those BHCs with insufficient capital managed to raise fresh funds to comply with the regulatory minimum Tier 1 common capital ratio (4%) within six months after the SCAP's results were published (the Treasury's CAP, a government backstop, was also available for a last resort if BHCs failed to raise the needed capital from private markets). The DFAST, on the other hand, ensures that large BHCs have sufficient consolidated capital to absorb losses under highly adverse market conditions in an acute stress; however to achieve adequate capital on an aggregate basis, BHCs are required to conduct regular own stress tests once or twice a year.

In contrast to the SCAP and DFAST, the CCAR is a broader exercise and more microprudential in nature as it focuses on creating a proactive culture where banks will have a natural propensity to develop robust internal mechanisms for capital adequacy and capital planning, and because of this, the CCAR is considered to be *"forward-looking"* as opposed to the SCAP that focused only on outcomes indicating adequate capitalization or needed re-capitalization (Fed, 2011).

In the 2012 CCAR, the focus was still the original 19 BHCs that took part in the 2009 SCAP, but the Federal Reserve's final rule in November 2011 increased the number of BHCs to 30. Although the new 11 BHCs with consolidated assets of $50 billion or more were not included in the 2012 CCAR (took part in 2014 DFAST), they were required to submit their capital plans to the Federal Reserve to be evaluated in a separate process called the 2012 Capital Plan Review (CapPR) as they were subject to different requirements. BHCs were asked to make two sets of projections under *"BHC scenarios"* (one baseline and one stress scenario, developed by the bank) and *"supervisory scenarios"* (one baseline and one stress scenario, developed by the Federal Reserve) over the stress testing horizon spanning Q3 2011 through Q4 2013.

The 19 BHCs provide the required input data to the Federal Reserve, where analysts calculate the stress testing projections using a set of models either developed or selected by the Federal Reserve. In the 2012 CCAR scenarios, extreme but plausible events were assumed; real GDP contracts sharply through Q4 2012; the unemployment rate climaxes at little over 13% in mid-2013; the U.S. equity prices loose half of their Q3 2011 values through Q4 2012; the U.S. house prices plunge in excess of 20% by the end of 2013; foreign real GDP growth contracts (the euro area, the UK, developing Asia, and Japan), and growth slowdowns in Europe and Asia in 2012. The SCAP was informative but it lacked capital planning aspect, the CCAR was expected to be even more informative as the Federal Reserve "...believes that providing information about both the results of the stress scenario projections and the methodology will provide useful context for market participants, analysts, academics, and others to interpret the results" (Fed, 2012).

Table 2.2: Federal Reserve stress tests: CCAR & DFAST

Federal Reserve estimates in the severely adverse scenario

Loss Elements	2012 CCAR 19 BHCs		2013 DFAST 18 BHCs		2014 DFAST 30 BHCs		2015 DFAST 31 BHCs		Aggregate Average 2011 through 2016	
	Actual Q3 2011	Stressed Q4 2013	Actual Q3 2012	Stressed Q4 2014	Actual Q3 2013	Stressed Q4 2015	Actual Q3 2014	Stressed Q4 2016	Actual	Stressed
Tier 1 common ratio (%)	10.1	6.3	11.1	7.7	11.5	7.8	11.9	8.4	11.15	7.55
Tier 1 capital ratio (%)	12.3	7.8	12.9	9.1	12.9	8.5	13.5	8.6	12.90	8.50
Total risk-based capital ratio (%)	15.5	11.2	15.7	11.7	15.6	11.0	16.2	11.0	15.75	11.23
Tier 1 leverage ratio (%)	7.4	4.7	8.0	5.9	8.4	5.9	8.8	5.9	8.15	5.60
	$ Billion	PLR %	$ Billion	PLR %	$ Billion	PLR %	$ Billion	PLR %	$ Billion	PLR %
Loan losses	341	8.1	316.6	7.5	366.1	6.9	340.3	6.1	341	7.15
First lien mortgages, domestic	61	7.3	60.1	6.6	62.8	5.7	39.7	3.6	55.9	5.8
Junior liens and HELOCs, dom.	56	13.2	37.2	9.6	43.5	9.6	34.0	8.0	42.68	10.1
Commercial and industrial	67	8.2	60.5	6.8	62.3	5.4	67.8	5.4	64.4	6.45
Commercial real estate, dom.	24	5.2	32.9	8.0	48.9	8.4	52.8	8.6	39.65	7.55
Credit cards	92	17.2	87.1	16.7	93.0	15.2	82.9	13.1	88.75	15.55
Other consumer	26	5.9	26.8	6.1	32.5	6.0	35.1	5.8	30.1	5.95
Other loans	16	2.3	11.9	1.8	23.2	2.7	28.0	2.9	19.78	2.43
	$ Billion	PAA %	$ Billion	PAA %	$ Billion	PAA %	$ Billion	PAA %	$ Billion	PAA %
Pre-provision net revenue	294	2.5	267.8	2.4	315.9	2.3	309.6	2.1	296.8	2.33
Provisions	324	---	317.2	---	398.6	---	381.9	---	355.3	---
Real. losses/gains on securities	31	---	12.9	---	7.0	---	17.8	---	17.18	---
Trading and counterparty losses	116	---	97.0	---	98.1	---	102.7	---	103.5	---
Other losses/gains	45	---	36.0	---	29.3	---	29.3	---	34.9	---
Net income before taxes	-222	-1.9	-194.1	-1.7	-217.1	-1.6	-222.2	-1.5	-161.5	-2.3

Source: Federal Reserve (Fed, 2012; 2013b; 2014b; and 2015b); PLR: Portfolio loss rates; PAA: Percent of average assets

BHC: Bank Holding Company; CCAR: Comprehensive Capital Analysis and Review; DFAST: Dodd-Frank Act Stress Test

Notes: After the SCAP (2009), the US Federal Reserve created two new stress testing programs. The results of 2012 CCAR indicated that 19 BHCs with consolidated assets over $50 billion had sufficient capital ratios which were above the hurdle rate of 5% Tier 1 capital. Although the financial losses before taxes improved, but they were still significantly high ($222 billion). The detailed explanation and comparisons are provided pp 96-98.

Table 2.3: Projected Tier 1 common ratio under the severely adverse scenario

18 BHCs in DFAST 2013; 19 in CCAR 2013; 30 in CCAR/DFAST 2014; and 31 in CCAR/DFAST 2015	DFAST 2013		CCAR 2013	DFAST 2014		CCAR 2014	DFAST 2015		CCAR 2015
	Actual Q3 2012	Stressed Q4 2014	Q4 2012 Q4 2014	Actual Q4 2013	Stressed Q4 2015	Q4 2013 Q4 2015	Actual Q4 2014	Stressed Q4 2016	Q4 2014 Q4 2016
Ally Financial Inc.	7.3	1.5	1.78	7.9	6.3	6.3	9.7	7.9	7.1
American Express Company	12.7	11.3	4.97	12.8	14.0	8.4	13.2	15.5	8.2
Bank of America Corporation	11.4	6.9	6.04	11.1	6.0	5.0	11.3	7.4	6.8
Bank of New York Mellon Corporation	13.3	15.9	13.21	14.1	16.1	12.7	13.9	16.0	11.4
BB&T Corporation	9.5	9.4	7.76	9.4	8.4	8.1	10.5	8.1	7.1
BBVA Compass Bancshares, Inc.	---	---	---	11.6	8.5	8.1	11.0	6.3	6.3
BMO Financial Corp.	---	---	---	10.8	7.6	7.6	11.5	9.0	9.0
Capital One Financial Corporation	10.7	7.4	6.69	12.7	7.8	5.6	12.7	9.5	7.0
Citigroup Inc.	12.7	8.9	8.82	12.7	7.2	6.5	13.4	8.2	7.1
Citizens Financial Group, Inc.	---	---	---	13.9	10.7	9.0	12.9	10.7	9.8
Comerica Incorporated	---	---	---	10.7	8.6	7.8	10.6	9.0	7.9
Deutsche Bank Trust Corporation	---	---	---	---	---	---	36.6	34.7	34.7
Discover Financial Services	---	---	---	14.7	13.7	8.7	14.8	15.3	10.4
Fifth Third Bancorp	9.7	8.6	7.50	9.9	8.4	7.5	9.6	7.9	6.9
The Goldman Sachs Group, Inc.	13.1	8.2	5.26	14.2	9.2	5.7	15.2	9.9	5.8
HSBC North America Holding, Inc.	---	---	---	14.7	6.6	6.6	14.0	8.9	8.9
Huntington Bancshares Incorporated	---	---	---	10.9	7.4	6.0	10.3	9.0	7.9
JP Morgan Chase & Co.	10.4	6.8	5.56	10.5	6.7	5.5	10.9	6.5	5.0
KeyCorp	11.3	8.0	6.75	11.2	9.3	8.0	11.3	9.9	8.5
M&T Bank Corporation	---	---	---	9.1	6.2	6.7	9.8	7.3	6.9
Morgan Stanley	13.9	6.4	5.62	12.6	7.6	5.9	15.0	8.8	5.9
Northern Trust Corporation	---	---	---	13.1	11.7	10.0	12.8	12.4	10.8
The PNC Financial Services Group, Inc.	9.5	8.7	8.55	10.3	9.0	8.1	11.0	9.5	8.0
Regions Financial Corporation	10.5	7.5	7.00	11.0	9.0	8.2	11.8	8.3	6.8
Santander Holdings USA, Inc.	---	---	---	13.7	7.3	7.9	11.0	9.4	9.4
State Street Corporation	17.8	13.0	9.65	15.5	14.7	11.4	13.9	14.3	10.8
SunTrust Banks, Inc.	9.8	7.3	6.91	9.9	9.0	8.0	9.6	8.2	7.3
U.S. Bancorp	9.0	8.3	6.61	9.3	8.3	6.6	9.5	8.6	7.3
Wells Fargo & Company	9.9	7.0	5.94	10.6	8.2	8.7	10.8	7.6	6.2
Zions Bancorporation	---	---	---	10.5	3.6	8.1	11.9	5.1	5.1

Source: Federal Reserve (Fed, 2013a,b; Fed, 2014a,b; Fed, 2015a,b)

BHC: Bank Holding Company; CCAR: Comprehensive Capital Analysis and Review; DFAST: Dodd-Frank Act Stress Test

Notes: The projected Tier 1 ratios of the 31 BHCs are provided. The detailed explanation and comparisons are provided pp 96-98.

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As illustrated in Table 2.2 and 2.3, most of the 19 BHCs prior to the 2012 CCAR had sufficient capital ratios above the benchmark 5% Tier 1 common ratio, but the enormous projected losses ($534 billion, a slight improvement over the SCAP's $600 billion) resulted in a massive decline of more than $300 billion (from $741 to $438) in the aggregate Tier 1 common capital for the course of the stress testing horizon (Q3 2011 to Q4 2013). Subsequently, the projected aggregate net loss (-$222 billion) sets a record as the lowest in the history of the U.S. banking industry (Table 2.2), largely attributable to most regulatory capital ratios dropping more than 36% (Tier 1 common ratio, Tier 1 capital ratio, and Tier 1 leverage ratio) and the total risk-based capital ratio declining close to 28%. Detailed BHCs capital ratios are given in Table 2.3.

High projected losses and low pre-provision net revenue (PPNR) caused at least 3-4 BHCs, whose post-stress Tier 1 common ratios below hurdle rate of 5% set by the Federal Reserve, to become subject to the Federal Reserve's objections to their planned capital actions (Table 2.3). The nature of stress tests in the U.S. has changed vastly since the Congress enacted the Dodd-Frank Wall Street Reform and Consumer Protection Act in July 2010 which required 18 BHCs to undergo the Dodd-Frank supervisory stress test (DFAST) in 2013 (the requirements were implemented in October 2012). The Federal Reserve and its supervisors have the responsibility of designing and conducting system-wide (i.e. CCAR and DFAST) and bank-run stress tests.

Since the SCAP (2009) and the CCAR (2011), the BHCs' common equity Tier 1 (CET1) ratios have improved significantly; adding $380 billion (from $412.5 billion at the end of 2008 to $792 billion at the end of 2012). This huge increase made the weighted average common equity Tier 1 ratio of the 19 BHCs double (from 5.6% in Q4 2008 to 11.14% in Q4 2012). The Federal Reserve attributes this sizable increase to "...a significant accretion of common equity through retained earnings". BHCs have also raised equity from external sources, including the equity raised in connection with the redemption of U.S. government investments under the Troubled Asset Relief Program and following the SCAP (Fed, 2013a).

Even though losses have been moderating (Table 2.2), the Federal Reserve's loss projections suggest that the BHCs would still face substantially high losses under the severely adverse scenario. Over the stress testing horizon of nine quarters, the projected losses were $462 billion at the 18 BHCs in the DFAST 2013 and $501 billion at the 30 BHCs in the DFAST 2014. Table 2.2 shows that the aggregate Tier 1 common ratios fall from an actual 11.14% (Q3 2012) to a stressed 7.7% in Q4 2014 (a reduction of 30.9%) and from an actual 11.5% (Q3 2013) to a stressed 7.8% in Q4 2015 (a decrease of 32.18%). High losses and low projected pre-provision net revenue (PPNR) at the BHCs result in net loss before taxes of -$194 billion in DFAST 2013, -$217 billion in DFAST 2014, and -222.2 billion in DFAST 2015.

After the Federal Reserve's quantitative analysis (derived from the results of the DFAST and bank-run stress tests) and qualitative assessment (BHCs' capital planning processes), the Federal Reserve makes decisions to reject or object to BHCs' proposed capital actions. As shown in Table 2.3, the Federal Reserve has objected to capital plans of 12 BHCs in the last four years, the details of which are explained in Fed (2013a; 2014a; 2015a); four BHCs in CCAR 2013 (the Goldman Sachs and JP Morgan Chase received a non-conditional objection, allowing original capital actions to continue but subject to BHCs resolving the Federal Reserve's suggested impediments by the end of September 2013; Ally Financial and BB&T Corporation received an objection); five BHCs in CCAR 2014 (Citigroup, Citizens Financial, HSBC North

America, Santander Holdings, and Zions Bancorporation received an objection); and three BHCs in CCAR 2015 (Bank of America, Deutsche Bank Trust, and Zions Bancorporation).

Table 2.4: Loan losses in the severely adverse scenario

in billions of dollars	SCAP 2009	CCAR 2012	DFAST 2013	DFAST 2014	DFAST 2015
Loan losses (projected)	499	342	317	366	340
First lien mortgages, domestic	102	61	60	63	40
Junior liens and HELOCs, domestic	83	56	37	44	34
Commercial and industrial	60	67	61	62	68
Commercial real estate, domestic	53	24	33	49	53
Credit cards	82	92	87	93	83
Other consumer	35	26	27	33	35
Other loans	84	16	12	23	28

Source: Fed (2009b; 2012; 2013b; 2014b; 2015b); see table 2.3 for denotation.

Notes: First lien mortgages and credit cards related losses were a major concern in the U.S. This table illustrates the improvement made in the levels of mortgage related losses.

Table 2.4 shows a major improvement in the projected loan losses since the Fed's SCAP, but the loss levels are still significant. In the aggregate, the projected loan losses has declined from \$499 billion in 2009 to \$340 billion in 2015. First lien mortgages, junior liens and HELOCs saw the biggest drop; a decrease of 60%, from a combined \$185 billion to \$74 billion.

In parallel with the U.S., the Committee of European Banking Supervisors (CEBS) was also mandated by the Economic and Financial Affairs Council (ECOFIN) to conduct a coordinated an EU-wide macro stress testing exercise for the period of 2009-2010, which was based on banks' consolidated assets at the end of 2008. The objective of the CEBS (2010) was "...to provide policy information for assessing the resilience of the EU banking system to possible adverse economic developments and to assess the ability of banks in the exercise to absorb possible shocks on credit and market risks, including sovereign risks". Contrary to the SCAP, the focus of the EU-wide stress test was not to check whether individual banks had capital shortfalls or recapitalization needs. In the CEBS (2009), similar to the SCAP, the consolidated assets of the 22 SIBs with substantial cross-border activities represented over 60% of all assets and 50% of loans originated in the EU banking sector.

Table 2.5: Crisis stress tests: jurisdictions and authorities

Jurisdiction	Stress Testing Exercise	Stress Tester	Participating Authorities
United States	CSAP 2009, Bottom-up (BU) - Top-down (TD)	Authorities	Federal Reserve, Federal Deposit Insurance Corporation (FDIC), and Office of the Comptroller of Currency (OCC)
European Union	CEBS 2009, BU with a peer review using ECB parameters	Authorities	National supervisory authorities, CEBS, European Commission (EC) and European Central Bank (ECB)
	EBA 2010, BU with a TD analysis, ESRB/ECB	Authorities	National supervisory authorities, CEBS, EC and ECB
	European Banking Authority (EBA) 2011	Authorities	National supervisory authorities, EBA, EC, ECB and European Stability Risk Board (ESRB)
Ireland	PCAR 2011 (Prudential Capital Assessment and Review), BU	Authorities (loan loss inputs from BlackRock Solutions	Central Bank of Ireland (CBI)
Spain	Top-down (TD) 2012	Oliver Wyman and Roland Berger	Banco de España (BdE), Ministry of Economy and Competitiveness (MEC), the Troika, representatives from two EU countries
	Bottom-up (BU) 2012	Oliver Wyman	BdE, MEC, the Troika and EBA

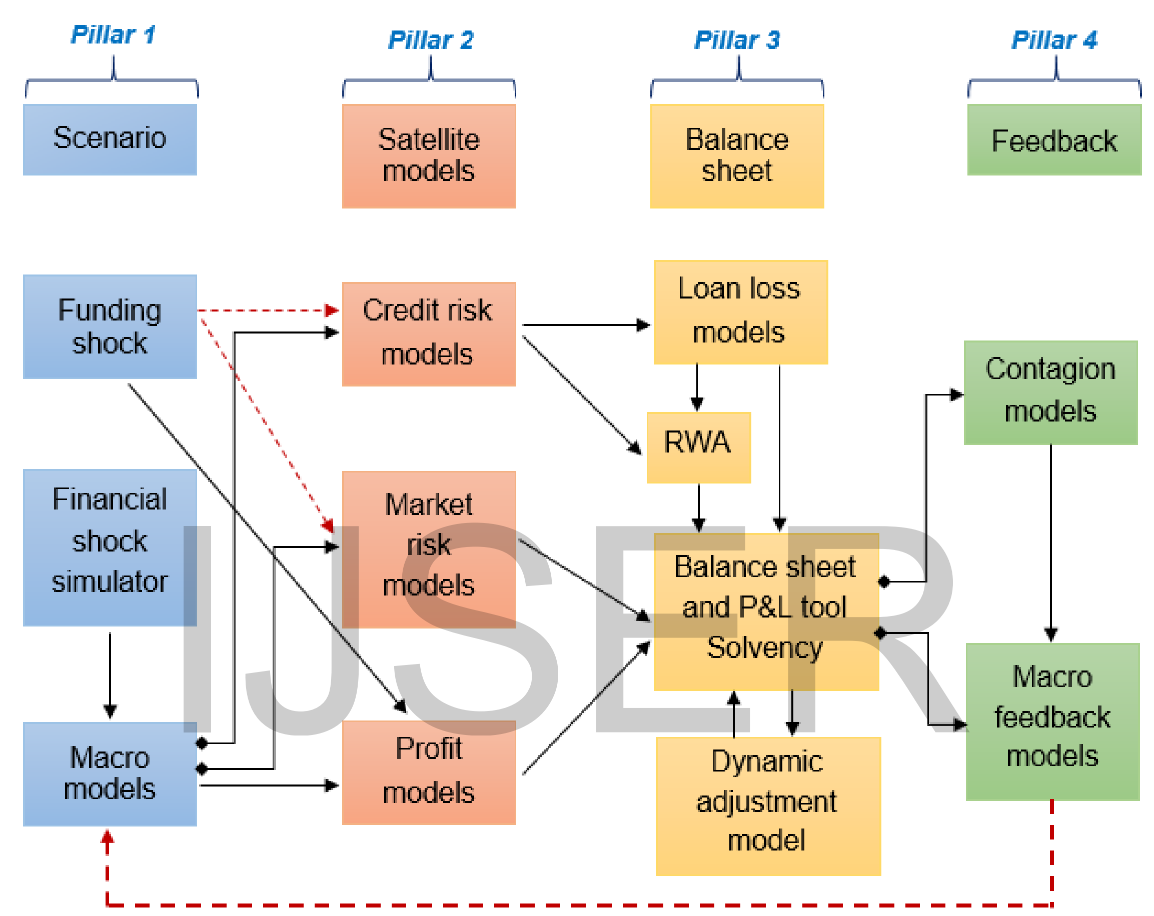
Source: Ong & Pazarbasioglu (2013)

Notes: For the success of a stress testing exercise, it is very important to decide what stress testing approach to employ and to determine what authorities need to participate. This table shows a comparison among jurisdictions. Mainly, a top-down, bottom-up, or a hybrid approach was used; except the stress test of Ireland, the participating authorities in other jurisdictions included a wide range of government branches.

As the “new normal” (e.g., Ong & Pazarbasioglu, 2013), the bank solvency stress tests were used in the U.S. and the EU to restore confidence as the GFC deepened sharply, promising massive losses in the aggregate. However, the comparison suggests that stress tests across two regions differed in several key aspects (e.g. Table 2.5); in stark contrast to the SCAP (benchmark), the CEBS and EBA bungled on their first EU-wide stress tests, largely due to varying degrees of effectiveness, governance, and absence of a financial backstop. Wall (2013) argues that a government-provided backstop enables supervisors to identify tail risks better. The SCAP was a defining moment in the GFC as it provided credible and market-demanded information regarding the projected post-stress losses of the 19 BHCs (e.g., Bernanke, 2013).

Stress tests must be credible and reliable; to achieve that, Tarullo (2010) argues that stress tests must be consistent and comparable; furthermore, stress tests must be rigorous with exceptional but plausible scenarios. Effective governance of stress tests is also of great importance. While the Federal Reserve's SCAP resulted in positive impact on the BHCs' market valuations in the U.S., the EU-wide stress tests involving many jurisdictions had negative impact on the equity market in euro zone as the results of the CEBS (2010) and EBA (2011) were not sufficiently granular; besides, the CEBS (2009) did not even publish bank-specific results, only indicated in a brief summary that all 22 banks achieved 6% or higher post-stress threshold Tier 1 capital.

The EU-wide stress tests use the ECB bank solvency framework (Figure 2.1), where the *first pillar* deals with the scenario design phase which includes macro financial variables as ingredients used in creating severe enough scenarios to be imposed on banking sectors. The *second pillar* employs top-down satellite models which translate the effects of scenarios on balance sheet components of banks and measure banks' loss absorption capacity. The *third pillar* involves assessing bank solvency using the *balance sheet module* which gives the resultant projected P&Ls produced by the satellite models. The *fourth pillar* looks beyond the first-round impact on bank capital adequacy, it investigates second-round effects arising from contagion within and across financial systems along with feedback effects to the real economic activity; liquidity and interbank exposures need to be stress tested as well (ECB, 2013).



Source: Adapted from ECB (2013)

Notes: Bank solvency has become a central focus in recent years, and the thesis used this framework throughout the analyses to understand and explain interactions as well as linkages between banks' operations involving exogenous and endogenous shocks.

Figure 2.1: ECB bank solvency framework

As illustrated in Figure 2.1, the ECB solvency framework, similar to a stress testing framework, begins with the scenario design (pillar 1) where funding shock resulting from credit and market risks are considered. Macro factors and their impact on credit and market exposures (loan losses) as well as profitability (ROA and ROE) are taken into account.

Table 2.6: Crisis stress tests: macro-financial parameters scorecard

Parameter		Application to Stress Tests							
Variable	Indicator	US	European Union			Ireland	Spain		
		SCAP 2009	CEBS 2009	CEBS 2010	EBA 2011	PCAR 2011	FSAP 2012	TD 2012	BU 2012
Growth	Real GDP	x	x	x	x	x	x	x	x
	Real GNP					x			
	Nominal GDP						x	x	x
Employment	Unemployment	x	x	x	x	x	x	x	x
	Employment					x			
Price evolution	CPI		2/		x	x	x	x	x
	HICP				x	x			
	GDP deflator					x	x	x	x
Consumption	Private					x			
	Government					x			
Trade	Exports					x			
	Imports					x			
	Balance of payments					x			
Income and investment	Investment					x			
	Personal disposable income					x			
Real estate	Real estate prices	x	x	x	x	x	x	x	x
	Comm. property		x	x	x	x			
	Resid. property		x	x	x	x	x	x	x
	Land							x	x
Interest rate	Up to 1 year		2/	x	x		x	x	x
	Up to 5 year		2/					x	x
	More than 5 years		2/	x	x		x	x	x
Exchange rate	Relative to U.S. dollar		2/	x	x		x	x	x
Stock market	Stock price index		2/	x	x		x	x	x
Credit to other resident sectors	Households						x	x	x
	Non-financial corporate						x	x	x

Source: Ong & Pazarbasioglu (2013)

2/ Information not disclosed.

Notes: Macro-financial parameters used in stress tests are widely disparate. This scorecard shows what macro parameters were used by the U.S., European Union, Spain, and Ireland. This is important and works as a road map for countries which are attempting for the first time to design and conduct micro and macro stress tests.

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Table 2.7: Crisis stress tests: risk factors scorecard

Risk Factor			Application to Stress Tests							
Risk type	Nature of accounting	Exposures	US	European Union			Ireland	Spain		
			SCAP 2009	CEBS 2009	CEBS 2010	EBA 2011	PCAR 2011	FSAP 2012	TD 2012	BU 2012
Credit Risk	…	Residential mortgage	x	1/	x	x	x	x	x	x
		First lien	x							
		Second lien	x							
		Commercial / industrial loans	x							
		Corporate loans		1/	x	x	x	x	x	x
		RE developers						x	x	x
		SME loans				x	x		x	x
		CRE loans				x	x			
		Fin. inst. loans		1/	x	x				
		Consumer loans (including credit cards)	x	1/	x	x	x		x	x
		Revolving loans				x				
		Public works							x	x
		Sovereign exposure in available-for-sale (AfS) banking book				x				
		Other loans	x							
Market Risk	Trading book	Sovereign portfolio	x	1/	x	x	x	x		
		Financial ins. portfolio	x	1/	x	x	x	x		
		Other securities (MBS and other ABS)	x				x			
		Private equity holding	x							
		Counterparty credit exposures to OTC derivatives	x							
	Banking book (AfS)	Sovereign portfolio	x					x		
		Financial ins. portfolio	x					x		
		Other securities (MBS and other ABS)	x				x			
	Banking book (HtM)	Sovereign portfolio	x							
		Financial ins. portfolio	x							
		Other securities (MBS and other ABS)	x				x			
Operational Risk						x	x			
Separate liquidity test						2/	x	x		

Source: Ong & Pazarbasioglu (2013)

1/ Information not disclosed, HtM: Hold to maturity, AfS: Available for sale

2/ The EBA conducted a confidential thematic review of liquidity funding risks.

Notes: Deciding the right risk factors to stress test is very crucial, therefore choosing wrong risk factors will adversely affect the outcome and may result in further losses. This scorecard shows the risk types stress tested by the U.S., European Union, Spain, and Ireland. Again, this is very important as a roadmap.

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The focus of the CEBS 2010 EU-wide stress testing exercise is on credit and market risks with close attention paid to the European sovereign debt; the assessment of capital adequacy was a central focus, which excluded stress testing of liquidity risk directly. The sample size increased little more than fourfold to 91 banks, 26 large cross-border banking groups and 65 domicile credit institutions (22 large SIBs with sizable cross-border activities took part in the CEBS 2009 exercise), representing two-thirds (65%) of the aggregate assets (€28,032 billion as of year-end 2009) of the entire EU banking sector. The stress testing horizon is two years (2010 and 2011), during which the scenarios are applied to the consolidated bank data at the end of 2009. The scenarios are developed by the CEBS in coordination with the ECB (estimates for the adverse scenario as well as real estate price evolution) and the EU Commission. The benchmark scenario assumes 1% GDP growth for EU27, before reaching 1.7% in 2011 (Table 2.8); unemployment is high, the consumer price inflation is stable except in some countries where inflation declines or moves up due to country-specific cyclicality (CEBS, 2010a).

Table 2.8: Key macro-economic variables in CEBS 2010 scenarios

Regions	Actual %			Benchmark %		Adverse %	
	2008	2009	2010 Q1	2010	2011	2010	2011
EU27							
GDP (y-o-y)	0.7	-4.2	0.2	1.0	1.7	0.0	-0.4
Unemployment (% labor force)	7.0	8.9	9.6	9.8	9.7	10.5	11.0
Euro area							
GDP (y-o-y)	0.6	-4.1	0.2	0.7	1.5	-0.2	-0.6
Unemployment (% labor force)	7.5	9.4	10.0	10.7	10.9	10.8	11.5
US							
GDP (y-o-y)	0.4	-2.4	0.7	2.2	2.0	1.5	0.6
Unemployment (% labor force)	5.8	9.3	9.7	10.0	10.2	10.2	11.1

Source: The Committee of European Banking Supervisors (CEBS, 2010a)

Notes: It is extremely complex to incorporate macroeconomic variables in the stress test. There are many different variables but GDP, unemployment, and interest rate are popularly used.

The results of the CEBS 2010 indicate that the aggregate Tier 1 capital ratio falls little over one percent under the adverse scenario (from 10.3% in 2009 to 9.2% by the end of 2011), which includes sovereign shock and €169.6 billion of a government backstop till July 1 2010. The aggregate losses under the adverse scenario for the two-year stress testing horizon is €565, of which; €472.8 billion associated with impairment losses, €25.9 billion belonged to trading losses, and €67.2 billion arose from additional sovereign shock (of this amount, €38.9 billion related to the losses in the trading book). Under the adverse scenario, seven banks failed to meet the benchmark Tier 1 capital ratio of 6%, resulting in an overall capital shortfall of €3.5 billion; however, the CEBS emphasizes that the benchmark rate is not a regulatory requirement because the CRD – Capital Requirements Directive set the minimum Tier 1 capital ratio at 4% (CEBS, 2010a). The EBA conducted a new EU-wide stress test in 2011, 90 banks participated.

Ong and Pazarbasioglu (2013) have shown that the earlier EU-wide stress testing programs have contrasted with the U.S. SCAP in terms of macro financial parameters used (Table 2.6) and risk factors assumed (Table 2.7). Cardinali and Nordmark (2011), Ellahie (2012), and Petrella and Resti (2013) suggest that the CEBS (2010a) stress test was uninformative; as a result, disclosure of the test results caused a decline in equities. Beltratti (2011) argues that EBA (2011) stress test was informative in terms of methodologies and scenarios. Stress testing literature exemplifies that public disclosure of macro stress testing results along with methodologies and scenarios provides generalized benefits just as adequate disclosures reduce opacity of banks (Gick & Pausch, 2012; Morgan et al., 2010). The CEBS (2010a) EU-wide stress testing exercise suffered a huge puncturing blow when Ireland requested financial assistance after the results were published; further, instability ascended in markets when the systemically important Dexia

(Belgium) and Bankia (Spain) required restructuring shortly after passing the EBA 2011 stress test (EBA, 2011). Zandi and Zemcik (2014) feel that the EU still faces integration issues due to national discrepancies, governance, and economic variations. EU-wide stress tests are less credible because scenarios are arbitrary, capital definitions are different, and no supplemental scenarios for large banks with high risk exposures. In the wake of stress testing disappointments in the euro area early on, the opponents argue that the EBA has catching-up to do to reach the standards equivalent to the US Federal Reserve and the UK Prudential Regulatory Authority.

Table 2.9: Stylized categorization of stress tests

<table>
<tr><th></th><th>Type</th><th>Aim</th><th>Use</th><td rowspan="4">Region-wide micro- prudential stress tests:

Hybrid in methods and aims; multiple applications

Either bottom up or top down

Focus on comparability</td></tr>
<tr><td>Banks</td><td>Banks own stress testing (risk, portfolio or institution)</td><td>Risk management</td><td>Banks’ risk management and planning</td></tr>
<tr><td>Supervisors</td><td>Micro- prudential stress tests (risk, portfolio or institution)</td><td>Bank-by-bank information on risks and vulnerabilities</td><td>Supervisory risk analysis and action, early warning tools</td></tr>
<tr><td>Macroprudential authorities</td><td>System-wide macro-prudential stress tests (institution)</td><td>Aggregated information on systemic risks</td><td>Systemic stability, economic policy implications</td></tr>
</table>

Source: European Banking Authority (EBA, 2014)

Notes: Stress testing began as microprudential conducted by banks for own risk management purposes, but today the typology of stress testing was expanded to include two more which are mandatory for banks to participate and all three stress tests may be conducted simultaneously; microprudential stress test conducted by supervisors and macroprudential stress test as a crisis management tool conducted by central banks only. All three stress tests are conducted across ASEAN-5.

Since the CEBS 2010, EU governments took necessary steps to strengthen banks’ balance sheet; as a result, the starting average core Tier 1 capital ratio (CT1R) of 90 banks in the exercise was 8.9% which included €160 billion government backstop and €50 billion retained earnings. The results of the EBA 2011 EU-wide stress testing suggests that 20 banks would fall below the hurdle CT1R of 5% over the two-year stress testing horizon, which would result in an overall capital shortfall of €26.8 billion. However, when banks' raising capital actions are taken into account, only eight banks fail to meet the minimum CT1R of 5% and the capital shortfall is reduced to €2.5 billion, but one of the concerning outcomes of the exercise is that 16 banks' CT1Rs are close to the border line between 5% and 6% (EBA, 2011).

Table 2.10: 2014 EU-wide stress test results for Q4 2013 - Q4 2016

European Banking Authority estimates in the adverse scenario

Country/Region	Tier 1 common ratio			Number of failed banks			Shortfall € million
	AQR Adjusted 2013	2016		2016			
		Baseline	Adverse	Total	Baseline	Adverse	
All EU banks	11.1	11.6	8.5	123	14	24	**24,189**
Italy	9.5	9.3	6.1	15	8	9	9,413
Greece	9.9	8.0	2.0	4	2	3	8,721
Cyprus	4.4	9.5	-1.0	3	1	3	2,365
Portugal	11.1	10.1	5.9	3	0	1	1,137
Austria	10.5	10.6	7.4	6	1	1	865
Ireland	13.2	12.2	7.0	3	0	1	855
Belgium	14.0	11.9	7.2	5	0	2	540
Germany	12.8	12.8	9.1	24	1	1	228
Slovenia	15.9	14.4	6.1	3	0	2	65
France	11.3	11.8	9.0	11	1	1	0
Demark	14.2	15.4	11.7	4	0	0	0
Finland	16.4	17.6	12.0	1	0	0	0
Hungary	15.9	17.0	11.9	1	0	0	0
Latvia	9.8	10.5	7.7	1	0	0	0
Luxembourg	15.9	15.1	11.2	2	0	0	0
Malta	10.7	13.2	8.9	1	0	0	0
Netherlands	11.6	12.2	8.9	6	0	0	0
Norway	11.3	14.4	11.3	1	0	0	0
Poland	13.3	15.4	12.3	6	0	0	0
Spain	10.4	11.6	9.0	15	0	0	0
Sweden	15.3	16.9	13.7	4	0	0	0
United Kingdom	9.8	11.2	7.8	4	0	0	0
After capital raising	---	---	---	123	0	14	**9,500**

Source: European Banking Authority (EBA, 2014)

Notes: The SCAP by the Federal Reserve was followed by the EU's own version of macro stress tests, but the Committee of European Banking Supervisors (CEBS) and its successor the European Banking Authority (EBA) bungled on their EU-wide stress tests. This table illustrates the main results of the 2014 EU-Wide Stress Test. The aggregated capital shortfall of all EU banks, compared to those of the U.S., is relatively small.

The 2014 EU-wide stress test is coordinated by the EBA and conducted with cooperation from the ESRB, the EC, the ECB, and competent authorities from national jurisdictions. With respect to the EBA 2011 (no stress test was conducted in 2012), the stress testing horizon is raised to three years (2013-16) and the bank sample size has increased to 123 banking groups across the EU (including Norway) with a consolidated assets of €28,000 billion (over 70% of the aggregate EU banking sector). The threshold Tier 1 common ratio for adverse and baseline scenarios are set at 5.5% and 8.0% respectively (Table 2.10). First time in the EBA (2014) exercise, the weighted average Tier 1 common ratio has been subject to the asset quality review-AQR which has reduced the starting ratio as of end 2013 from 11.5% to 11.1% (40bps impact).

The impact is even greater in the adverse scenario, the projected aggregate Tier 1 common ratio is 8.5% (falls by 260bps), the main impact is a capital shrinkage of €261 billion (€67 billion of which arises from risk exposures) over the stress testing horizon of three years. In the adverse scenario, 24 banks (compared with 20 banks in the EBA 2011 stress test) end up falling below the 5.5% hurdle rate which results in an aggregate capital shortfall of €24.6 billion (€26.8 billion previously); after banks' capital raising actions in 2014, the capital shortfall is reduced to €9.5 billion (as opposed to €2.5 billion in the 2011 stress test) which belongs to 14 banks (Table 2.10). In the 2016 EU-wide stress test, bank data as of year-end 2015 will be used and last three years (2015 to 2018). As in the U.S. DFAST, Tier 1 common, and Tier 1 capital, total risk-based capital, and leverage ratios will be reported each year of the stress testing horizon.

2.2.3 Stress Testing Experience of ASEAN-5

In the wake of augmented financial turbulence coupled with increased complexity of banking supervision (helped by financial innovations and a surge in capital flows) and the resultant high-magnitude macro events (e.g. the Asian crisis of 1997-98), the IMF and World Bank were prompted to jointly initiate Financial Sector Assessment Program (FSAP) in 1999 to assess the resilience of financial sectors in member countries (IMF & World Bank, 2003). Stress testing is an integral component of an FSAP, which measures to see how individual banks together with the entire financial system can withstand extreme but plausible shocks. To date, the IMF has completed more than two-thirds of the 188 member-FSAPs, however the process is moving slow; thus, the IMF has expanded the initial goal of one FSAP per month to 24 FSAPs per year, but the current rate is still 17 to 19 per year (IMF, 2004a).

FSAPs attempt to identify strengths and weaknesses in the financial system through stress testing, and the focus of an FSAP is twofold: to gauge the stability of the financial sector and to assess its potential contribution to growth and development of non-financial sectors of the economy (IMF, 2013a). Hilbers (2001) sees three components of an FSAP as critical; (1) an assessment of micro/macro prudential reforms and development needs; (2) an assessment of vulnerabilities to macroeconomic and financial factors and; (3) an assessment of existing banking standards, laws, rules, codes, regulation, and supervision (for a longer perspective, see Blaschke et al., 2001 for earlier examples of stress testing; Krenn, 2001 for market risk; Evans et al., 2000 for macroprudential indicators; IMF & World Bank, 2003 for analytical tools; Boss, 2002 for macro stress test; Schneider & Leibrecht, 2006 for model description).

According to the IMF's definition, stress tests "…assess key risks and vulnerabilities arising from macro-financial linkages by assessing the impact of exceptional but plausible shocks to key macroeconomic variables on the soundness of the financial system" (IMF & World Bank, 2003). In September 2013, the IMF decided to incorporate the FSAP into its surveillance program known as *"Article IV Consultation"*; to promote stability, SIBs in 25 jurisdictions are required to undergo stress testing every five years. Due to FSAP's resource intensive nature, the work is shared; the IMF examines the soundness of financial sectors through stress testing; and the World Bank focuses on developmental aspects of financial sectors and their key contributions to advancement of other non-financial sectors.

The voluntary nature of FSAP has been criticized since the GFC; the proponents argue that countries voluntarily choosing to undergo FSAP or not may potentially impose instability on the global financial system; as such, the US, Indonesia, and Malaysia have not undergone nor requested participation prior to the GFC. Malaysia initially refused to participate in the IMF administered program due to resentments towards IMF's policy responses handling the Asian crisis; a widely perceived belief suggests that interest rate hikes and inappropriate fiscal measures of the IMF during and after the Asian crisis caused further deterioration in ASEAN-5 economies (BCBS, 1999a). Many in the crisis-affected countries assert that, giving the state of economies and frail banking systems, the IMF should have at least raised interest rates moderately and fiscal targets should have been less rigid. The IMF strongly defended its actions arguing that policy choices were limited without alternatives. Since 2006, central banks of ASEAN-5 have been designing/conducting own stress tests (Siregar, 2011).

The GFC has revealed flaws that FSAPs in some instances were unable to detect common sources of risks including liquidity, sovereign, and cross-border linkages; these were later addressed by the IMF and World Bank (2005a, b). FSAP has been initially praised as a forward-looking process for making stress tests systematic and consistently applied across the world, but misleading results (e.g. Iceland 2008) not only caused loss of credibility and left a scuff on the unblemished reputation of the IMF and World Bank. Iceland's financial system was on the brink of collapsing in contrast to remarks bluntly made by the IMF "As recognized by staff, liquidity ratios are high and capital levels are well above minimum levels. Banks pass liquidity tests as required by the Central Bank and their capital ratios remain above required minimums in rigorous stress tests conducted by the Financial Supervisory Authority" (IMF, 2008).

2.2.3.1 Stress Testing Experience of Indonesia

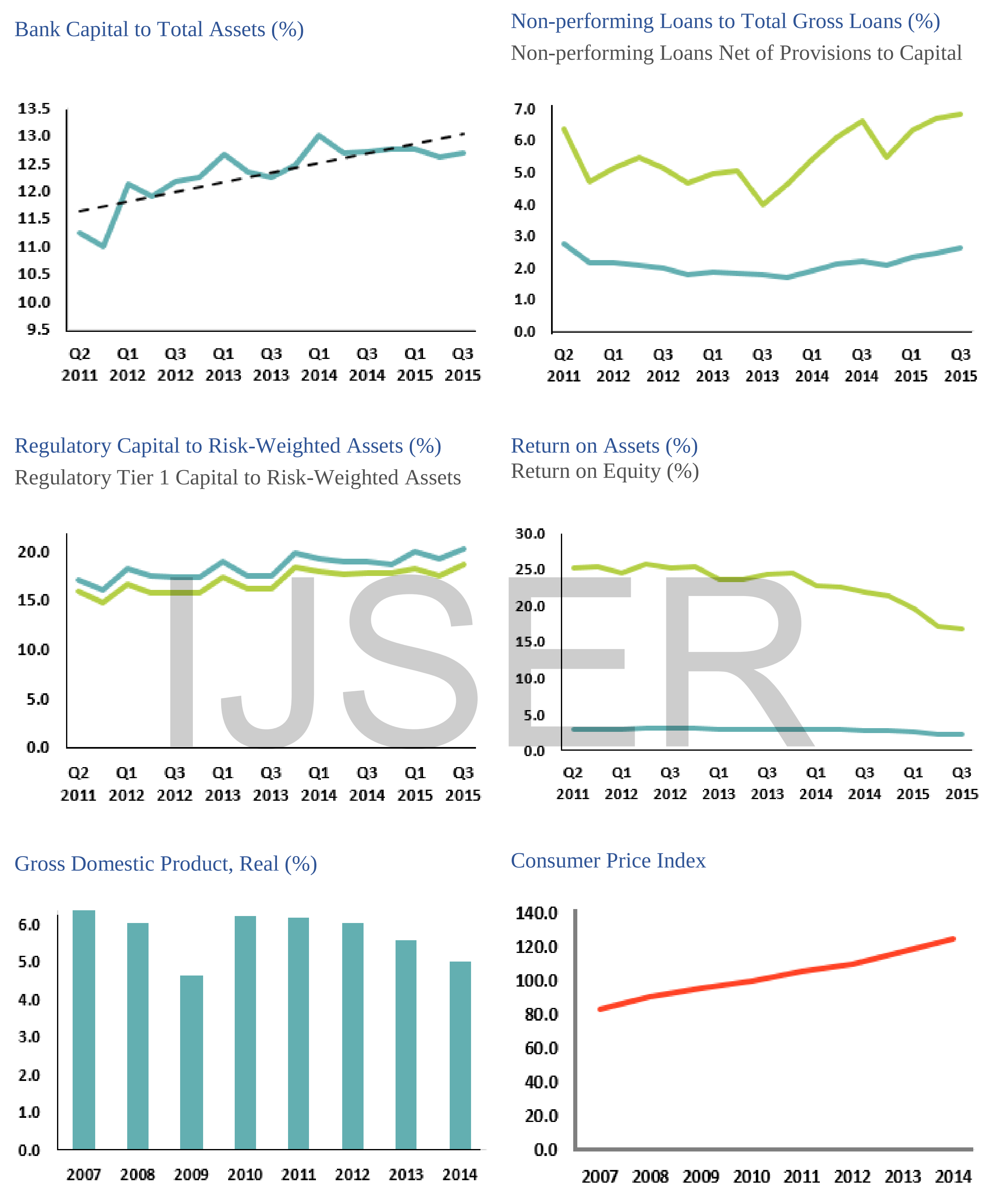
Indonesia went through the Financial System Stability Assessment (FSSA) during October 6-16, 2009 and February 24-March 10, 2010. The main findings suggest that Indonesia's sound micro and macroprudential policies along with structural reforms enabled Indonesia to recover quickly from the sweeping effects of the GFC. The remarkable financial progress was also aided by a more stable political environment and a healthy financial system. Indonesia's success however is eclipsed by persistent issues of weak transparency and governance.

Despite Indonesia's relentless efforts and remarkable achievements in the supervisory and macroeconomic frameworks, the financial system still remains to be fragile and susceptible to exogenous shocks as the financial sector's depth (e.g., non-financial sector is in infancy) and contribution to other sectors remain to be improved to catch up with peers within ASEAN-5. The low investors' confidence towards Indonesian securities is undermined by weaknesses in the enforcement of law in terms of creditors' rights and legal protection for regulators and supervisors. The results of stress tests show that Indonesia's strained banks (as they are the only source for credit) are vulnerable to credit risk while some mid-sized banks may face liquidity risk in the event of a financial crisis. To strengthen its oversight, the BI Act of 1999 overhauled banking supervision, insurance, and securities under one supervisory agency (IMF, 2010a).

In the wake of tumbling commodity prices and the resultant severe downturn in recent years; Indonesia has focused on preserving stability and taming inflation through appropriate policy responses (e.g. no fuel subsidies) coupled with increased reserves to help stabilize rupiah's volatility against the dollar. In the face of uncertain macroeconomic environment and a sluggish recovery in advanced economies, Indonesia's near-term outlook nevertheless is positive, as the country is transitioning from a commodity-supported economy to innovation/technology-driven in an interconnected and closely integrated global environment that is fiercely competitive.

The GDP growth is forecasted at 5.2% in 2015 aided by rebounding equity prices and increased foreign inflows. Against this backdrop, the current account deficit is projected to narrow in 2015 (IMF, 2015a). The key results of the macro stress test based on end-September 2009 data for commercial banks show that under the stress scenario Indonesian banks face substantial losses arising from large exposures to credit risk which seems to be the main source of risk. Under the TD test, the aggregate CAR of 17.8% drops to post-stress CAR of 6.8% and NPLs climax at 31.5% in Q3 2011 resulting in capital shortfalls which lead to a number of insolvent banks.

Among ASEAN-5, stress testing results show that Indonesia has the lowest per-capita GDP and inequality in wealth-sharing between rich and poor has a much wider gap compared with peers. Under the BU stress test, although insolvency risk is high (three out of the eight domestic banks are undercapitalized), no bank becomes insolvent, whereas 7 of 8 foreign-owned banks fall below regulatory minimum and one bank becomes insolvent. The details of the sensitivity test shows that Indonesia's banks are varied in terms of sensitivity; while all banks are sensitive to interest rate shocks in the banking book, large and medium-sized banks are sensitive to liquidity risk and the largest banks are vulnerable to concentration risk. The IMF's BU test shows that if 10 largest borrowers fail, banks' CARs on average drop as much as 6.5% (IMF, 2010a).



Sources: IMF (2014), data extracted from IMF Data Warehouse on 7/29/2014 www.elibrary.imf.org

Notes: Financial soundness indicators of Indonesia before the stress test.

Figure 2.2: Financial soundness indicators of Indonesia

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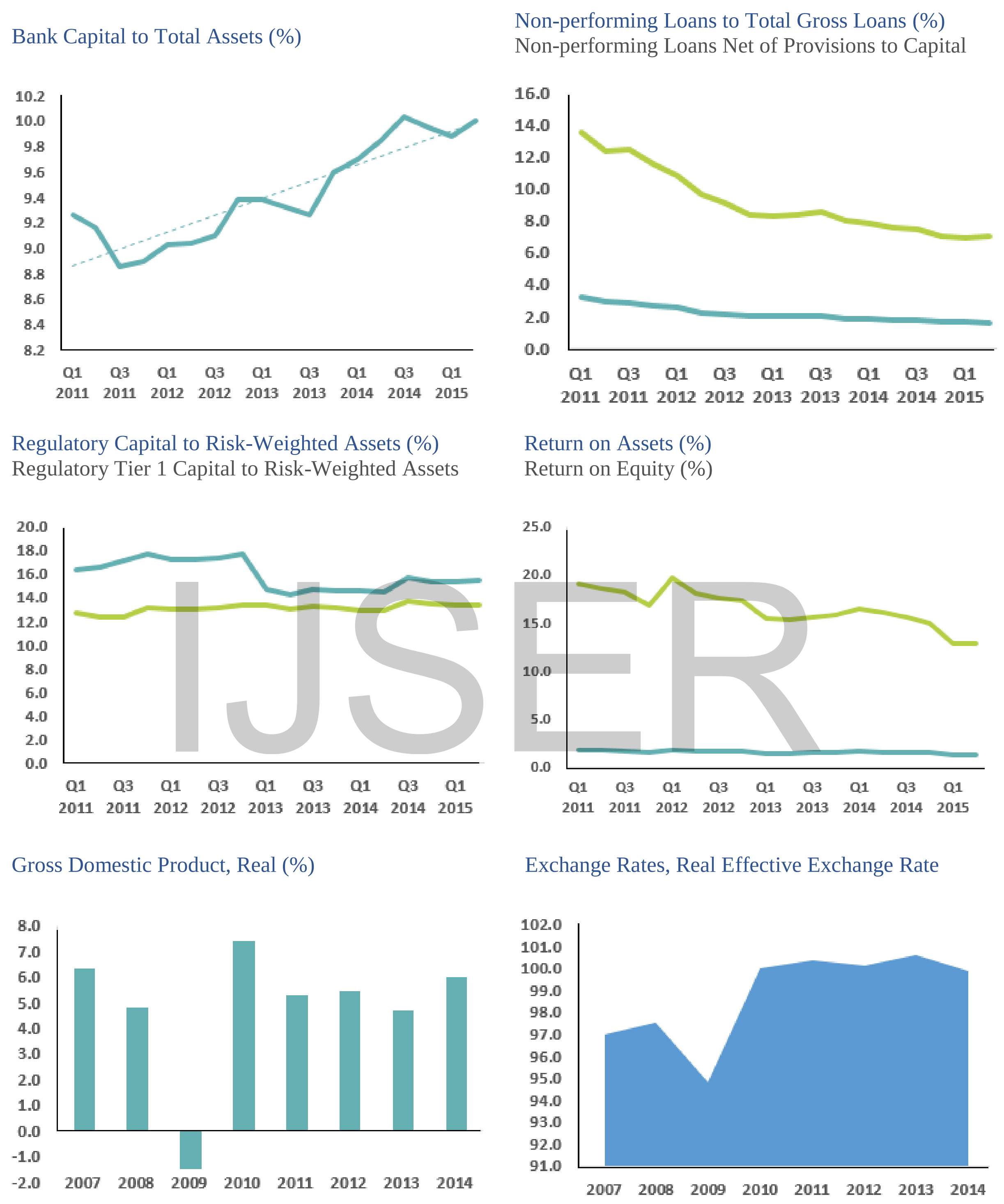
2.2.3.2 Stress Testing Experience of Malaysia

Malaysia underwent FSAP in April and September 2012, the results were discussed with Malaysian authorities in December 2012. Thanks to the successful initiatives of the ten-year Financial Sector Masterplan (2001–2010) led by the Bank Negara Malaysia (BNM) and the parallel-run Capital Market Masterplan (CMP1) led by the Securities Commission, Malaysia (unlike its peers) has escaped the severe consequences of the GFC. Malaysia's financial sector went through great transformation; the end result is a strengthened financial sector complemented by strong and rigorous regulatory and supervisory framework. Stress tests indicate that Malaysia's banking system is comfortably capitalized and resilient to withstand economic and market shocks, but not without some risks; overreliance on demand deposits augments liquidity risk and rising household debt increases default risk (IMF, 2013b).

Malaysia's well-diversified economy is expected to experience a sizable decline, from 5.9% in 2014 to 4.8% in 2014. Extremely low oil and gas prices will keep inflationary pressures subdued and cause a reduction in the current account surplus; however, revenue loss due to lower commodity prices is expected to be offset by the elimination of oil subsidies and manufacturing exports favored by a weaker exchange. Surging house prices and fast rising household debt (Figure 2.3) pose a threat to financial stability and may lead to a possible real estate bubble to form; although rising real interest rates globally (triggered by US policy tightening) will curb growth of financial risks eventually, enhanced stress tests and further macroprudential measures may be necessary (IMF, 2015b). Malaysia's stress tests use a forecasting period to 2016; during which, each bank has been subject to credit, market, and liquidity stress tests as well as sensitivity shocks (e.g., interest rate, exchange rate, and equity price moves).



Sources: IMF (2014), data extracted from IMF Data Warehouse on 7/29/2014 www.elibrary.imf.org

Notes: Financial soundness indicators of Malaysia before the stress test.

Figure 2.3: Financial soundness indicators of Malaysia

Banks underwent contagion stress test to gauge the effects of interbank exposures. Baseline (growth remains around 5%) and two adverse scenarios (extreme but plausible market events) are used; the latter assume a deep recession in 2013 and prolonged low growth, plus high unemployment and lower house prices. The aggregate capital adequacy (36 banks) remains above 8% under the baseline scenario, but smaller Islamic banks (with lower starting capital) fall below the threshold rate of 4% Tier 1 capital under the adverse scenario. The results of stress tests reveal that capital shortfalls for banks in the adverse scenarios are substantial (IMF, 2013b).

Table 2.11: Five day implied cash flow test under medium liquidity stress

Minimum number of days of survival	Number of bank failures	Survival rate of banks (percent %)	Survival of assets (percent %)
0	0	100.0	100.0
1	0	100.0	100.0
2	0	100.0	100.0
3	0	100.0	100.0
4	2	94.4	83.8
5	6	83.3	70.4

Sources: IMF (2013b), BNM

Notes: Almost a decade after the GFC, more central banks are conducting liquidity stress tests in addition to micro and macro stress tests. In the BNM's liquidity test, some banks failed only after the 3rd day of runs on deposits, but those banks with capital shortfalls raised new capital to comply with the minimum capital rules.

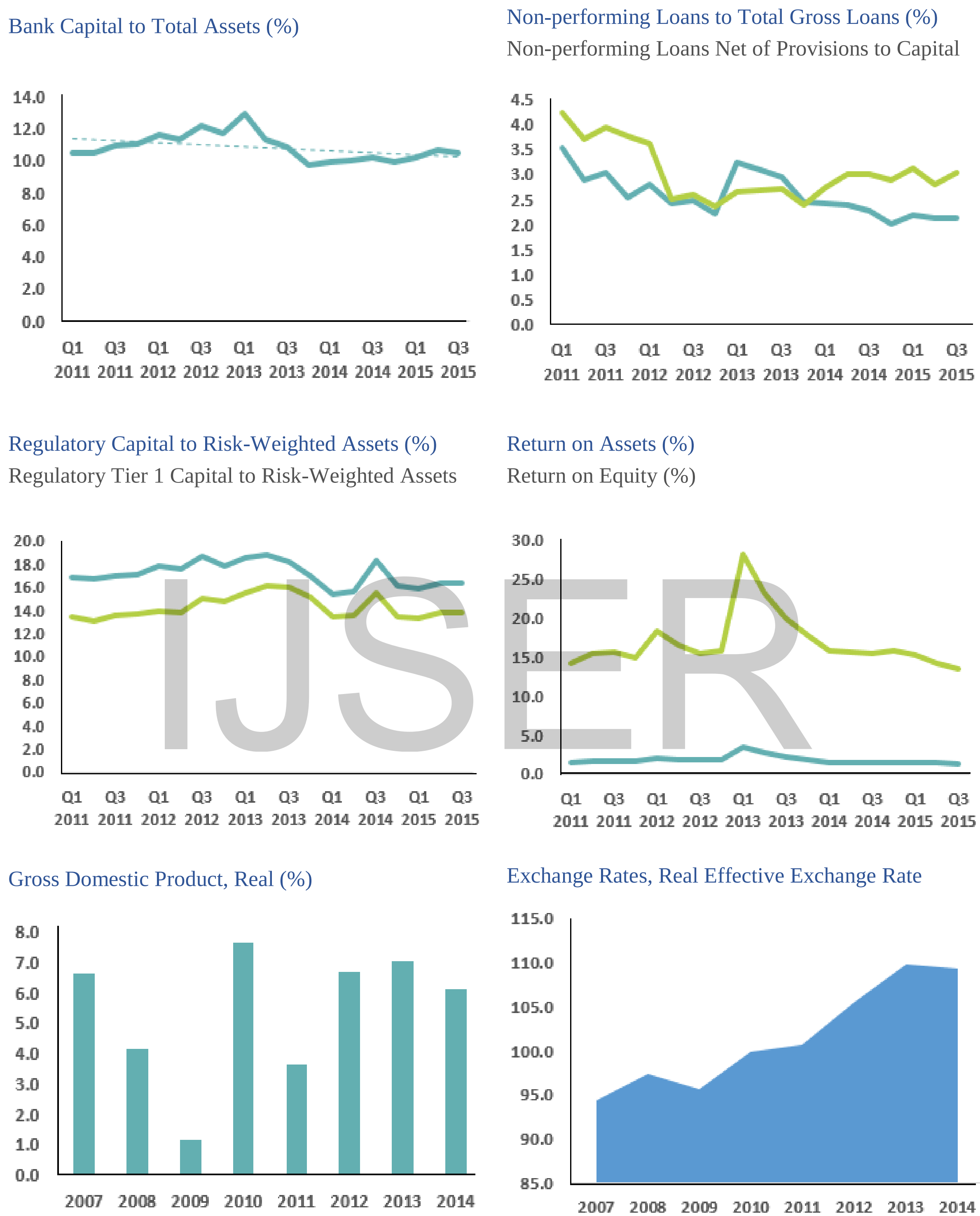
In terms of liquidity, there is a potential risk that 85% of funding source comes from deposits at call (close to 30% is retail, 37% from businesses, 16% from financial institutions). Under the short-term daily liquidity TD stress tests (Table 2.11), six smaller banks fail after the fifth day. As illustrated in the BU liquidity shock test over one month horizon, banks face a capital shortfall of $6.4 billion in U.S. dollar-denominated assets and liabilities; however for ringgit denominated assets and liabilities, banks have a post-stress surplus of RM 24 billion. Also, it is concerning that more than half (55%) of bank lending is to households, the debt of which in a decade has increased about 80% (44.6% in 2000) to reach 74% of GDP in 2011. The gross NPL ratio appears to be slightly lower than some regional peers; at end-2011, NPL and provision coverage were 2.7% and 99.6% respectively compared with the region's average 2.0% and 114.7%. Credit risk shocks produce more losses than market risk shocks and some banks' capital ratios are adversely impacted (200 – 560bps) by the Basel II and III capital rules (IMF, 2013b).

2.2.3.3 Stress Testing Experience of Philippines

Philippines' Article IV consultation has been concluded in August 2015 (initial FSAP took place in 2002), which shows that the Philippine economy is strong (expanded 6.1% in 2014) despite worsening global prospects. The Philippine remarkable economic performance is aided by current account surplus of 4.4% of GDP in 2014, foreign reserves of $81 billion (June 2015) that translates to over 400% of short-term debt by residual maturity, fiscal deficit of 0.6% (which is set at 2% of GDP in 2015 for infrastructure and social programs) and public debt at 36.4% of GDP. Although inflation rose to 4.9% in August 2014 before retreating to 1.2% in June 2015, soft commodity prices along with lower fuel costs will keep inflation at low-end of the target band (3±1) set by the Bangko Sentral ng Pilipinas (BSP). Monetary gains from low oil prices will be offset by adverse impact of El Niño on food prices. Based on positive developments and remittances, the economy is projected to expand 6.2% in 2015 and 6.5% in 2016 (IMF, 2015c).

The financial sector of Philippines is not deep enough compared with peers, but it has made huge progress in banking sector since the 2002 FSAP, but conversely, capital market (e.g., small equity and bond markets relative to peers) and insurance (still in infancy) are underdeveloped with feeble supervision; although state-owned finance firms are not systemically important, they are fiscal-contingent liabilities. Nonetheless, the banking sector is sufficiently capitalized and remains liquid; except for smaller banks (rural banks and thrifts), asset quality and provisions are high for larger banks. Stress testing results indicate that the ten largest banks are resilient to endure credit, market, and liquidity shocks under baseline and adverse scenarios. With the New Central Banking Act (NCBA), supervisory coordination has been improved significantly via the creation of the Financial Sector Forum consisting of BSP, PDIC (Philippine Deposit Insurance Corporation), SEC (Securities and Exchange Commission), and Insurance Commission.

Credit intermediation to private sector in Philippines is one of the lowest among ASEAN-5 (loans represent 35% of GDP and about 50% of banks' total assets) and housing loans by banks is only 4.5% of GDP which is still higher than Indonesia (2.5%) but far less from Thailand (17%) and Malaysia (26%). Non-bank segments are in infancy and the capital market is underdeveloped; as such, insurance (1% of GDP), corporate debt market (4% of GDP), mutual fund market and stock exchange are one of the smallest in Asia. As a result, conglomerates dominate the Philippine economy, owning seven of the ten largest banks plus a majority of the listed companies. The IMF conducted stress tests in conjunction with the BSP to gauge impact of macro scenarios on capital adequacy and liquidity. The following assumptions are considered under the adverse scenarios; sovereign spreads increase of 250bps, remittances decline by 12%, and export values decline by 50%. Concentration risk is also stress tested through several ways: each bank's largest borrower defaults, two largest default, five largest default, and five or more largest borrowers of the whole financial system default. Liquidity stress tests assume a run on deposits, full use of credit lines, 10% and 25% haircuts on debt securities (IMF, 2010b).



Sources: IMF (2014), data extracted from IMF Data Warehouse on 7/29/2014 www.elibrary.imf.org

Notes: Financial soundness indicators of Philippines before the stress test.

Figure 2.4: Financial soundness indicators of Philippines

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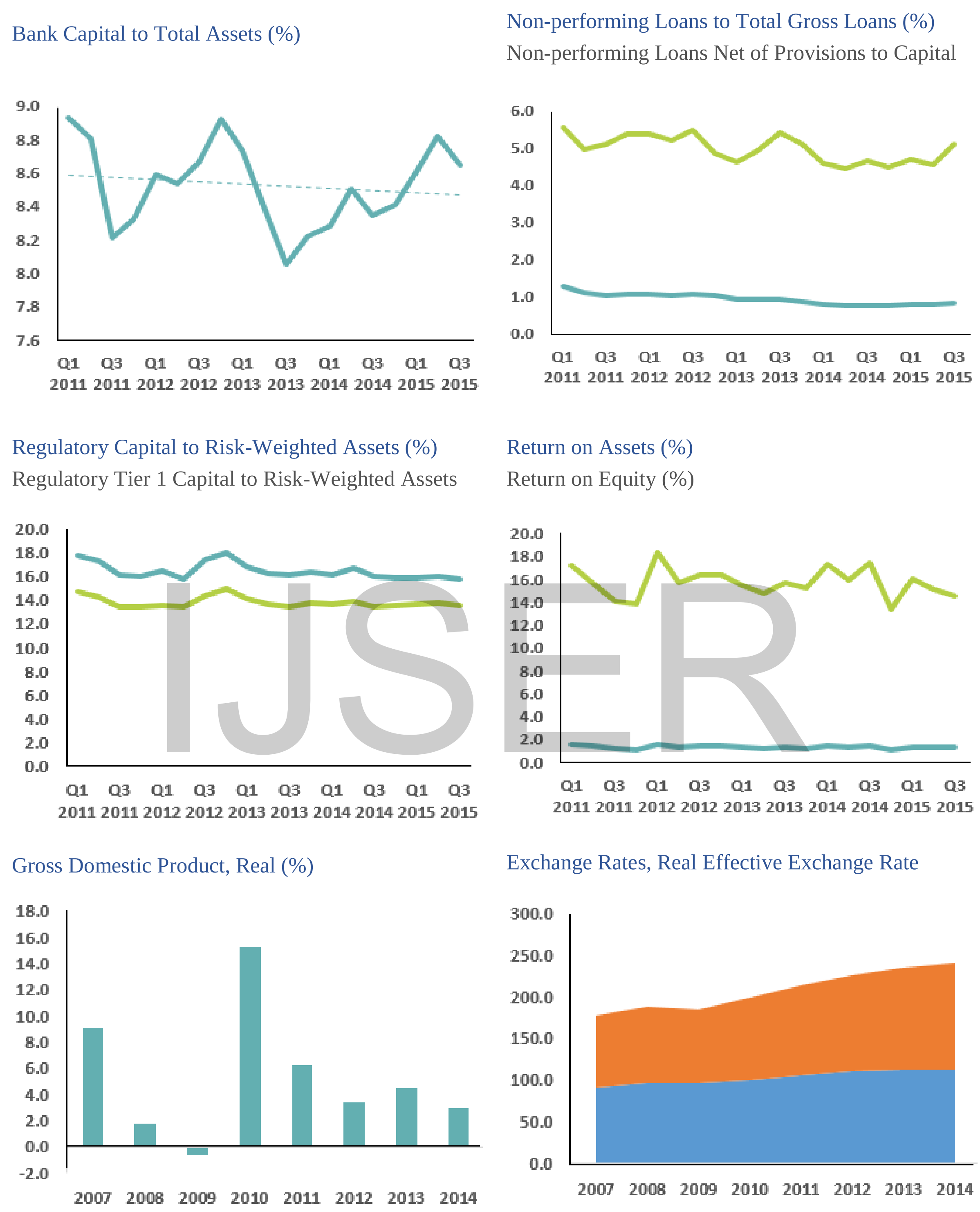
2.2.3.4 Stress Testing Experience of Singapore

Singapore, since independence from the United Kingdom for half a century ago, has achieved unprecedented economic performance, and the upshot is one of the highest living standards across the world. After a moderation in 2014 (from 4.4% in 2013 to 2.9% in 2014), growth is steady at 2.9% in 2015 underpinned by very low inflation (reduced to 1% in 2014 from 2.4% in 2013), comfortably high current account surplus (added another 1.2% to reach 19.1% in 2014), and favorable exchange rate compared to its peers; however, the Monetary Authority of Singapore (MAS) has intervened to ease the pace of appreciation of its currency, citing slower than expected global recovery coupled with low headline (0%) and core (1%) inflation in 2015. Nonetheless, the MAS is monitoring risk associated with private indebtedness (IMF, 2015d).

Singapore's big three domicile banks have fared well against the GFC and European sovereign debt crises, evinced in BU and TD stress tests conducted both by MAS and the IMF suggesting that virtually all banks are resilient to adverse and severely adverse macroeconomic scenarios, largely attributable to higher capital ratios (2% higher than the current 8% under Basel III) and lower leverage. Bank profitability is much higher than regional peers, as banks' revenue streams in this city state are well diversified with low NPLs and high provisions. Although stress tests conclude that trading losses may be trivial, credit losses from potentially elevated residential mortgage and corporate defaults would cause a significant deterioration in the capital base, resulting in capital shortfalls as well as re-capitalization needs. Stress tests have also identified that some banks, if downgraded by several notches, would be subject to liquidity shortage risk due to banks' lower coverage of U.S. dollar exposures; consequently, banks may end up requiring as much as 20% of foreign reserves, $50 billion currently (e.g. IMF, 2013c).



Sources: IMF (2014), data extracted from IMF Data Warehouse on 7/29/2014 www.elibrary.imf.org

Notes: Financial soundness indicators of Singapore before the stress test.

Figure 2.5: Financial soundness indicators of Singapore

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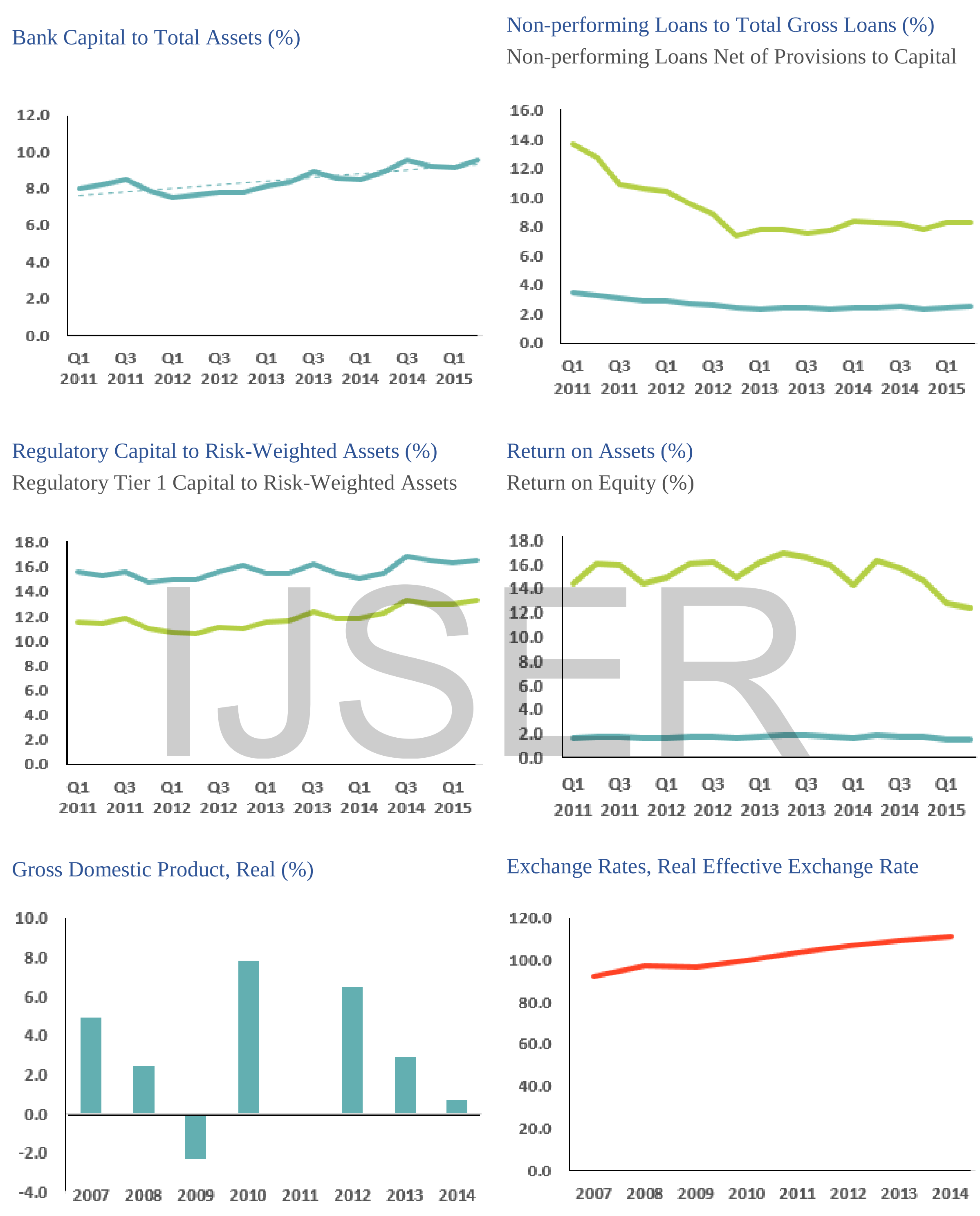
Interconnectedness and integration locally, regionally, and globally made Singapore become increasingly susceptible to shocks. Stress tests by the IMF or MAS indicate that Singapore is vulnerable to cross-border interbank exposures, which appear to arise from credit and funding shocks originating in a domino style in close trading partners such as the UK, Japan, South Korea, and the U.S. (however, domestic interbank exposures are limited). Singapore banks are ever more sensitive to spillover from both regional (Malayan and Thai banks) and international banks (Swiss, UK, and the U.S.), but the IMF and MAS point to Singapore's fully developed financial system with excellent payment, clearing and settlement infrastructures.

2.2.3.5 Stress Testing Experience of Thailand

Thailand has contracted sharply in 2014, as domestic consumption was severely affected by the political turbulence by a military coup taking over the government in May 2014 (a new election is scheduled to take place in 2016). Despite uncertainty and bouts of downside risks (soft commodity and oil prices, lower than expected production, and rising food costs), GDP growth is projected to expand 3.7% in 2015. Safeguarding financial and fiscal stability is a top priority for the Bank of Thailand (BOT), therefore it is very closely monitoring fast-pace growth of household debt and nonbank intermediation. Thailand's growth since the GFC has not regained momentum, still below pre-crisis levels when compared with peers (Indonesia, Malaysia, and Philippines). The growth is adversely affected by slowing global demand for Thai electronics products (gradually losing its global market share since the GFC). Capital and financial accounts saw a deficit of $15 billion in 2014, but net foreign direct investment (FDI) is positive (inward FDI in 2013-14 was $25 billion and outward FDI was $14 billion) and external debt is projected to decline from 37.9% of GDP in 2014 to 33.6% of GDP in 2020 (IMF, 2015d).



Sources: IMF (2014), data extracted from IMF Data Warehouse on 7/29/2014 www.elibrary.imf.org

Notes: Financial soundness indicators of Thailand before the stress test.

Figure 2.6: Financial soundness indicators for Thailand

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Thailand's financial sector is evidently more resilient today than it was during the home-grown Asian crisis of 1997-1998 thanks to the fiscal sustainability, enhanced monetary transparency, strengthened regulatory and supervisory frameworks, and improved governance; as a result, the average risk-weighted capital adequacy of most banks was 15% at end-2007. However, the results of stress tests conducted in April 2008 showed that most banks were vulnerable to credit risk and few banks were subject to liquidity risk; based on the outcome of stress tests, two weaker banks were re-capitalized and one bank was privatized (IMF, 2009).

Thailand's financial sector has transformed and grown significantly since the GFC (over 350% of GDP as of 2013); commercial banks' assets account for 128% of GDP versus 99% in 2007 (credit exposures during the same period rose from 154% to 197%. After showing a deficit of 0.6% in 2013, current account increased by 3.8% in 2014 which helped offset the financial account deficit; also during the course of 2014, valuation changes caused a decline of $10 billion in foreign reserves, bringing the total to $157 billion. Due to a sizable reduction in corporate tax rates (reduced from 30% to 23 in January 2012 and again to 20% in 2013) coupled with the slower growth, the government revenue decreased 1.6% of GDP to 22.5% in FY2013/14 while the spending remained at 24.3% of GDP. To boost the economy, the BOT has cut the policy rate by 25bps in November 2013 and once again in March 2014 (IMF, 2015d).

2.3 Basel Standards: Promoting Financial Stability

The collapse of the Bretton Woods system of fixed exchange rate regime in the early 1970s, the Arab-Israeli conflict – Yom Kippur War in 1973 (OPEC sharply raised oil prices), and the failure of Germany's Herstatt Bank in 1974 (a major shock in currency markets) induced financial instability, enough to rattle markets worldwide. These High-magnitude systemic events led to a surge in commodity prices and disrupted the world trade. Micro and macro factors prompted central bank Governors of the G-10 to engage in immediate cooperation and financial collaboration; the efforts in turn gave an imminent birth to the establishment of the Basel Committee in 1974, however the first official meeting was held in 1975.

The Basel Committee has claimed that it is not a supranational supervisory authority, rather it provides a common platform for its member-countries to be able to engage in regular and continual cooperation on banking supervisory matters. Nonetheless, the Basel Committee's voluntary nature of participation has been subject to heavy criticism; it is argued that the voluntary aspect exposes the global financial stability to systemic risk as certain G-SIBs and their home countries (e.g., the U.S.) may choose not to adopt Basel standards. The Basel Committee defends its voluntary participation that it possess no legal authority, its decisions and conclusions are only recommendations and not intended to imply a statutory force over its member nations' differing banking standards. As clearly stated in the Basel Committee's charter, its main objective is to strengthen banking regulation and supervision via conversion of capital standards to ensure that banks hold sufficient capital to absorb losses (BCBS, 2001a).

In the pre Basel world, internationally active banks across G-10 used varying approaches to measure capital adequacy; therefore, harmonization of disparate capital standards gained interest in the 1980s as internationally active banks had a tendency to invent loopholes to escape supervisory regulation/supervision. The *Concordat* of 1975 not only aimed to ensure that no bank escaped adequate banking regulation/supervision, but also set the foundation for the landmark consultative document *"International Convergence of Capital Measurement and*

Capital Standards" (commonly referred to as Basel I), which was approved by the G-10 Governors and released to banks in July 1988. Basel I (first international banking regulation), adopted by over 100 countries globally, had the objective of strengthening "the soundness and stability of the international banking system" (BCBS, 1988).

2.3.1 Basel I: The 1988 Capital Accord

Since the inception of the Basel Committee, some countries (the UK and the US in particular) have attempted to formalize capital requirements but the release of the 1988 Basel Accord (effective in December 1992) has spurred a widespread adoption by more than 100 countries worldwide. The underlying objectives behind having a common standard for internationally active G-10 banks are twofold: "...to strengthen the soundness and stability of the international banking system" and "...to reduce competitive inequalities" (BCBS, 1999b). Initially, Basel I was not meant for emerging market economies; therefore, it was not designed as a banking reform to assess unique risks of banks originated outside of the G-10 countries (BCBS, 2001b).

Over the years, Basel I has been subject to constant opposition on numerous grounds; the most forceful criticism relates to arbitrary risk categories (OECD and non-OECD origination) and corresponding simplistic risk buckets (0%, 10%, 20%, 50%, and 100%) associated with borrower types such as OECD or non-OECD sovereign states, banks, and private firms as demonstrated in Table 2.12. Proponents argue that broad categorizations of riskiness of Basel I framework fails to differentiate among degrees of risk and creates incentives for gaming the system through regulatory arbitrage as a way of substituting between more and less risky asset classes. The U.S. Federal Reserve Vice Chairman Ferguson (2003) elaborated in a speech that

"Basel I Accord is too simplistic to adequately address the activities of our most complex banking institutions" and the Basel Committee observed that insensitiveness of Basel I to credit risk caused significant distortions in cross-border lending (BCBS, 2004a).

Table 2.12: Basel I vs. Basel II risk categories and risk weights

Basel I risk weights and categories of on-balance sheet asset		
1.	0%	Cash claims on OECD governments and loans either collateralized or and guaranteed by them, claims on non-government domestic entities.
2.	20%	Claims on multilateral development banks incorporated within OECD and loans guaranteed by such entities, cash in collection, claims on OECD banks and short-term loans (less than one year).
3.	50%	Fully secured mortgage loans on residential properties either occupied by the borrower or rented out.
4.	100%	Claims on private sector, non-OECD banks (maturity of over one year), commercial firms owned by public entities, non-OECD governments, real estate, and equity issued by banks.

Basel II risk weights and credit assessments

Option 1: Sovereigns

Credit Assessment	AAA to AA-	A+ to A-	BBB+ to BBB-	BB+ to B-	Below B-	Unrated
Risk Weight	20%	50%	100%	100%	150%	100%

Option 2: Banks & Corporations

Credit Assessment	AAA to AA-	A+ to A-	BBB+ to BBB-	BB+ to B-	Below B-	Unrated
Risk Weight	20%	50%	50%	100%	150%	50%
Short-term Risk Weight	20%	20%	20%	50%	150%	20%
Corporate	20%	50%	100%	100%	150%	100%
ECA Risk Scores		0-1	2	3	4-6	7
Risk Weights		0%	20%	50%	100%	150%

Source: Basel Committee on Banking Supervision (BCBS, 1988; 2004)
Notes: Risk categories and risk weights applied in the calculation of RWAs and CAR.

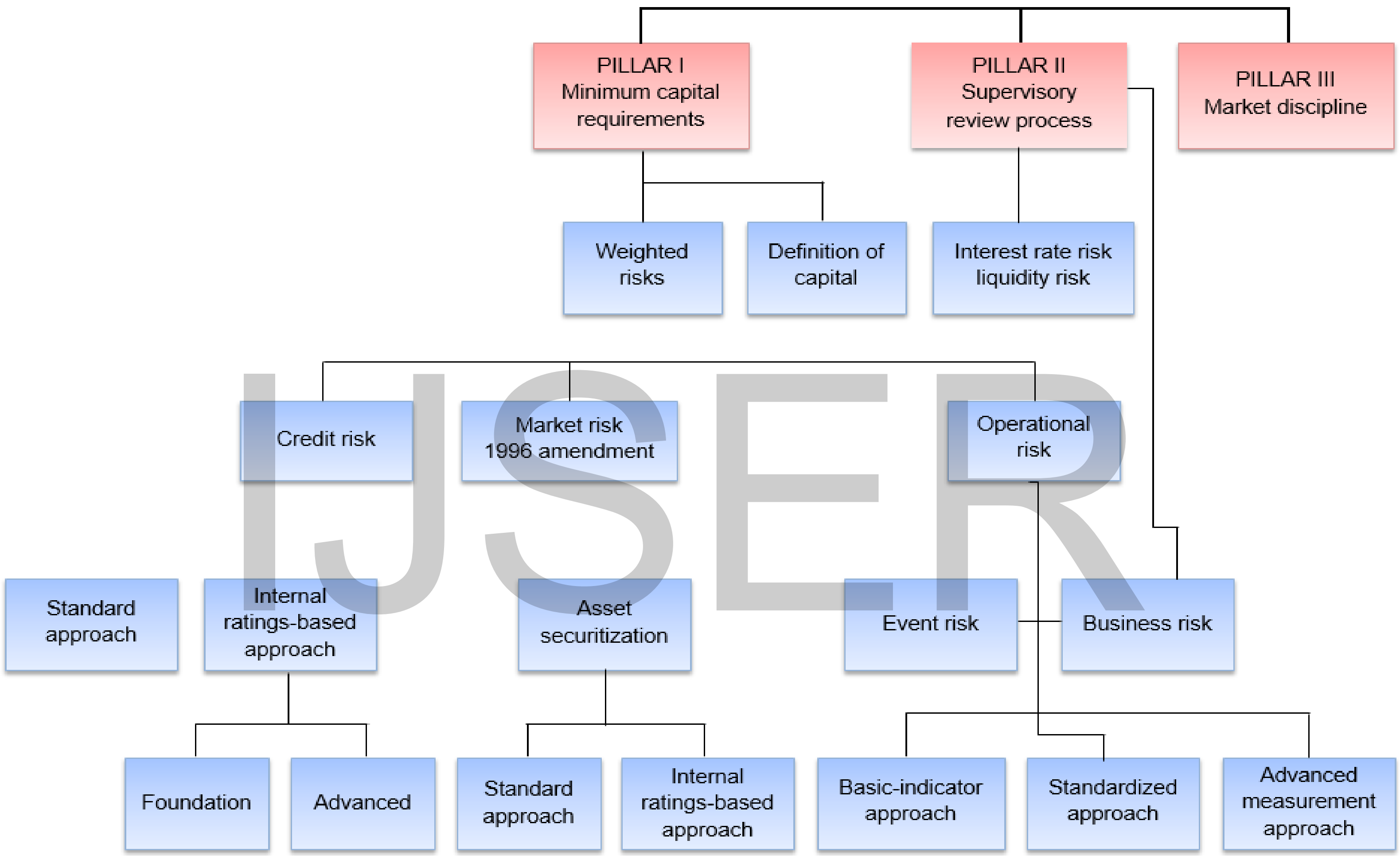
Credit risk (primary risk of counterparty default) was a paramount focus of Basel I; as such, equally important more complex risk types such as operational and liquidity risks (BCBS, 2001c) were left at the discretion of supervisors. Basel I has four pillars; pillar 1 defines capital elements, pillar 2 covers risk categories/risk weights; pillar 3 deals with target standard ratios; and pillar four describes transitional arrangements. The transitional period had two phases; banks were to meet an interim minimum capital of 7.25% by the end of 1990 and 8% by the end of 1992 when the observation period ended. The regulatory total minimum capital of 8% was divided into two Tiers; the core capital Tier 1 was set at 4% consisting of common stock and disclosed reserves such as retained earnings while Tier 2 capital is also set at 4% (100% of Tier 1) including supplementary elements such as undisclosed reserves (BCBS, 1988).

After a decade-long practice of the Basel I rules, the Basle Committee asked the Research Task Force to set up a Working Party to investigate the impact of formal capital requirements on bank capital and bank behavior towards risk-taking. The analysis went over 130 research papers and the Working Party concluded that Basel I induced a change of behavior for weak G-10 banks to hold more capital (higher capital ratios), but at the same time, Basel I led to a credit crunch in the 1990s (liquidity hoarding caused credit crunch) which was believed to exacerbate then already weak economic conditions and access to credit (BCBS, 1999b). The literature also suggests that the risk insensitiveness of Basel I to credit risk ushered greater risk-taking; consequently, some banks with propensity to invent loopholes began substituting between more and less risky assets and Jones (2000) argues that this behavior led to excessive leverage and capital arbitrage. On the contrary to the Basel Committee's main objectives, Basel I has failed to achieve fairness, consistency, and transparency among internationally active banks.

Basel I had many deficiencies that contributed to financial instability; for instance, "failure to capture major on- and off-balance sheet risks as well as derivative related exposures was a key destabilizing factor during the crisis" (BCBS, 2010a, p. 3). The risk insensitive rules of Basel I, according to Rodríguez (2002) and Elizalde (2007), encouraged greater risk-taking; enabled banks to accumulate a lot more capital than required through disintermediation, which caused credit squeeze in the 1990s; allowed banks to move higher-risk-weight assets between on-balance and off-balance sheet via securitization (Blundell-Wignall et al., 2014). Basel I produced inaccurate risk assessments, as risk models did not take into account the endogeneity nature of risk, especially in volatile markets. Therefore, Jackson et al. (1999) view the capital requirements of 8% RWAs as a form of another regulatory taxation imposed on banks. With the endorsement of the Basel Committee's 1996 market risk amendment, VaR became a mainstay but this too was blind to certain risks under extreme market conditions (Danielsson, 2000).

2.3.2 Basel II: The Revised Framework

The Asian crisis in the late 1990s is an indication of how the macroeconomic environment has changed since the release of Basel I in 1988; as such, the banking industry has evolved, trading has become complex, and risk management has been increasingly challenging for both banks, regulators, and supervisors. The shortcomings of Basel I coupled with mounting pressure from industry participants prompted the Basel Committee to introduce a *"revised framework"* commonly known as Basel II in June 2004 (implemented by 2006). Under Basel II, the capital definition remained unchanged at 8% (but more risk-sensitive). Basel II intends to strengthen the risk-coverage and to reduce excessive risk-taking through 3 pillars (Figure 2.7); minimum capital requirements (pillar 1), supervisory review (pillar 2), and market discipline (pillar 3).



Source: Andersen (2003)

Notes: The Basel II – Revised Framework was a huge improvement over Basel I, but its implementation was disrupted by the 2006 mortgage debacle.

Figure 2.7: Outline of Basel II revised framework

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The underlying objectives of the revised framework, as outlined by the Basel Committee, are; to make Banking systems resilient to shocks; to remove inequalities (i.e. discrepancies) through a "one-size-fits-all" approach; to constitute a significantly enhanced framework to assess risks; and to promote a greater market discipline. In terms of risk coverage, two new capital charges were introduced to move banks in the right direction and encourage them to put in place comprehensive risk-management frameworks for internal purposes (stress testing is an integral component); (1) an operational risk charge applies if financial losses are due to inadequate or lack of internal processes; (2) a mandatory concentration risk charge applies when a bank's risk exposures are concentrated on a single borrower, a sector, or a country (BCBS, 2004a).

Basel II introduced a set of new approaches to gauge capital adequacy and let banks use ratings provided by external credit assessment institutions (ECAIs). Smaller banks are required to use a standardized approach (BCBS, 2014b), similar to the bucket-risk approach (BCBS, 2001d), to calculate regulatory capital. Probably the most profound change introduced under Basel II vs. Basel I is to allow large banks to use a foundational (F-IRB) or advanced internal ratings-based approach (A-IRB) to compute capital adequacy (BCBS, 2001e). Due to extreme complexity and extensive data usage, both IRB approaches are subject to supervisor approval before banks can use own estimates of risk weights, which involve using sophisticated modelling and aggregation as banks using one of these advanced techniques are required to estimate each borrower's probability of default (PD), loss given default (LGD), and exposure at default (EAD).

As feared by many, Basel II resulted in increased cyclical lending and reduced capital inflows to developing and emerging market economies including ASEAN-5; as a result, most of these countries became subject to higher bank lending costs to finance their development projects which are seen as a gateway to leap into the next level of growth to catch up with the advanced nations. International bank lending was constraint under Basel II on account of two key changes; the distinction between OECD and non-OECD has been removed in Basel II (lower-rated countries will have access to higher cost of funds); individual borrowers including sovereign states with a rating of below B- (which carries a 150% risk weight) will see costs of capital rise significantly. Risk concentration was arguably the single largest cause behind the Asian crisis. Banks were excessively leveraged, fostered by a boom in the property sector (real estate), and the implosion of the bubble led to the collapse of the Thai economy in 1997 (first domino) before engulfing the adjacent countries. Basel II deals with concentration risk better under pillar II, which requires banks to put in place mechanisms to monitor credit quality (BCBS, 2004a).

The Basel Committee observed that risks were not covered properly in pillar 1 under Basel I (and the 1996 amendment to Basel I to incorporate market risk "...failed to detect and capture some key risk exposures in the trading book" (BCBS, 2011b)). Pillar 1 was predominantly about credit risk while other equally important risk types (e.g., operational, market, and liquidity) were ignored; further, risk inputs for calculating capital ratios were subjective with loopholes (or incentives) which enabled banks to game the system to show higher capital ratios than actual. Pillar 2 (the supervisory review process) is introduced, and with the help of stress testing, banks were required to hold higher capital with sufficient capital buffers. At the macroeconomic level, inefficient international markets leads to serious errors in the pricing of firms' future cash flows, this in turn makes firms' assets and liabilities either overvalued or undervalued. In that regard, the Basel Committee introduced pillar 3 (the market discipline) so that banks can be held accountable for the lack of or inadequate internal risk-assessment processes. There is a prevalent consensus among economists and banks that the systematic absence of a well-established market discipline plus insufficient disclosures played a role in the breakout of the GFC.

Basel I was insensitive to credit risk, but Basel II imposes many challenges and obstacles as well as financial burden on most banks, particularly those in developing countries and emerging markets. Although the majority of banks in Asia are domestically oriented (excluding banks located in Japan, Hong Kong, and Singapore), the lack of technical know-how (i.e. stress testing) combined with other important components such as trained and skilled human capital, infrastructure, technology, and financial resources is a major problem among ASEAN-5 and across Asia. Unlike Basel I, transparency, governance, and proper disclosures are the new essentials of the new Accord, which also provides too much discretion to national supervisors under pillar 2, but the supervisors (excluding advanced nations) are neither technically equipped nor they have the necessary capacity to ensure a level playing field.

Basel I clearly failed due to its structural flaws and shortcomings in practice, and Basel II was not even given an opportunity to be tested for its ability to withstand exogenous and endogenous shocks as its final implementation due at the end of 2006 was abruptly interrupted by the U.S. origin sub-prime crisis and the ensuing GFC in 2007-09. The proponents of the Basel II rules, including Caruana (2010) among others, strongly contend that Basel II is (as claimed) the main architect behind the GFC for two fundamental reasons: first, they argue that the GFC manifested itself on the basis of micro and macro factors (i.e. global imbalances, excessive risk-taking, and innovations) several years prior to the implementation of Basel II; second, they deduce that the majority of countries that adopted Basel II did so in 2007 or later (i.e. the U.S. and ASEAN-5). On the other hand opponents, including Saurina and Trucharte (2007), point out that Basel II would likely to increase procyclicality, exacerbate boom-bust cycles, cause deleveraging; the confluence of all this would lead to defaults due to contagion and counterparty risk.

Blundell-Wignall and Atkinson (2010) believe that the early Basel standards in many aspects were flawed with a number of deficiencies; for instance, no concentration risk charge applies under Basel II (allowing largest exposure in a firm or a sector), which was left for supervisor to deal in pillar 2, plus no clear differentiation among country-specific risks that mostly arise from variances in national regulatory and supervisory frameworks. Gordy (2003) argues that a single global risk factor of Basel II to capture firm defaults increases the likelihood of large capital shortfalls. Blundell-Wignall and Atkinson (2010) assert that Basel II raised procyclicality (underpinned by leverage ratio); capital adequacy calculations were varied and disparate across banks; and the use of IRB approaches reduced risk weights for large banks (Blundell-Wignall et al., 2014). Severe regulatory distortions under Basel I and II provided *too-big-to-fail* banks (creating moral dilemma) incentives to move assets off their balance sheets, this in turn made more capital available for investments. These unconventional on-and-off balance sheet moves created another nonfinancial intermediary commonly referred to as *shadow banking*.

The heavy reliance on external ratings provided by the ECAIs under Basel II played a crisis-intensifier role. The Basel Committee observed that the use of external ratings created three adverse incentives for banks; first, banks felt no real urgency to develop their own internal risk-assessment frameworks; second, ECAIs misused the rating process to issue artificially-inflated ratings to clients from whom they earned lucrative service fees (i.e. agency conflict); third, banks' overreliance on ECAIs resulted in *"cliff"* effect in capital requirements (BCBS, 2004a). The Basel Committee has introduced Basel III to address these issues effectively.

2.3.3 Basel III: A Resilient Global Banking System

Before even the ink was dry on the Basel II agreement, the Basel Committee got right back to work to lead the microprudential reform, prompted by the breakout of the GFC. A set of proposals (referred to as Basel III) were adopted in September 2010, which were enacted within Europe through the Capital Requirements Directive IV (CRD). But internationally, the first draft of the rules was to be released in mid-2011. Basel III is not a revision, it is an overhaul of Basel II, and significantly more rigorous, which imposes complex rules on banks. Nevertheless, the primary focus of the Basel Committee remains unchanged; that is, how Basel III capital rules are applied to risk-weighted assets when banks calculate their regulatory capital ratios. Due to the lack of/and limited availability of crisis-related bank data, the stringent Basel III rules tend to be dynamic in nature and will continue to evolve as new information comes to hand.

The Basel Committee stresses that Basel III, an improvement over Basel II, would reduce the probability of a crisis in the long-term; however, some banks may be subject to increased funding costs in the short-term due to higher capital requirements. The M&M theorem states that the cost of capital (the capital structure) is irrelevant to firm market value, and the theorem's owners Modigliani-Miller (1958) would argue that switching to a higher cost of debt (higher capital requirement) is offset by a lower cost of equity as a consequence of the reduced risk; in other words, a higher capital requirement by the Basel Committee is supposed to make banks safer and more resilient to future shocks arising from an acute financial stress. The probability of a crisis occurring is in fact very small, about once every quarter of a century, which translates to 4%; a high-rated (i.e. AAA) firm defaulting is even smaller (less than 2%), but when either event takes place, the cost to economies is significant; and a crisis' effect can range from 20%

to over 100% of state output loss. The Basel Committee's analysis of the long-term impact of Basel III on output indicates that if Basel III yields 1% reduction in the annual probability of a banking crisis, the expected benefit is 0.6% of GDP (a permanent effect on broader economy); if the effect is temporary, then the expected benefit is 0.2% of GDP (BCBS, 2010b).

The Basel Committee has assessed the economic impact of the Basel III reform, and the results suggest that for every percentage point increase in the capital ratio results in a 0.09% reduction in GDP from the baseline. In the same scenario, the impact of 1% increase in the liquidity requirement causes a 0.08% decline (BIS, 2011). These results are closely in line with the findings of the Long-term Economic Impact (LEI) group (BCBS, 2010b) and the Macroeconomic Assessment Group (MAG, 2010). The Basel Committee has performed another study to compare benefits and costs of the Basel III rules, the underlying message of the analysis is that higher liquidity and capital standards produce positive net benefits. The following factors lead to a larger estimate of net benefits: reduced procyclicality through countercyclical capital buffer; a premium paid by risk-averse investors for an expected banking crisis; banks' ability to absorb losses (helped by higher capital and liquidity) will mitigate the severity of crises; and increased non-bank intermediation will help reduce the overall cost (BCBS, 2010b).

Although examining banks' structural business models is not one of the Basel Committee's tasks, a frequently repeated question since the GFC asks whether microprudential reform should in fact be combined with policies that constrain banks' activities in various business segments (Blundell-Wignall et al., 2014). During the 1929 stock market crash and the Great Depression subsequently, the American public outcry resulted in the passage of the Glass-Steagall Act of 1933 which barred commercial banks from engaging in investment banking activities.

Table 2.13: Basel III phase-in arrangements

Shading in grey indicates transition periods – all dates are as of January 1st

	2013	2014	2015	2016	2017	2018	2019
Leverage ratio	Parallel run 2013 – 2017 Disclosure starts 2015					Migration to Pillar 1 (2018)	
Minimum CET1 ratio	3.5%	4.0%	4.5%	4.5%	4.5%	4.5%	4.5%
Capital buffer				0.625%	1.25%	1.825%	2.5%
Countercyclical buffer				Phase-in			0 to 2.5%
G-SIB surcharge				Phase-in			1.0 to 2.5%
Minimum common equity + capital buffer	3.5%	4.0%	4.5%	5.125%	5.75%	6.375%	7.0%
Phase-in deductions from CET1		20%	40%	60%	80%	100%	100%
Minimum Tier 1 capital	4.5%	5.5%	6.0%	6.0%	6.0%	6.0%	6.0%
Minimum total capital	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%	8.0%
Minimum total capital + conservation buffer	8.0%	8.0%	8.0%	8.625%	9.25%	9.875%	10.5%
Capital instruments that no longer Tier 1 or Tier 2	Phased out over 10-year horizon beginning 2013						
Liquidity coverage ratio LCR	Observation Begins 2011		Introduce minimum standard by 2015				
Net stable funding ratio NSFR	Observation Begins 2011				Introduce minimum Standard by 2018		

Source: Basel Committee on Banking Supervision (BCBS, 2010a)

Notes: The minimum capital requirement increased significantly (4.5% Tier 1 + 2.5% capital buffers). Two new liquidity standards (LCR > 100% and NSFR > 100%) and a leverage ratio (3%) have been introduced. Further, new charges (2.5% G-SIB surcharge) and a 2.5% countercyclical buffer apply. When the minimum capital requirements, capital buffers, and surcharges are added; banks may have as much as 13% capital charge.

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Financial deregulation since the 1980s undermined Glass-Steagall, which was repealed by the 1999 Gramm-Leach Bliley Act, signed into law by then the US President Bill Clinton. In a crisis situation, public pressure forces governments to intervene to make structural changes to banks' business models; the *Volcker rule* in the U.S. seeks to ban trading on own account; the 2011 *Vickers Report* by the Independent Commission on Banking (ICB) in the UK suggests a legal separation for commercial and investment activities; and the 2012 *Liikanen Report* in the EU, issued by the High-Level Expert Group (HLEG), wants to make trading a legal separate entity.

Since the announcement of Basel III in 2010, there has been a plethora of studies (academia and private) investigating adverse impact of Basel III on bank capital and lending spreads. Some of ASEAN-5 countries (e.g., Indonesia) have expressed grave concerns that most banks in the Asia region would be vulnerable to the stringent capital and liquidity rules as well as transparency, governance, and disclosure requirements under Basel III (Table 2.13). International bank lending to ASEAN-5 is usually short-term (one year or less) and local capital markets (except Singapore and Malaysia) are comparatively not deep enough; non-bank intermediation is in infancy, therefore a majority of banks here are domestically and regionally oriented.

The Basel Committee has improved the definition of capital significantly under Basel III, which was vague both in Basel I&II; each deduction from CET1 is clearly defined, Tier 2 capital is tightened (five-year maturity rule without redemption prior to the expiration), and Tier 3 capital is removed permanently. As illustrated in Table 2.13, the regulatory capital is markedly higher under Basel III; for instance, CET1 as a percent of RWA increases from 3.5% in 2013 to 4.5% by 2015, and Tier 1 capital moves to 6% from 4.5% over the same period (neither capital ratio increases further until 2019 when all the rules become effective). The total minimum capital

(Tier 1 + Tier 2) is kept unchanged at 8% excluding buffers and charges, but once they are factored in, then the new total may potentially increase to 15.5% by 2019 (8% + 2.5% capital buffer + 2.5% G-SIB surcharge + 2.5% countercyclical buffer). The capital conservation buffer initially starts at 0.625% in 2016 and rises by the same increment to reach 2.5% by 2019; however, the level of capital buffer may fluctuate during benign and stressed economic times and G-SIB surcharge (1% to 2.5%) is effective in 2019. Basel II has been criticized extensively for its procyclical nature; to deal with this issue, a countercyclical buffer is introduced, but the range (0% to 2.5%) will be decided by national supervisory authorities (BCBS, 2010a).

One of the lessons of the GFC was the weakness in risk coverage (i.e. agonizingly insufficient); this was, in most part, due to the heavy reliance on ECAIs, unregulated OTC derivatives exposures, wrong-way risk (bank exposure rises as the credit quality deteriorates), and mark-to-market losses (deterioration in the value of bank loans), banks failed to identify and capture massive on- and off-balance sheet risks as well as vulnerabilities to securitized derivatives; consequently, losses arose from these weaknesses were greater than outright counterparty defaults for the SIBs. To address the issues not covered under Basel II, the Basel Committee has introduced a series of measures since 2009 to enhance risk coverage and strengthen the global banking resilience under Basel III. Going forward, banks are required to use a stressed VaR inputs to calculate capital requirements for counterparty credit risk and market risk.

The Basel Committee introduced a Credit Valuation Adjustment (CVA) risk capital charge to address mark-to-market losses. Pre-GFC, OTC derivatives markets were outside of the traditional banking and subject to hardly any regulation; the exponential growth of derivatives since the 1990s coupled with interconnectedness due to fast-paced globalization has accelerated the buildup of systemic risk that amplified the crisis' aggregate loss. In order to strengthen market infrastructures, regulate OTC derivatives markets, and mitigate the buildup of systemic risk; the Basel Committee is supporting initiatives that will establish the Committee on Payments and Settlement Systems (CPSS), the International Organization of Securities Commissions (IOSCO), and central counterparties (CCPs). The overreliance on external ratings by the ECAIs under Basel II caused *"cliff effects"* in capital requirements; to eliminate them, banks are required to perform their own assessments of externally rated securitization exposures.

The excessive on- and off-balance sheet leverage in the banking sector played a crisis-intensifier role at the peak of the GFC, liquidity and leverage ratio issues are covered in (BCBS, 2013b, c); as a consequence, banks were forced to reduce leverage considerably, which amplified the speed of already descending asset prices. The confluence of these shocks exacerbated banks' losses, causing illiquidity in capital markets as well as a huge contraction in credit availability. The Basel Committee feels that the leverage in the banking sector has to be constrained to prevent the deleveraging process from becoming a destabilizing factor (as experienced in the GFC), a 3% leverage ratio (LR) therefore is introduced, but Norton (2013) contends 3% is large enough.

The GFC proved that strong capital base was important, but strong liquidity base was of equal importance; therefore, the Basel Committee is introducing a global liquidity standard to further strengthen the capital position of each bank. Liquidity Coverage Ratio (LCR) aims to ensure that banks have sufficient high quality liquid assets to handle net cash outflows during an acute short-term financial stress over a 30-day horizon; and the objective of Net Stable Funding Ratio (NSFR) is to require banks to have sufficient amount of stable funding to take care of required stable funding over 1-year horizon; both ratios have to be greater than 100 (BCBS, 2010a).

Although Basel III has made progress towards strengthening capital definition, before its full implementation date of January 2019, it has been overly criticized and subject to resistance from academia (e.g. Goodhart, 2013) and even from regulators (Haldane & Madouros, 2012). The basis of the main criticism concerns the use of statistical econometric models to calculate minimum capital. Haldane (2011) argues that, based on empirical evidence, the regulatory framework is open to gaming and Basel III as the previous two capital standards are unable to prevent systemic shocks from hitting the financial system. Also, the critical systemic role of capital has been ignored at both times as regulators focused on microprudential aspects of banks' behavior under extreme but plausible scenarios. Carmassi and Micossi (2012) assert that the global banking system became vulnerable to shocks due to low capital and high leverage.

Hoenig (2013) argues that the Basel III capital does not reflect the reality since it is nothing but an illusion and Norton (2013) suggests that 3% LR is insufficient for the U.S. too-big-to-fail BHCs; according to a research by the FDIC (which has been criticizing the Basel III risk-weighting approach), this figure has to be doubled (at least 6%) so that the largest SIBs can properly address "...trading book risk weighting variations..." and "...underpricing of risks", which are associated with too-big-to-fail BHCs (Blundell-Wignall & Roulet, 2013). The aggregate results of the 2011 Basel III monitoring exercise (BCBS, 2012b) indicates that the 212 participating banks (103 group 1 banks with Tier 1 capital of €3 billion, remaining 109 banks are group 2) would have an overall capital shortfall of €47.4 billion for minimum CET1 of 4.5% (€38.8 billion by group 1) and €518 billion for a CET1 target of 7% (€485.6 billion by group 1). In terms of capital shortfalls, Blundell-Wignall and Roulet (2013) see that the upshot is no surprise because the negative aspect of IRB approach (e.g., banks estimate risk weights of assets using their internal models) of Basel II is transferred to Basel III; further, they assert that LCR and NSFR will potentially face the same dilemma as they "mimic" the capital adequacy.

2.3.4 Adoption and Implementation Progress of Basel Standards

The Basel Committee introduced Basel I in July 1988; after four years of development and consultations, Basel I finally came into effect in December 1992. As the first global banking standard, Basel I was a milestone in its attempt to converge disparate capital measures across internationally active banks within G-10. Although it was initially designed for G-10 banks, the sudden and unexpected breakout of the systemic Asian crisis in the late 1990s made Basel I become a global standard. Basel I is now an important part of the prudential regimes in over 100 countries worldwide. As discussed before, Basel I faced widespread criticism causing a lot of dissatisfaction regarding its very simplistic risk-insensitive approach to credit risk. The intensifying pressure from industry participants and academia prompted the Basel Committee to introduce Basel II: Revised Framework in June 2004 which became available in mid-2006; however, its final implementation process was disrupted by the U.S. origin sub-prime debacle in 2006 and the ensuing GFC in 2007-09. Once the GFC's widespread panic receded and major markets in Europe and the U.S. stabilized, the implementation of Basel II resumed stronger than prior to the GFC, 121 countries have either adopted or in the process of adopting Basel II.

ASEAN-5 countries have made remarkable strides over the past three decades to bring their domestic banking sectors in line with Basel II and Basel III standards. However, the speed and effectiveness of their Basel II implementations had been disparate and largely varied; moreover, ASEAN-5 countries (Singapore has always been an early adopter among peers) only managed to complete their Basel II implementation between 2008 and 2012 (Table 2.14). The Financial Stability Institute report (FSI, 2015) indicates that 109 non-Basel / non-EU jurisdictions have provided updates on their implementation progress and based on the information, 94 of them have either implemented Basel II (89 for Basel III) or in the process of implementation.

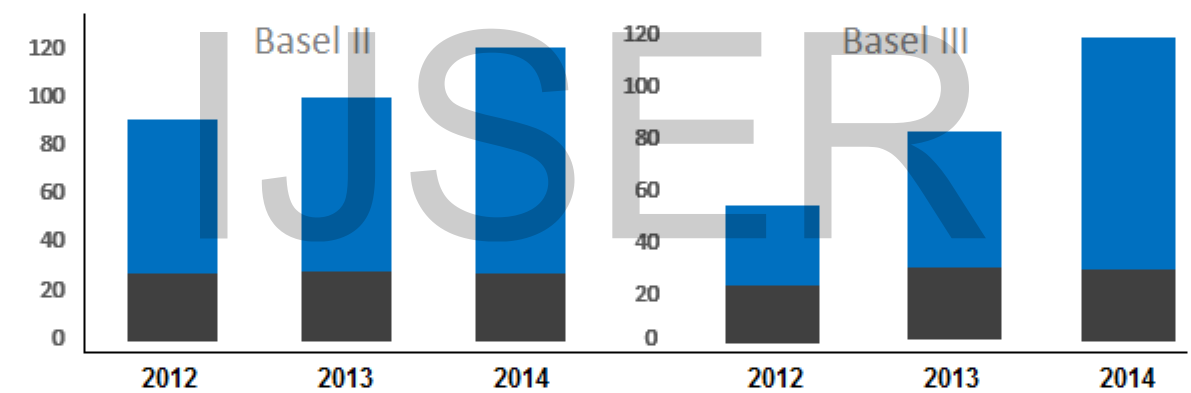
Table 2.14: ASEAN-5 implementation status on Basel II

Elements	Indonesia		Malaysia		Philippines		Singapore		Thailand	
SA	4	2008	4	2008	4	2007	4	2006	4	2008
FIRB	4	2008	4	2010	1	NA	4	2006	4	2008
AIRB	4	2010	4	2010	1	2010	4	2007	4	2009
BIA	4	2008	4	2008	4	2007	4	2006	4	2008
TSA	4	2008	4	2008	4	2007	4	2006	4	2008
AMA	4	2008	1	NA*	1	NA*	4	2006	4	2012
SMM	4	2008	4	2008	4	2003	4	2006	---	NA*
IM	4	2008	4	2008	4	2003	4	2006	---	NA*
P2	4	2008	4	2010	4	2011	4	2006	4	2010
P3	4	2008	4	2010	4	2007	4	2006	4	2008

Source: FSI (2015), BIS

SA = standardized approach, FIRB = foundation internal ratings-based approach, AIRB = advanced IRB approach; Pillar 1 – operational risk: BIA = basic indicator approach, TSA = standardized and alternative standardized approach, AMA = advanced measurement approaches; Pillar 1 – market risk: SMM = standardized measurement method, IM = internal models; P2 = Pillar 2; P3 = Pillar 3; NA* = developments are monitored. Status indicators are as follows: 1 = draft regulation not published, 2 = draft regulation published, 3 = final rule published, 4 = final rule in force, 5 = not applicable.

A number of developing countries and emerging markets often complain that they are rushed with very challenging phase-in arrangements for Basel II, 2.5, and III. For instance, Singapore, as the only mature economy among ASEAN-5, fully implemented risk coverage enhancements under Basel 2.5, which imposes higher capital requirements on banks for the trading book and complex securitization exposures related to derivatives. The adoption of internal model approach for market risks is limited across ASEAN-5 where securitization risks are insignificant and re-securitization structures do not exist. Against this background, the Basel 2.5 rules had been viewed as immaterial based on the country-specifics and are not considered for implementation by Indonesia. Similarly, the Bangko Sentral ng Pilipinas - BSP of the Philippines communicated to the Basel Committee that it plans to implement Basel 2.5 enhancements together with Basel III implementation. Thai banks have no pillar 1 risk and the required enhancements to pillar 2 can be addressed under the current pillar 2; however, the BOT will make its final decision whether Basel 2.5 is necessary after the results of its QIS.



	2012	2013	2014	2012	2013	2014
Others	64	73	94	32	52	89
BCBS	27	27	27	19	27	27

Sources: BCBS (2014a); FSI (2015)

Figure 2.8: FSI survey on Basel II and Basel III implementation
Implemented or in process of implementation

Although Malaysia's securitization and trading markets have grown a great deal in recent years (its exposure to structured finance products such as ABS and SPEs is limited), these markets are still comparatively small and their potential risks are manageable by the existing framework.

The Bank Negara Malaysia (BNM) still implemented elements of the Basel 2.5 to strengthen banking resilience; Pillar 1 was implemented in 2009, requiring banks to conduct tightened credit analysis on ECAI-rated securitization products; the BNM also issued guidance on Pillar 2 in 2013 to address inadequate risk assessment processes; and Pillar 3 was implemented in 2010 to improve disclosures of securitization exposures in the banking book (FSI, 2015).

Table 2.15: Adoption status of Basel III in member jurisdictions

	October	2012	2013	2014
Risk-based capital standard	Final rules in force	0	12	27
	Final rules issued (not in force)	7	14	---
	Draft rules issued	18	1	---
LCR	Final rules in force	---	1	3
	Final rules issued (not in force)	---	10	16
	Draft rules issued	---	4	7
Leverage ratio (disclosure standard)	Final rules in force	---	---	4
	Final rules issued (not in force)	---	---	11
	Draft rules issued	---	---	8
G-SIB and D-SIB standards	Final rules in force	---	1	4
	Final rules issued (not in force)	---	10	8
	Draft rules issued	---	0	6

Source: BCBS (2014a)

As evinced in the fifth update report of the Basel Committee to G-20 leaders (Table 2.15), the final rules of the risk-based capital are in force in the 27 member jurisdictions in 2014 (more than doubled over 2013), which are on track implementing Basel III in accordance with the pre-set objectives by the Basel Committee. Although all 27 members have issued final rules on risk-based capital standards, the progress on other elements is moving somewhat slower.

As of January 2014, 14 members had issued final or draft rules on G-SIB or D-SIB, but only 4 had final rules in force; 23 had issued final or draft rules on the Liquidity Coverage Ratio (LCR), just 3 had final rules in force; and 19 members had issued final or draft rules on the leverage ratio, 4 had final rules in force (Table 2.15). By September 2014, over 90% of the 27 member jurisdictions had final or draft rules on G-SIB or D-SIB (23), LCR (26), and LR (23). In terms of consistency with the globally agreed Basel III minimum standards, the Basel Committee's assessments undertaken or planned (2012-16) show that a majority of the 27 member jurisdictions are compliant. Since the Basel Committee's last report to update G-20 leaders on Basel III implementation, the aggregated capital base across all 27 member-jurisdictions has improved substantially. The main points of the report indicate that the largest drop was in the average common equity Tier 1 (CET1) shortfall, decreased from €400 billion in 2011 to €15 billion at the end of 2013 (a 96% reduction); furthermore, the CET1 capital ratio has also improved by almost 7.4% to reach 10.2% of RWAs (was 9.5%). Except a few smaller banks, most banks are in compliance with Basel III rules ahead of the 2019 deadline, (BCBS, 2014a).

The GFC and its severe contagion process along with enormous financial losses has created a real urgency amongst ASEAN-5 to adopt Basel III (Table 2.16) to ensure financial stability. The peer pressure, which is culturally significant in Asia but more so within ASEAN-5, has increased the speed of adoption and implementation. The steady progress is on track, but not without minor country-specific variations. The founding members of ASEAN-5 have confirmed their full commitment to implementing Basel III. Each country has established its roadmap for the phase-in timetable; however, some aspects of the Basel III rules have been either modified, partially implemented, or cancelled as required or relevant to banking systems in these countries.

Table 2.16: Implementation status on Basel III
by member and non-member jurisdictions

Elements	Indonesia		Malaysia		Philippines		Singapore		Thailand	
Liq (LCR)	1	2014	3	2015	2	2015	1	2014	1	2014
Def Cap	4	2014	4	2013	4	2014	4	2010	4	2013
Risk cov	1	2013	1	NA	2	2013	4	2010	4	2013
Conserv	1	2014	1	2015	4	2014	3	2012	3	2012
C-cycl	1	2014	1	2015	5	NA*	3	2012	3	2012
LR	2	2014	1	TBA	2	2014	4	2010	1	*
D-SIBs	2	2013	1	TBA	3	2013	1	2016	1	*
G-SIBs	2	2013	1	NA	5	NA	4	2014	5	NA

Source: FSI (2015), BIS

Liq = liquidity standard; Def cap = definition of capital; Risk cov = risk coverage; Conserv = capital conservation buffer; C-cycl = countercyclical capital buffer; LR = leverage ratio.
Status indicators are as follows: 1 = draft regulation not published; 2 = draft regulation published; 3 = final rule published; 4 = final rule in force; 5 = not applicable; TBA = to be announced
NA* Developments are still being monitored.
* The BOT has been conducting QIS to assess appropriateness and implications, no final decision yet.

Among ASEAN-5 nations, Indonesia and Singapore are the only Basel member-jurisdictions. Singapore's assessment was done by the Basel Committee and the status report was published in March 2013; Indonesia's assessment is planned for September 2016, but the preparation work will be undertaken during 2015. Albeit some non-Basel Committee jurisdictions have voiced grave concerns regarding the stringent Basel III rules, most countries have been making steady progress in the adoption of the Basel III standards ahead of the January 2019 deadline.

Singapore and Indonesia (only members of the Basel Committee from ASEAN-5) have successfully implemented risk-based capital under Basel III; however, implementation of other elements are still in initial stages in Indonesia (consultative documents on Liquidity Coverage Ratio - LCR and Leverage ratio - LR have been issued in Q4 2014, and D-SIB rules will be imposed in 2016). Due to its complex and open financial system, Singapore is a frontrunner in implementing Basel III and stress testing. Singapore has already implemented the G-SIB rules in January 2014 (the four of ASEAN-5 countries have no G-SIBs) and LCR by mid-2014, but the D-SIB requirements are expected to be implemented as of January 2016.

The Philippines has made concrete efforts towards implementing Basel III rules, the only element that the BSP is not considering to implement is the countercyclical capital buffer because the country's financial sector is the smallest compared to peers and its exposure to structured finance and securitization products is almost none. The BOT of Thailand conducted Quantitative Impact Studies (QIS) to assess whether LCR was relevant in Thai financial system. Except the Credit Valuation Adjustment (CVA) capital charge, the BOT has implemented risk coverage enhancements and the rules have been fully in force since January 2013. Due to the size and nature of their financial system, the Philippines and Thailand currently are not pursuing implementation of the rules related to countercyclical capital buffer (FSI, 2015).

The BNM has not finalized its decision to formally adopt the Leverage Ratio under Basel III, but the ongoing analysis (observation) since 2012 to study its appropriateness must be concluded with a final decision by the 2018 deadline set by the Basel Committee. Also, the BNM sees no need to implement the Risk Coverage enhancements under Basel III because it is pointed out that the current framework (Pillar 1 was already strengthened in 2009 under Basel 2.5) is both adequate and sufficient to detect, capture, and control derivative and securitization related risk exposures. The BNM is still not settled on D-SIB, the BNM feels that it may need to implement the D-SIB rules as Malaysian banking system has become more complex over the years as domicile banks are forming into BHCs, but to implement G-SIB is not necessary.

After the Basel Committee's announcement of the new Basel III standard as a replacement of Basel II, plethora of studies embarked on investigating potential long-term impact of Basel III in terms of bank capital, spreads, and state output. Among the recently published academic research and private sector headed studies (IIF, 2011), five key studies are considered *"official"* due to their respected results by the industry, or received with skepticism as the results of a study by the Institute of International Finance significantly parted from the rest. Although structures and forms of the models used in the referenced studies vary, their theoretical foundations are based on the Black-Scholes (1973) option pricing theory, the Sharpe's CAPM, or the Merton (1974) structural model of default. The majority of these studies used proprietary econometric models with the exception of Slovik and Cournède (2011) did not disclose to the general public the methodologies, models, and assumptions used to drive to the studies' published results.

2.4 Chapter Summary

The thesis explores five seminal theories or models that became the pillars of the modern finance as well as the foundation building-blocks of both private and academic research. A great majority of models, theories, or approaches used in finance has been directly or indirectly based on these path-breaking works. The thesis described them on theoretical grounds and then identified their paradigm-shifting natures. Next chapter presents models, methodologies, and the data. First, the thesis estimates the cost impact of higher capital ratios of Basel III on the banking sectors of ASEAN-5 and analyzes the results statistically. Second, the thesis constructs a macro stress testing framework through which TD stress test is used in Malaysia's banking sector to assess how it actually withstands the assumed shocks. Finally, the stress testing results are analyzed in terms of capital adequacy and the needed capital injection by the government.

CHAPTER 3
RESEARCH METHODOLOGY

3.0 Introduction

In this chapter, the thesis assesses the cost impact of Basel III capital and liquidity requirements on bank capital, lending spreads, and the state output across ASEAN-5 economies. In response to higher capital and liquidity requirements, ASEAN-5 banks are assumed to pass a portion of the borrowing cost of funds to bank customers by raising their lending rates. The thesis also focuses on the macro stress testing of Malaysia's banking sector to assess its resilience to extreme but plausible scenarios and to examine its capital position in the aggregate. Malaysia-wide stress test is based on top-down (TD) approach consisting of one baseline and two adverse scenarios; the results are informative to central banks, supervisors, and bank executives.

Because the banking operation is at the epicenter of financial intermediation and there is no perfect substitute for it in capital markets, the broader economic activity is adversely affected by increases in the cost of funding. To compensate for the higher capital and liquidity requirements of Basel III, banks are forced to raise lending rates, reduce lending volumes or cut down operational costs by downsizing. The upshot of these policy reforms and the resultant actions often lead to a reduction in investment and a shrinkage in state output (Yan et al., 2011).

3.1 Data and Capital Definitions

Aggregated bank data is used for eight years covering the period 2011 to 2019, during which the phase-in arrangements of higher capital and liquidity requirements, conservation buffers, leverage ratio, G-SIB surcharge, and countercyclical buffer began. Bank specific balance sheet and income statement identities were collected from various sources such as Bankscope, banks' own websites for quarterly financial statements and annual reports. The macroeconomic data covers the period of 1997 to 2008, collected from central bank database, IMF Data Warehouse, the Basel Committee, the Bank for International Settlements, the World Bank Development Indicators and the World Bank (2003) database for banking crises.

The analyses in this section focus on ASEAN-5 banks excluding non-financial intermediaries. A total of 108 banks from Indonesia (104 privately-controlled and 4 government-controlled commercial banks), 56 from Malaysia (43 privately-controlled commercial and 13 investment banks), 19 from Philippines (17 privately-controlled and 2 government-controlled commercial banks), 6 from Singapore (5 privately-controlled commercial banks and one foreign subsidiary); 16 privately-controlled commercial banks from Thailand. The thesis has used the following capital definitions based on the Basel III capital and liquidity standards (BCBS, 2010a);

Common Equity Tier 1 (CET1) ratio = Common Equity Tier 1 capital / RWAs = 4.5%

Tier 1 capital ratio = Total Tier 1 capital / RWAs = 6.0%

Total capital ratio = (Tier 1 capital + Tier 2 capital) / RWAs = 8.0%

Leverage ratio = Tier 1 capital / Total exposure = $\geq$ 3%

Net Stable Funding Ratio (NSFR) = Available stable funding / required stable funding = ≥ 100

Liquidity Coverage Ratio (LCR) = HQLAs / Net liquidity outflows over 30-day period = ≥ 100

HQLA: High quality liquid assets

3.2 Economic Cost of Basel III

The current regulatory environment continues to put downward pressure on bank profitability via higher capital and liquidity requirements under Basel III. In response to having to hold more capital, banks are pressured to raise lending spreads to pass a portion of the higher funding cost to bank customers. The new capital and liquidity regulation affect economic activity, hinder the process of credit growth, and thereby dampen the chances of economic recovery. Besides the negative impact, the tighter capital ratios are argued to make the global banking system more resilient, thereby reduce the probability of crises occurring. Since the introduction of the Basel III rules fully effective by 2019, a plethora of studies have provided assessments of Basel III impact on Bank capital, bank lending, and lending spreads (BCBS, 2010b; MAG, 2010a,b; Angelini et al., 2011; Santos and Elliott, 2012; Slovik and Cournède, 2011; and King, 2010).

3.2.1 Methodology

The regulatory reforms introduced in the aftermath of the GFC is projected to impose significant costs on banks and banking sectors across ASEAN-5 arising from higher capital requirements, additional capital buffers, and new liquidity standards (BCBS, 2010a). A bipartite analyses was performed; first, the cost impact of Basel III on bank capital, lending spreads, and the GDP was estimated; second, the economic benefit of Basel III was investigated based on the assumption that a strengthened financial system underpinned by rigorous banking supervision will reduce the probability of future crises; as a result, banking sectors will be less prone to systemic crises.

The models used in recently published studies differ in many aspects. In line with most studies, dynamic stochastic general equilibrium (DSGE) model and vector error correction model

(VECM) have been utilized. Each model type has advantages and disadvantages; in contrast to VECM, DSGE models are the only approach allowing counterfactual experiments with policy scenarios where the effects of the new Basel III reforms on economic output and its variability can be studied. The DSGE models also have weaknesses in quantifying endogenous risk and defaults; thus, available DSGE models are fully or partially calibrated (Angelini et al., 2011).

MAG (2010a) used a semi-structural model such as VECM model in connection with the vector autoregression (VAR) approach to estimate the log-run relationships among a small sample of macro variables for the U.S. The main advantage of VECM is that it helps unravel the demand and supply curve factors, however there are disadvantages as well; the important of which is that VECM models do not allow counterfactual experiments. Roger and Vlček (2011) use two versions of DSGE models to assess the macroeconomic impact of higher capital and liquidity requirements imposed by the Basel reforms; one analysis is based on data and parameters for the Euro area and the second one is based on the United States. In both analyses, exogenously determined liquidity is in the form of bank assets held in low-risk government bonds. In other studies liquidity requirement is determined endogenously (e.g. Dellas et al., 2010) and Gambacorta (2010) used liquidity-to-deposit ratio in the VECM model for the U.S.

3.2.2 Basel III Impact on Bank Capital

Under strict conditions (i.e. perfect markets, tax irrelevance, no policy guarantees), Modigliani and Miller (1958) argue that a bank's capital structure (i.e. higher equity-based capital) is irrelevant to its weighted average cost of capital. However, in the real world, markets are imperfect surrounded by distortions favoring debt issuance over equity because not only interest expense on debt is tax deductible but a host of implicit and explicit government guarantees exist (i.e. FDIC). The Basel III agreement raises capital requirements substantially; effective as of 2015 onward, the minimum CET1 ratio is increased from 2% to 4.5% and Tier 1 capital ratio from 4% to 6% of RWAs. By January 2019, the minimum capital requirement becomes 7% while the total capital requirement (8%) can reach to 15.5% including a conservation buffer of 2.5%, a G-SIB surcharge of 2.5% , and a countercyclical buffer of 2.5% (BCBS, 2010a).

The elements of capital must be defined clearly before any empirical or analytical (i.e. DSGE) analyses can be performed. Most studies since 2010 analyzed the impact of Basel III standards on banks via capital instruments. Locarno (2011), Giordana and Schumacher (2012), and Angelini et al. (2011) used CAR, LCR, NSFR; Slovik and Cournède (2011), Miles at al. (2012), Gauthier et al. (2012) used CAR; Milne (2013), Boissay (2011), Barrell et al. (2010a, b), and Hartlage (2012) used LCR; differently from the rest, Cincotti et al. (2012) and Georg (2011) used countercyclical buffer and G-SIB surcharge respectively; in addition to CAR and LCR, Kato et al. (2011) used countercyclical buffer. The capital definitions were from BCBS (2010a).

Krug et al. (2014) define the key ratio of the minimum risk-weighted capital adequacy requirement (CAR) as the Core Capital Quota (CCQ) for bank (i) at time (t). BCBS (2010a) defines the ratio as common equity Tier 1 (CET1) / RWAs (increased to 4.5% under Basel III).

$$\mathrm{CCQ}_{i,t} = \mathrm{Core\ Capital}_{i,t} \,/\, \mathrm{RWAs}_{i,t} \geq 4.5\% \qquad (3.2.2.1)$$

The aggregate data used in the analysis is from 2013Q1 to 2015Q4 for ASEAN-5 countries.

During the severe episode of the GFC, banks experienced a freeze in short-term funding. The second microprudential capital component is the liquidity coverage ratio (LCR) with the objective of making undisrupted accessibility to short-term funding channels to avoid unnecessary stress in a 30-day period during which banks should have sufficient HQLAs to cover cash outflows.

$$\mathrm{LCR}_{i,t} = \frac{\text{High Quality Liquid Assets (HQLA)}_{i,t}}{\text{Net Cash Outflows (30 days)}_{i,t}} \geq 100 \qquad (3.2.2.2)$$

$$\text{Net Cash Outflows}_{i,t} = E\left[C_{i,t}^{Out}\right] - \min\left\{E\left[C_{i,t}^{in}\right]\right\}, 0.75 * E\left[C_{i,t}^{Out}\right] \qquad (3.2.2.3)$$

$$E\left[C_{i,t}^{Out}\right] = c_{i,t}^{Out} + \sum_{k=1}^{n} \lambda_k^l * l_{i,t,k} \qquad (3.2.2.4)$$

Where c_i^{Out} denotes the contractual cash flows between (t) and (t+30), λ_k^l is the run-off rate $l_{i,t}$ of type $(k = 1,2, \dots n)$ under the assumed stress scenario (Keister & Bech, 2012). In these analyses, the assumed run-off rates are 10% for retail deposits and 100% for wholesale deposits. Cash in-flows are computed similar to cash out-flows, applied to assets rather than liabilities.

$$E\left[C_{i,t}^{in}\right] = c_{i,t}^{in} - \sum_{k=1}^{n} \lambda_k^a * a_{i,t,k} \qquad (3.2.2.5)$$

Where λ_k^a represents the run-off or default rate for assets under distress. Under Basel III, three new requirements are imposed on banks; capital buffer of 2.5% is introduced to reduce procyclicality (0.625% by 2015 and fully phased-in by 2019), with that, CET1 increases to 7% (4.5%+2.5%); to avoid excessive credit growth, 0-2.5% countercyclical buffer is applied; excessive credit expansion and leverage are linearly correlated, so a leverage ratio of 3% as a cap to prevent a severe procyclical deleveraging process as observed during the GFC. The Basel Committee stated that this was a major destabilizing factor (BCBS, 2010a).

$$\mathrm{LR}_{i,t} = \frac{\text{Tier 1 Capital}_{i,t}}{\text{Total Assets}_{i,t}} \geq 3\% \qquad (3.2.2.6)$$

The GFC showed that contagion related losses were significant as the interconnectedness among systemically important banks has steadily risen since the Asian crisis in the late 1990s.

Following the collapse of Lehman Brothers, and more specifically during the worst episode of the GFC, one bank's increased probability of failure or default created a snowball effect resulting in a cascade of defaults among financial and non-financial institutions. To alleviate risk-taking and market distortions, the Basel Committee imposed up to 2.5% surcharge on G-SIBs (BCBS, 2011b). The level of surcharge is set based on a bank's score, calculated as;

$$\text{Total Score}_{i,t} = \frac{1}{3}\sum_{k=1}^{3} S_{i,t,k} \qquad \text{(score of bank i)} \qquad (3.2.2.7)$$

Next, to determine a bank's size (whether an SIB or not), the size of its total assets is measured against the consolidated assets of the entire banking sector;

$$S_{i,t,1} = \frac{\text{Total Assets}_{i,t}}{\sum_{j=1}^{n} \text{Total Assets}_{j,t}} \qquad (3.2.2.8)$$

A bank's interconnectedness to other banks is measured in the context of borrowed and lent funds along with AAA-bonds held at the central bank; in other words, its total exposures and liabilities within the interbank market; mathematically (e.g. Krug et al., 2014);

$$S_{i,t,2} = \frac{1}{3}\left(\frac{\text{Loans}_{i,t}^{IB} + \text{AAA} - \text{Bonds}_{i,t}^{CB}}{\sum_{j=1}^{n} \text{Loans}_{j,t}^{CB} + \sum_{j=1}^{n} \text{AAA} - \text{Bobds}_{j,t}^{CB}} + \frac{\text{Credits}_{i,t}^{IB}}{\sum_{j=1}^{n} \text{Credits}_{j,t}^{IB}} + \frac{\text{Credits}_{i,t}^{IB}}{\text{Credits}_{i,t}^{IB} + \text{Deposits}_{i,t}} \right) \qquad (3.2.2.9)$$

The final equation deals with the substitutability in the event of a failure. The low-score banks are dispensable while high-score banks are indispensable until substitution becomes available.

$$S_{i,t,3} = \frac{\text{Payments send}_{i,t}}{\sum_{j=1}^{n} \text{Payments}_{j,t}} \quad (3.2.2.10)$$

3.2.3 Basel III Impact on Lending Spreads

The thesis followed the model developed by Slovik and Cournède (2011) in order to measure the impact of a one percentage point increase in capital requirements of Basel III on lending spreads across the five founding members of ASEAN-5. In the analysis, the sensitivities of bank lending rates to higher capital ratios are estimated by using two categories of balance sheet assets; bank lending assets stored on banking books (i.e. credit to households and non-financial firms) and other bank assets held on trading books (i.e. interbank loans and government bonds).

$$r_t^{AL} * AL + r_t^{AO} * AO = r_t^{L} * L + r_t^{E} * E \quad (3.2.3.1)$$

$$r_{t+1}^{AL} * AL + r_t^{AO} * AO = r_t^{L} * \left(L - \frac{RWAs}{100}\right) + r_t^{E} * \left(E + \frac{RWAs}{100}\right) \quad (3.2.3.2)$$

$$\left(r_{t+1}^{AL} - r_t^{AL}\right) = \frac{(r_t^{E} - r_t^{L})}{AL} * \frac{RWAs}{100} \quad (3.2.3.3)$$

Where AL represents lending assets to total assets (%), AO is other assets to total assets (%), L is liabilities to assets (%), E is common equity to total assets (%), RWA is risk weighted assets to total assets (%), r_t^{AL} is return on lending assets (%), r_t^{AO} is return on other assets (%), r_t^{L} is cost of borrowing, r_t^{E} is cost of equity. The first equation assumes that the return on bank assets equal to cost of capital; the impact of a 1 pp increase to RWAs is incorporated in the next equation; and the last equation calculates the impact of Basel III by combining the first two.

Angelini et al. (2011) assessed the long-term economic impact of the Basel III rules on 30 G-SIBs using the dynamic stochastic general equilibrium family (DSGE), the analysis of counterfactual experiments via macroeconomic models is consistent with the other so called *"official studies"* conducted by the Macroeconomic Assessment Group report (MAG, 2010a; 2010b) and the Long-term Economic Impact (LEI) report (BCBS, 2010b). The MAG (2010a) analysis allowed banks to improve capital ratios by issuing new liquidity, increasing retained earnings, reducing dividend payouts, and cutting operational costs. Locarno (2011) used a semi structural model to estimate the impact of Basel III on lending spreads across banks in Italy.

Similarly, Gerali et al. (2010) used a DSGE model to estimate the impact of Basel III on lending spreads in Euro area. One of the key assumptions used was that banks generally conserve capital from retained earnings to comply with the desired (v) ratio of capital ($\mathrm{K_t}$) to loans ($\mathrm{L_t}$) but the ratio has deviated on account of higher capital ratios under Basel III. To compensate the increased cost of funding, the loan rates (interest rates) $\mathrm{R_t^L}$ is set as:

$$\mathrm{R_t^L} = \text{monetary policy rate} - \mathrm{K_b}\left(\frac{\mathrm{K_t}}{\mathrm{L_t}} - \mathrm{V}\right)\left(\frac{\mathrm{K_t}}{\mathrm{L_t}}\right)^2 \qquad (3.2.3.4)$$

Albertazzi and Marchetti (2010) investigated whether contraction in credit supplied associated with low bank capitalization that led to bankruptcies following the fall of Lehman Brothers. Their empirical analysis begins with estimating the equation below (Kapan & Minoiu, 2013).

$$\Delta \mathrm{l_{b,i}} = \alpha + \beta \mathrm{k_b^{low}} + \gamma' \mathrm{d_i} + \eta_\mathrm{i} + \mathrm{u_{i,b}} \qquad (3.2.3.5)$$

Where $\Delta \mathrm{l_{b,i}}$ denotes the change in outstanding loans extended by bank b to firm i and divided by the firm's total assets; $\mathrm{k_b^{low}}$ is a dummy for low-capitalized banks; $\mathrm{d_i}$ is a vector of additional bank characteristics; and η_i is a firm-specific fixed-effect, that allows the authors to control for firm's credit demand as well as any other firm's characteristic.

, uses VAR and VECM on six macroeconomic and credit variables; as such, Y is the log of real GDP, $(r - \pi)$ is the real short-term interest rate, $(i - r)$ is the spread between the lending rate and the money market rate, L is the log of real loan volume, LIQ is the log of the real liquidity ratio CAP is the capital-to-asset ratio; mathematically is shown as;

$$\begin{aligned} L &= \underset{(0.015)}{1.229}\, Y - \underset{(0.049)}{0.273}(i - r) \\ i - r &= \underset{(0.679)}{2.573}\, LIQ + \underset{(0.897)}{3.023}\, CAP \end{aligned} \tag{3.2.3.6}$$

Locarno (2011) assert that supply-constrained equilibrium as a model can be used to assess access demand, the size of which can be an indicator as to how lending spreads behave. He postulates a relationship between short-term rates on loans and the overnight interest rate:

$$\Delta r_t = \gamma * \frac{CR_t}{\bar{L}_{t-1}} = \gamma * \frac{L_t^d - \bar{L}_t}{\bar{L}_{t-1}} \text{ with } \gamma > 0 \tag{3.2.3.7}$$

Where Δr_t denotes the change in the interest rate spread, CR_t is credit rationing, L_d^t is the notional demand of loans and $\check{L}_t$ are observed loans. Credit rationing thus is a function of observables and of the unknown parameter γ. Next, Locarno (2011) develops a model for the supply of credit:

$$\bar{L}_t = L_t^d(*) - CR_t = L_t^d(*) - D_t\left(\frac{1}{\gamma}\Delta r_t\right) * \bar{L}_{t-1} \tag{3.2.3.8}$$

Where D_t denotes a dummy variable that equals zero when the market is in equilibrium.

Šútorová and Teplý (2013) employ the simultaneous equations model to analyze the impact of the higher capital requirements under Basel III on the lending rates for 594 European banks during the 2006–2011 period. In their analysis, they follow the model developed by Chami and Cosimano (2001, 2010); the loan rate settings and provision of loans are based on the assumption that banks follow the basic principles of Bertrand competition, meaning banks follow the same policy and each bank sets its loan rate in a coordinated manner within competition.

Šútorová and Teplý (2013) states that the level of loans provided depends on *"the elasticity of demand for loans"*, the supply side factors (the marginal cost of loans), given by;

$\mathrm{MC_L} = \mathrm{C_L} + \mathrm{C_D} + \mathrm{r^D}$ and the cost of capital is given by the impact on lending rates;

$$\mathrm{r^L} = \beta_0 + \beta_1 \frac{\mathrm{K}}{\mathrm{A}} + \beta_2 \mathrm{r^D} + \beta_3 \mathrm{C_L} + \beta_4 \mathrm{C_D} + \beta_5 \mathrm{r^K} + \beta_6 \ln \mathrm{Assets} + \beta_7 \mathrm{g} + \beta_8 \pi + \varepsilon_3 \quad (3.2.3.9)$$

Where $\mathrm{r^L}$ represents the interest income ratio; (K/A) is the CET1/total capital ratio; $\mathrm{r^D}$ is the interest expense ratio; *CL* – the ratio of non-performing loans to assets (originally the non-interest costs of loans); $\mathrm{C_L}$ is the non-interest expense ratio; $\mathrm{r^K}$ is the cost of capital, ROAE; $\ln \mathrm{Assets}$ is the natural logarithm of assets; g, π is the real GDP growth and inflation (CPI).

Šútorová and Teplý (2013) developed an equation to estimate the elasticity of demand for loans;

$$\ln \mathrm{Loans} = \gamma_0 + \gamma_1 \ln \mathrm{r^L} + \gamma_2 \mathrm{g} + \gamma_3 \pi + \gamma_4 \ln \mathrm{Assets} + \varepsilon_4 \quad (3.2.3.10)$$

Where ln Loans is the natural logarithm of loans provided; $\ln \mathrm{r^L}$ is the natural logarithm of the interest income ratio; g is the real GDP growth; π is the inflation rate, measured by the CPI; ln Assets is the natural logarithm of assets. In the analysis for the coefficient in equation, Šútorová and Teplý (2013) made two expectations; first, an increase in the loan rate r^L should lead to a decrease in demand for loans, and the coefficient γ_1 is an exact measure of the demand elasticity for loans. Second, real GDP growth and the level of inflation are expected to be positively related to the level of loans in the economy (γ_3, $\gamma_4 > 0$).

Caggiano and Calice (2011) quantified the impact of the increased capital and liquidity rules on lending spreads employing VECM and DSGE models.

$$LS_{t,i} = \alpha_i + \beta_1 CAR_{i,t} + \beta_2 ROE_{i,t} + \beta_3 r_{i,t} + \varepsilon_{i,t} \qquad (3.2.3.11)$$

Where LS represents the lending spread; CAR is the capital and reserves to total asset ratio; ROE is the return on equity; and, r is the real interest rate (p. 15).

3.2.4 Basel III Impact on Steady State Output

Inadequate capital (both in quality and quantity) along with insufficient liquidity is a serious threat to the normal-functioning (i.e. financial stability) of the financial system as a whole. The cost of a systemic crisis as in financial losses to economies as a consequence of lower capital and liquidity requirements can be unprecedented as observed during and in the aftermath of the GFC of 2008. To project the impact of higher capital and liquidity of Basel III on output loss within ASEAN-5, the thesis followed Yan et al. (2011), Caggiano and Calice (2011) who used a Vector Error Correction Model (VECM). Prior to the empirical work, the definitions for Tangible Common Equity (TCE) and Net Stable Funding Ratio (NSFR) are provided.

$$\text{TCE} / \text{RWA} = \text{Common Equity} - \text{Intangibles} - \text{Goodwill} / \text{RWA} \qquad (3.2.4.1)$$

$$\text{NSFR} = \text{Available stable funding (ASF)} / \text{Required stable funding (RSF)} \qquad (3.2.4.2)$$

To reduce the heteroskedastic problem, the variables were put into logarithmic forms; real GDP (Y), real bank lending (L), return on equity (ROE), capital ratio (TCE / RWA), and liquidity ratio (NSFR). Next, the variables were set in VAR (treated as endogenous) to estimate the impact of the increased capital and liquidity requirements on output loss.

$$Z_t = \mu + \sum_{k=1}^{p} \Phi_t Z_{t-k} + \epsilon_t\,, \quad t = 1,2,\ldots.T, \qquad \epsilon_t \sim VWN(0, \Sigma) \tag{3.2.4.3}$$

Where $Z_t = [Y,\ i - \pi, r - i,\ L, ROE, NSFR, TCE\ /\ RWA\ ]$; the number of lags (p) is set to 3 based on the Akaike information criteria (AIC). The Augmented Dickey Fuller (ADF) test shows that the variables have one unit root. The equation in (6) was rearranged as a reduced-form error correction model. Then Johansen's trace test is applied to rank the order of integration of the matrix (Π) which determines the number of cointegrating r; α is a $(n * r)$ matrix of loading coefficients and β is a $(n * r)$ matrix of cointegrating vectors (Yan et al., 2011).

$$\Delta Z_t = \Pi(\mu, Z_{t-1}) + \sum_{k=1}^{p-1} \Gamma_k \Delta Z_{t-k} + \eta dum_t + \epsilon_t \tag{3.2.4.4}$$

$$t = 1,2,\ldots.T \qquad \Pi = (\Theta_1 - I) = \alpha\beta'$$

Several log-run relationships among the variables used in the analysis. First log-run relationship relates to how banks set lending spreads, mathematically;

$$r - i = \gamma_0 + \gamma_1 TCE\ /\ RWA + \gamma_2 NSFR \tag{3.2.4.5}$$

The second relationship is a commodities and credit curve supply, showing how a hike in lending rates arising from increased cost of funding due to higher capital and liquidity requirements of Basel III triggers a contraction in credit markets, this may lead to a reduction in the aggregate level of investment activity and steady state output (Bernanke & Blinder, 1988).

$$Y = \alpha_0 + \alpha_1(i - \pi) + \alpha_2(r - i) + \alpha_3 ROE \tag{3.2.4.6}$$

The third is a log-linear log-run relationship, representing a lending demand curve which is a positive function of the real GDP, where volume increases when the real GDP expands; but an inverse relationship exists between lending demand and lending spreads, meaning lending volume contracts when lending spreads increase due to higher capital ratios under Basel III.

$$L = \beta_0 + \beta_1 Y + \beta_2(r - i) \tag{3.2.4.7}$$

The fourth log-term relationship depends on the previous three. Bank profitability is closely tied to GDP growth which is positively or negatively underpinned by lending volume and spreads.

$$ROE = \delta_0 + \delta_1 L + \delta_2(r - i) + \delta_2(i - \pi) \tag{3.2.4.8}$$

Slovik and Cournède (2011) analyzed the cost impact of Basel III on output loss across the three main OECD economies using adjusted semi-elasticities of the OECD New Global Model. They argue that banks holding insufficient levels of capital will make them become more prone to crises affecting GDP growth negatively. Albertazzi and Marchetti (2010), in their analysis of Italy's banking sector during 2007-2009, found evidence that low bank capitalization led to a contraction in the credit supply following the collapse of Lehman Brothers.

Santos and Elliott (2012) investigated the cost impact of higher capital and liquidity requirements of Basel III on economic growth of the U.S., Europe, and Japan through a loan pricing formula. However, "the study focuses on the long-term outcomes, rather than transitional costs, and does not attempt to measure the economic benefits of these reforms" (p. 4). Conversely, the MAG (MAG, 2010a; 2010b), reconvened by the Financial Stability Board and the BCBS, estimated the short-term transition costs due to the new Basel III reforms.

$$L * (1 - t) \geq E^{*}r_e) + \left((D^{*}r_d)\right) + C + A - O) * (1 - t) \qquad (3.2.4.9)$$

Where L denotes the effective interest rate on the loan, including the annualized effect of fees; t is the marginal tax rate for the bank; E is the proportion of equity backing the loan; r_e is the required rate of return on the marginal equity; D is the proportion of debt and deposits funding the loan, assumed to be the amount of the loan minus E; r_d is the effective marginal interest rate on D, including indirect costs of raising funds, such as from running a branch network; C is the credit spread, equal to the probability-weighted expected loss; A is the administrative and other expenses related to the loan; and O is the income and expense items related to the loan.

All of the studies mentioned in this section of the analyses have the same conclusion that higher capital and liquidity requirements are negatively correlated with the lending spread. Caggiano and Calice (2011) used the following panel data model to estimate the impact of lending spreads on real GDP output. Where Y denotes the real GDP, mathematically;

$$Y_{i,t} = \mu_i \gamma_1 LS_{i,t} + \gamma_2 r_{i,t} + u_{i,t} \qquad (3.2.4.10)$$

In addition to the cost impact of tighter prudential requirements on steady state output levels, Angelini et al. (2011) measure the cost effect on welfare using a formula derived by Van den Heuvel (2008). The objective of their analysis is to determine the permanent loss in consumption as expressed in percentage which is a deviation from the baseline scenario to avoid tightening.

$$\text{Cost} = \frac{D}{C}(R^E - R^d - g_D)\frac{\Delta\bar{V}}{(1-\bar{v})} \qquad (3.2.4.11)$$

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Where D represents total deposits; C is the aggregate consumption; R^E is the risk-adjusted return on equity; R^d is the average interest rate on total deposits; $\Delta\bar{v}$ is the welfare cost of raising capital ratios; g_D is the share in the non-interest cost, bound by $0 \leq g_D \leq g/D$ where g is the operating expenses minus non-interest income. When $g_D = 0$ indicates an upper bound on cost and when $g_D = g/D$ is a lower bound on cost. An alternative version of the formula as follows;

$$\text{Cost} = \frac{D}{C}\left[\frac{(R^L - R^d - g/L)}{\bar{v}} - g_D\right]\frac{\Delta\bar{v}}{(1-\bar{v})} \qquad (3.2.4.12)$$

Where R^L denotes the average return on total assets, loan losses, and provisions; L is the total assets of the banking system. The above formula differently than the previous is used to test for the robustness of the financial system as a whole. This method, when compared with DSGE and VECM models, is simpler but it does not take into account the effects of liquidity regulation.

3.2.5 Economic Benefit of Basel III

The underlying basis for the economic benefits of increased capital and liquidity requirements is the fact that a more resilient banking system would be less prone to costly crises with unthinkable disruptions to foregone output (i.e. the GFC). Higher capital ratios, buffers, and tightened liquidity also lead to fewer output volatility. This, even in the absence of crises, produces positive impact on welfare. The recorded historical data shows that banking crises are infrequent (once every 20-25 years) and the probability of their occurrence is less than 5% (BCBS, 2010e). During 1985-2009, G-10 countries faced crises with a probability of 5.2% (Reinhart and Rogoff, 2009) and 4.1% (Laeven & Valencia, 2008). Since the Asian crisis of 1997-98, ASEAN-5 countries have been subject to bouts of micro and macro shocks and the ensuing volatility, but no member country experienced a real crisis.

To synthesize the impact of higher capital and liquidity requirements of Basel III on the probability of a crisis occurring, the binary-state model (e.g. Yan et al., 2011) was used where the probability of crises depends on each explanatory variable linearly:

$$\mathrm{Pr}_t = \Phi(\alpha_i \mathrm{TCE/RWA}_t + \beta_i \mathrm{NSFR}_t + \gamma_i Z_{it} \qquad (3.2.5.1)$$

Where $\mathrm{TCE/RWA}_t$ denotes the ratio of tangible common equity capital and risk-weighted assets and net stable funding ratio; Z_t is the vector of macroeconomic variables such as the real estate price inflation (RPI_t) and the current account balance ratio (CA_t); P_r is the probability of a crisis occurring; and Φ denotes a cumulative normal distribution function usually used in standard probit models. An alternative non-linear-in-factor probit model by Kato et al. (2010) as follows;

$$\mathrm{Pr}_t = \Phi(\alpha_i \mathrm{TCE/RWA}_t * \mathrm{NSFR}_t + \beta_i Z_{it} \qquad (3.2.5.2)$$

Financial or economic crises result in costs to economies in terms of foregone output, but the systemic banking crises are ever more damaging, costly (i.e. severe losses during the worst episode of the crisis), and longer lasting in terms of their farfetched effects. Caggiano and Calice (2011) developed the following formula to calculate the benefit of a reduced probability of crises due to increased capital and liquidity requirements under Basel III for a sample of 53 African nations over nearly three decades (Laeven & Valencia, 2008; 2010).

$$\mathrm{Benefit} = \Delta\mathrm{Prob}\{\mathrm{crises}\} * \Delta\mathrm{GDP} \qquad (3.2.5.3)$$

The calculation of the positive impact of Basel III on financial stability in terms of reduced probability of systemic crises and welfare involves a two-part analysis; first, the cost of output loss (ΔGDP) is calculated and the loss is characterized as temporary or permanent. However, the thesis does not make this distinction because the cost of no crisis in the financial history was permanent. Second, the reduced probability of crises helped by tighter capital and liquidity regulations is estimated using a multivariate logit model. After these two steps are done, the last step is to multiply the ΔGDP with the obtained probability figure.

Next, the thesis uses a multivariate logit model developed by Demirgüç-Kunt and Detragiache (1998) to estimate the impact of higher capital and liquidity requirements on the probability of a crisis occurring. Where $P_{t,i}$ denotes a binary variable and assumed to depend on a vector of k explanatory variable ($x_{t,i}$); β is the vector of parameters. $P_{t,i} = 1$ if country (i) is hit by a crisis at time (t), and $P_{t,i} = 0$ in the case of no crisis. Log-likelihood is maximized as;

$$\ln(L) = \sum_{t=1}^{T} \sum_{i=1}^{n} \{P_{t,i} \ln[F(\beta' x_{t,i})] + (1 - P_{t,i} \ln[1 - P_{t,i}]\} \quad (3.2.5.4)$$

The thesis used explanatory variables that were obtained quarterly from Bankscope, publicly disclosed financial statements and annual reports published by banks, International Financial Statistics, and respective central banks' databases: TCE/RWA (definition provided by BCBS, 2010a), NSFR (net stable funding ratio), ROE (return on equity), i (average interbank rate), π (inflation rate as CPI% change), r (clearing banks' rates for different loan types), RPI (real estate price inflation as % change in the index), CA (the ratio of current account balance to nominal GDP rate), GDP Y (ASEAN-5 GDP), L (aggregate lending volume to the private sector).

Following the general-to-specific approach, the benefits of higher capital and liquidity rules were estimated using three sets of explanatory variables of banking crises across ASEAN-5 economies: real economy indicators (real GDP growth, real interest rate); macro indicators (the current account balance, inflation rate); and banking indicators (credit growth, CAR). To calculate the marginal effect of higher capital ratios on the probability of crisis, x_j is the j-th explanatory variable included in the vector of regressor and y_i is the dependent variable.

$$\frac{\partial E(y_i|x_i,\beta)}{\partial x_{ij}} = f(-x_i'\beta)\beta_j \qquad (3.2.5.5)$$

Where $E(y_i|.)$ denotes the conditional expected value of y_i, β is the vector of parameters and f (.) is the logistic function (e.g. Caggiano and Calice, 2011). Next, same as in BCBS (2010b), variable ratios are mapped based on OLS regression: $Z_i = \beta X_i + \varepsilon_i$ Where Z_i denotes the CAR as the main ratio (i.e. regulatory capital plus reserves to total assets) and X_i is the Tier1/RWA.

Some studies (e.g. Tarashev & Zhu, 2008) using the portfolio model estimated the probability of systemic banking crises where the entire banking system is treated as a portfolio. In these analyses, default correlations are based on Moody's KMV and a banking crisis is assumed to be systemic when in excess of four SIBs fail. The PDs of banks are estimated using a simple logit model (e.g. BCBS, 2010e), linking capital and liquidity ratios to the likelihood of default.

$$PD(banks) = f(-0.5 - 50 * Cap_{-1} - 3 * L_{Liq_{-1}}) \qquad (3.2.5.6)$$

Where Cap represents the ratio of TCE to total assets and L_Liq the ratio of customer deposits to total liabilities. All the coefficients are statistically significant at least at $\alpha = 0.05$ (5%).

The Bank of England (BoE) quantified the probability of a banking crisis via using Merton (1974) style structural credit risk model (e.g. Elsinger et al., 2006). This type of analysis focuses on two main channels of risks; (i) the risk that banks fail due to the correlation between their asset values and the market values of their equity; (ii) interconnectedness and interbank network effects can cause failures resulting from balance sheet links among banks. Persistent volatilities in equity prices are directly reflected in the values of banks' assets, therefore continued deterioration in the asset value can cause a bank's equity to fall below the PD point.

Gauthier et al. (2010) used stress testing to assess the impact of more stringent capital and liquidity requirements on six major Canadian banks. Their analysis focused on counterparty risk and asset fire sales which take place when the Tier 1 capital ratio falls below the hurdle rate of 7% imposed by the Canadian regulator. Cifuentes et al. (2005) show that contagion occurs through the channels of counterparty risk and mark-to-market losses.

3.3 Macro Stress Testing in Malaysia

Global liquidity glut combined with the historically low interest rates in the U.S. and across the world created an asset boom mania turning ordinary people into avid buyers. This in turn persuaded banks to expand credit into riskier segments via lax and predatory lending (Schwartz, 2009). Banks, in Malaysia and throughout the world, are both contributors to imbalances and receivers of adverse impact arising from pro-cyclicality, on-and off-balance sheet exposures, and excessive leverage. Constructed stress tests in the thesis were conducted to test the resilience of Malaysia's banking sector to vulnerabilities resulting from exogenous shocks.

After the failure of microprudential stress tests, mainly used by individual banks and supervisors since the late 1990s, the GFC marked the birth of macro stress testing as a crisis management tool. The U.S. was first to use it in 2009 followed by Europe and the UK. Although Europe bungled with its first two EU-wide stress testing programs designed and conducted by the CEBS (2010a) and its successor EBA (2011), the widely perceived success of the Federal Reserve's SCAP (Fed, 2009a,b) spurred worldwide implementations; but the results were widely varied.

3.3.1 Methodology

The thesis follows the stress testing model developed by Čihák (2007b); as an improvement, actual bank data is used in the Malaysia-wide stress test ("MAST") as opposed to hypothetical banks and banking data. A top-down (TD) macro stress testing approach is employed with the objective of assessing credit, interest rate, and exchange rate risks under one baseline and two adverse scenarios. The focus was on measuring the aggregate impact resulting from tighter capital and liquidity regulation of Basel III plus the assumed macro shocks, and how to express them in terms of variables such as capital adequacy and capital injection as a percentage of GDP.

Macro stress testing, as a crisis-management tool, became indispensable in the macroprudential toolbox available to central banks and supervisors across banking sectors around the globe (e.g. Borio et al., 2012). Bernanke (2013) points out that macro stress tests are *"forward-looking"* providing protection against *"so-called tail risks"*. The Basel Committee argues that adequately designed macro stress tests with extreme but plausible scenarios "…improve banking sectors' ability to absorb shocks arising from an acute financial and economic stress" (BCBS, 2010a).

The stress testing horizon of the MAST is three years based on annual data from 2013 to 2015 (Q4), and covers the entire banking sector consisting of 56 entities as deposit takers. As of end-2015, 31 domicile banks controlled MR1.82 trillion of the total financial assets (18 banks owned 74.6% or RM1.74 trillion and 13 investment banks controlled only 3.26% or about RM84 billion). The 25 domestically incorporated foreign-controlled banks enjoyed 22.26% (or RM520 billion) of the consolidated banking assets. The largest five banks in Malaysia account over 70% of the total financial assets, consistent with that in advanced economies (IMF, 2013b; 2015b).

The stress testing scenarios developed and employed in the MAST are simply hypothetical rather than forecasts. The baseline scenario follows a normal course of economic activity, consistent with the latest IMF World Economic Outlook projections for Malaysia (i.e. 5% GDP growth). Adverse and severely adverse scenarios assume a recession, slower recovery, and higher unemployment. In the adverse scenarios, banks are negatively impacted by higher capital and liquidity ratios. The main results of the stress tests are merely indications based on the assumptions and trajectories for a number of key variables describing the nature of economic activity in Malaysia which may or may not reflect the actual developments or market events.

3.3.2 The Typology of Stress Testing

Stress testing is categorized along two key dimensions; microprudential (BU is used by individual banks for internal risk management purposes and by the supervisors for "*Pillar II Solvency"* under Basel III), macroprudential (for surveillance (BU and TD are used in the IMF FSAPs) central banks and the supervisor community use them to assess financial stability), and macroprudential (used by central banks as a crisis management tool since 2009). There is also liquidity stress testing which is less advanced and not linked to solvency.

Microprudential stress testing

BU stress tests are conducted by individual banks to quantify the impact of tail risks (due to extreme but plausible shocks) on the value of portfolios or the bank as a whole (e.g. Haldane, 2009). Under Basel III, banks are required to put in place enhanced and forward-looking micro stress testing frameworks to assess risk exposures via internal models (BCBS, 2009). BU stress tests in most countries focus on credit risk which is the main source of risk affecting the soundness of banks and banking sectors. The disadvantage of BU stress testing is that the assessment of liquidity risk is not part of it plus contagion risk and feedback effects to the real economy are ignored (Sorge, 2004). Macro BU stress testing (i.e. the IMF FSAP) is used by central banks and supervisors to assess the resilience of a bank or the banking sector to external shocks (Jones et al., 2004). As a crisis management tool, BU stress have been applied *vertically* (i.e. the Federal Reserve's SCAP in 2009) or *horizontally* in the UK (Aikman et al., 2009).

Macroprudential stress testing

TD stress tests are used by central banks or supervisors to assess the impact of the assumed scenarios (hypothetical or/and historical) to banks or banking sectors via proprietary in-house models, tools, or approaches. Two strands of macro stress testing models exist; (i) models that link macro variables to micro risk drivers (i.e. credit risk); (ii) and integrated models that take into account liquidity risk and feedback effects (Foglia, 2009). Macroeconomic models do not deal with financial sector variables, therefore satellite models such as reduced-form are employed to map macro shocks into measurable form (i.e. asset quality).

Most TD stress testing models measure credit risk (i.e. counterparty default) in terms of loan loss provisions and non-performing loans, or default rates (PDs) of households and private sectors. In TD stress tests, the analysis is carried out by supervisors at a centralized level, whereas in BU stress tests, banks compute loss distributions on a provided scenario and then send the results to the central bank for aggregation (Sorge, 2004). Alternatively, banks can carry out stress testing calculations at a decentralized level without the central bank aggregating their results. Although the decentralized approach provides some advantages (i.e. detailed modelling helped by richer data and expertise), it may not effectively capture contagion and feedback effects (Čihák & Heřmánek, 2005). The Basel Committee stresses that BU and TD approaches should be used to capture second-round liquidity and systemic effects (BCBS, 2013d).

Stress testing is overly misunderstood and often confused with macroeconomic forecasting and early-warning indicators. Before explaining in detail the important elements of the macro stress test used in this thesis, it would be informative to outline the conceptual differences between them. The following is based on Sorge (2004), macroeconomic forecasting can be described as;

$$\mathrm{E}\,(\tilde{x}_{t+1}) = g_1\,\{X^t, Z^t\} \tag{3.3.2.1}$$

Where t represents the history of past events of a random variable up to time (t); $g_1$is the forecasting function that maps variables X and other factors Z into a vector of expected outcomes that take place in the future. An early-warning indicators model is described as;

$$\mathrm{P}\,(\tilde{x}_{t+1} \geq \bar{x}) = g_2\,\{X^t, Z^t\} \tag{3.3.2.2}$$

The problem with an early-warning mechanism is to identify subsets of X and Z as leading signals to predict the probability of a future crisis. When some critical macroeconomic variables (X) go over the pre-set thresholds, a crisis occurs (i.e. $\tilde{x}_{t+1} \geq \bar{x}$) and no crisis if $\tilde{x}_{t+1} \leq \bar{x}$.

The underlying difference between stress testing and the other two is that early-warning indicators and macroeconomic forecasting models use historical data as an input, but micro or macro stress tests use historical or/and hypothetical scenarios along with several assumptions as inputs to assess how individual banks or banking sectors can withstand extreme but plausible shocks which have not yet occurred. The consequences of $\tilde{x}_{t+1} \geq \bar{x}$ can be evaluated as;

$$\Omega\left(\tilde{Y}_{t+1}\,/\,\tilde{x}_{t+1} \geq \bar{x}\right) = f\,\{X^t, Z^t\} \tag{3.3.2.3}$$

Where $\widetilde{Y}_{t+1} \,/\, \tilde{x}_{t+1} \geq \bar{x}$ is the aggregate measure of the distress of the financial system ($\widetilde{Y}_{t+1}$) restricted to the tail events ($\tilde{x}_{t+1} \geq \bar{x}$). Ω (.) denotes the metric used to compare the vulnerabilities of the financial system across portfolios and scenarios.

3.3.3 The Variables Used in MAST

Before an element of financial data can be used as a variable to measure the impact of stress tests, it must first meet two conditions of properties; (1) in assessing the financial soundness, a variable should be measurable/quantifiable, interpretable, and comparable with other variables; (2) and it should be linked to various risk factors so that econometrics, analytical, and statistical analyses can be performed. A list of commonly used variables is adopted from Čihák (2007b).

Capital is a key measure of impact due to its close link as well as implications on solvency, but capital as a standalone variable is not a clear indication of vulnerability to shocks in an acute stress. To make capital a critical variable in the measurement of financial soundness, it needs to be looked at in the form of a ratio (i.e. Tier 1 capital / RWAs or capital as percent of GDP).

Three important capital ratios used in stress tests as variables are the following:

$$\begin{aligned}
&\text{CET1 Ratio} = \text{CET1 Capital} \,/\, \text{RWAs} = 4.5\% \\
&\text{Tier 1 Capital Ratio} = \text{Total Tier 1 Capital} \,/\, \text{RWAs} = 6\% \qquad (3.3.3.1) \\
&\text{Total Capital Ratio} = (\text{Tier 1 Capital} + \text{Tier 2 Capital}) \,/\, \text{RWAs} = 8\%
\end{aligned}$$

Where CET1 represents common equity Tier 1 capital, RWA is the risk-weighted asset

As an assessment, the capital adequacy ratio (CAR) is used as a key variable and calculated as;

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$$CAR = RC / (CRWA + MRWA + ORWA) = p \qquad (3.3.3.2)$$

Where RWA denotes risk-weighted assets (i.e. $\mathrm{RWA} = \sum \mathrm{W}_i \mathrm{A}_\mathrm{i}$); RC is the regulatory capital, CRWA is the risk-weighted credit risk, MRWA is the risk-weighted market risk, ORWA is the risk-weighted operational risk, and p is the minimum CAR (10.50% in the analyses). The threshold rate of 10.50% CAR is 2.5% higher than the total capital requirement of 8% under Basel III. This hurdle rate is also significantly higher than all of the micro and macro stress tests conducted in the U.S., Europe, and Japan. Using the above equations, RWAs are computed as;

$$\mathrm{RWA} = \mathrm{p}\ (10.50\%) \ * (\mathrm{CRWA} + \mathrm{MRWA} + \mathrm{ORWA}) + \sum \mathrm{W}_\mathrm{i} \mathrm{A}_\mathrm{i} \qquad (3.3.3.3)$$

Another important variable used in the macro stress testing framework is the capital injection expressed as a percentage of GDP. When a bank falls below the hurdle rate (i.e. CAR of 10.50%), it is required to bring its CAR to the minimum capital requirement level by available options, one of which is a temporary capital injection (i.e. backstop) provided by the government. A bank that fails to raise the necessary capital is assumed to be insolvent.

$$\rho = \frac{\mathrm{C} + \mathrm{I}}{\mathrm{RWA} + \mathrm{qI}} \qquad (3.3.3.4)$$

Where C denotes the bank's current regulatory capital, RWAs are the existing risk-weighted assets (i.e. RWA = 8% * (market risk + operational risk) + $\sum \mathrm{W}_i \mathrm{A}_\mathrm{i}$), I is the capital injection (as a government intervention or an injection by the bank owners), q is the percent of (I) that is put into use immediately to comply with the minimum CAR (P = 10.50% of RWAs in the analysis).

$$\mathrm{I} = \frac{\rho\ \mathrm{RWA} - \mathrm{C}}{1 - \mathrm{q}\rho} \quad \text{If } \mathrm{C} < \rho\ \mathrm{RWA}\text{; I = 0 otherwise} \qquad (3.3.3.5)$$

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If q = 0, then the capital injection (I = 0) is not used, at least not for increasing the RWAs to comply with the minimum regulatory CAR (p = 10.50%). If p is substituted with 10.50% in the equation, I = 0.105 * RWA – C. If q > 0, the needed capital injection is higher.

3.3.4 Credit Risk in MAST

At the heart of the traditional banking business lies credit risk, which is the primary risk of default by firms and counterparties. The size and nature of risk has grown substantially over the years inducing the development of large-scale risk assessment models such as stress testing. The adequate measurement of credit risk and market risk have become a central focus for banks, regulatory supervisors, and central banks. However, measuring credit risk is a complex process due to its multidimensional aspects. The thesis adopts a mechanical approach developed by (Čihák, 2007b) to assess how a credit squeeze due to the assumed shocks in adverse scenarios effect non-performing loans (NPLs), concentration of risk, and the probability of default (PD).

In the MAST, four stress shocks are applied to assess credit risk; ***credit shock 1*** is in the baseline scenario (considered to be an adjustment rather than a shock). After the necessary adjustments to the provisioning standards, the new provisioning rules are the following: 2% for pass loans, 5% for special-mention loans, 15% for sub-standard loans, 30% for doubtful loans, and 100% for loss loans. The value of the collateral is 50%, therefore the assumed haircut is also 50%.

Credit shock 2 under adverse scenario is applied to the aggregate levels of non-performing loans (NPLs), which triggers an across-the-board decline in asset quality. This in turn reduces the value of RWAs and capital, putting strain on the banking sector's ability and capacity to absorb losses. The provisioning rates in the baseline scenario are increased; 5% for pass loans, 10% for special-mention loans, 25% for sub-standard loans, and 50% for doubtful loans. Banks under the adverse scenario undertake additional provisioning by 38% compared to the baseline.

Credit shock 3 is applied to several key sectors of the economy. In addition to non-performing loans in credit shock (2), a portion of the performing sectoral loans become new NPLs. As such, 4% in interbank loans, 2% in general government, 8% nonfinancial corporations, 6% domestic sectors, 6% other financial corporations, 4% nonresidents, and 4% other.

Credit shock 4 is applied to concentration risk to determine the number of failures among the largest counterparties and the assumed provisioning rates of those failures. The assumed number of large exposures becoming NPLs is 3 under the adverse scenario.

A bank's credit exposure and the cost of replacing it is the largest when the counterparty defaults. Most large banks use highly sophisticated Monte Carlo simulations to calculate credit risk of their lending portfolios. Although measuring credit risk is similar to the measurement of market risk (i.e. VaR), credit risk models are enormously complex involving a great number of parameters, and due to extremely heavy data loads credit risk calculation could take several days even with the use of the most powerful computers. The following is based on (Ieda et al., 2000).

A bank or a portfolio has n exposures, the default mode can be expressed mathematically;

$$L = \sum_{i=1}^{n} D_i v_i (1 - r_i) \qquad D_i = \begin{cases} 1 & (\text{Probability } P_i) \\ 0 & (\text{Probability } 1 - P_i) \end{cases} \tag{3.3.4.1}$$

Where n denotes the number of exposures, p_v is the default rate of exposure (i) in the future, v_i is the amount of exposure, r_i is the recovery rate $(0 \leq r_i \leq 1)$, and L is the portfolio loss taking a random variable 1 or 0. When the loss is an indiscrete value, the expected value for L;

$$E[L] = \sum_{i=1}^{n} P_i v_i (1 - r_i) \tag{3.3.4.2}$$

Where E denotes the expected value for L; differently than in equation (3.4.4.1), ne is sufficiently large whereas the interval between values is sufficiently small.

The Basel Committee formulated the Standardized Approach (SA-CCR) for measuring exposure at default (EAD) for counterparty credit risk (CCR). Mathematically:

$$\text{Exposure at default under SA} = \text{EAD} = \text{alpha} * (\text{RC} + \text{PFE}) \tag{3.3.4.3}$$

Where RC represents the replacement cost, PFE is the potential future exposure, alpha equals 1.4. If the bank owes a counterparty money it has no exposure to, RC = $\max\{V - C; 0\}$ where V is the value of a derivative contract in the netting set and C is the haircut value of net collateral held. The replacement cost for margined trades: RC = $\max\{V - C; TH + MTA - NICA; 0\}$. Where V and C are defined as unmargined, TH is the positive threshold before there is a margin call, and MTA is the transfer amount for the counterparty to satisfy margin call (BCBS, 2014b).

Aziz and Charupat (1998) estimate credit exposure and loss of a portfolio of derivatives via Monte Carlo simulation; actual exposure (AE), total exposure (TE), and potential exposure (PE).

$$AE(c, t) = \max\{0, V(c, t)\} \tag{3.3.4.4}$$

Where V(c, t) denotes the value of contract (c) at time (t), AE(c, t) is the maximum amount of loss at default or replaced at (t). The potential exposure is an additional maximum amount of loss at default that occurs not at time (t) but at some time τ which is between t and maturity (T):

$$PE(c, t) = max\{0, max_{t < \tau \leq T}\{PV_t[V(c, \tau)] - V(c, t)\}\} \tag{3.3.4.5}$$

Where $\mathrm{PV_t}(*)$ represents the function transforming future values to present values (PV) at time (t). Total exposure (TE) is the maximum potential loss at time (t). Mathematically;

$$\mathrm{TE(c,t) = AE(c,t) + PE(c,t)} \tag{3.3.4.6}$$

The potential loss cannot be greater than the total exposure which includes present and future.

3.3.5 Interest Rate Risk in MAST

Banks use various techniques to assess interest rate sensitivities of assets and liabilities to changes in interest rates. The thesis uses *"gap"* and *"duration"* techniques from (Čihák, 2007b) to measure the direct interest rate risk arising from maturity and repricing mismatches. Rising interest rates have negative impact on bank capitalization and risk-weighted regulatory capital, thus an increase in interest rates creates a gap in interest income and interest expense. Assets and liabilities are sorted into three time-to-repricing buckets (0-3, 3-6, and 6-12 months), and *"duration"* method is used to calculate the impact of interest rate changes on bonds.

$$\frac{\Delta \mathrm{A(r_A)}}{\mathrm{A(r_A)}} \cong \frac{-\mathrm{D_A \Delta r_A}}{(1+\mathrm{r_A})} \quad , \frac{\Delta \mathrm{L(r_L)}}{\mathrm{L(r_L)}} \cong \frac{-\mathrm{D_L \Delta r_L}}{(1+\mathrm{r_L})} \tag{3.3.5.1}$$

Where $\mathrm{D_A}$ and $\mathrm{D_L}$ represent duration, $\mathrm{A(r_A)}$ and $\mathrm{L(r_L)}$ are the values of assets and liabilities of the banking sector, and $\mathrm{r_A}$ and $\mathrm{r_L}$ are the annual interest rates of assets and liabilities.

To examine the adverse effect of interest sensitivities of assets on capital adequacy ratio, the above formula is rewritten as;

$$\frac{\Delta[\mathrm{C(r_A, r_L)/A_{RW}(r_A)}]}{\Delta \mathrm{r_A}} \cong -\frac{(\mathrm{L/A_{RW}})}{1+\mathrm{r_A}} \tag{3.3.5.2}$$

$$\left(D_A - D_L \frac{1 + r_A}{1 + r_L} \frac{\Delta r_L}{\Delta r_A}\right) \frac{1 - \frac{\Delta A_{RW}}{A_{RW}} \frac{C}{\Delta C}}{1 - \frac{\Delta A}{A} \frac{C}{\Delta C}}$$

The thesis assumes that risk-weighted assets move proportionately to total assets.

Based on the assumption that $\Delta A_{RW}/A_{RW} = \Delta A/A$, the equation in 3.4.4.8 can be simplified;

$$\frac{\Delta[C(r_A, r_L)/A_{RW}(r_A)]}{\Delta r_A} \cong -\frac{(L/A_{RW})}{1 + r_A} GAP_D \tag{3.3.5.3}$$

As the final equation, the duration gap can be defined as;

$$GAP_D = D_A - D_L \frac{1 + r_A}{1 + r_L} \frac{\Delta r_L}{\Delta r_A} \tag{3.3.5.4}$$

The logic behind how most banks make money from interest rate differentials is quite simple, they move low-interest short-term liabilities into long-term higher interest rate assets. This is all good, but the ineffective management of this process could lead to severe maturity mismatches between interest sensitive assets and liabilities when interest rates increase. To avoid that, the following conditions must be maintained: $D_A \gg D_L$, $r_A > r_L$ and $GAP_A > 0$.

3.3.6 Foreign Exchange Risk in MAST

Foreign exchange risk is one of the key variables measured in the MAST, which can stem from different sources of exposures including but not limited to imports and exports, open positions in foreign currencies, accounts receivables and payables as well as assets and subsidiaries valued in foreign currency. As in Čihák (2007b), the thesis measures the impact of an exchange rate shock on the capital adequacy ratio (CAR) for annual basis from 2013Q1 to 2015Q4.

Several assumptions have been made; the capital (C) and the risk-weighted assets ($\mathrm{A_{RW}}$) are in domestic currency units; a depreciation in the exchange rate (e) results in a proportional decline in the value of the net open position (F); this in turn adversely affect capitalization and leads to a reduction in capital: $\Delta\mathrm{e}/\mathrm{e} = \Delta\mathrm{F}/\mathrm{F},$ where $\mathrm{F} \neq 0$ and $\Delta\mathrm{C}/\Delta\mathrm{F} = 1$

$$\frac{\Delta[\mathrm{C(e)}/\mathrm{A_{RW}(e)}]}{\Delta\mathrm{e}} \cong \frac{\frac{\mathrm{F}}{\mathrm{e}}\mathrm{A_{RW}} - \mathrm{C}\frac{\Delta\mathrm{A_{RW}}}{\Delta\mathrm{C}}\frac{\mathrm{F}}{\mathrm{e}}}{\mathrm{A_{RW}^2}} \cong \frac{1}{\mathrm{e}}\,\frac{\mathrm{F}}{\mathrm{C}}\,\frac{\mathrm{C}}{\mathrm{A_{RW}}}\left(1 - \frac{\Delta\mathrm{A_{RW}}}{\Delta\mathrm{C}}\,\frac{\mathrm{C}}{\mathrm{A_{RW}}}\right) \qquad (3.3.6.1)$$

Where $\Delta\mathrm{C}/\Delta\mathrm{e} = \Delta\mathrm{F}/\Delta\mathrm{e} = \mathrm{F}/\mathrm{e}$ and the symbol $\cong$ indicates that the equation is an approximation for larger than infinitesimal fluctuations. The above equation can be simplified as;

$$\Delta[\mathrm{C(e)}/\mathrm{A_{RW}(e)}] \cong \frac{\Delta e}{e}\,\frac{F}{C}\,\frac{C}{A_{RW}}\left(1 - \frac{\Delta\mathrm{A_{RW}}}{\Delta\mathrm{C}}\,\frac{\mathrm{C}}{\mathrm{A_{RW}}}\right) \qquad (3.3.6.2)$$

Where $\Delta\mathrm{A_{RW}}/\Delta\mathrm{C}$ reflects the degree of proportional movements of capital and the risk-weighted assets. When $\Delta\mathrm{A_{RW}}/\Delta\mathrm{C} = 0$, it means that capital and the risk-weighted assets did not have a co-movement, in other words, while no change occurred in the value of risk-weighted assets, the change in capital equals the exchange rate shock times the net open position to capital (F/C) and capital adequacy ratio ($\mathrm{C}/\mathrm{A_{RW}}$). The equation in 3.4.6.1 is a linear approximation and it would not be suitable for large banks where the impact on capital tends to be non-linear.

Banks' risk exposures to foreign exchange risk is more manageable than credit and market risks. Most central banks (including the BNM) impose limits on transactions and positions related to foreign exchange, therefore the direct depreciation effect as well as solvency risk is rather small. Besides the direct foreign exchange risk exposure, indirect foreign exchange risk can arise from a depreciation (or appreciation) in the corporate sector's assets and liabilities in foreign currencies. The stress testing literature, including the published results of FSAPs, shows that the assessment of the banking sector's indirect foreign exchange risk is more crucial than its direct risk exposure because getting a complete picture of the former has been more challenging in most countries even with advanced banking systems as opposed to the latter.

Next, the indirect foreign exchange risk in Malaysia's banking sector is assessed. Denoted the debt of the corporate sector ($D_c e$), equity ($E_c e$), open exchange position ($F_c e$), and made the very same assumptions in the formulation of the direct foreign exchange risk previously;

$\Delta E_c/\Delta e = \Delta F_c/\Delta e = F/e$, the impact of indirect exchange risk on corporate leverage (D_c/E_c)

$$\frac{\Delta[D_c(e)/E_c(e)]}{\Delta e} \cong \frac{\frac{\Delta D_c}{\Delta E_c}\frac{F_c}{e}E_c - D_c\frac{F_c}{e}}{E_c^2} \cong -\frac{1}{e}\frac{F_c}{E_c}\left(\frac{D_c}{E_c} - \frac{\Delta D_c}{\Delta E_c}\right) \quad (3.3.6.3)$$

The corporate sector's leverage increases if it is in short position and the exchange rate depreciates. The impact of the indirect foreign exchange risk on the NPL/TL ratio can be computed since the corporate leverage and the NPL to total loans (TL) ratio is positively correlated. Mathematically;

$$\Delta(\mathrm{NPL/TL}) \cong a\Delta[D_c(e)/E_c(e)] \cong -\frac{\Delta e}{e}\frac{F_c}{E_c} \quad (3.3.6.4)$$

Where $\Delta(\mathrm{NPL/TL})/\Delta(D_c/E_c) = a > 0$ when $\Delta D_c/E_c = 0$ Boss et al. (2004) empirically show that the change in the NPL/TL ratio equals the change in exchange rate times the net FX open position and times the parameter (a). Credit shocks under adverse scenarios have the potential of moving the existing performing loans into non-performing category, and to assess the impact on capital, differentiate C/A_{RW} by substituting for NPL/TL in 3.4.6.4, mathematically;

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$$\Delta\left(\frac{C}{A_{RW}}\right) \cong \frac{\Delta e}{e}\frac{TL}{A_{RW}}\left(1-\frac{C}{A_{RW}}\frac{\Delta A_{RW}}{\Delta C}\right)\pi\frac{F_c}{E_c}\,a\left(\frac{D_c}{E_c}-\frac{\Delta D_c}{\Delta E_c}\right) \tag{3.3.6.5}$$

Where the assumption are made that the additional provisions are expressed as a fixed percentage of NPLs (π) and deducted from capital; this increases banks' vulnerability.

3.4 Models Used in Analyses

The thesis has used a list of models to assess the impact of higher capital and liquidity regulation of Basel III on bank capital, lending rates, and state output; also to analyze the results of macro stress testing of Malaysia's banking sector to see how it withstand the assumed hypothetical shocks in adverse scenarios. It followed the Dynamic Stochastic General Equilibrium (DSGE) models constructed by Gerali et al. (2010), Roger and Vlček (2011), and Yan et al. (2011).

3.4.1 Stochastic General Equilibrium (DSGE)

Most studies assessing the cost impact of the new Basel III regulation on banks have employed a family of DSGE models as they provide distinct advantages (Angelini et al., 2011). For instance, DSGE models allow counterfactual experiments and it is possible to synthesize the effect of policy changes on macroeconomic variables in the short-term and long-term.

The following is based on Roger and Vlček (2011); in a closed economy DSGE model, banks are subject to capital and liquidity requirements. The economy is made up of many agents, and banks use deposits from these agents (mainly households) to make loans to entrepreneurs and other households. Households are divided into patient households and impatient households (low discount factor, loans are used to finance expenditure). However, both household types maximize their utility functions via consumption and housing.

In Angelini et al. (2011), there are two consumer types, I = 1, 2 with two utility functions $\mathrm{U_i}$, the steady state welfare can be computed as;

$$\mathrm{W(C_1, C_2) = w_1 * U_1(C_1) + w_2 * U_2(C_2)} \qquad (3.4.1.1)$$

Where $\mathrm{C_1}$ denotes vectors of variables, and the weights $\mathrm{w_1}$ and $\mathrm{w_2}$ indicate importance of the two consumers similar to the patient and impatient households in Roger and Vlček (2011). The two household types or two consumer types have certain assumed constraints; In Beau et al. (2012), the budget constraint household's utility function is expressed as;

$$\mathrm{E_0} \sum_{\mathrm{t=0}}^{\infty} (\beta^{\mathrm{R}})^{\mathrm{t}} \log(\mathrm{C_t}) + \varphi_{\mathrm{t}} \log\left(\mathrm{L_t^h}\right) - \frac{1}{1+\eta} (\mathrm{N_t})^{1+\eta} \qquad (3.4.1.2)$$

Where $\mathrm{C_t, L_t^h, N_t}$ denote consumption, housing, and hours worked. In Roger and Vlček (2011), the housing is only traded between patient and impatient households: $\bar{\mathrm{h}} = \mathrm{h_t^p + h_t^i}$ where $\bar{\mathrm{h}}$ denotes the supply of housing, $\mathrm{h_t^p}$ is the demand housing by patient households, and $\mathrm{h_t^i}$ is the demand housing by impatient households. Patient households incur costs due to utility gains:

$$\frac{\mathrm{K^h}}{2}\left(\frac{\mathrm{h_t^p}}{\mathrm{h_{t-1}^p}} - 1\right)^2 \mathrm{h_t^p} \qquad (3.4.1.3)$$

$$\lambda_t^p(j) = \frac{1}{c_t^p(j) - \rho^h \overline{c}_{t-1}^p}$$

$$\frac{\eta^h}{h_t^p(j)} + \lambda_{t+1}^p(j)\beta_p\left[q_{t+1}^h + \kappa_h\left(\frac{h_{t+1}^p(j)}{h_t^p(j)} - 1\right)\left(\frac{h_{t+1}^p(j)}{h_t^p(j)}\right)^2\right] =$$

$$= \lambda_t^p(j)\left[q_t^h + \kappa_h\left(\frac{h_t^p(j)}{h_{t-1}^p(j)} - 1\right)\frac{h_t^p(j)}{h_{t-1}^p(j)} + \frac{\kappa_h}{2}\left(\frac{h_t^p(j)}{h_{t-1}^p(j)} - 1\right)^2\right] \qquad (3.4.1.4)$$

$$\lambda_t^p(j) = \lambda_{t+1}^p(j)\beta_p\left(1 + i_t^d\right)$$

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Where C_t^p denotes final consumption goods by the patient households, provide a specific type of labor l_t^p, demand housing h_t^p and supply deposits d_t. Patient households own all firms and banks in the model, receiving firms' and banks' profits Π_t, lump-sum transfers from government Γ_t net labor income insurance V_t^p, and λ_t^p is the Lagrange multiplier of the optimization problem.

In Roger and Vlček (2011) impatient households finance expenditures via bank loans, only borrow up to a fraction of their expected household wealth $(1 + i_t^{bi})b_t^i(j)p_t \leq m^i q_{t+1}^h h_t^i(j)$. The impatient household optimization consists of budget and collateral constraints (3.4.1.5);

$$\lambda_t^i(j) = \frac{1}{c_t^i(j) - \rho^h \overline{c}_{t-1}^i}$$

$$\frac{\eta^h}{h_t^i(j)} + \lambda_{t+1}^i(j)\beta_i \left[q_{t+1}^h + \kappa_h \left(\frac{h_{t+1}^i(j)}{h_t^i(j)} - 1 \right) \left(\frac{h_{t+1}^i(j)}{h_t^i(j)} \right)^2 \right] + \mu_t^i(j) m^i q_{t+1}^h$$

$$= \lambda_t^i(j) \left[q_t^h + \kappa_h \left(\frac{h_t^i(j)}{h_{t-1}^i(j)} - 1 \right) \frac{h_t^i(j)}{h_{t-1}^i(j)} + \frac{\kappa_h}{2} \left(\frac{h_t^i(j)}{h_{t-1}^i(j)} - 1 \right)^2 \right]$$

$$\lambda_t^i(j) = \mu_t^i(j)\left(1 + i_t^{bi}\right) + \lambda_{t+1}^i(j)\beta_p\left(1 + i_t^{bi}\right)$$

Where impatient households in the model are assumed to consume the final consumption goods C_t^i, offer a specific type of labor l_t^i, demand housing h_t^i and loans b_t^i, w_t^i is the nominal wage index and i^{ib} is the interest rate on loans to impatient households, m^i is the maximum loan-to-value ratio, and q_{t+1}^h is the expected house price in t+1 (Iacoviello, 2005). Banks use deposits from patient households and own capital to provide loans to impatient entrepreneurs.

In Beau et al. (2012), entrepreneurs maximize utility function, subject to borrowing constraint given by: $R_t B_t^E \leq \theta_t E_t(q_t + 1L_t^E)$ where $E_t(q_t + 1L_t^E)$ represent the expected house price in t+1 and L_t^E is the entrepreneur's holding in housing wealth, $\theta_t = \bar{\theta} Z_t^\theta$ is the loan-to-value, Iacoviello (2005) used $\theta = 0.35$ as a shock in Z_t^θ, a positive shock can relax loan-to-value ratio.

In Roger and Vlček (2011), the j-th entrepreneur maximizes its discounted utility by;

$$E_0 \sum_{t=0}^{\infty} \beta_e^t \left[\ln(C_t^e(j) - p^h C_{t-1}^{-e} \right] \overrightarrow{C_t^e(j), k_t^e(j), l_t^e(j), b_t^{be}(j)} \max \tag{3.4.1.6}$$

Where entrepreneurs consume final goods C_t^e, demands capital k_t^e and labor l_t^e for producing intermediate good y_t and obtain bank loans b_t^e for expenditures, subject to production function;

$$y_t(j) = a_t[((k_{t-1}^e(j))^{1-\alpha}(l_t^e(j))]^\alpha \tag{3.4.1.7}$$

Same as both patient and impatient households, entrepreneurs are subject to a budget constraint;

$$p_t C_t^e(j) + W_t l_t^e(j) + q_t^k k_t^e(j) + (1 + i_{t-1}^{be}) b_{t-1}^{be}(j) p_{t-1} \tag{3.4.1.8}$$

$$= p_t^w y_t(j) + q_t^k (1 - \delta) k_{t-1}^e(j) + p_t b_t^e(j)$$

Where q_t^k denotes the price of capital, w_t is the wage paid by the entrepreneur for homogenous labor, i_t^{be} is the interest rate on loans paid by the entrepreneur, δ is the depreciation on physical capital due to inflation or exchange rate, p_t^w is the cost of the intermediate production.

The entrepreneur faces a collateral constraint on loans when the deterministic discount factor falls below that of the patient household (β_p); $\beta_e < \beta_p$, q_{t+1}^k is the price of capital at t+1.

Capital producers buy depreciated capital k_{t-1}^e at time (t) from entrepreneurs and optimize it, subject to a capital accumulation equation. Where the new created capital is j_t and Ξ^e denotes the pricing kernel of entrepreneurs.

$$E_0 \sum_{t=0}^{\infty} \Xi_{0.t}^{e}\left[q_t^k k_t^e - q_t^k(1-\delta)k_{t-1}^e - p_t j_t\right] \overrightarrow{k_t^e, j_t} \max \quad (3.4.1.9)$$

$$k_t^e = (1-\delta)k_{t-1}^e + \left[1 - \frac{K^j}{2}\left(\frac{j_t}{j_{t-1}} - 1\right)^2\right] j_t$$

The intermediate production of the entrepreneur is transformed into final goods $\bar{y}_t(f) = y_t(f)$ where $y_t(f)$ represents demand for intermediate production by the f-th firm which maximizes profit via price $p_t(f)$ and demand which are subject to the limited stochastic opportunity $(1 - \xi_p)$, the equation to optimize price contracts is expressed as;

$$E_0 \sum_{t=0}^{\infty} \xi_p^t \Xi_{0,t}^p [p_t(f)\bar{y}_t(f) - p_t^w y_t(f)] \overrightarrow{p_t(f), y_t(f)} \, max \quad (3.4.1.10)$$

$$\bar{y}_t(f) = \left(\frac{p_t(f)}{p_t}\right)^{-\frac{1+\epsilon^p}{\epsilon^p}} \bar{y}_t$$

Banks are at the epicenter of financial intermediation. For the derivation of the model, two layers of banks are assumed; wholesale banks and retail branches. Banks collect deposits d_t, accumulate banking capital k_t^b and provide loans b_t^b. The real banking profits are computed as;

$$\Pi_{t+1}^b = \left(1 + i_t^{bi}\right) b_t^i + (1 + i_t^{be}) b_t^e \quad (3.4.1.11)$$

$$+(1 + i_t)\eta_t b_t - \left(1 + i_t^d\right) d_t - k_t^b - \frac{K^b}{2}\left(\frac{k_{t-1}^b}{W_{t-1}^a b_{t-1}}\right)^2 k_{t-1}^b$$

Where $\Xi_{0,t}^p$ represents pricing kernel of patient households (the assumed owners of all banks) $b_t = d_t + k_t^b$ denotes the bank assets i_t^b is the interest rate on wholesale loans, i_t is the policy rate, w_t^a is the risk weight. Banks use $1 - \omega$ of the capital to make dividend payments to the patient households, and ω is a constant fraction of the capital used to accumulate capital.

The behavior of bank capital is expressed in the equation below. Banks raise wholesale rate i_t^b to make additional profits or to compensate a portion of the increasing funding cost due to higher capital/liquidity ratios under Basel III. Where δ^b denotes the depreciation rate of bank capital.

$$k_t^b = (1-\delta^b)k_{t-1}^b + \frac{p_{t-1}}{p_t}\omega\Pi_{t-1}^b \qquad (3.4.1.12)$$

The increased cost of capital induces necessary interactions between the capital adequacy position and the effect of monetary policy. Against the backdrop of rising cost of bank capital, banks are forced to raise lending rates and the widening spreads as a consequence may have contractionary effect on consumption, investment, and ultimately GDP growth.

Retail banks generate profits by buying the assets (b^b) of wholesalers, pay a nominal interest rate (b^b), put a markup, and then sell loans to patient households and entrepreneurs $n \epsilon \{i, e\}$, but retail banks face a problem of optimizing $1-\xi$ of capital via new loans $n \epsilon \{i, e\}$;

$$E_0 \sum_{t=0}^{\infty} \Xi_{0,t}^p \xi_n^t \left[\left(1+i_t^{bn}(j)\right) b_t^n(j)p_t - \left(1+i_t^b\right)b_t^n(j)p_t\right] \underset{i_t^{bn}}{\longrightarrow} max$$

$$b_t^n(j) = \left(\frac{1+i_t^{bn}(j)}{1+i_t^{bn}}\right)^{\frac{\vartheta}{1-\vartheta}} b_t^n \qquad (3.4.1.13)$$

The interest rates on deposits are less sticky than loans. Monetary policy rates follow a common Taylor rule. Where $\bar{r}$ describes the real policy neutral rate, Δp_t is the inflation rate on consumer prices, π^{target} is the inflation target, parameters θ_1 and θ_2 determine policy stance.

$$i_t = \phi_i i_{t-1} + (1-\phi_i)(\bar{r} + \Delta p_t + \phi_p(\Delta p_t - \pi^{target})) \qquad (3.4.1.14)$$

Governments do not have infinite spending C_t^g, the adjustment is necessary and made proportion relative to nominal consumption of patient households. Government spending is financed through taxes and bonds, but the budget is subject to constraints, mathematically;

$$P_t C_t^g + P_{t-1}\eta_{t-1}b_{t-1}(1 + i_{t-1}) = P_t\eta_t b_t + \Gamma_t \tag{3.4.1.15}$$

In Beau et al. (2012), the effects of various shocks are studied across two policy regimes. The first one follows the Vanilla Taylor rule which describes the relationship how short-term interest rate responds to deviations from inflation $\widetilde{\pi}_{t-1}^C$ and output $\widetilde{y}_{t-1}$.

$$r_t = (1 - \gamma_R)\left[\gamma_\pi \widetilde{\pi}_{t-1}^C + \gamma_y \widetilde{y}_{t-1}\right] + \gamma_R r_{t-1} + Z_t^r \tag{3.4.1.16}$$

Where γ_R denotes the inertia of interest rates, γ_π is the coefficient for inflation gap, γ_y is the coefficient for output gap, and Z_t^r describes a monetary shock.

In the second policy regime *"lean against the wind Taylor rule"* the central bank raises in response to the higher-than-normal credit growth. Where $\widetilde{b}_{t-1}$ denotes the lagged deviation of real credit, γ_b is the weight used in the monetary policy action.

$$r_t = (1 - \gamma_R)\left[\gamma_\pi \widetilde{\pi}_{t-1}^C + \gamma_y \widetilde{y}_{t-1} + \gamma_b \hat{b}_{t-1}\right] + \gamma_R r_{t-1} + Z_t^r \tag{3.4.1.17}$$

3.4.2 Testing for Normality

The thesis has used several statistical methods to determine whether the results of the Basel III and stress testing analyses are normally distributed or not. Some of the widely employed techniques are W/S test, Jarque-Bera test, Shapiro-Wilk test, Kolmogorov-Smirnov test, and

D'Agostino test. Normality is a common assumption in most statistical procedures, which include the t-test, the analysis of variance (ANOVA), tests for the regression coefficients, and the F-test for homogeneity of variances. The normal distribution concept first appeared about three centuries ago (in 1733) in the works of Abraham de Moivre (Patel & Read, 1996).

First, the Kolmogorov-Smirnov (KS) test is run in SPSS (version 20) to see whether the collected data sets are normally distributed or non-normally distributed. Probabilities > 0.05 mean the data are normal, and probabilities < 0.05 mean the data are not normal. Based on SPSS output results, either parametric or non-parametric tests are performed (Filliben, 1975; Jarque & Bera, 1987; Shapiro & Wilk, 1965): The common hypotheses used are:

H_0: The sample data are not significantly different than a normally distributed population.

H_a: The sample data are significantly different than a normally distributed population.

When the data of the thesis is tested for normality, the expectation is that the data set should be no different than normal so that the null hypothesis (H_0) is accepted and the alternative hypothesis (H_a) can be rejected. SPSS is used in the statistical analyses, H_0 is accepted if the data outputs > 0.05 and rejected (H_0) if the data < 0.05. If the SPSS output probabilities are < 0.05, then the data are non-normally distributed and are significantly different from normal.

3.4.3 Shapiro – Wilk Test for Normality

Shapiro and Wilk (1965) introduced a statistical procedure for testing distributional assumptions and testing for normality. The objective with normality tests is to see if the data is independent and normally distributed for unknown mean μ and unknown variance σ^2. For that let $y' =$

$y_1, \ldots, y_n$ denote a vector of ordered random observations. If $\{y'\}$ is a normally distributed sample, then it may be expressed as: $y_i = \mu + \sigma x_i$ $(i = 1,2, \ldots n)$

The generalized least-square theorem (e.g. Lloyd, 1952), $(y - \mu 1 - \sigma m)' V^{-1}(y - \mu 1 - \sigma m)$ where $1' = (1,1, \ldots ,1)$. The linear unbiased estimates are expressed as (Shapiro & Wilk, 1965);

$$\widehat{\mu} = \frac{m'V^{-1}(m1' - 1m')V^{-1}y}{1'V^{-1}1m'V^{-1}m - (1'V^{-1}m)^2} \quad (3.4.3.1)$$

$$\widehat{\sigma} = \frac{1'V^{-1}(1m' - m1')V^{-1}y}{1'V^{-1}1m'V^{-1}m - (1'V^{-1}m)^2} \quad (3.4.3.2)$$

For symmetric distributions, $1'V^{-1}m = 0$, then;

$$\widehat{\mu} = \frac{1}{n}\sum_{1}^{n} y_i = \bar{y}, \text{ and } \widehat{\sigma} = \frac{m'V^{-1}y}{m'V^{-1}m} \quad (3.4.3.3)$$

Let $S^2 = \sum_1^n (y_i - \bar{y})^2$ denote the usual symmetric unbiased estimate of $(n - 1)\sigma^2$ The W test statistic for normality is defined as;

$$W = \frac{R^4\,\widehat{\sigma}^2}{C^2S^2} = \frac{b^2}{S^2} = \frac{(a'y)^2}{S^2} = \left(\sum_{i=1}^{n} a_i y_i\right)^2 \Big/ \sum_{i=1}^{n}(y_i - \bar{y})^2 \quad (3.4.3.4)$$

3.4.4 W/S Test for Normality

This is a simple test, which requires only the standard deviation of the sample and the data range. This test is based on q statistic: $q = w / s$, where w denotes the range of data and s is the standard deviation. Since W/S test uses a range, the null hypothesis (H_0) is accepted if the calculated values fall within range, and rejected H_0 if the values fall outside of the range.

3.4.5 Jarque – Bera Test for Normality

Jarque – Bera (JB) test, a goodness-of-fit, shows whether or not the skewness and kurtosis of the data set match a normal distribution. If the JB test statistic equals zero (JB = 0), it means that the distribution of the sample has zero skewness and 3 kurtosis. The JB values are assumed to increase if the skewness moves farther away from zero and the kurtosis farther away from 3.

$$k_3 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^3}{ns^3} \qquad k_4 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^4}{ns^4} - 3 \tag{3.4.5.1}$$

Where n represents the sample size, x is the each observation, s is the standard deviation, k_3 is the skewness, and k_4 is the kurtosis. Based on skewness and kurtosis values, JB is computed;

$$\mathrm{JB} = \mathrm{n}\left(\frac{(\mathrm{k}_3)^2}{6} + \frac{(\mathrm{k}_4)^2}{24}\right) \tag{3.4.5.2}$$

3.4.6 The Mann – Whitney U Test

The thesis uses the Mann-Whitney U non-parametric test (Mann & Whitney, 1947) to investigate if two independent groups are homogenous and come from the same distribution. The two main tests are performed as one-sided (one-tailed) or two-sided (two-tailed). In the one-tailed test, if the statistic values fall within the specified tail of its sampling distribution, the null hypothesis H_0 would be rejected because the alternative hypothesis H_a stipulates that the variable of one group is stochastically larger, and two groups do not come from the same distribution. In the two-tailed test, H_0 is tested against $\mathrm{H}_\mathrm{a}$or (H_1) and if the values of the sampling distribution fall in either tail, $\mathrm{H_0}$ is rejected and $\mathrm{H_a}$ would stipulate that the variable of one group is stochastically larger than that of the second group (Wilcoxon, 1945).

Some assumptions need to be satisfied before the Mann-Whitney U test (i.e. one-tailed or two-tailed) is performed; (i) the two independent groups under study are randomly selected from the target population; (ii) measurements and observations enjoy independence within and between groups; (iii) the measurement scale of the data and the observations are ordinal and continuous.

Let xi be the number of observations in the first group, and yj in the second group; then the probability p can be technically expressed as; $\mathrm{H_0: p(xi > yj) = 1/2}$ and $\mathrm{H_1: p(xi > yj) \neq 1/2}$ The null hypothesis $\mathrm{H_0}$ is rejected if one group is significantly larger than the other regardless of the difference being positive or negative. In the Mann-Whitney U test, a U statistic is computed for each group (x: first group and y: second group), mathematically;

$$\mathrm{Ux = nxny + nx\frac{(nx+1)}{2} - Rx} \qquad \mathrm{Uy = nxny + ny\frac{(ny+1)}{2} - Ry} \tag{3.4.6.1}$$

Where nx denotes the number of observations in the first group 1, ny is the number of observations in the second group, Rx and Ry are the sum of the ranks respectively. In cases where the number of observations in $nx\ and\ ny$ is larger than eight, a normal distribution rules apply. Where N denotes the total number of observations $(nx + ny)$, $\mathrm{\mu u}$ is the average of the U distribution, and σu corresponds to its standard deviation. Mathematically;

$$\mathrm{\mu u = \frac{(nx\ * ny)}{2} = \frac{(Ux + Uy)}{2}} \qquad \mathrm{\sigma u = \sqrt{((nx\ * ny) * (N+1))/12}} \tag{3.4.6.2}$$

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In a situation where there is a tie between the groups, a normal approximation is used with an adjustment to the standard deviation. Where N denotes $(nx + ny)$, g is the number of ties, and tj is the number of equal ranks in the second group (Nachar, 2008).

$$\mathrm{\sigma u} = \sqrt{\left(\frac{\mathrm{nx} \ast \mathrm{ny}}{\mathrm{N(N-1)}}\right)(\left(\frac{\mathrm{N}^3 - \mathrm{N}}{12}\right) - \sum_{j=1}^{g}((\frac{\mathrm{tj}^3 - \mathrm{tj}}{12}))} \tag{3.4.6.3}$$

3.6 Chapter Summary

The Basel III reforms are expected to have a significant impact on bank capital, lending spreads, and economic activity (i.e. output loss) across ASEAN-5. These along with other macro factors are expected to contribute to a reduction in GDP growth in each of ASEAN-5, however the size and nature of the estimated impact is varied. A modified DSGE model is employed to analyze how the interactions of higher capital and liquidity requirements of Basel III affected funding costs for ASEAN-5 banking sectors during the period of four years from 2015 to 2019.

The thesis examined the benefit of higher capital and liquidity regulations under Basel III on financial stability through the reduced probability of future crises (it was assumed that higher capital and liquidity regulation will contribute positively to mitigating future crises). A macro stress testing was constructed where a top-down stress testing exercise was conducted to assess the resilience of Malaysia's banking sector and to determine how it was able to withstand hypothetical shocks in adverse and severely adverse scenarios. Detailed descriptions were provided for the statistical models to be used to analyze the results of the thesis.

CHAPTER 4
RESULTS AND DISCUSSION

4.0 Introduction

The propagation of systemic banking crises triggered by *too-big-to-fail* financial institutions is not new; in that series, the GFC is only the most recent event. This chapter provides the findings from a careful analysis of the data as well as the empirical estimation of the results via the DSGE model, loan pricing model, a macro stress testing, and normality tests for statistical analysis in SPSS which are the primary techniques used in the thesis. The hypotheses along with the thesis' general and specific objectives outlining various aspects of the interactions between the cost impact of Basel III and stress testing in thesis have been tested and the implications of the results have been discussed relevant to the extent of the literature review and methodology chapters.

4.1 Basel III Impact on Bank Capital

The thesis assessed the cost impact of higher capital and liquidity rules (i.e. NSFR ratio) under Basel III. In the analyses, it estimated the impact of one percentage point (pp) rise in the capital ratio on bank capital, lending rates, and the steady state output relative to the baseline. The thesis also estimated the potential economic benefit of the Basel III rules resulting from a reduced probability of financial crises in the future. There is a consensus among the industry participants that tighter capital and liquidity regulation will positively contribute to the soundness of banking sectors, and as a consequence, they will be less vulnerable to shocks arising from macro factors. The methodology mainly relies on analytical and statistical models covered in the later pages.

The new Basel III rules have increased capital and liquidity requirements significantly; common equity Tier 1 (CET1) from 2% to 4.5% of RWAs and the Tier 1 ratio from 4% to 6% in force by January 2015. Besides capital ratios, the Basel Committee introduced additional capital buffer (2.5%), countercyclical buffer (0-2.5%), G-SIB surcharge (1-2.5%), leverage ratio (3%), and two new liquidity standards (LCR and NSFR) fully effective as of 2019 (BCBS, 2010a).

Besides the increased cost of funding due to tighter capital and liquidity requirements, banks will incur operational costs related to the adoption and implementation of the new Basel III rules. But nevertheless, since the Asian crisis of 1997-98, banks across ASEAN-5 have been gradually improving their capital ratios. Moreover, central banks (the BNM and the MAS in particular) in the founding members of ASEAN-5 have been imposing more stringent capital requirements (at least 2% more than Basel III) than the U.S., Europe, and Japan.

To examine whether tighter capital and liquidity requirements of Basel III, partially effective as of 2015 (i.e. 4.5% CET1, 2.5% buffer) resulted in capital shortfall for ASEAN-5 banking sectors, two key capital ratios are calculated. Central banks and the supervisory community use the ratios to assess capital positions of individual banks and banking sectors in the aggregate.

4.1.1 Results of the Impact on Capital

The sample size of the thesis is 205 banks across ASEAN-5 (explained in section 3.2). For the purpose of an econometric study, banking data and macroeconomic data have been compiled from different sources such as bankscope, respective central bank database, the World Bank, the IMF, Eurostat, the Basel Committee, the Bank for International Settlements, and individual banks' own websites. In order to calculate the capital adequacy ratio (or total capital to RWAs), it was critical to compute its three capital components such as Tier 1 capital, Tier 2 capital, and the total risk-weighted assets; Total capital ratio = (Tier 1 capital + Tier 2 capital) / RWAs = 8%, however, a 10.50% is used as a benchmark CAR for the purpose of this thesis.

For the Tier 1 capital ratio, the total Tier 1 capital was calculated and was divided by the RWAs using the following formula: Tier 1 capital ratio = Total Tier 1 capital / RWAs = 6.0%. The results are illustrated in Table 4.1. After a quick look at the aggregate CARs and Tier 1 capital ratios of the banking sectors of ASEAN-5, it can be concluded that both ratios are at least two percentage points higher than what the Basel Committee requires (8% under Basel III).

Table 4.1: Key capital ratios of banking sectors across ASEAN-5

	Bank capital percent of RWAs					Average	Raise capital by 2019
	2011	2012	2013	2014	2015		
Indonesia							
CAR	16.08	17.58	18.45	18.92	19.77	18.16	0
Tier 1	15.29	15.96	17.00	17.82	18.09	16.83	0
Malaysia							
CAR	16.93	17.35	14.57	15.03	15.41	15.86	0
Tier 1	12.68	13.16	13.21	13.26	13.39	13.14	0
Philippines							
CAR	16.89	17.97	18.11	16.34	16.18	17.10	0
Tier 1	13.46	14.40	15.73	14.01	13.62	14.24	0
Singapore							
CAR	16.84	16.97	16.43	16.19	15.88	16.46	0
Tier 1	13.99	14.07	13.77	13.69	13.71	13.85	0
Thailand							
CAR	15.35	15.44	15.67	16.01	16.43	15.78	0
Tier 1	11.43	10.87	11.83	12.58	13.19	11.98	0

Note: Author's calculations.

The data used is submitted by national authorities to the IMF following the Financial Soundness Indicators (FSI) Compilation Guide and for dissemination through FSIs website. Deviations from FSI compilation Guide and complementary explanations are indicated in country's metadata. The thesis omitted from the data *Non FSI Reporters: Data for this indicator may not follow the FSI Compilation Guide.

When the detailed results of the Table 4.1 data are interpreted, Indonesia's capital ratios on average are substantially higher than its peers. Before analyzing the data statistically, it would not be a misinterpretation if it was concluded that the banking sectors of ASEAN-5 were well capitalized. The main focus of this thesis was banking sectors as a whole, no particular attention was paid to the soundness of banks at the individual level. Thus, the assumptions, reasoning, and conclusions are based on the aggregate results obtained from the capital analysis. At the individual bank level in each of ASEAN-5 countries, some smaller banks may face capital and liquidity issues, but this concern was left to the respective national supervisors to deal with and take all necessary measures to ensure financial stability at both micro and macro levels.

The recurrence of high-magnitude crises since the late 1990s prompted ASEAN-5 banking sectors to achieve remarkable strides in bringing their capital ratios in line with the Basel III rules or even higher. Looking at the results in Table 4.1 (2011-2015), Indonesia's banking sector has the highest average CAR and Tier 1 ratio (18.16%, 16.83% respectively) while Thailand's banking sector has the lowest ratios (15.78%, 11.98%). The remaining three countries are close to each other; Malaysia (15.86%, 13.14%), Philippines (17.10%, 14.24%), and Singapore (16.46%, 13.85%). On average, ASEAN-5 has a CAR of 16.67% and a Tier 1 of (14.01%).

Although banks conserve capital on an ongoing basis, the capital raising spree that began in 2014 seems to come to an end since ASEAN-5 banking sectors are comfortably capitalized, well above the minimum Basel III requirement of 4.5% CET1, the target of 7% including a 2.5% capital buffer, 6% Tier 1, and 8% total capital (CAR). This does not infer that some smaller banks would not be affected adversely to face capital and liquidity issues, even when all the Basel III rules become fully effective by the 2019 deadline. Even with the fully-phased Basel

III reforms by the 2019 deadline, ASEAN-5 banks would have adequate capital and sufficient liquidity to comply with the substantially increased capital and liquidity requirements. Banks in Indonesia and Thailand improved their average CAR and Tier 1 ratio since the taper tantrum in May 2013 and the subsequent August rout in the same year (BIS, 2015a), while Malaysia, Philippines, and Singapore experienced declines in their y-o-y ratios.

In the Financial System Stability Assessment (FSSA), the IMF has often praised the strong capital positions of ASEAN-5 banking sectors. For Indonesia, the IMF said that "...a high capital and earnings buffer has provided a cushion against macroeconomic volatility" (IMF, 2010a). On Malaysia, the IMF said that "...banking institutions are well capitalized. Asset quality has improved significantly over the last five years and banks are profitable" (IMF, 2013b). For Philippines, the IMF's view was "...although macroeconomic risks remain elevated, the banking system is well-capitalized and liquid, and asset quality is generally high" (IMF, 2010b). The IMF pointed out that "Singapore is one of the largest financial centers in the world" and banks' "...high capitalization could offset potential losses, including from large exposures to real estate" (IMF, 2013c). The IMF stated that Thailand's "...banking fundamentals have strengthened, with most Thailand banks reporting high levels of capital and solid profitability" (IMF, 2009).

4.1.2 Statistical Analysis of the Impact on Capital

Statistics is important because without it, the research data and numerical findings would be just numbers. Statistics were used as a scientific approach to analyze the systematically collected data and their quantitative results in order to understand and interpret the relationships among different variables. Parametric and non-parametric techniques were employed to analyze the results, Miller (1956), Morgan et al. (2004), Kolmogorov (1933), and Shapiro and Wilk (1965).

The following hypothesis was postulated and the results were illustrated in Tables 4.2 to 4.13:

H_1: Basel III capital ratios result in a higher cost impact on bank capital across ASEAN-5.

The operational hypothesis H_5 was also tested. The null hypothesis indicates that the opposite case of the hypothesis (i.e. failing to reject) or retaining the null hypothesis means that the difference in means between ASEAN-5 and others is not statistically significant. The objective is to reject the null hypothesis to show the effects of Basel III on ASEAN-5 is more significant.

Table 4.2: Descriptive statistics of CAR

In per cent		IN	MY	PH	SG	TH	ASEAN5	Group 1 banks	Group 2 banks	G-SIB
N	Valid	5	5	5	5	5	5	71	109	30
	Missing	0	0	0	0	0	0	0	0	0
Mean		18.1600	15.8580	17.0980	16.4620	15.780	16.6740	14.8920	15.0200	14.7520
Median		18.4500	15.4100	16.8900	16.4300	15.670	16.6500	14.7900	15.1000	14.7500
Mode		16.08	14.57	16.18	15.88	15.35	16.42	14.01	14.35	13.85
Std. Dev.		1.40682	1.21660	.90071	.45130	.44385	.24704	.65431	.55520	.60210
Range		3.69	2.78	1.93	1.09	1.08	.64	1.79	1.45	1.65

Notes: Author's estimates (IBM SPSS, version 20)

The results indicated that CAR of ASEAN-5 (M = 16.67, SD = .25) were significantly different than Group 1 banks (M = 14.89, SD = .65), Group 2 banks (M = 15.02, SD = .55) and G-SIB (M = 14.75, SD = .60). Indonesia had the highest mean of CAR whereas Malaysia and Thailand had lower means than ASEAN-5 average.

1: The aggregate data for ASEAN-5 is from the IMF's Financial Soundness Indicators (FSI).
IN: Indonesia; MY: Malaysia; PH: Philippines; SG: Singapore; TH: Thailand

2: Took the average CAR and Tier 1 ratios of the sampling populations in 2011-2015. The aggregate data for group 1 banks (101), group 2 banks (109), and G-SIBs (30) are from the Basel Committee (BCBS, 2016). The participating 101 group 1 banks also included 30 G-SIBs; out of which, 14 banks from Japan, 13 from the U.S., 8 from Germany, 6 from China, 6 from Canada, 5 from the UK, 5 from France, 5 from India, 5 from Korea, 4 from Australia, 4 from Sweden, 3 from Singapore, and 2 from Indonesia (group 2 banks).

Descriptive Statistics is the starting point in the analysis of Basel III impact on capital. It gives us critical information in the table and graph forms. Descriptive statistics mainly focuses on statistics related to the mean, median, mode and standard deviation used to evaluate the central tendency. If the data is normally distributed, values would stay close to the mean (average).

Table 4.3: Descriptive statistics of Tier 1 capital ratio

In per cent		IN	MY	PH	SG	TH	ASEAN5	Group 1 banks	Group 2 banks	G-SIB
N	Valid	5	5	5	5	5	5	71	109	30
	Missing	0	0	0	0	0	0	0	0	0
Mean		16.8320	13.140	14.2440	13.846	11.980	14.0080	12.300	12.090	12.190
Median		17.0000	13.210	14.0100	13.770	11.830	14.2700	12.200	12.000	12.200
Mode		15.29	12.68	13.46	13.69	10.87	13.37	11.45	11.20	12.20
Std. Deviation		1.19636	.27102	.90710	.17286	.91940	.45323	.63344	.81425	.57489
Range		2.80	.71	2.27	.38	2.32	1.03	1.75	2.10	1.60

Notes: Author's calculations (IBM SPSS, version 20); see Table 4.2 for the sources of data.

The results indicated that Tier 1 capital ratio of ASEAN-5 (M = 14.00, SD = .45) were significantly different than Group 1 banks (M = 12.30, SD = .63), Group 2 banks (M = 12.09, SD = .81) and G-SIB (M = 12.19, SD = .57). Among ASEAN-5, Indonesia had the highest mean and Thailand had the lowest.

Descriptive statistics were run on aggregate CAR and Tier 1 ratios of 215 banks from 27 countries, and the results are illustrated in Table 4.2 (CAR) and Table 4.3 (Tier 1). The data employed in this thesis is in the aggregate form, which is a representation of the banking sector as a whole (as well as a fair representation of the global banking system).

$$\bar{x} = \frac{1}{2}\sum_{i=1}^{n} x_i = (x_1 + x_2 + \cdots x_n|n), \qquad \bar{x} = \frac{\sum x_i}{n}$$

$$\mu = \frac{\sum x_i}{N}$$

, the population means (μ) of CAR for all groups = 15.33% is substantially higher than the means of Tier 1 ratio = 12.65%.

The descriptive statistics indicate that the average mean of CAR and Tier 1 ratio of ASEAN-5 (16.67%, 14.01% respectively) are significantly higher than group 1 banks (14.89%, 12.30%), group 2 banks (15.02%, 12.09%), and G-SIBs (14.75%, 12.19%). On country level, Indonesia has the highest CAR and Tier 1 among all groups under thesis (18.16%, 16.83% respectively), followed by Philippines (17.10%, 14.24%). The average CAR of banks in Indonesia is at least 1.5% higher than ASEAN-5 average (16.67%); its average Tier 1 ratio is even much higher, 16.83% compared to 14.01%. While Thailand has the lowest CAR and Tier 1 ratio among peers, (15.78% and 11.98%), the CAR and Tier 1 ratios of Malaysia and Singapore are lower than ASEAN-5 average. Thailand is the only ASEAN-5 whose average aggregate Tier 1 ratio is lower than group 1 banks (12.30%), group 2 banks (12.09%), and G-SIBs (12.19%).

It is not the focus here, but one can also calculate geometric and harmonic mean, given by;

$$\bar{x}_{\mathrm{geom}} = \left(\prod_{i=1}^{n} x_i\right)^{1/n} = \sqrt[n]{x_1 \cdot x_2 \cdots x_n}$$

$$\bar{x}_{\mathrm{harm}} = \frac{n}{\sum_{i=1}^{n} \frac{1}{x_i}} = \frac{n}{\frac{1}{x_1} + \frac{1}{x_2} + \cdots + \frac{1}{x_n}}$$

The median (the middle value) of a sample is not as informative as the mean. To find the median, all values are rearranged (ranked) from smallest to largest; if the sample size (*n*) is even, the median is simply half of n (i.e. $\frac{n}{2}$), but if *n* is an odd number, then the median = $1 + (n - 1)/2$. In the case, the average median of CAR (16.02%) is nearly three percentage points higher than the size of the median of Tier 1 ratio (13.39%). The mode is a numeric value that is repeated more than once in the distribution; there could be multiple modes. Virtually all CAR and Tier 1 data populations had multiple modes, as the general rule, the smallest value is used.

The next two important elements of the descriptive statistics are the measurement of sample (s^2) variance and standard deviation (s). Many differing definitions exist, but variance of a sample can be defined as the mean sum of the squares of the deviations of the data.

$$s^2 = \frac{1}{(n-1)} \sum_{i=1}^{n} (x_i - \bar{x})^2 \qquad s = \sqrt{\text{variance}} = \frac{1}{(n-1)} \sum_{i=1}^{n} (x_i - \bar{x})^2$$

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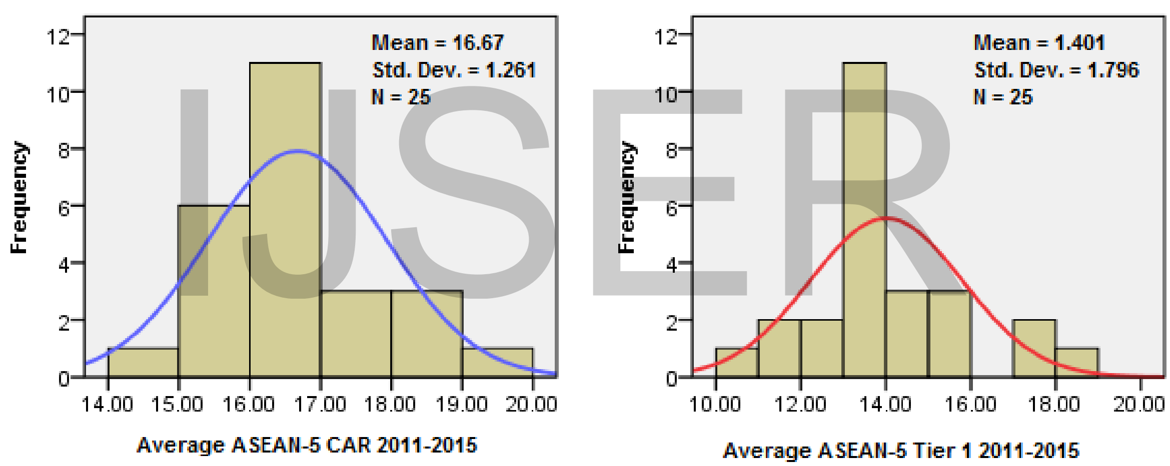
These equations can be simplified further; where variance denotes $(\sigma^2) = \sum(x_i - \mu)^2/N$, and again after obtaining the variance, it is rather easy to calculate standard deviation $(\sigma) = \sqrt{\sigma^2}$ where $\bar{x}$ is the sample mean x_i is the value of i-th item, μ is the mean, and N is the sample size.

Descriptive statistics can be very effective as a visual representation of the data using histograms (Figure 4.1). Most statistics would be interested to see that the observation is independent, normally distributed, and the two populations have equal variances. Histograms give us quick hints about normality, skewness, as well as the degree of variance in populations' means.

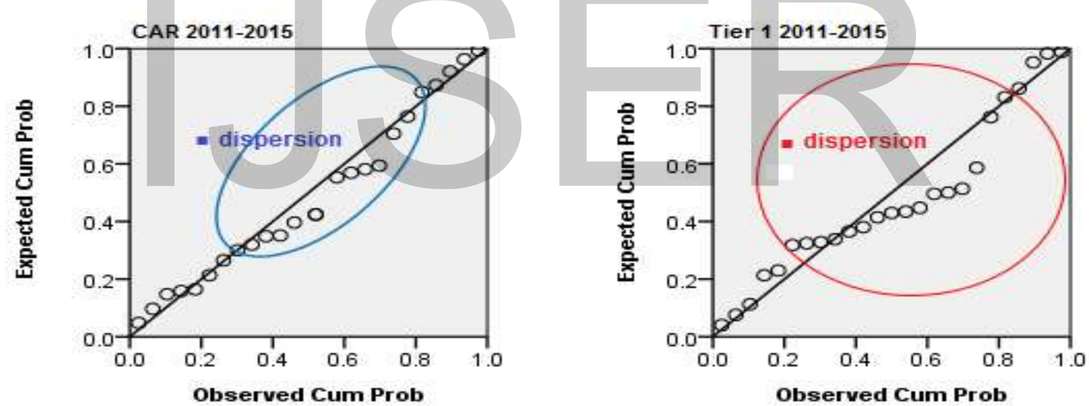


Note: Author's analysis (IBM SPSS, version 20)

Figure 4.1: Histogram of CAR and Tier 1, with normal curve

The histograms of CAR and the Tier 1 ratio demonstrate that each aggregated data had a normal distribution. However, when the histograms of the sampling years from 2009 to 2015 were viewed individually, the histogram for each year showed a distribution that was skewed to the right or left which was an indication of dispersion of data caused by deviations from the means. In a perfectly normal distribution (where the assumption of normality and equal variances are not violated), the observed values would be expected to stick very close to the mean; in other words, close to the line of null hypothesis assuming no difference between groups' means.

Again in Figure 4.1, although both distributions had variance and outliers, the distribution of Tier1 had a larger variance than that of CAR. In general, variance causes dispersion of the data spreading out and away from central tendency and dispersion causes the data to become skewed. A normal distribution skewed to the right (longer tail on the right) indicates that the coefficient of the skewness is positive. A distribution with the longer tail is on the left suggests that the population is normally distributed, but skewed to the left where the coefficient of the skewness is negative. Therefore, the skewness can be viewed as an abstraction from the central tendency.



Note: Author's analysis (IBM SPSS, version 20)

Figure 4.2: Normal P-P plot of CAR and Tier 1 capital ratio

The probability p-values plots in Figure 4.2 shows that, although each sampling data had a normal distribution, there is a dispersion which suggests that some values of CAR and Tier 1 spread away from the straight line (the line of the null hypothesis). In a dispersion, the values spreading out from the mean suggests an abstraction as well as a departure from normality. The straight line is formed through a process where the observed cumulative probabilities of the data is compared against the expected cumulative probabilities. The observed values deviating from the expected probability suggests a move away from the line of central tendency. Dispersion in CAR and the Tier 1 data corresponded with the May taper tantrum and August rout in 2013 triggered by the US monetary tightening, which rattled markets across ASEAN-5. The effect was observed in the average CAR which dropped consecutively in 2013 and 2014 (Table 4.4).

Table 4.4: Kolmogorov-Smirnov test for CAR

		2011	2012	2013	2014	2015
N		9	9	9	9	9
Normal Parameters[a,b]	Mean	15.6356	16.2644	16.0578	16.0400	16.3889
	Std. Deviation	1.27855	1.38102	1.45870	1.23528	1.33672
Most Extreme Differences	Absolute	.191	.251	.189	.241	.288
	Positive	.176	.203	.189	.241	.288
	Negative	-.191	-.251	-.154	-.202	-.232
Kolmogorov-Smirnov Z		.574	.753	.566	.722	.865
Asymp. Sig. (2-tailed)		.896	.623	.906	.674	.444

Notes: Author's calculations (IBM SPSS, version 20)

The hypothesis H_1 and H_5 were tested, and retained. The aggregate CAR of ASEAN-5 was a lot higher than advanced economies, but not statistically significant. The data was normally distributed, *p* values > .05. The assumption of normality was met, strong evidence suggested that there was no significant departure from normality. The analysis failed to reject the null hypothesis, and concluded that there was no significant difference in CAR between ASEAN-5 and the other groups.

One-Sample Kolmogorov-Smirnov Test (for goodness of fit) tests the null hypothesis in an unknown distribution with an unknown distribution function $\gamma(x)$, which is compared against an empirical distribution with a pre-specified distribution function $\gamma * (x)$. The most common use of the Kolmogorov-Smirnov (K-S) test is to check whether the assumption of normality in the analysis of variance is violated (Kolmogorov, 1933). The K-S is based on assumptions that the sample is a random and the sample contains $\mathrm{x}_1 , \mathrm{x}_2, \dots, \mathrm{x}_\mathrm{n}$ the hypothesis is tested as;

The results of the One-sample Kolmogorov-Smirnov test, set out in Table 4.4, suggest that average CAR in 2011-2015 are normally distributed; in other words, the assumption of normality was not violated. The *p*-values of CAR (.896, .623, .906, .674, and .444) > .05, suggesting that a parametric test must be used. The hypotheses H_1, H_6, and H_{10} were tested; based on the these results, the null hypothesis (of no difference) was retained and concluded that there was no statistically significant difference in CAR between banking sectors of ASEAN-5 and those of the Group 1 banks, Group 2 banks, and G-SIBs.

Although the CAR and Tier 1 ratio of ASEAN-5 were not statistically and significantly different, they were higher than those in advanced economies (H_1). Higher capital ratios, required by under Basel III, also meant higher cost impact of Basel III capital regulation on banks across ASEAN-5 (H_2). Capital adequacy ratio and Tier 1 capital ratio are key indicators of financial stability and any bank failing to comply with the Basel III minimum capital requirements (i.e. 4.5% of Tier 1 and 10.5% of CAR) are considered to be insolvent. According to the IMF and the Basel Committee, higher capital ratios make banks across ASEAN-5 more stable, a positive relationship exists between higher capital ratios and banking stability (H_6).

The results of the K-S test outset in Table 4.5 indicated that the data were normally distributed. The assumption of normality was met, where the *p*-values of Tier 1 (.639, .972, .770, .631, and .237) > .05. Thus, an independent samples *t*-test (parametric) to test the hypothesis via Levene's test for homogeneity of variances or *t*-statistics for equality of means. As the previous analysis, H_1, H_6, and H_{10} were tested. The analysis failed to reject the null hypothesis, and concluded that the groups' means were not significantly different from each other. While the means of Tier 1 ratio recorded a year-over-year (y-o-y) increase from 2011 to 2015 (larger increases in 2012 and 2013), the means of CAR faced declines in 2012, 2013, and 2014 before picking up in 2015.

Table 4.5: Kolmogorov-Smirnov test of Tier 1 capital ratio

		2011	2012	2013	2014	2015
N		9	9	9	9	9
Normal Parameters[a,b]	Mean	12.6856	13.1167	13.5833	13.6533	13.9778
	Std. Deviation	1.44839	1.59090	1.81633	1.72396	1.60001
Most Extreme Differences	Absolute	.248	.162	.221	.249	.344
	Positive	.248	.162	.221	.249	.344
	Negative	-.153	-.085	-.167	-.225	-.250
Kolmogorov-Smirnov Z		.743	.487	.664	.748	1.033
Asymp. Sig. (2-tailed)		.639	.972	.770	.631	.237

Note: Author's calculations (IBM SPSS, version 20)

The hypothesis H_1 and H_5 were tested, and retained. Each independent variable data was normally distributed, as all *p* values > .05; strong evidence suggested that there was no significant departure from normality. The analysis failed to reject the null hypothesis, and concluded that there was no significant difference in Tier 1 capital ratio between ASEAN-5 and the other groups. Failing to reject the null hypothesis of H_5 meant that the relationship between higher capital ratios and financial stability was not significant. A parametric test would be used for further hypothesis testing.

When the ASEAN-5 banks and banking sectors are compared with those in the advanced nations, the results are similar and there is no statistically significant difference; the thesis ran a separate analysis to compare the capital ratios of ASEAN-5 against those of 118 countries.

Table 4.6: Kolmogorov-Smirnov test of CAR and Tier 1 capital ratio

		Tier 1	CAR
N		123	123
Normal Parameters[a,b]	Mean	10.8824	16.6590
	Std. Deviation	2.60579	3.55763
Most Extreme Differences	Absolute	.086	.128
	Positive	.086	.128
	Negative	-.052	-.072
Kolmogorov-Smirnov Z		.950	1.416
Asymp. Sig. (2-tailed)		.328	.036

Notes: Author's calculations (IBM SPSS, version 20).

The hypothesis H_1 and H_5 were tested. The Tier 1 data was normally distributed, *p* (.328) > .05, the null hypothesis was retained, and concluded that the difference in Tier 1 of ASEAN-5 and that of 118 countries was not statistically significant. CAR data was non-normally distributed, so the first assumption of normality was violated as *p* (.036) < .05. The null hypothesis was rejected, concluded that the difference in CAR between ASEAN-5 and 118 countries was statistically significant, The aggregate sample for CAR and Tier 1 ratio of ASEAN-5 banks had a normal distribution when compared with 71 Group 1 banks, 109 Group 2 banks, and 30 G-SIBs; However when the results of ASEAN-5 CAR are compared with those of 118 countries, the results of the K-S test (Table 4.6) indicates that the first assumption of normality was not met, Sig. p (.036) < $\alpha = 0.05$, the hypothesis was rejected and concluded that the difference in CAR means between ASEAN-5 banks and those across 118 countries was significant, so a non-parametric test must be used.

Table 4.7: Mann-Whitney U test ranks of CAR and Tier 1

	Group	N	Mean Rank	Sum of Ranks
CAR	ASEAN-5	5	112.40	562.00
	The World	118	59.86	7064.00
	Total	123		
Tier 1	ASEAN-5	5	106.80	534.00
	The World	118	60.10	7092.00
	Total	123		

Notes: Author's calculations (IBM SPSS, version 20).

The hypothesis H_1 and H_5 were tested. The results indicated that the mean rank of CAR for ASEAN-5 112.40 (N=5) was significantly higher than the world 59.86 (N= 118). The mean rank of Tier 1 for ASEAN-5 106.80 (N = 5) was significantly higher than the world 60.10 (N = 118).

Table 4.8: Mann-Whitney U test statistics of CAR and Tier 1

	CAR	Tier 1
Mann-Whitney U	43.000	71.000
Wilcoxon W	7064.000	7092.000
Z	-3.241	-2.869
Asymp. Sig. (2-tailed)	.001	.004

Notes: Author's calculations (IBM SPSS, version 20).

The hypothesis H_1 and H_5 were tested. Mann-Whitney U test results were strong evidence to reject the null hypothesis, and concluded that the difference in CAR (M.W. = 43.000, $p = .001 < .05$) and Tier 1 (M.W. = 71.000, $p = .004 < .05$) between ASEAN-5 and 118 countries was statistically significant. Rejecting the null hypothesis meant that there was positive relationship between higher capital ratios and financial stability across ASEAN-5.

The Mann-Whitney *U* test was conducted to evaluate whether the mean ranks of CAR and Tier 1 ratio of ASEAN-5 banking sectors differed significantly from those across 118 countries.

ASEAN-5 banking sectors had an average rank of 112.40 in CAR and 106.80 in Tier 1 capital ratio, while banking sectors across 118 countries had 59.86 and 60.10 respectively (Table 4.7). The test results were in the expected direction and significant (Table 4.8), z = -3.241 (CAR) and -2.869 (Tier 1), p (.001 and .004 respectively). Because Sig. p values were < $\alpha = 0.05$, the null hypothesis was rejected and concluded that the groups' mean ranks were significantly different.

Table 4.9: Group statistics of CAR and Tier 1 capital ratio

CAR	Group	N	Mean	Std. Deviation	Std. Error Mean
2011	1	5	16.4180	.69244	.30967
	2	4	14.6575	1.19335	.59668
2012	1	5	17.0620	.97661	.43675
	2	4	15.2675	1.19533	.59767
2013	1	5	16.6460	1.63606	.73167
	2	4	15.3225	.89872	.44936
2014	1	5	16.4980	1.44733	.64727
	2	4	15.4675	.69964	.34982
2015	1	5	16.7340	1.73918	.77778
	2	4	15.9575	.53406	.26703
Tier 1 capital ratio					
2011	1	5	13.3700	1.44210	.64493
	2	4	11.8300	1.03179	.51590
2012	1	5	13.6920	1.87314	.83770
	2	4	12.3975	.91087	.45544
2013	1	5	14.3080	2.05575	.91936
	2	4	12.6775	1.09241	.54620
2014	1	5	14.2720	2.05443	.91877
	2	4	12.8800	.92876	.46438
2015	1	5	14.4000	2.07273	.92695
	2	4	13.4500	.65574	.32787

Notes: Author's calculations (IBM SPSS, version 20)

Group 1: ASEAN-5; Group 2: 210 banks from 27 countries; hypothesis H_1 and H_5 were tested. The means of CAR and Tier 1 for ASEAN-5 were the highest in 2012 and 2015 respectively. This increase may be partially due to the fact that the observation period for Basel III capital standard ended in 2013 and 4.5% Tier 1 of risk-weighted assets became effective as of 2015.

Independent-Samples t-Test, a parametric test, was used to compare the means of two independent and unrelated groups. Statistically, $H_0 = \mu_1 - \mu_2 = 0 \rightarrow \mu_1 = \mu_2$, which assumes no significant difference between CAR and Tier 1 ratio of ASEAN-5 banking sectors and those of other groups. The alternative hypothesis naturally is the opposite of the null; $H_1 = \mu_1 \neq \mu_2$.

Two *t*-tests were conducted to compare CAR and Tier 1 ratio between ASEAN-5 and another group consisting of 210 banks from 27 countries, the group statistics of which are demonstrated in Table 4.9. Looking at the means of CAR between two groups, ASEAN-5 CAR data is more significant in 2011 (1.76%) and 2012 (1.79%) than in 2013 (1.32%), 2014 (1.03%), and 2015 (0.78%). The picture in Tier 1 capital ratio is about the same, the means of Tier 1 of ASEAN-5 are significantly higher than those of the second group where the average difference between the groups' means ranged from 0.95% to 1.63% (Table 4.10).

An independent samples *t*-test was used to test the hypotheses H_1, H_2, and H_6. The results (Table 10) indicated that the second assumption, the equality of variances (or referred to as homogeneity of variances), $H_0 = \sigma_1^2 - \sigma_2^2 = 0 \rightarrow \sigma_1^2 = \sigma_2^2$) was met. The Levene's F test is commonly used method to check whether two independent groups have equal variances; for the Levene's test, the priori significance alpha (α) level was set at 0.05. In the Levene's test, the F values of CAR of ASEAN-5 banking sectors and those across 27 countries were; t (7) = 1.053, .272, 2.281, .766, 2.141; Sig. p (.339, .618, .175, .410, .187) > .05. Based on the p values, *"Equal variances assumed"* must be used. As a result, the null hypotheses were retained which concluded that the difference in means of CAR and Tier 1 between ASEAN-5 and 27 countries were not significantly different. 210 Banks in these 27 advanced countries are considered stable and their financial resilience is confirmed by the IMF's Financial Soundness Indicators (FSIs); CAR and Tier 1 are main indicators of financial soundness and solvency test. Therefore, there is a positive relationship between higher capital ratios and banking stability (H_6).

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Table 4.10: Independent samples test of CAR and Tier 1 capital ratio

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	95% Confidence Interval of the Difference	
									Lower	Upper
CAR										
2011	EVA	1.053	.339	2.791	7	.027	1.76050	.63082	.26884	3.25216
	EVNA			2.619	4.584	.051	1.76050	.67225	-.01578	3.53678
2012	EVA	.272	.618	2.487	7	.042	1.79450	.72167	.08801	3.50099
	EVNA			2.424	5.816	.053	1.79450	.74024	-.03081	3.61981
2013	EVA	2.281	.175	1.441	7	.193	1.32350	.91873	-.84894	3.49594
	EVNA			1.541	6.377	.171	1.32350	.85864	-.74777	3.39477
2014	EVA	.766	.410	1.295	7	.236	1.03050	.79565	-.85091	2.91191
	EVNA			1.401	5.996	.211	1.03050	.73575	-.77011	2.83111
2015	EVA	2.141	.187	.851	7	.423	.77650	.91258	-1.38140	2.93440
	EVNA			.944	4.908	.389	.77650	.82235	-1.34943	2.90243
Tier 1 capital ratio										
2011	EVA	.343	.577	1.790	7	.117	1.54000	.86028	-.49424	3.57424
	EVNA			1.865	6.958	.105	1.54000	.82588	-.41528	3.49528
2012	EVA	1.285	.294	1.256	7	.249	1.29450	1.03065	-1.14260	3.73160
	EVNA			1.358	6.014	.223	1.29450	.95350	-1.03734	3.62634
2013	EVA	2.500	.158	1.421	7	.198	1.63050	1.14755	-1.08302	4.34402
	EVNA			1.525	6.279	.176	1.63050	1.06938	-.95823	4.21923
2014	EVA	1.092	.331	1.244	7	.253	1.39200	1.11878	-1.25350	4.03750
	EVNA			1.352	5.800	.227	1.39200	1.02946	-1.14819	3.93219
2015	EVA	2.334	.170	.872	7	.412	.95000	1.08980	-1.62697	3.52697
	EVNA			.966	4.960	.379	.95000	.98323	-1.58362	3.48362

Notes: Author's calculations (IBM SPSS, version 20)

The hypothses H_1 and H_5 were tested. In the Levene's test, the F values in CAR of ASEAN-5 and 27 countries were; t (7) = 1.053, .272, 2.281, .766, 2.141; Sig. p (.339, .618, .175, .410, .187) > .05. Based on these results, "*Equal variances assumed"* must be used; the null hypothesis was retained, and homogeneity of variances was met. The difference in CAR and Tier 1 of ASEAN-5 was significantly different than those of 27 countries.

Another independent samples t-test was conducted for the Tier 1 data between ASEAN-5 and the other group. As illustrated in Table 4.10, the results of this t-test are similar to that of CAR.

The *p* values are greater than the significance alpha ($\alpha = 0.05$), so the null hypothesis was retained and concluded that there was no significant difference between the groups' means. If the *p* values were less than α (0.05), the *t* statistic would have been computed and the second line titled as the *"Equal variances not assumed"* would have been used to test the hypothesis. Then the *t*-statistics was calculated by dividing the observed mean difference by the standard error of the difference telling us how many standard error units the observed data was from the mean of the population where $\mu_1 - \mu_2 = 0$; $t = \left((\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)\right) / S_{\bar{x}_1 - \bar{x}_2}$.

Table 4.11: Paired samples statistics of CAR and Tier 1 capital ratio

		Mean	N	Std. Deviation	Std. Error Mean
CAR					
Pair 1	ASEAN-5	16.6740	5	.24704	.11048
	Group 1 banks	14.8920	5	.65431	.29262
Pair 2	ASEAN-5	16.6740	5	.24704	.11048
	Group 2 banks	15.0200	5	.55520	.24829
Pair 3	ASEAN-5	16.6740	5	.24704	.11048
	G-SIB	14.7520	5	.60210	.26927
Tier 1 capital ratio					
Pair 1	ASEAN-5	14.0080	5	.45323	.20269
	Group 1 banks	12.3000	5	.63344	.28328
Pair 2	ASEAN-5	14.0080	5	.45323	.20269
	Group 2 banks	12.0900	5	.81425	.36414
Pair 3	ASEAN-5	14.0080	5	.45323	.20269
	G-SIB	12.1900	5	.57489	.25710

Notes: Author's calculations (IBM SPSS, version 20)

The results of paired sample statistics indicated that the mean ranks of ASEAN-5 for CAR and Tier 1 were significantly different than Group 1 banks, Group 2 banks, and G-SIB.

A paired samples test was conducted to analyze how significantly the average means of both CAR and Tier 1 ratio of banks across ASEAN-5 differed from the same ratios of 210 banks across 27 countries. The results of the paired samples statistics are illustrated in Table 4.11, the paired samples correlations in Table 4.12, and the paired samples *t*-test in Table 4.13. The average aggregate CAR and Tier 1 ratio of ASEAN-5 are clearly more significant than those of other groups. The largest of difference in CAR is 1.78% between ASEAN-5 and group 1 banks (101 banks, of which 13 are from the U.S., 14 are from Japan, 8 from Germany, and 30 are G-SIBs). In terms of Tier 1 capital ratio, group 1 banks and ASEAN-5 have the smallest difference compared to other groups, and conversely group 2 banks and ASEAN-5 have the largest gap.

Table 4.12: Paired Samples Correlations of CAR and Tier 1 Capital Ratio

		N	Correlation	Sig.
CAR				
Pair 1	ASEAN-5 & Group 1 banks	5	.255	.679
Pair 2	ASEAN-5 & Group 2 banks	5	.072	.908
Pair 3	ASEAN-5 & G-SIB	5	.318	.602
Tier 1 capital ratio				
Pair 1	ASEAN-5 & Group 1 banks	5	.840	.075
Pair 2	ASEAN-5 & Group 2 banks	5	.859	.062
Pair 3	ASEAN-5 & G-SIB	5	.852	.067

Notes: Author's calculations (IBM SPSS, version 20)

Paired samples correlation takes into account relation (non-independence) between the two samples' means. The null hypothesis stated that there was no difference in CAR and Tier1 of ASEAN-5 and other groups. The CAR of ASEAN-5 and Group 2 banks is correlated.

The paired samples correlations (Table 4.12) in the means of CAR between ASEAN-5 and other groups is weak (the p values .679, .908, .602 > $\alpha = 0.05$). Although p values of Tier 1 data is also greater than the pre-set Sig. alpha, correlations between ASEAN-5 and other groups are better since the Sig. p values of Tier 1 capital ratio are a lot smaller than those of CAR.

The t statistic (Table 4.13 and Table 14) for pair 1 in CAR (ASEAN-5 & Group 1 banks), t = 6.248, and $p = 0.003 < 0.05$ showed that the probability of this outcome occurring by chance was very small under the null hypothesis. Therefore the null hypothesis was rejected and concluded that the CAR of ASEAN-5 was significantly higher than that of Group 1 banks. The other results would be reported in the same way since all *p* values were less than the priori alpha ($\propto = .05$). With the *p* values < 0.05, there was a strong evidence that the means in CAR and Tier 1 of ASEAN-5 and 210 banks across 27 countries were statistically and significantly different.

Table 4.13: Paired samples *t*-test of CAR

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Diff.				
					Lower	Upper			
Pair 1	ASEAN-5 & Group 1 banks	1.78200	.63779	.28523	.99009	2.57391	6.248	4	.003
Pair 2	ASEAN-5 & Group 2 banks	1.65400	.59117	.26438	.91997	2.38803	6.256	4	.003
Pair 3	ASEAN-5 & G-SIB	1.92200	.57347	.25646	1.20994	2.63406	7.494	4	.002

Notes: Author's calculations (IBM SPSS, version 20)

The hypothesis H_1 and H_5 were tested. Pair 1 (M = 1.78, SD = .6378, t (4) = 6.248, *p* (.003) < .05 (all other results would be written the same way as *p* values > .05), the null hypothesis would be rejected and concluded that the difference in means between ASEAN-5 and other groups was statistically significant. These results also showed that CAR of ASEAN-5 was significantly higher than other groups. Rejecting the null hypothesis meant that there was positive relationship between higher capital ratios and financial stability.

Table 4.14: Paired samples *t*-test of Tier 1 capital ratio

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Dev.	Std. Error Mean	95% Confidence Interval of the Diff.				
					Lower	Upper			
Pair 1	ASEAN-5 & Group 1 banks	1.70800	.35238	.15759	1.27047	2.14553	10.838	4	.000
Pair 2	ASEAN-5 & Group 2 banks	1.91800	.48422	.21655	1.31676	2.51924	8.857	4	.001
Pair 3	ASEAN-5 & G-SIB	1.81800	.30327	.13562	1.44145	2.19455	13.405	4	.000

Note: Author's calculations (IBM SPSS, version 20)

The hypothesis H_1 and H_5 were tested. Pair 1 (M = 1.71, SD = .3524, t (4) = 10.838, p (.000) < .05, the null hypothesis would be rejected and concluded that the difference in means between ASEAN-5 and other groups was statistically significant. Rejecting the null hypothesis meant that there was positive relationship between higher capital ratios and financial stability across ASEAN-5.

4.1.3 Concluding Remarks

The Basel III agreement raised the minimum capital ratios significantly. Effective as of 2015, banks must meet 7% minimum regulatory capital (4.5% of CET1 plus 2.5% of capital buffers). The objective of the analysis in this section was to assess the cost impact of higher capital rules under Basel III on bank capital across ASEAN-5 banking sectors. CAR and Tier 1 capital ratio were calculated using the data submitted by national authorities to the IMF following the Financial Soundness Indicators (FSI) Compilation Guide and for dissemination through FSIs.

CAR and Tier 1 capital ratio requirements under Basel III are 8% and 6% respectively; 10.50% of CAR and 6% of Tier 1 were used as the benchmark rates in this study. The main results of analyses indicated that the banking sectors across ASEAN-5 were well capitalized (16.67% of CAR and 14.01 of Tier 1) to meet the minimum target ratio of 7% by 2015; further, banking sectors in the aggregate needed no re-capitalization or capital injection by the government.

Parametric and non-parametric statistics techniques were employed to analyze the findings and to test the hypotheses H_1 and H_5. Although the aggregate CAR and Tier 1 of ASEAN-5 are at least two percentage points higher than those found in advanced economies, the main results of the K-S test, independent samples *t*-test, and Levene's test showed that the analyses failed to reject the null hypothesis of no difference, and concluded that the groups' means were not significantly different from each other. The Mann-Whitney *U* test was employed to assess how CAR and Tier 1 ratio of ASEAN-5 banking sectors differed from those across 118 countries. The K-S test results indicated that the first assumption of normality was violated, the hypothesis was rejected concluded that CAR and Tier 1 of ASEAN-5 were significantly different.

4.2 Basel III Impact on Lending Spreads

Higher funding costs put pressure on bank profitability. Therefore, tighter capital and liquidity requirements under Basel III are viewed by many as an additional tax imposed on banks. Against this backdrop, all banks are assumed to adjust accordingly to pass a portion of the costs to customers in terms of higher rates on loans generated or services provided. This section is based on Slovik and Cournède (2011) study, through which, the cost impact of Basel III on lending spreads is estimated. The underlying assumption in the analysis is that banks are assumed to react to a one percentage point (pp) increase in bank capital relative to risk-weighted assets.

Aggregated balance sheets of ASEAN-5 banking sectors are used. Input data from two categories of balance sheet items are utilized to show that banks' funding costs are equal to their returns on assets, which are directly influenced by the cost of liabilities and equity. Bank lending assets (AL) stored on banking books and other bank assets (AO) such as interbank loans and government bonds held on trading books to consolidated banking sector balance sheets.

4.2.1 Results of the Impact on Lending Spreads

The analysis in this section estimated the cost impact of Basel III capital regulation on lending spreads across banking sectors of ASEAN-5. The following hypothesis is postulated and the results are outset in Tables 4.17 to 4.21:

H_2: Basel III capital ratios result in a higher cost impact on lending spreads across ASEAN-5.

H_0: Basel III capital ratios do not result in a higher cost impact on lending spreads across ASEAN-5. Operational hypotheses H_7 and H_{10} are also tested.

ASEAN-5 banks and banking sectors are comfortably capitalized (explained previously in section 4.2.1), but the macro events since 2013 have proved that ASEAN-5 banking sectors still tend to be highly susceptible to exogenous shocks originating in the U.S., Europe, and Japan. Rejecting the null hypothesis of no difference would mean that the increase in lending spreads across ASEAN-5 due to higher capital ratios would be statistically different and significant.

The analysis involves three steps, all figures are in percentages unless indicated otherwise. In the first step, it is shown how return on assets was equal to cost of funding: The left side of the equation implies the return on assets: $\mathrm{r_t^{AL}} * \mathrm{AL} + \mathrm{r_t^{AO}} * \mathrm{AO} = \mathrm{r_t^{L}} * \mathrm{L} + \mathrm{r_t^{E}} * \mathrm{E}$. the return on lending assets ($\mathrm{r_t^{AL}}$) is computed and multiplied by lending assets (AL), added return on other assets ($\mathrm{r_t^{AO}}$) and multiplied it by other assets to total assets ratio (AO). On the right side of the equation, the cost of borrowing ($\mathrm{r_t^{L}}$) is computed and multiplied by liabilities to total assets ratio (L), added cost of equity ($\mathrm{r_t^{E}}$), and multiplied that by common equity to total assets ratio (E).

Second step incorporated the effect of a one pp increase in capital ratios relative to RWAs. As expected, this negatively affected the bank financing structures, in turn funding costs. The left side of the equation in step one remains unchanged, but in the right side, a one percentage rise was added in capital: $\mathrm{r_t^{AL}} * \mathrm{AL} + \mathrm{r_t^{AO}} * \mathrm{AO} = \mathrm{r_t^{L}} * \left(\mathrm{L} - \frac{\mathrm{RWA}}{100}\right) + \mathrm{r_t^{E}} * \left(\mathrm{E} + \frac{\mathrm{RWA}}{100}\right)$.

Against the backdrop of rising funding costs along with the assumption that the financing costs of debt and equity remain constant, banks are forced to make necessary adjustments to their existing lending rates to compensate in terms of passing a portion of the increased cost to customers. Adding a one percentage increase in capital to the equation in step two reduced the bank's debt financing proportion to its equity capital. The M&M theorem supports equity

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financing as opposed to debt financing, Modigliani and Miller (1958) argue that switching to equity from debt reduces bank leverage. On the contrary to nonfinancial firms, the banking sector has a very high leverage and relies considerably less on debt financing (Berlin, 2011). High leverage normally indicates distress, and for this, Fama and French (1992) excluded banks from their equity return analysis. DeAngelo and Stulz (2013) label banks as *"different"* and conclude that the M&M theorem's leverage irrelevancy is inapplicable to banking sectors.

In the third and final step of the analysis, the results indicated that a one percentage increase in the ratio of bank capital to RWAs pushed lending spreads higher. Increases in bank lending spreads generated additional return on lending assets for banks ($r_{t+1}^{AL} - r_t^{AL}$). The additional return on lending assets is equal to cost of equity minus cost of borrowing, divided by the ratio of lending assets to total assets relative to RWAs: $\left(r_{t+1}^{AL} - r_t^{AL}\right) = (r_t^{E} - r_t^{L})/AL * \frac{RWA}{100}$.

Table 4.15: Impact of 1% increase in bank capital on lending spreads

	$r_t^E - r_t^L$	AL	RWA	$r_{t+1}^{AL} - r_t^{AL}$
	basis points-bps	percentage-bps	percentage-bps	basis points-bps
Indonesia	32.5	66.5	70.7	34.5
Malaysia	24.8	57.6	63.8	27.5
Philippines	21.6	49.1	64.9	28.6
Singapore	24.4	59.5	60.9	24.9
Thailand	38.5	76.7	71.3	35.8
Average	28.36	61.88	66.32	30.26

Notes: Author's estimates

To meet the minimum target capital requirement of 7% under Basel III by 2015, a 1% increase in CET1 would force ASEAN-5 banks (a four-year implementation) to increase the lending spreads by 30.26 bps in the aggregate, which translates to little over 7.5 bps per annum even though monetary policy decisions are usually taken in increments of 25 bps. The main results of the analysis point to a linear relationship between higher capital ratios and the resultant increases in lending spreads. Banks are assumed to take actions and make proper adjustments in light of increasing funding costs. Therefore, banks have an intuitive reaction to recuperate a portion of the ascending costs due to regulatory tightening via increasing service fees or/and lending spreads charged by banks on loans.

Table 4.15 demonstrates the results of the impact analysis of a one pp increase in the TCE ratio on bank lending spreads by 2015. The estimates are based on the calculation of the aggregated bank balance sheets. To meet the minimum capital requirements under Basel III as of 2015, ASEAN-5 banks would have to increase their lending rates by 30.26 bps on average. At country-level; Indonesia (34.5 bps), Malaysia (27.5 bps), Philippines (28.6 bps), Singapore (24.9 bps), and Thailand (35.8 bps). The aggregate ASEAN-5 result is more than twofold of 14.4 bps estimated by Slovik and Cournède (2011), 15 bps by MAG (2010), and 14 bps by BCBS (2010b), The estimates are higher but they are still broadly consistent with results of the recently published studies; but due to important limitations, the analyses' results were open to errors.

Table 4.16: Basel III impact on lending spreads

Country	2015*	2016	2017	2018	2019
Indonesia	34.50	42.40	53.20	62.50	72.40
Malaysia	27.50	35.40	44.20	55.70	66.50
Philippines	28.60	34.70	43.40	54.40	69.80
Singapore	24.90	31.80	39.60	46.40	54.60
Thailand	35.80	46.40	57.50	66.90	77.80
Average	30.26	38.14	47.58	57.18	68.22

Notes: Author's estimates; * The cumulative impact from Table 4.15 (2011-2015).

The increase in lending spreads by 2019 more than doubles compared with the estimated 30.26 bps rise by 2015. To meet the minimum capital requirement of 10.5% fully effective as of 2019, ASEAN-5 banks would have to increase the lending spreads by 68.22 bps in the aggregate. These results are higher than most studies' findings which are about 40 bps for eight years.

The analysis is bipartite, first the impact of 1 pp rise in TCE ratio on lending spreads was analyzed that banks had to increase in order to meet the Basel capital rules effective as of 2015. Second, the impact of the Basel III reforms on bank lending rates by 2019 (after eight years of implementation) was estimated. To meet the minimum capital requirements of Basel III fully effective as of 2019, ASEAN-5 banks would have to increase their lending rates by 68.22 bps on average. Banks in Thailand has to raise their lending rates higher than banks in Singapore, 77.8 bps versus 54.6 bps. Malaysia and Singapore are in a close range, 66.5 bps and 69.8 bps respectively; Indonesia (72.4 bps) is the second highest rate compared to peers.

ASEAN-5 banks would need to increase their lending spreads on average by 68.22 bps (or 8.5 per annum) after eight years of implementation to meet the Basel III capital requirements fully effective as of January 1st 2019. Notwithstanding noticeable differences in banking structures, the nature of intermediation, capital levels, and capitalization needs vary across ASEAN-5 countries. The estimates of impact on lending spreads are within a close range and broadly in line with the results of other studies found in the banking regulation and supervision literature.

4.2.2 Statistical Analysis of Impact on Lending Spreads

The main results obtained through the use of analytical and statistical models demonstrated that the cost impact of Basel III capital regulation on lending spreads was higher across ASEAN-5. Excluding the IIF (2011) report, the estimates of this thesis were broadly consistent with those findings found in several of the recently published studies. To give the results more meaning, the findings were statistically compared with those of the Slovik and Cournède (2011) study. As in the capital analysis, several basic statistics techniques were applied to compare the thesis' findings with those of the referenced study. The descriptive statistics showed that the means in lending spreads increased y-o-y, starting with 24.63 (2015) and ending with 61.75 (2019).

As illustrated in Table 4.17, the K-S test for lending spreads indicated that all *p*-values were greater than the priori significance level *p* (.995) > 0.05). Each sampling population from 2015 to 2019 had a normal distribution, indicating that the first assumption of normality was met.

Based on this, parametric statistics must be used. The analysis failed to reject the null hypothesis of no difference and concluded that the difference in lending spreads between ASEAN-5 and advanced economies were not significantly different than normal. Next, the independent samples *t*-test along with paired samples test were employed to test the hypothesis.

Table 4.17: Kolmogorov-Smirnov test of lending spreads

		2015	2016	2017	2018	2019
N		8	8	8	8	8
Normal Parameters[a,b]	Mean	24.63	32.63	42.50	51.63	61.75
	Std. Dev.	8.879	8.879	10.014	11.338	13.530
Most Extreme Differences	Absolute	.148	.145	.190	.185	.191
	Positive	.134	.145	.190	.100	.115
	Negative	-.148	-.105	-.166	-.185	-.191
Kolmogorov-Smirnov Z		.419	.409	.539	.523	.540
Asymp. Sig. (2-tailed)		.995	.996	.934	.947	.932

Notes: Author's calculations (IBM SPSS, version 20)

The hypothesis H_2 and H_6 were tested. Tier 1 data was normally distributed, so the first assumption of normality was met, i.e. p (.995, .996, .934, .947, and .932) > .05. It was concluded that the analysis failed to reject the null hypothesis, meaning the difference in lending spreads between ASEAN-5 and advanced countries was not statistically significant. Retaining the null hypothesis also meant that the relationship between higher lending spreads and financial stability was not significant.

One sample *t*-test was conducted to compare increases in lending spreads between ASEAN-5 and advanced economies. As outset in Table 4.18, Japan had significantly less (M = 24.8, SD = 8.228) increase in lending spreads than the general population mean of (M = 42.6). The data for Japan was not normally distributed, the first assumption of normality was violated; therefore, the null hypothesis was rejected, t (4) = -4.837, p (.008) < .05, and concluded that the difference in lending spreads between ASEAN-5 and Japan was significantly different. In the cases of the U.S. and EU, each group sample was normally distributed t (4) = -.467, -.932; Sig. p (.665, .404) > .05; the null hypothesis was retained, and concluded that the difference in lending spreads between ASEAN-5 and both the U.S. and EU was not significantly different.

Among ASEAN-5, Singapore (M = 39.60) is the only country with a negative mean difference. Malaysia (M = 45.80) and Philippines (M = 46.20) had small mean differences while Thailand (M= 57) and Indonesia (M = 52.60) had the largest impact. The effect size of this difference is *d* = 3.53 (substantially larger than Cohen's large effect of .80).

Table 4.18: One-sample test of lending spreads

	Test Value (population mean) = 42.6					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
ID	1.472	4	.215	10.000	-8.86	28.86
MY	.465	4	.666	3.200	-15.92	22.32
PH	.495	4	.647	3.600	-16.60	23.80
SG	-.572	4	.598	-3.000	-17.55	11.55
TH	1.938	4	.125	14.400	-6.23	35.03
US	-.467	4	.665	-4.400	-30.57	21.77
EU	-.932	4	.404	-5.800	-23.08	11.48
JP	-4.837	4	.008	-17.800	-28.02	-7.58

Note: Author's calculations (IBM SPSS, version 20)

The hypothesis H_2 and H_6 were tested. Except Japan (i.e. $p = .008 < .05$, the null hypothesis was rejected), each lending spread data was normally distributed; t (4) = .1.472, .465, .495, -.572, 1.938, -.467, -.932; Sig. p (215, .666, .647, .598, .125, .665, .404). The analysis failed to reject the null hypothesis, and concluded that the difference in lending spreads between ASEAN-5 and other groups was not significantly different, also its relationship to financial stability was not significant.

Due to the gradual integration of ASEAN-5 into major financial markets and international trading hubs, since 1990s ASEAN-5 have become increasingly susceptible to monetary policy decisions (i.e. tightening or expansive) in the U.S., EU, and Japan (also referred to as the three main OECD economies). The results illustrated in Table 4.19 indicated that the aggregate mean of lending spreads for ASEAN-5 banking sectors was more than twofold of banking sectors across the three main OECD economies. This suggested that ASEAN-5 banks increased lending spreads more than other groups. An independent samples test was conducted to test the homogeneity of variances via the Levene's test (equality of variances) and *t*-statistics.

Table 4.19: Group statistics of lending spreads

	Group	N	Mean	Std. Deviation	Std. Error Mean
2015	ASEAN-5	5	30.40	4.506	2.015
	OECD	3	15.00	3.606	2.082
2016	ASEAN-5	5	38.00	5.788	2.588
	OECD	3	23.67	4.041	2.333
2017	ASEAN-5	5	47.60	7.570	3.385
	OECD	3	34.00	7.937	4.583
2018	ASEAN-5	5	57.00	8.000	3.578
	OECD	3	42.67	11.372	6.566
2019	ASEAN-5	5	68.20	8.556	3.826
	OECD	3	51.00	14.731	8.505

Notes: Author's calculationss (IBM SPSS, version 20)

The results indicated that the mean in lending spreads between ASEAN-5 and other groups was significantly different, which suggested that the cost impact of Basel III capital ratios on lending spreads across ASEAN-5 was higher than that of the U.S., EU, and Japan. A higher cost impact on lending spreads caused ASEAN-5 banks to increase lending spreads more and faster than other groups from 2011 to 2015. By 2019, the difference in lending spreads narrowed.

In the Levene's test (Table 4.20), the F value of lending spreads between ASEAN-5 and the three OECD economies in 2015 was; F (.636), Sig. p = .455 > .05 (2016, 2017, 2018, and 2019 were expressed exactly the same way). Since all the Sig. (*p*) values were greater than the priori α = .05, the data was normally distributed and the assumption of equal variances was met. Based on these results, the analysis failed to reject the null hypothesis of no difference, and concluded that the difference in lending spreads between groups was not statistically significant. Given no violation of Levene's test for homogeneity of variances, *"Equal Variances Assumed"* must be used and the *t*-test not assuming homogeneous variances would not be calculated. If a violation of Levene's test for homogeneity of variances occurred, *"Equal Variances Not Assumed"* would be used; and a *t*-test not assuming homogeneous variances would be calculated. The report for all results would be written as; t (6) = 5.316, Sig. p = .003 < .05; d = 3.88. The effect size for this analysis (d = 3.88) was found to exceed Cohen's 1988 for a large effect (.80).

Table 4.20: Independent samples test of lending spreads

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	95% Confidence Interval of the Difference	
									Lower	Upper
2015	E. V. A	.636	.455	4.989	6	.002	15.400	3.087	7.847	22.953
	E. V. NA			5.316	5.215	.003	15.400	2.897	8.044	22.756
2016	E. V. A	1.555	.259	3.724	6	.010	14.333	3.849	4.915	23.752
	E. V. NA			4.113	5.663	.007	14.333	3.485	5.682	22.985
2017	E. V. A	.024	.881	2.420	6	.052	13.600	5.619	-.149	27.349
	E. V. NA			2.387	4.159	.073	13.600	5.697	-1.983	29.183
2018	E. V. A	.557	.484	2.119	6	.078	14.333	6.764	-2.217	30.884
	E. V. NA			1.917	3.222	.145	14.333	7.477	-8.562	37.229
2019	E. V. A	1.167	.321	2.140	6	.076	17.200	8.038	-2.468	36.868
	E. V. NA			1.844	2.833	.168	17.200	9.326	-13.491	47.891

Notes: Author's calculations (IBM SPSS, version 20)

The hypothesis H_2 and H_6 were tested. Given no violation of the Levene's test for homogeneity of variances, *"Equal Variances Assumed"* must be used and the *t*-test not assuming homogeneous of variances would not be calculated. The F values in lending spreads of ASEAN-5 and advanced countries were; t (6) = .636, 1.555, .024, .557, 1.167; Sig. p (.455, .259, .881, .484, .321) > .05. There was no strong evidence to reject the null hypothesis, concluded that the difference in means of lending spreads between ASEAN-5 and other groups was not statistically significant. Failing to reject the null hypothesis meant that the relationship between higher lending spreads and financial stability was not significant.

One-way Analysis of Variance (ANOVA) was also performed to evaluate increases in lending spreads between and within groups. One-way ANOVA is used to compare the mean differences between ASEAN-5 banking sectors and those of the advanced economies; the output results are set out in Table 4.21. The level of increases differed significantly among the two groups in 2015 and 2016; F (1, 6) = 24.889, p (.002) < .05 and F (1, 6) = 13.867, p (.010) < .05 respectively. The null hypothesis was rejected and concluded that the difference the groups' means were statistically significant. The null hypothesis was retained in 2017, 2018, and 2019 as the *p* values > .05; F (1, 6) = 5,858, p (.052) > .05; F (1, 6) = 4.491, p (.078) > .05 and F (1, 6) = 4.579, p

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(.076) > .05 respectively, and concluded that there was no strong evidence to reject the null hypothesis that the population means were all equal.

Table 4.21: One-way ANOVA of lending spreads

		Sum of Squares	df	Mean Square	F	Sig.
2015	Between Groups	444.675	1	444.675	24.889	.002
	Within Groups	107.200	6	17.867		
	Total	551.875	7			
2016	Between Groups	385.208	1	385.208	13.867	.010
	Within Groups	166.667	6	27.778		
	Total	551.875	7			
2017	Between Groups	346.800	1	346.800	5.858	.052
	Within Groups	355.200	6	59.200		
	Total	702.000	7			
2018	Between Groups	385.208	1	385.208	4.491	.078
	Within Groups	514.667	6	85.778		
	Total	899.875	7			
2019	Between Groups	554.700	1	554.700	4.579	.076
	Within Groups	726.800	6	121.133		
	Total	1281.500	7			

Notes: Author's calculations (IBM SPSS, version 20)

The hypothesis H_2 and H_6 were tested. The difference in means of lending spreads between ASEAN-5 and other groups in 2015 and 2016 was statistically significant as the p (.002) and p (.010) < .05. In these years, the hypothesis was rejected and concluded that the difference in means was statistically significant. The hypothesis was retained in 2017, 2018 and 2019; the conclusion and the report would be exactly the opposite of that in 2015 and 2016.

One-way ANOVA is used to compare the mean differences between ASEAN-5 banking sectors and those of the three main OECD economies; the output results are set out in Table 4.21. The level of increases differed significantly among the two groups in 2015 and 2016; F (1, 6) = 24.889, p (.002) < .05 and F (1, 6) = 13.867, p (.010) < .05 respectively. The null hypothesis was rejected that the two group population means were equal, and the null hypothesis in 2017, 2018, and 2019 was retained because the *p* values > .05; F (1, 6) = 5,858, p (.052) > .05; F (1, 6) = 4.491, p (.078) > .05 and F (1, 6) = 4.579, p (.076) > .05 respectively.

Table 4.22: Studies on impact of regulatory tightening on lending spreads

Study	Method	Increase in Lending Spread
This Thesis	1 pp rise in capital ratios Banks raise lending rates by 2015	34.5 bps across ASEAN-5
This Thesis	1 pp rise in capital ratios Banks raise lending rates by 2019	68.2 bps across ASEAN-5
MAG (2010)	1 pp rise in capital ratios 25% liquidity requirement Implementation of NSFR	28 bps 15 bps Between 57 bps and 71 bps
MAG (2010)	1 pp rise in the TCE ratio with monetary policy	0.08 bps (ECB MCM model) 0.29 bps (ECB CMR model) 0.79 bps (FRB/US model)
MAG (2010)	1 pp rise in the TCE ratio without monetary policy	0.16 bps (ECB MCM model) 0.25 bps (ECB CMR model) 0.31 – 0.36 bps (FRB/US model)
BCBS (2010b)	Synergy in capital and NSFR No synergy	14 bps to meet NSFR 25 bps to meet NSFR
BCBS (2010b)	1 pp rise in capital ratios Implementation of NSFR Capital and liquidity regulation	52 bps (U.S.) and 52 bps (Euro area) 25 bps (U.S.) and 25 bps (Euro area) 66 bps (U.S.) and 66 bps (Euro area)
King (2010)	Synergy in capital and liquidity No synergy	12 bps to meet NSFR 24 bps to meet NSFR
IIF (2011)	2 pp rise in Tier 1, total capital No monetary policy response	468 bps (U.S.), 291 bps (Euro area), and 202 bps (Japan) in 2011-2015
IIF (2011)	2 pp rise in Tier 1, total capital No monetary policy response	243 bps (U.S.), 328 bps (Euro area), and 181 bps (Japan) in 2012-2019
Angelini et al. (2011)	2 pp rise in the TCE ratio 25 % liquidity requirement	26 bps 14 bps (40 bps as combined)
Angelini et al. (2011)	2 pp rise in the TCE ratio 50 % liquidity requirement	26 bps 25 bps (51 bps as combined)
Gerali et al. (2010)	1 pp rise in the TCE ratio	31 bps (by 2017)
Slovik and Cournède (2011)	1 pp rise in capital ratios After a 5-year implementation	64 bps (U.S.), 54 bps (Euro area), and 35 bps (Japan)
Santos and Elliott (2012)	1 pp rise in the TCE ratio	28 bps (U.S.), 18 bps (Euro area), and 8 bps (Japan)
Miles et al. (2012)	2 pp rise in capital ratios Large M-M effect is assumed	18 bps
Cecioni (2010)	1 pp rise in the TCE ratio	0.03 bps (by 2018)

Note: MM refers to Modigliani & Miller (1958); pp denotes percentage point; bps denotes basis points.

This table is of great importance because it gives the reader the opportunity to view the findings of the most recently published studies in one place and to have a chance to compare them with the findings of the analyses undertaken in this thesis. A more proper for this table is actually the Literature Review, but without this table, it would be difficult to determine whether the findings of this thesis are in line with other studies.

4.2.3 Concluding Remarks

As previously mentioned, the Basel III agreement raised the minimum capital ratios significantly. Even before the final deadline, ASEAN-5 banks are not worried about meeting the higher capital ratios when all the rules are completely phased in on January 1st 2019. To meet the target ratio of 7% by 2015 and 10.5% by 2019, ASEAN-5 banks are assumed to react intuitively to rising funding costs; to recoup a portion of the rising costs imposed, some upward adjustments are expected to be made in service fees or/and interest rates charged on loans.

The objective of the analysis in this section was twofold; first, to assess the impact of 1% increase in CET1 on lending spreads across ASEAN-5 (after a four-year implementation); second, under the same scenario, to assess the cost impact of higher capital ratios on lending spreads by 2019 (after an eight-year implementation). To meet the target capital ratio of 7% (4.5% CET1 + 2.5% capital buffers) as of 2015, ASEAN-5 banks would have to increase the lending rates by 30.26 bps on average. To meet the minimum capital requirements of 10.5% (8% total capital + 2.5% capital buffers) by 2019, ASEAN-5 banks would have to increase their lending rates by 68.22 bps on average (these are high but consistent with other studies).

Parametric and non-parametric statistics techniques were employed to analyze the findings and to test the hypotheses H_3 and H_8. The main results of the K-S test, one-sample *t*-test, independent samples *t*-test, and one-ANOVA test indicated that there was no strong evidence to reject the null hypothesis of no difference. In the one-sample *t*-test, the difference in means of ASEAN-5 and Japan was statistically significant; $t\ (4) = -4.837$; Sig. $p\ (.008) < .05$. One-way ANOVA, the null hypothesis was rejected in 2015 and 2016, and concluded that the difference in means between ASEAN-5 and other groups were statistically significant as $p\ (.002)$ and $p\ (.01) < .05$.

4.3 Basel III Impact on Steady State Output

While more rigorous capital regulation is projected to increase banks' costs of funding, it is also assumed to strengthen the resilience of banking sectors to shocks under highly adverse market conditions. The intuition behind this assumption is that a shift from debt (less costly) to equity (more costly) capital structure will contribute positively to the soundness of banks, thus reduce the probability of future crises (Modigliani & Miller, 1958). However, a widespread concern is that equity financing negatively affects banks' ROEs, this forces banks to respond submissively by raising lending rates which may reduce steady state output in the process (e.g. King, 2010).

The analysis in this section follows models developed by Yan et al. (2011), Caggiano and Calice (2011), and Angelini et al. (2011) who estimated the effect of Basel III capital and liquidity rules (i.e. NSFR) on steady state output. Yan et al. (2011) used the binary-state model and the VCEM model to estimate the impact of the Basel III reforms on the UK economy. Caggiano and Calice (2011) investigated the impact of tighter capital and liquidity regulation on a panel of 53 African economies using a combination of binary-state and multivariate logit models. Angelini et al. (2011) assessed the long-term economic impact of Basel III using DSGE models. The findings of the former two studies provided empirical evidence that higher capital ratios together with the NSFR would result in a significant net benefit in the UK and African economies under study. The latter study projected a reduction in the steady state output in the range of 0.08-0.15%.

The following hypotheses are postulated and the results are illustrated in Tables 4.25 to 4.38:

H_3 Basel III capital ratios result in a higher economic cost across ASEAN-5.

H_4 Basel III capital ratios result in a higher economic benefit across ASEAN-5.

The operational hypotheses below are also tested. The null hypotheses are postulated the opposite of the hypotheses. Rejecting the null hypotheses provide evidence that they are true.

H_5 There is a positive relationship between higher capital ratios and banking stability.

H_7 There is a positive relationship between sufficient liquidity and banking stability.

H_8 There is a negative relationship between financial crisis and GDP growth.

The analyses undertaken attempted to reject the null hypotheses, and to conclude that regulatory tightening under Basel III would cause an increase in the steady state output across ASEAN-5.

4.3.1 Results of the Impact on Steady State Output

First, the explanatory variables to be used were determined in the binary state model because the calculation of the probability of a banking crisis occurring depended on the interaction of each explanatory variable, mathematically; $\mathrm{Pr_t} = \Phi(\alpha_i \mathrm{TCE/RWA_t} + \beta_i \mathrm{NSFR_t} + \gamma_i Z_{it})$, where NFSR denotes the net stable funding ratio, TCE/RWA is the tangible common equity capital ratio, Z_t represents macroeconomic variables such as $\mathrm{RPI_t}$ as the real estate price inflation and $\mathrm{CA_t}$ as the current account balance ratio. These variables were in the log-form. As in standard probit models, Φ was used and P_r denoted the likelihood of a crisis materializing.

The Augmented Dickey Fuller (ADF) test (e.g. Yan et al., 2011) showed that there might be four cointegrating relationships; namely, TCE/RWA (CAR was used in the simulations), NSFR (long-term liquidity), and the average 3-month lending rates charged by banks for new generated loans. Next, Johansen's trace test was applied to the variables, where α is an $n * r$ matrix of loading coefficients and β is an $n * r$ cointegrating vectors. The test results indicated that determinants of a crisis across ASEAN-5 might have long-term interactions (Table 4.23).

Table 4.23: Johansen cointegration trace test

	test	α = 10%	α = 5%	α = 1%
r ≤ 6	8.25	8.42	10.33	13.79
r ≤ 5	12.48	14.25	14.97	19.80
r ≤ 4	22.38	20.68	23.40	28.60
r ≤ 3	29.20	26.10	29.24	32.81
r ≤ 2	32.85	30.95	35.26	41.74
r ≤ 1	41.95	38.25	41.60	47.32
r ≤ 0	59.81	44.64	48.29	54.45

Note: Author's calculations

The thesis expanded the binary state model following Caggiano and Calice (2011), and included the capital adequacy ratio (λ), year-over-year GDP growth rate (δ), real GDP per capita (ξ), private credit growth (ψ), private credit as a ratio of GDP (φ), foreign exchange reserve (ϱ), change in trade (τ), current account balance (Ω) to nominal GDP, real estate price inflation rate adjusted by the GDP deflator (Γ), real interest rate (r), and currency depreciation (d).

As the first step in the general model, some of the explanatory variables have been progressively reduced to a list of fewer variables via general-to-specific approach that are statistically significant at 0.10 (10%) level. As in Caggiano and Calice (2011), at the conclusion of the process of variable reduction, three specific categories of variables were obtained that formed three sets of indicators; real economy (GDP growth and interest rate), macro (current account and exports), and financial (capital adequacy ratio and credit growth). The probit estimation results are set out in Table 4.24, the negative sign of the estimated coefficient on CAR implies that tighter capital and liquidity regulation can contribute positively to the bank's ability to prevent a banking crisis in the magnitude of the GFC. Conversely, the positive sign on inflation and the real interest rates suggests that higher rates can trigger a rise in the probability of crisis.

Table 4.24: The indicators of a banking crisis

	Model 6	Model 5	Model 4	Model 3	Model 2	Model 1
λ	-0.678***	-0.453**	-0.585**	-0.570**	-0.646**	-0.438**
φ	0.027*	0.026*	0.032*	0.036*	0.029*	0.016
δ	-0.167***	-0.156***	-0.173***	-0.178***	-0.191***	-0.157***
r	0.261***	0.274***	0.277***	0.221**	0.224**	0.226**
τ	0.031*	0.032*	0.036*	0.034*	0.034*	0.028
Ω	0.128**	0.157***	0.168***	0.177***	0.179***	0.154***
ψ		0.221	0.385	0.395	0.399	0.512
ϱ			-0.263	-0.277	-0.296	-0.241
Γ				0.030	0.028	0.033
ξ					-0.001	-0.001
d						0.004
R^2	0.171	0.173	0.178	0.186	0.186	0.164

Notes: Author's calculations
Data extracted from IMF Data Warehouse: www.elibrary.imf.org
* ** *** denote significance levels of 10%, 5%, and 1% respectively.

Looking at the results of Table 4.24, as expected, CAR (λ) is the most critical determinant of a banking crisis among ASEAN-5 banking sectors. Although banks across ASEAN-5 have at least two percentage point higher CARs than banks in the U.S., Europe, and Japan under Basel III, they are still highly susceptible to macro shocks. The second most important indicator is the level of private credit as percent of GDP (φ); in an acute financial stress, excessive corporate leverage can lead to a cascade of defaults as observed during the Asian crisis in the late 1990s and exactly a decade later in the GFC. It is no surprise that GDP growth (δ) is in top three of a crisis' determinants; when growth shrinks relative to the baseline, it could be a sign of issues in various segments of the economy, negatively affecting consumption and causing a contraction in economic activity. The last two indicators are changes in real interest rate and exports volume; a majority of ASEAN-5 transformed from export dependent to domestic consumption.

To see the effects of higher capital ratios, the marginal effect of a change was calculated in an explanatory variable via $\partial \mathrm{E}(\mathrm{y_i}|\mathrm{x_i}, \beta)/\,\partial \mathrm{x_{ij}} = \mathrm{f}(-\mathrm{x_i'}\beta)\beta_\mathrm{j}$ where $\mathrm{x_j}$ is the j-th explanatory variable in vector of regressor and $\mathrm{y_i}$ is the dependent variable, $\mathrm{E}(\mathrm{y_i}|.)$ is the conditional expected value of $\mathrm{y_i}$, β is the vector of parameters, and f(.) is the logistic function. Next, a simple OLS regression was run for the mapping of Tier 1 ratio to RWAs (BCBS, 2010e).

Similar to Angelini et al. (2011), MAG (2010), and BCBS (2010b); the cost impact of Basel III under three scenarios was assessed; first, calculated the impact of a one percentage increase in the TCE/RWA ratio without liquidity tightening on GDP growth across ASEAN-5; second, added a 25% increase in the liquidity requirement; and third, increased the liquidity requirement to 50%. The main results illustrated in Table 4.25 suggest almost a linear correlation between the regulatory tightening under Basel III and increases in the level of steady state output. For a one percentage point increase in TCE / RWA without liquidity tightening, the average impact on the steady state output across ASEAN-5 was 0.33% (0.085% per annum). When added a 25% increase in the liquidity requirement, the fall in output increased by 33.3% to 0.44%. A 50% increase in liquidity led to a bigger reduction of 0.54% in GDP growth which is more than 50% of the fall in output in the first scenario where no liquidity tightening was considered.

The key results of the impact analysis of economic cost due to regulatory tightening are set out in Table 4.25; according to which, the fall in steady state output increased considerably responding to each percentage point rise in the TCE ratio. The cost of the Basel III capital regulation peaked at a 6 pp rise in regulatory capital, but the cost impact was much more significant with additional liquidity requirements. After four years of implementation, the results indicated that the economic cost of higher capital ratios to ASEAN-5 would be 0.33%, or about

0.09% per annum, but the size of the reduction in GDP growth compared to the baseline tripled for a 6 pp rise in capital regulation. A 0.09% decline in annual basis is more than twice the estimate of a 0.04% fall in output found by Slovik and Cournède (2011) and MAG (2010). In the former study, the GDP shrank by 0.20% after five years of implementation; whereas in the later study, the horizon was four and a half years and the fall in output was estimated to be 0.19%. The cost of the new Basel III reforms was varied and more significant at country-level.

Table 4.25: Steady state output loss due to regulatory tightening

Increase in TCE/RWA	Rise in liquidity	Indonesia	Malaysia	Philippines	Singapore	Thailand	Average
%	%	(percentage deviation from baseline after a 4-year implementation)					
1	0	0.34	0.32	0.35	0.29	0.36	0.33
2	0	0.46	0.40	0.49	0.34	0.48	0.43
3	0	0.58	0.50	0.60	0.42	0.62	0.54
4	0	0.69	0.62	0.73	0.51	0.75	0.66
5	0	0.85	0.76	0.90	0.68	0.92	0.82
6	0	1.01	0.90	1.04	0.85	1.08	0.98
Median loss in output		0.64	0.56	0.67	0.47	0.69	0.61
1	25	0.45	0.42	0.46	0.38	0.47	0.44
2	25	0.56	0.51	0.58	0.46	0.55	0.53
3	25	0.74	0.68	0.81	0.63	0.76	0.72
4	25	0.93	0.82	0.98	0.77	1.00	0.90
5	25	1.05	0.98	1.11	0.92	1.15	1.04
6	25	1.22	1.14	1.29	1.08	1.30	1.21
Median loss in output		0.84	0.75	0.90	0.70	0.88	0.81
1	50	0.54	0.51	0.56	0.47	0.62	0.54
2	50	0.72	0.66	0.75	0.60	0.75	0.70
3	50	0.88	0.79	0.93	0.74	0.90	0.85
4	50	1.05	0.96	1.10	0.88	1.13	1.02
5	50	1.24	1.10	1.28	1.06	1.32	1.20
6	50	1.38	1.36	1.45	1.26	1.50	1.39
Median loss in output		0.97	0.88	1.02	0.81	1.02	0.94

Note: Author's calculations

The hypothesis H_3 and H_8 were tested. First, the cost impact of higher capital ratios on steady state output was calculated, the increase in TCE in one percentage point increment from 1% to 6%; second, in addition to higher capital ratios, a 25% liquidity requirement was added; third, in addition to higher capital ratios, a 50% liquidity requirement was added. The largest loss in output across ASEAN-5 was projected to be when the TCE was increased by 6% and 50% liquidity was added.

Throughout the statistical analyses, Singapore seems to have the lowest impact stemming from regulatory tightening under the Basel III, while Thailand along with Indonesia are subject to a higher cost impact. The average country-level impact for a 1 pp increase in the TCE capital ratio are; Indonesia (0.34%), Malaysia (0.32), Philippines (0.35), Singapore (0.29), and Thailand (0.36). When a 25% liquidity requirement was added, the fall in output increased more than 30% in each of ASEAN-5 members; Indonesia (0.45%), Malaysia (0.42%), Philippines (0.46%), Singapore (0.38%), and Thailand (0.47%). For ASEAN-5, a 25% liquidity tightening meant a further 31% decline in the level of output on average (i.e. contraction in economic activity).

A 50% liquidity requirement caused a much bigger fall in output, 0.54% across ASEAN-5. At country-level; Indonesia (0.54%), Malaysia (0.51%), Philippines (0.56%), Singapore (0.47%), and Thailand (0.62%). Although the output response to tighter capital regulation is not perfectly linear, doubling the increase in regulatory capital leads to nearly the same magnitude of reduction in GDP growth. Even though ASEAN-5 countries and their banking sectors are varied, the impact of the regulatory tightening on output falls in a close range.

The analysis quantified economic benefits of tighter capital and the resultant reduced probability of crisis, the level of impact is expressed as a gain in output and the main results are illustrated in Table 4.26. Economic benefits stemming from reduced probability of crisis (RPC) due to higher capital ratios in annual basis were rather insignificant; a 1 pp rise in the TCE ratio with a 4.65% RPC caused a 0.18% gain in output across ASEAN-5 after four years of implementation (about 0.05% annually). For a 5 pp rise in capital regulation with a 2.75% RPC rate, the magnitude of gain in output tripled (0.54%), suggesting that a positive correlation existed between higher capital ratios, reduced probability of crisis rates, and the resultant gain in output.

At 6 pp rise in capital regulation plus 2.5% RPC, the average gain GDP growth was 0.63% (0.16% per annum). The country-level economic benefits in the above scenario were; Indonesia (0.69%), Malaysia (0.67%), Philippines (0.58%), Singapore (0.60%), and Thailand (0.63%).

Table 4.26: Economic benefits due to reduced probability of crisis

Increase in TCE/RWA	Probability of crisis	Indonesia	Malaysia	Philippines	Singapore	Thailand	Average
%	%	(expected gain as % of GDP after a 4-year implementation)					
1	4.65	0.19	0.17	0.16	0.18	0.21	0.18
2	4.15	0.26	0.27	0.25	0.23	0.29	0.26
3	3.60	0.37	0.41	0.32	0.32	0.36	0.36
4	3.10	0.49	0.52	0.40	0.40	0.43	0.45
5	2.75	0.60	0.58	0.49	0.53	0.51	0.54
6	2.50	0.69	0.67	0.58	0.60	0.63	0.63
Median benefit		0.43	0.47	0.36	0.36	0.40	0.40

Notes: Author's calculations

The hypothesis H_4 and H_8 were tested. Economic benefits of higher capital ratios under Basel III were calculated based on the assumption that higher capital ratios reduce the probability of financial crises; the reasoning behind this assumption infers that banks with strong capital positions will be better enabled to deal with the first several panic days of the crisis, this would also prevent funding freeze.

Notwithstanding the recurrence of crises in recent memory, the occurrence of a banking crisis is rare, about once every 20 or 25 years which makes the probability of crisis in the range of 4% and 5%. The estimates provided by three major studies covering the past three decades of financial and banking crises across G-10 are in a very close range. According to the Basel Committee, it is less than 5% (BCBS, 2010e), 5.2% by Reinhart and Rogoff (2009), and 4.1% by Laeven and Valencia (2008). Historically, Asia has been more prone to crises than G-10, so the starting probability of crisis at 7% TCE to RWAs is 4.65%.

As illustrated in Table 4.27, economic benefits due to higher capital ratios and liquidity regulation generated larger benefits than that of her capital ratios and the resultant reduced probability of crisis (Table 4.26). A 1 pp rise in the TCE ratio with 95% NSFR resulted in an average gain of 0.25% in steady state output after four years of implementation, which is 38.9% higher than the gain of 0.18% in output generated by a 1 pp rise in the TCE in conjunction with 4.65% RPC rate. The estimated economic benefit across ASEAN-5 for a 6 pp with 100% NSFR increased more than fourfold, 1.09% as opposed to 0.25% at 1 pp with 95% NSFR.

Table 4.27: Economic benefits due to liquidity tightening

Increase in TCE/RWA	NSFR	Indonesia	Malaysia	Philippines	Singapore	Thailand	Average
%	%	(expected gain as % of GDP after a 4-year implementation)					
1	0.95	0.26	0.23	0.26	0.24	0.28	0.25
2	0.96	0.40	0.36	0.39	0.35	0.44	0.39
3	0.97	0.60	0.55	0.57	0.49	0.63	0.57
4	0.98	0.82	0.73	0.70	0.60	0.87	0.74
5	0.99	0.94	0.89	0.92	0.78	1.02	0.91
6	100.0	1.13	1.05	1.09	0.97	1.19	1.09
Median benefit		0.71	0.64	0.63	0.55	0.75	0.66

Notes: Author's calculations

The hypothesis H_4 and H_8 were tested. Short-term (LCR) and long-term (NSFR) were introduced by the Basel Committee to strengthen banks' ability to manage risk exposures related to counterparty default. Under the new Basel III rules, it is mandatory for banks to have sufficient amount of stable funding to take care of required stable funding over 1-year horizon, which also alleviates maturity mismatches.

Rather than estimating economic benefits of different scenarios in terms of a gain in steady state output, the analysis investigated whether these scenarios generated economic benefits when they were combined (Table 4.28). It was assumed that tighter capital regulation involved increasing TCE ratio by 1 pp increments, starting with 1 pp and ending with 6 pp); reduced probability of crisis, as a complement to financial stability, was assumed to be the upshot of higher capital ratios, which began with 4.65% at 1pp and gradually reduced to 2.5% at 6 pp; liquidity regulation started with 95% NSFR at 1pp and ended with 100 NSFR at 6 pp rise in the TCE.

Table 4.28: Economic benefits due to regulatory tightening

Increase in TCE/RWA	Probability of crisis	NSFR	Indonesia	Malaysia	Philippines	Singapore	Thailand	Average
%	%	%	(expected gain as % of GDP after a 4-year implementation)					
1	4.65	0.95	0.51	0.47	0.49	0.44	0.53	0.49
2	4.15	0.96	0.82	0.78	0.72	0.63	0.75	0.74
3	3.60	0.97	1.13	1.03	0.94	0.79	1.07	0.99
4	3.10	0.98	1.45	1.34	1.19	1.03	1.38	1.28
5	2.75	0.99	1.64	1.53	1.44	1.26	1.64	1.50
6	2.50	100.0	1.82	1.70	1.74	1.54	1.89	1.74
Median benefit			1.29	1.19	1.07	0.91	1.23	1.14

Notes: Author's calculations

The hypothesis H_4 and H_8 were tested. The analysis presented in this table re-calculated the economic benefits of Basel III by combining the three assumptions; higher capital ratios, reduced probability of crisis, and increased net stable funding coverage. Economic benefits due to regulatory tightening across ASEAN-5 are the highest at 6% increase in TCE, 2.5% probability of crisis, and 100% NSFR.

The results of the analysis of economic benefits due to regulatory tightening are set out in Table 4.28, which indicated that each increment of capital increase in the TCE ratio in conjunction with the corresponding reduced probability of crisis and NSFR led to a gain in steady state output. The average gains in output across ASEAN-5 for 1 pp with 4.65% RPC, 1pp with 95% NSFR, and combined were; 0.18%, 0.25%, 0.49% respectively. At country-level; Indonesia (0.19%, 0.26%, 0.51%), Malaysia (0.17%, 0.23%, 0.47%), Philippines (0.16%, 0.26%, 0.49%), Singapore (0.18%, 0.24%, 0.44%), and Thailand (0.21%, 0.28%, 0.53%).

The estimated gain in output was noticeably larger in the combined scenario as opposed to individual analyses of the economic benefits of RPC and NSFR. The economic benefit peaked at 6 pp – 2.50% RPC, 6 pp – 100% NSFR, and combined (0.63%, 0.95%, 1.74% respectively); country-level, Indonesia (0.69%, 1.13%, 1.82%), Malaysia (0.67%, 1.05%, 1.70%), Philippines (0.58%, 1.09%, 1.74%), Singapore (0.60%, 0.97%, 1.54%), and Thailand (0.63%, 1.19%, 1.89%). After computing economic costs (i.e. loss in steady state output) and economic benefits (gain in output) of regulatory tightening; to get net benefits, simply costs were subtracted from benefits which, not surprisingly, was the highest at 6 pp rise in the TCE capital ratio.

Table 4.29: Net economic benefits due to regulatory tightening

TCE RWA	benefit* cost**	Indonesia	Malaysia	Philippines	Singapore	Thailand	Average	Net benefit
%	%	(Net benefit as % of GDP after 4-year implementation)					%	%
1	benefit	0.51	0.47	0.49	0.44	0.53	0.49	0.16
1	cost	0.34	0.32	0.35	0.29	0.36	0.33	
2	benefit	0.82	0.78	0.72	0.63	0.75	0.74	0.31
2	cost	0.46	0.40	0.49	0.34	0.48	0.43	
3	benefit	1.13	1.03	0.94	0.79	1.07	0.99	0.45
3	cost	0.58	0.50	0.60	0.42	0.62	0.54	
4	benefit	1.45	1.34	1.19	1.03	1.38	1.28	0.62
4	cost	0.69	0.62	0.73	0.51	0.75	0.66	
5	benefit	1.64	1.53	1.44	1.26	1.66	1.51	0.68
5	cost	0.85	0.76	0.90	0.68	0.92	0.82	
6	benefit	1.82	1.70	1.74	1.54	1.89	1.74	0.76
6	cost	1.01	0.90	1.04	0.85	1.08	0.98	

Notes: Author’s calculations

* Benefit calculations include a reduced probability of crisis and NSFR conditions.

** The cost is the output loss due to higher capital requirements without tighter liquidity rules.

The hypothesis H_4 and H_8 were tested. Rejecting the null hypothesis would indicate that higher capital ratios would lead to a higher GDP growth. The net economic benefits across ASEAN-5 were computed by subtracting economic costs from economic benefits. The hypotheses H_3 and H_4 were also confirmed.

The main results of the net benefits analysis are set out in Table 4.29, indicating that both costs and benefits due to regulatory tightening increased in proportion to the increments of increases in the regulatory capital requirements. After a four-year implementation, the fall in steady state output due to a 1 pp rise in the TCE was 0.33% on average and the benefit in terms of a gain in output was 0.49%; as a result, the net benefit was 0.16% (or 0.04% per annum). The annual net benefit nearly doubled (0.08%) stemming from a 2 pp rise in the TCE ratio. The amount of net benefits was reduced substantially with additional liquidity tightening; as such, a 25% liquidity together with a 1 pp rise in the TCE ratio resulted in even a bigger loss in output (0.39%) which reduced the net benefit to 0.10%. A 50% liquidity requirement caused a further reduction in the net benefit which was reduced to 0.02% after deducting a 0.47% cost. The main results of the analysis showed that there was a correlation and almost a linear relationship between regulatory tightening and economic performance underpinned by reduced probability of crisis and NSFR. Both levels of costs and benefits rose in proportion to increases in capital and liquidity levels. The net benefit peaked for a 6 pp rise in the TCE ratio, at which level, the average cost impact of Basel III on output was 0.98% and the benefit was 1.74%, bringing the final net benefit figure to 0.76%. The obtained estimates in this thesis may or may not reflect the actual developments.

4.3.2 Statistical Analysis of the Impact on Steady State Output

Statistics were run on the data to analyze both economic costs (a loss in the steady state output) and economic benefits (a gain in output) across ASEAN-5 due to regulatory tightening. This was a bipartite analysis; first, assessed economic costs of higher capital and liquidity tightening under the new regulatory standards. Second, assessed economic benefits via higher capital, NFSR, and the assumption of reduced probability of crisis. The results of the cost analysis were compared with those of Angelini et al. (2011) using an independent samples *t*-test and ANOVA.

The results of the K-S test in Table 4.30 indicated that the assumption of normality was met in all samples' distributions because each Sig. *p*-value was greater than the priori alpha (i.e. p = .981 > 0.05). The null (H_0) hypothesis was retained and concluded that the difference in means between ASEAN-5 and the U.S., Europe, and the UK from Angelini et al. (2011) was not significantly different. The outcomes of the K-S test indicated that parametric statistics must be used. Based on the Sig. *p* values > 0.05; an independent samples *t*-test and a one-way ANOVA were used to test the hypothesis via Levene's F-statistic for equal variances and *t*-statistic for equal means (i.e. the homogeneity of variances assumption). This test was significant to show that the means of ASEAN-5 were larger than those of the U.S., Europe, and the UK; more than twofold of the median impact, but substantially less than the mean of the maximum impact.

Table 4.30: Kolmogorov-Smirnov test of economic cost

		IN	MY	PH	SG	TH	ASN5	US	EU	UK	MAX	MED
N		9	9	9	9	9	9	9	9	9	9	9
Normal Parameters	Mean	.8911	.8189	.9344	.7500	.9489	.8689	.6900	.6022	.7067	1.463	.4189
	Std. Dev.	.3069	.3078	.3225	.3018	.3424	.3170	.2556	.2371	.2593	.4351	.1533
Most Extreme Differences	Absolute	.156	.142	.161	.135	.164	.147	.139	.135	.132	.173	.163
	Positive	.156	.142	.161	.135	.164	.147	.125	.126	.132	.131	.163
	Negative	-.106	-.087	-.112	-.087	-.115	-.095	-.139	-.135	-.127	-.173	-.146
Kolmogorov-Smirnov Z		.468	.425	.482	.405	.491	.442	.417	.404	.396	.518	.490
Asymp. Sig. (2-tailed)		.981	.994	.974	.997	.969	.990	.995	.997	.998	.951	.970

Notes: Author's calculations

IN: Indonesia; MY: Malaysia; PH: Philippines; SG: Singapore; TH: Thailand; ASN5: ASEAN-5; US: United States; EU: Euro area; UK: United Kingdom; MAX: Maximum; MED: Median; TCE: Tangible common equity.
TCE 2NL, TCE 4NL, and TCE 6NL denote the impact of only capital without liquidity tightening.
TCE 2L25, TCE 4L25, and TCE 6L25 denote the impact of capital and 25% liquidity tightening.
TCE 2L50, TCE 4L50, and TCE 6L50 denote the impact of capital and 50% liquidity tightening.

The hypothesis H_3 and H_8 were tested. The analysis failed to reject the null hypothesis and concluded that the difference in means of ASEAN-5 and other groups was not statistically significant; all *p* values > .05.

An examination of the groups' means set out in Table 4.31 indicate that the impact of higher capital requirements without liquidity regulation on steady state output is higher across ASEAN-5 than the three main OECD economies studied by Angelini et al. (2011). To see the effect of tighter liquidity, an additional 25% liquidity requirement was added; in the initial capital increases up to 4% of TCE/RWA, the fall in output across ASEAN-5 banking sectors was still slightly less than those found in Angelini et al. (2011). However, when the liquidity tightening was increased to 50%, ASEAN-5 banking sectors were affected more, and the magnitude of the impact was marginally higher than that of the U.S., Europe, and the UK. ASEAN-5 banks have been conserving capital since 2012; the capital raising spree coupled with higher capital ratios than Basel III helped ASEAN-5 mitigate impact of shocks due to regulatory tightening.

Table 4.31: Group statistics of economic cost

	Group	N	Mean	Std. Deviation	Std. Error Mean
TCE 2NL	1	6	.4333	.05645	.02305
	2	5	.3440	.20256	.09059
TCE 4NL	1	6	.6600	.08718	.03559
	2	5	.6140	.28953	.12948
TCE 6NL	1	6	.9767	.08687	.03547
	2	5	.8940	.40716	.18209
TCE 2L25	1	6	.5317	.04262	.01740
	2	5	.5020	.32614	.14586
TCE 4L25	1	6	.9000	.09011	.03679
	2	5	.7900	.40006	.17891
TCE 6L25	1	6	1.2067	.08524	.03480
	2	5	1.0500	.47418	.21206
TCE 2L50	1	6	.6967	.05820	.02376
	2	5	.6900	.47339	.21171
TCE 4L50	1	6	1.0233	.09223	.03765
	2	5	.9400	.51493	.23028
TCE 6L50	1	6	1.3900	.08198	.03347
	2	5	1.1620	.52609	.23527

Note: Author's calculations (IBM SPSS, version 20); see Table 4.29 for denotations.

The hypotheses H_3 and H_8 were tested. Group statistics illustrated that the economic cost due to the regulatory tightening of Basel III was higher for ASEAN-5 than other groups. The difference in means of economic cost between ASEAN-5 and other groups increased when 25% and 50% liquidity requirements were added in addition to the higher capital ratios.

Using an alpha level of .05, an independent samples *t*-test was conducted to test the homogeneity of variances via Leven's test and the equality of means via the *t*-statistic in case Levene's test is violated. All F values in the Levene's test, except TCE 2L25 (Sig. $p = .044 < .05$) and TCE 2L50 (Sig. $p = .039 < .05$) were greater than the significance alpha $\alpha = 0.05$; therefore, "Equal

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variances assumed" is used and the *t*-statistic would not be computed. For TCE 2L25 and TCE 2L50, "Equal variances not assumed" is used and *t*-statistic would be computed; the assumption of homogeneity of variances was violated in these two samples and met in all other cases.

Table 4.32: Independent samples test of economic cost

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	95% Confidence Interval of the Difference	
									Lower	Upper
TCE 2NL	E. V. A	3.574	.091	1.043	9	.324	.08933	.08565	-.10441	.28308
	E. V. NA			.956	4.519	.387	.08933	.09347	-.15884	.33750
TCE 4NL	E. V. A	2.630	.139	.373	9	.718	.04600	.12333	-.23298	.32498
	E. V. NA			.343	4.606	.747	.04600	.13429	-.30826	.40026
TCE 6NL	E. V. A	3.531	.093	.489	9	.636	.08267	.16898	-.29959	.46492
	E. V. NA			.446	4.304	.677	.08267	.18551	-.41834	.58368
TCE 2L25	E. V. A	5.506	.044	.223	9	.829	.02967	.13306	-.27133	.33066
	E. V. NA			.202	4.114	.850	.02967	.14689	-.37375	.43308
TCE 4L25	E. V. A	3.558	.092	.660	9	.525	.11000	.16654	-.26674	.48674
	E. V. NA			.602	4.339	.577	.11000	.18266	-.38188	.60188
TCE 6L25	E. V. A	4.019	.076	.802	9	.443	.15667	.19525	-.28502	.59835
	E. V. NA			.729	4.216	.504	.15667	.21490	-.42813	.74146
TCE 2L50	E. V. A	5.793	.039	.035	9	.973	.00667	.19290	-.42970	.44303
	E. V. NA			.031	4.101	.976	.00667	.21304	-.57912	.59246
TCE 4L50	E. V. A	4.562	.061	.393	9	.703	.08333	.21200	-.39624	.56290
	E. V. NA			.357	4.214	.738	.08333	.23334	-.55173	.71840
TCE 6L50	E. V. A	4.459	.064	1.058	9	.318	.22800	.21557	-.25966	.71566
	E. V. NA			.959	4.162	.390	.22800	.23764	-.42179	.87779

Note: Author's calculations (IBM SPSS, version 20); see Table 4.29 for denotations.

The hypotheses H_3 and H_8 were tested. In the Levene's test (equality of variances), no violation of the Levene's test for homogeneity of variances except when 25% and 50% liquidity requirements were added for the first time. In cases of no violation, *"Equal Variances Assumed"* must be used where the *t*-test not assuming homogeneous of variances would not be calculated. In cases of violation, *"Equal Variances Not Assumed"* must be used where the *t*-test not assuming homogeneous of variances would be calculated. In the seven simulations, *p* values > .05, there was not enough evidence to reject the null hypothesis, concluded that the difference in the means between ASEAN-5 and other groups was not statistically significant. In two simulations, the null hypotheses would be rejected because *p* values (.044 and .039) < .05, and concluded that the difference in means between ASEAN-5 and other groups was statistically significant. ASEAN-5 banks reacted more to tightening of liquidity regulation, but as the fears receded the difference in means between groups did not significantly deviate from normal.

As shown in Table 4.32; in the Levene's test, the F values; t (9) = 3.574, 2.630, 3.531, 3.558, 4.019, 4.562, 4.459; Sig. p (.091, .139, .093, .092, .076, .061, .064) > .05. Based on these results, the analysis failed to reject the null hypothesis and concluded that the difference in means between ASEAN-5 and other groups was not statistically significant. The F values in TCE 2L25 and TCE 2L50 were; t (9) = 5.506, Sig. p (.044); and t (9) = 5.793, Sig. p (.039) < 0.05; there was strong evidence to reject the null hypothesis of no difference, and concluded that the difference in means between ASEAN-5 and other groups was statistically significant.

Cohen's d was calculated to see the effect size statistics where p values were less than .05. Cohen's d evaluates how samples' means deviate from zero and measures the size of difference expressed in standard deviation unis (d = 0 meets the assumption of equality of means).

$\mathrm{d} = \mathrm{t}\sqrt{\frac{\mathrm{n}_1 + \mathrm{n}_2}{\mathrm{n}_1\mathrm{n}_2}}$, where t denotes the obtained t-statistic and n_1 is the total sample size for group 1 and n_2 is the total sample size for group 2.

t (4.114) = .202, p > .850, d = 0.12, this means that the effect of "Equal variances not assumed" is smaller than Cohen's .80 large effect; also indicates that the group means are in a close range.

$$d = .202\sqrt{\frac{6+5}{6*5}} = .202\sqrt{\frac{11}{30}} = .202\sqrt{.36667} = .202 * 0.6055 = 0.12$$

t (4.101) = .031, p > .971, d = 0.019 (very small effect)

$$d = .031\sqrt{\frac{6+5}{6*5}} = .031\sqrt{\frac{11}{30}} = .031\sqrt{.36667} = .031 * 0.6055 = 0.019$$

Next, a One-way Analysis of Variance (ANOVA) is performed to evaluate the means between the thesis (ASEAN-5) and those of Angelini et al. (2011) who estimated the impact of Basel III on banks across the U.S. Europe, and the UK. One-way ANOVA asks whether the group means are equal or not; the main results illustrated in Table 4.33 indicate that the level of fall in steady state output due to regulatory tightening was not significantly different than normal.

Table 4.33: ANOVA of economic cost

		Sum of Squares	df	Mean Square	F	Sig.
TCE 2NL	Between Groups	.022	1	.022	1.088	.324
	Within Groups	.180	9	.020		
	Total	.202	10			
TCE 4NL	Between Groups	.006	1	.006	.139	.718
	Within Groups	.373	9	.041		
	Total	.379	10			
TCE 6NL	Between Groups	.019	1	.019	.239	.636
	Within Groups	.701	9	.078		
	Total	.719	10			
TCE 2L25	Between Groups	.002	1	.002	.050	.829
	Within Groups	.435	9	.048		
	Total	.437	10			
TCE 4L25	Between Groups	.033	1	.033	.436	.525
	Within Groups	.681	9	.076		
	Total	.714	10			
TCE 6L25	Between Groups	.067	1	.067	.644	.443
	Within Groups	.936	9	.104		
	Total	1.003	10			
TCE 2L50	Between Groups	.000	1	.000	.001	.973
	Within Groups	.913	9	.101		
	Total	.913	10			
TCE 4L50	Between Groups	.019	1	.019	.155	.703
	Within Groups	1.103	9	.123		
	Total	1.122	10			
TCE 6L50	Between Groups	.142	1	.142	1.119	.318
	Within Groups	1.141	9	.127		
	Total	1.282	10			

Note: Author's calculations (IBM SPSS, version 20); see Table 4.29 for denotations.

The hypotheses H_3 and H_8 were tested. The difference in means of economic cost due to the Basel III rules between ASEAN-5 and other groups was not statistically significant as all the *p* values > .05. Based on these results, there was no strong evidence to reject the null hypothesis.

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From the cost analysis of the Basel III impact on steady state output, the analysis demonstrated that ASEAN-5 banking sectors were not significantly different than those of the U.S., Europe, and the UK. On the contrary, ASEAN-5 banking sectors were more resilient to shocks resulting from tighter capital and liquidity when compared with advanced economies. The analysis also investigated how ASEAN-5 banking sectors differed from each other in terms of economic benefits arising from higher capital and liquidity requirements plus reduced probability of crisis.

Table 4.34: Kolmogorov-Smirnov test of economic benefit

		RPC1pp	RPC2pp	RPC3pp	RPC4pp	RPC5pp	RPC6pp
N		5	5	5	5	5	5
Normal Parameters[a,b]	Mean	.1820	.3560	.2600	.4480	.5420	.6340
	Std. Dev.	.01924	.03782	.02236	.05450	.04658	.04615
Most Extreme Differences	Absolute	.141	.229	.127	.229	.202	.182
	Positive	.141	.229	.127	.229	.202	.169
	Negative	-.127	-.171	-.127	-.189	-.193	-.182
Kolmogorov-Smirnov Z		.316	.513	.285	.513	.451	.408
Asymp. Sig. (2-tailed)		1.000	.955	1.000	.955	.987	.996

		NSFR1pp	NSFR2pp	NSFR3pp	NSFR4pp	NSFR5pp	NSFR6pp
N		5	5	5	5	5	5
Normal Parameters	Mean	.2540	.3880	.5680	.7440	.9100	1.0860
	Std. Dev.	.01949	.03564	.05310	.10550	.08718	.08295
Most Extreme Differences	Absolute	.221	.184	.167	.164	.209	.132
	Positive	.179	.184	.129	.153	.165	.119
	Negative	-.221	-.143	-.167	-.164	-.209	-.132
Kolmogorov-Smirnov Z		.494	.411	.374	.368	.468	.295
Asymp. Sig. (2-tailed)		.968	.996	.999	.999	.981	1.000

Note: Author's calculations (IBM SPSS, version 20)

RPC: Reduced probability of crisis; NSFR: Net stable funding ratio.

The hypotheses H_4, H_7 and H_8 were tested. Two K-S test of economic benefits were conducted; first, reduced probabilities of crisis and higher capital ratios were analyzed. The data was normally distributed, and the analysis failed to reject the null hypothesis as all the p values > .05. Second analysis combined the higher capital ratios with NSFR; the first assumption of normality was met and the null hypothesis was retained, and concluded that the difference in means of economic benefit across ASEAN-5 was not statistically significant. A parametric test would be use to test the hypothesis.

Two K-S tests were conducted, the results both tests are illustrated in Table 4.34, which tested the obtained estimates of output gain due to higher capital ratios and reduced probability of crisis. Each 1 pp rise in the TCE ratio corresponded with a reduced probability rate of crisis; as such, RPC1pp denotes reduced probability of crisis stemming from a 1% rise in the TCE at 4.65% of probability, RPC2pp: 4.15%, RPC3pp: 3.60%, RPC4pp: 3.10%, RPC5pp: 2.75%, and RPC6pp: 2.5%. The assumption of normality was met as all *p*-values were greater than the significance alpha (i.e. $p = 1.000 > 0.05$). The analysis failed to reject the null hypothesis and concluded that the groups' means in output gains were not significantly different than normal.

The second K-S test analyzed the benefits of tighter regulation (i.e. NSFR) expressed as a gain in steady state output (Table 4.34). Similar to the first K-S test, the net stable funding ratio (NSFR) corresponded with a 1 pp rise in the TCE/RWA ratio. As such, NSFR1pp denoted a 1 pp rise in the TCE ratio at 95% NSFR, NSFR2pp: 2 pp at 96%, NSFR3pp: 3 pp at 97%, NSFR4pp: 4 pp at 98%, NSFR5pp: 5 pp at 99%, and NSFR6pp was 6 pp at 100%. The results of the K-S test indicated that all Sig. *p* values were greater than the alpha level (i.e. $p = .968 > 0.05$). The null hypothesis was retained and concluded that the difference in groups' means was not significant. The contribution of NSFR to output gain was higher than that of the RPC because the likelihood of crisis could be reduced to a level, but never eliminated.

A paired samples test was conducted to see whether paired samples were significantly different or not; the paired samples statistics and paired samples correlations are illustrated in Table 4.35 and Table 4.36 respectively. In this test, a paired samples *t* looks at the nature of the relation between two samples, which must have non-independence in order to be correlated. The groups' means clearly showed that the economic benefit of a reduced probability of crisis was less than that of NSFR, and the mean differences increased substantially after the initial 1 pp rise in the TCE. The economic benefit from a 6 pp rise in the TCE ratio with 100% NSFR was the largest.

Table 4.35: Paired samples statistics of economic benefit

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	RPC1pp	.1820	5	.01924	.00860
	NSFR1pp	.2540	5	.01949	.00872
Pair 2	RPC2pp	.2600	5	.02236	.01000
	NSFR2pp	.3880	5	.03564	.01594
Pair 3	RPC3pp	.3560	5	.03782	.01691
	NSFR3pp	.5680	5	.05310	.02375
Pair 4	RPC4pp	.4480	5	.05450	.02437
	NSFR4pp	.7440	5	.10550	.04718
Pair 5	RPC5pp	.5420	5	.04658	.02083
	NSFR5pp	.9100	5	.08718	.03899
Pair 6	RPC6pp	.6340	5	.04615	.02064
	NSFR6pp	1.0860	5	.08295	.03709

Notes: Author's calculations (IBM SPSS, version 20)

The hypotheses H_4, H_7 and H_8 were tested. The results indicated that the economic benefit was the largest across ASEAN-5 when higher capital ratios (i.e. 6pp increase) were combined with a reduced probability of crisis (i.e. at 2.5%) and net stable funding ratio (100% or greater).

Table 4.36: Paired samples correlations of economic benefit

		N	Correlation	Sig.
Pair 1	RPC1pp & NSFR1pp	5	.640	.245
Pair 2	RPC2pp & NSFR2pp	5	.753	.142
Pair 3	RPC3pp & NSFR3pp	5	.306	.616
Pair 4	RPC4pp & NSFR4pp	5	.389	.518
Pair 5	RPC5pp & NSFR5pp	5	-.092	.883
Pair 6	RPC6pp & NSFR6pp	5	.293	.633

Note: Author's calculations (IBM SPSS, version 20)

The hypotheses H_4, H_7 and H_8 were tested. The results demonstrated that there was a positive correlation between economic benefits and higher capital ratios along with reduced probability of crisis and NSFR equal to or greater than 100%. The data for each pair was normally distributed, the first assumption of normality was met. Based on the results where all of the p values > .05, the analysis failed to reject the null hypothesis and concluded that the difference in means of economic benefit across ASEAN-5 was not statistically significant. Only Pair 5 was negatively correlated, the difference in means was statistically significant.

The paired samples correlations confirmed that the economic benefit due to higher capital and liquidity was more significant in pairs containing higher TCE and NSFR. A negative correlation (-0.092) with a high Sig. p (.883 > 0.05) indicated that the effect of 1 pp rise in the TCE in conjunction with 95% NSFR and 4.65% RPC was substantially smaller than the scenario where capital increased by a 6 pp along with 100% NSFR and 2.50% RPC.

Table 4.37: Paired samples test of economic benefit

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	RPC1pp & NSFR1pp	-.07200	.01643	.00735	-.09240	-.05160	-9.798	4	.001
Pair 2	RPC2pp & NSFR2pp	-.12800	.02387	.01068	-.15764	-.09836	-11.988	4	.000
Pair 3	RPC3pp & NSFR3pp	-.21200	.05495	.02458	-.28024	-.14376	-8.626	4	.001
Pair 4	RPC4pp & NSFR4pp	-.29600	.09813	.04389	-.41785	-.17415	-6.745	4	.003
Pair 5	RPC5pp & NSFR5pp	-.36800	.10257	.04587	-.49535	-.24065	-8.023	4	.001
Pair 6	RPC6pp & NSFR6pp	-.45200	.08228	.03680	-.55416	-.34984	-12.284	4	.000

Note: Author's calculations (IBM SPSS, version 20)

The hypotheses H_4, H_7 and H_8 were tested. The results indicated that the null hypothesis was rejected since the *p* values (.001, .000, .001, .003, .001, and .000) < .05; based on this, the null hypothesis was rejected and concluded that the difference in means of all pairs was statistically significant. This meant that the difference in means of contribution to economic benefit between RPC and NSFR was statistically significant.

A paired-samples test was conducted, and the results are set out in Table 4.37. Looking at the observed *t*-statistic in *pair 1*, t = -9.798, and the Sig. p = .001; concluded that the probability of this result occurring by chance was extremely small under the null hypothesis of no difference. Therefore, the null hypothesis was rejected, since all Sig. p values < 0.05. In pair 6, the mean of negative 0.45200 and the

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t-statistic of negative 12.284 with $p = .000 < .05$ indicated that the size of economic benefit in terms of gain in output was substantially high for a 6 pp rise in the TCE ratio with 100% (or higher) NSFR.

The impact of a one percentage point increase in the TCE ratio of risk weighted assets combined with liquidity (LCR and NSFR) tightening on bank lending, regulatory capital, and lending spreads tend to vary significantly, this was contributed by the selection of a modelling approach and assumptions employed by different studies. The MAG (2010) assessed the macroeconomic impact of the regulatory tightening under Basel III and measured the cost that banks would have to incur making the transition to rigorous capital and liquidity standards (Table 4.38). In the analyses, the impact of a 1 pp rise in the TCE ratio and the resultant deviation from the baseline scenario is assessed over the four years of implementation. The main results of the analyses indicated that economies would face transitional costs arising from regulatory tightening, but the negative impact would be alleviated in the long-term. The main findings of the study showed the US Federal Reserve's FRB/US model resulted in the largest impact.

Table 4.38: Varying impact of Basel III due to modelling approach

	ECB MCM Model	ECB CMR Model	Federal Reserve FRB/US Model
Without monetary policy			
Increase in spreads only	-0.08%	-0.29%	-0.79%
Increase in spreads due to changes in lending standards	-0.19%	---	-0.89%
With monetary policy	-0.16%	-0.25%	-0.31% to -0.36%

Source: MAG (2010)

MCM model: Multi-country model with endogenous policy; CMR model: Medium-to-large DSGE model; FRB/US model with endogenous monetary policy.

The cost impact of Basel III capital and liquidity regulation differed depending on what modelling approach was employed. The approach used by the Federal Reserve resulted in the largest impact.

4.3.3 Concluding Remarks

Several analyses were done to estimate the economic cost (i.e. a loss in output) and economic benefit across ASEAN-5 due to regulatory tightening under Basel III. The analysis of economic cost was subdivided into three analyses; the first analysis calculated the cost impact of a 1 pp rise in the TCE ratio, the result was a fall in output of -0.33% on average relevant to the baseline after four years of implementation, the fall reached -0.98 at 6 pp; the second analysis calculated the cost impact of higher capital ratios and a 25% liquidity requirement, which resulted in a loss in output of -0.44% at 1 pp and -1.21% at 6 pp; in the third analysis, a 50% liquidity requirement was added which caused a decline in output of -0.54 at 1 pp and -1.39 at 6 pp.

The analysis of economic benefit was bipartite analysis; the first analysis quantified the economic benefit of reduced probability of crisis (RPC), the level of which was expressed as a gain in output. A 1 pp rise in the TCE ratio with a 4.65 RPC resulted in a gain in output of 0.18% on average after four years of implementation, which increased to 0.63% at 6 pp with a 2.5% RPC. The second analysis estimated the economic benefit of NSFR as liquidity tightening, and the result was a gain in output of 0.25% on average at 1 pp with 95% NSFR which peaked at 1.09% at 6 pp with 100% NSFR. To determine the net economic benefits, all three assumptions were employed in a separate analysis; higher capital ratios, reduced probability of crisis, and increased net stable funding. The estimated net economic benefits due to regulatory tightening across ASEAN-5 on average were 0.49% at 1 pp and 1.74 at 6 pp with 2.5% RPC and 100% NSFR.

The hypotheses H_3, H_4, H_5, H_7, and H_8 were tested. The results of the several analyses indicated that the cost impact of Basel III capital ratios on output across ASEAN-5 was higher but the economic benefits outweighed the economic costs in the long-term. The main results of the K-S tests and ANOVA of economic cost indicated that the analyses failed to reject the null hypotheses (all p values > .05) and concluded that the difference in means of economic cost between ASEAN-5 and other groups was not statistically significant. The main results of the independent samples test of economic cost produced mixed outcomes; in seven of the 9 scenarios, $p > .05$ and there was not enough evidence to reject the null hypothesis (means were not statistically significant); in two instances, p values (.044 and .039) < .05, based on these results the null hypothesis was rejected and concluded that the difference in means between ASEAN-5 and other groups was statistically significant. The results indicated that ASEAN-5 banks reacted more to tightening of liquidity regulation than other groups, but as the fear of liquidity tightening receded the means of groups did not significantly deviate from normal.

The main results of the economic benefit analyses indicated that the estimated economic benefit across ASEAN-5 was the largest (i.e. a gain of 1.74% in output) when the final analysis combined all three assumptions; 6 pp rise in the TCE ratio, 2.5% probability of crisis, and 100% net stable funding. To estimate the net economic benefit in terms of a gain in output was simply computed by subtracting the average cost of 0.98% across ASEAN-5 from the average benefit of 1.74%, which was a 0.76% gain in output at 6 pp with 2.5% RPC and 100% NSFR. The country-specific economic benefits among the ASEAN-5 were; Indonesia (0.81%), Malaysia (0.80%), Philippines (0.70%), Singapore (0.69%), and Thailand (0.81%). The results are within a very close range, meaning that the difference in means was not statistically significant.

The main results of the K-S test indicated that the difference in means within ASEAN-5 was not significantly different as there was no strong evidence to reject the hypothesis. In the paired sample test, the contribution to the level of economic benefits was analyzed by pairing the RPC with the NSFR. The results indicated that the null hypothesis was rejected and concluded that the difference in means of PRC and NSFR was statistically significant.

Table 4.39: Studies on impact of regulatory tightening on steady state output

Study	Method	Reduction in Steady State Output
This Thesis	1 pp rise in capital ratios After a 4-year implementation	0.33% across ASEAN-5
This Thesis	25% liquidity requirement After a 4-year implementation	0.44% across ASEAN-5
This Thesis	50% liquidity requirement After a 4-year implementation	0.54% across ASEAN-5
BCBS (2010b)	1 pp rise in capital ratios Plus liquidity standards	0.6% in total 0.08% annually for 8 years
MAG (2010)	1 pp rise in capital ratios	0.22% after eight years 0.13% after twelve years
MAG (2010)	25%, 50% liquidity requirement	0.08%, 0.15% respectively
Angelini et al. (2011)	1 pp rise in capital ratios No liquidity requirement	0.09% (another 0.08% arises from meeting the NSFR requirement)
Angelini et al. (2011)	2 pp rise in the TCE ratio No liquidity requirement	0.24% (Euro area), 0.29% (US), 0.29% (Italy and UK)
Angelini et al. (2011)	2 pp rise in the TCE ratio Plus 25% liquidity requirement	0.34% (Euro area), 0.40% (US), 0.45% (Italy and UK)
Angelini et al. (2011)	2 pp rise in the TCE ratio Plus 25% liquidity requirement	0.48% (Euro area), 0.56% (US), 0.56% (Italy and UK)
Slovik and Cournède (2011)	1 pp rise in capital ratios After a 5-year implementation	0.19% (US), 0.30% (Euro area), and 0.11% (Japan); 0.23% across three OECD economies
Slovik and Cournède (2011)	100 bps rise in lending rates After a 4-year implementation	0.93% (US), 2.10% (Euro area), and 1.33% (Japan), 1.45% across three OECD economies
Oxford Economics (2013)	1, 4, 10 pp rise in capital ratios After a 9-year implementation	0.14%, 0.60%, 1.4% respectively
IIF (2011)	2 pp rise in Tier 1, total capital No monetary policy response	0.60% (U.S.), 0.60% (Europe), and 0.80% (Japan) in 2011-2015
IIF (2011)	2 pp rise in Tier 1, total capital No monetary policy response	0.10% (U.S.), 0.40% (Europe), and 0.30% (Japan) in 2012-2019
Miles et al. (2012)	2 pp rise in capital ratios Large M-M effect is assumed	0.15% in the UK
Lown & Morgan (2004)	8 pp shock to credit standards No long-term rates in the VAR	0.5% 0.3%
Swiston (2008)	20 pp tightening in lending	0.75% in the U.S. after one year 1.25% in the U.S. after two years

Note: MM refers to Modigliani & Miller (1958); pp denotes percentage point; bps denotes basis points.

This table is of great importance because it gives the reader the opportunity to view the findings of the most recently published studies in one place and to have a chance to compare them with the findings of the analyses undertaken in this thesis. A more proper for this table is actually the Literature Review, but without this table, it would be difficult to determine whether the findings of this thesis are in line with other studies.

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4.4 Macro Stress Testing of Malaysia's Banking Sector

The propagation of financial crisis induced by the failure of SIBs prompted financial authorities worldwide to pay a closer attention to strengthening regulation and banking supervision. Internationally, multilateral organizations (i.e. the IMF developed FSIs in Table 4.40) played a crucial role in the collective efforts of developing enhanced tools and models to assess banking resilience. As a result, macroprudential stress testing became a central focus.

Notwithstanding a decade-long highly praised micro and macroprudential reforms introduced by ASEAN-5 countries, the farfetched implications of the GFC clearly proved that ASEAN-5 countries are still overly susceptible to developments in G-2. As such, policy normalization in the United States, the Federal Reserve's interest rate lift-off by 25 bps in December of 2015, and the increased probability of another rate hike by the Fed in end-2016 stirred equity markets across ASEAN-5 and made their currencies plummet against the dollar. Other macro events such as the new slow-growth path of China, global imbalances, reemerged weaknesses in the Euro area, expansive and accommodative monetary policies in G-2 contribute to the volatility.

A majority of financial crises throughout history have stemmed from banks' inability to detect and control risks. Since the banking operation revolves around a constant inventory of risks, the utmost task of bank executives is to manage these risks properly to avoid serious disruptions to short-term and long-term funding channels, as nocuous interactions among different risk types could lead to a contraction in credit markets. During and in the aftermath of both the Asian crisis and the GFC, banks were at the epicenter of unprecedented financial losses. The recurrences of crises and the ensuing turmoil made stress testing a necessity for the BNM and its supervisors to safeguard financial stability in Malaysia during benign and menace economic periods.

Table 4.40: Financial soundness indicators employed (FSIs)

Capital adequacy	Regulatory capital to risk-weighted assets Regulatory Tier 1 capital to risk-weighted assets Nonperforming loans net of provisions to capital Capital to assets Large exposures to capital
Asset quality	Nonperforming loans to total gross loans Sectoral distribution of loans to total loans Geographical distribution of loans to total loans
Earnings and profitability	Return on assets Return on equity Interest margin to gross income Noninterest expenses to gross income Trading income to total income Personnel expenses to noninterest expenses Spread between reference lending and deposit rates
Liquidity	Liquid assets to total assets (liquid asset ratio) Liquid assets to short-term liabilities Spread between highest and lowest interbank rate Customer deposits to total (non-interbank) loans Average bid-ask spread in the securities market Average daily turnover ratio in the securities market
Sensitivity to market risk	Net open position in foreign exchange to capital Gross asset position in financial derivatives to capital Gross liability position in financial derivatives to capital Foreign-currency-denominated loans to total loans Foreign-currency-denominated liabilities to total liabilities Net open position in equities to capital Real estate prices Residential real estate loans to total loans Commercial real estate loans to total loans
Other indicators	Assets to total financial system assets Assets to GDP
Non-financial indicators	Total debt to equity Return on equity Earnings to interest and principal expenses Net foreign exchange exposure to equity Number of applications for protection from creditors
Households indicators	Household debt to GDP Household debt service and principal payments to income

Source: Sorge (2004); IMF: Fund, http://www.imf.org/external/np/sta/fsi/eng/fsi.htm

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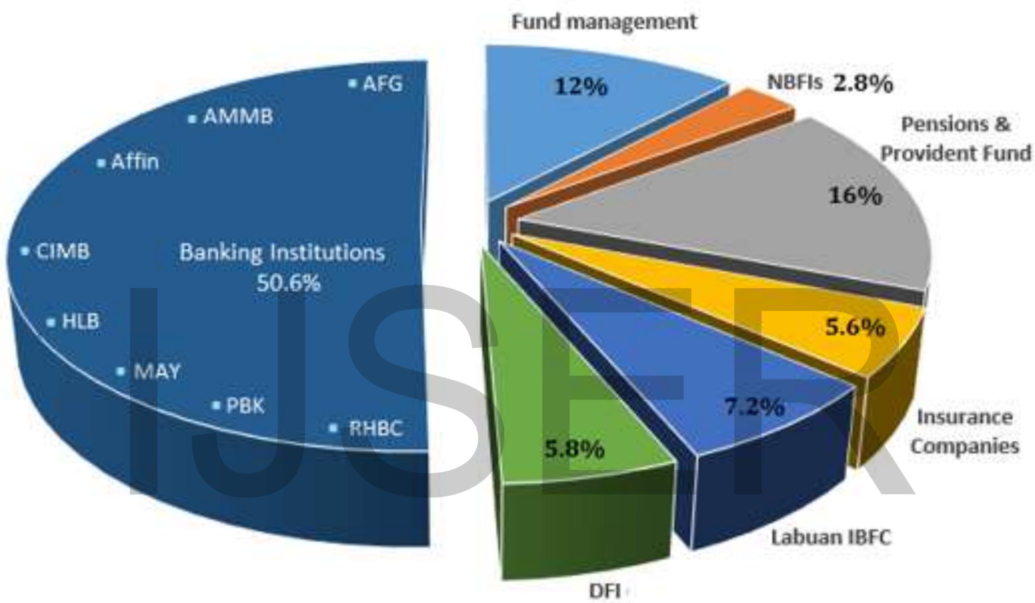
Malaysia's banking sector, in terms of the number of domicile commercial banking groups, is only about one-third of what it was in 1986; after a banking overhaul, the number has been reduced to 8 from 22 in the 1980s (Affin, AMMB, AFG, CIMB, HLB, MAY, PBK, and RHBC). As shown in Figure 4.3, the banking consolidation was not just confined to banks; finance companies, discount houses, securities firms, and merchant banks also underwent consolidation.

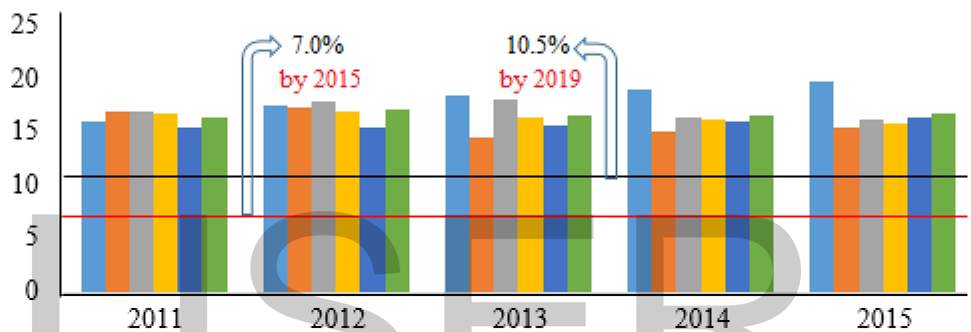


Source: Author's analysis; data is from BNM and IMF (2013b)

Figure 4.3: Malaysian banking sector structure (by asset share)

Among ASEAN-5, Malaysia's banking sector is well capitalized (both in quality and quantity of capital). With 15.41% aggregate risk-weighted capital adequacy ratio (ASEAN-5 average is 16.67%), banks are profitable and do not foresee any issue meeting Basel III capital requirements fully effective as of 2019. The sector's gross NPL ratio has dropped consecutively since 2011, and by 2015, 1.6% NPL is lower than ASEAN-5 average of 2.0%; moreover, any uncovered portion of the NPLs could be easily covered by the collaterals in banks' possession.

The pre-macro stress testing CAR of Malaysia's banking sector was at least two percentage points higher than those of advanced economies. This was attributable to the fact that the BNM requires banks to meet substantially higher capital ratios than the regulatory capital minima required under Basel III. The Basel III target ratio of 7% became fully effective as of 2015 (4.5% Tier 1 plus 2.5% capital buffer) and 10.50% (8% total capital plus 2.5% capital buffer) is effective as of 2019. The Figure 4.4 shows CAR of Malaysia's banking sector and peers.



	2011	2012	2013	2014	2015
Indonesia	16.08	17.58	18.45	18.92	19.77
Malaysia	16.93	17.35	14.57	15.03	15.41
Philippines	16.89	17.97	18.11	16.34	16.18
Singapore	16.84	16.97	16.43	16.19	15.88
Thailand	15.35	15.44	15.67	16.01	16.43
ASEAN-5	16.42	17.06	16.65	16.50	16.73

Source: Author's analysis; data is from BNM and IMF (2013b)

Figure 4.4: Pre-stress testing capital adequacy ratio (CAR %)

The average CAR of Malaysia's banking sector from 2011 to 2015 is 15.85%, which is below ASEAN-5 average of 16.67%. The solid red line on the above graph represents the 7% target ratio and the black solid line is the minimum capital requirement of 10.50% effective as of 2019. In the previous section of Basel III impact on bank capital, CAR and Tier 1 ratios of ASEAN-5 were already calculated and compared against the capital ratios of 210 banks across 27 advanced economies which also included 30 globally-systemically important banks (G-SIBs).

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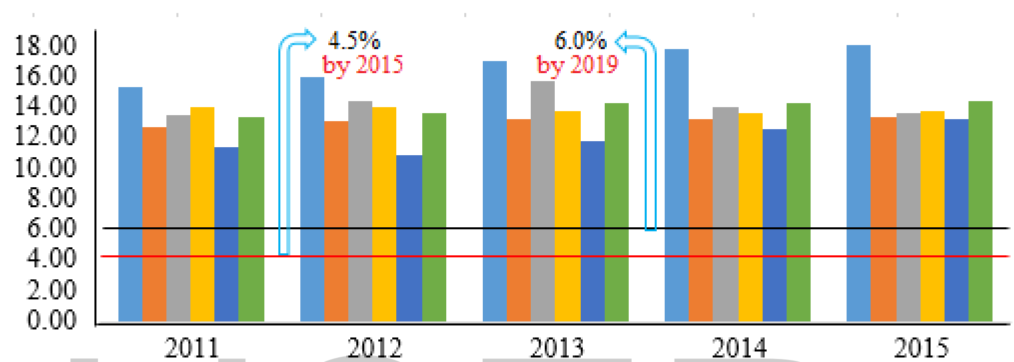
Similar to the aggregate CARs illustrated in Figure 4.4, the pre-macro stress testing Tier 1 ratio of Malaysia's banking sector as well as the Tier 1 ratios of peers are noticeably higher than those of advanced economies. Higher CAR and Tier 1 ratio underpinned by strong regulation and banking supervision helped Malaysia to escape the GFC without a major dent in its economy.



	2011	2012	2013	2014	2015
Indonesia	15.29	15.96	17.00	17.82	18.09
Malaysia	12.68	13.16	13.21	13.26	13.39
Philippines	13.46	14.40	15.73	14.01	13.62
Singapore	13.99	14.07	13.77	13.69	13.71
Thailand	11.43	10.87	11.83	12.58	13.19
ASEAN-5	13.37	13.69	14.31	14.27	14.40

Source: Author's analysis; data is from BNM and IMF (2013b)

Figure 4.5: Pre-stress testing Tier 1 capital ratio (%)

Malaysia and Thailand are the only two countries among ASEAN-5 whose Tier 1 capital ratios fell below ASEAN-5 average each of the five years from 2011 to 2015. Three macroeconomic scenarios were used covering the period of 2013 to 2015. The baseline scenario is for adjustment purposes (not a stress scenario), in which Malaysia's economy followed an expected course where the GDP was estimated to expand by 5% forecasted by the latest IMF WEO. In adverse scenario, a sharp recession was assumed in 2014 followed by a slow recovery, while in severely adverse scenario the economy was assumed to experience protracted low growth fostered by

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strained banks due to loan losses arising from defaults, higher unemployment, and falling house and asset prices. The exercise (MAST) was based on market risk and credit risk parameters which are the main sources of capital deterioration, and carried out on the basis of annual data.

Table 4.41: Pre-stress testing financial and macroeconomic indicators

Financial soundness indicators*	2013	2014	2015	Average
Regulatory capital to risk-weighted assets	14.57	15.03	15.52	15.04
Regulatory Tier 1 capital to risk-weighted assets	13.21	13.26	13.42	13.30
Non-performing loans net of provisions to capital	8.34	7.49	6.99	7.61
Non-performing loans to total gross loans	1.96	1.76	1.62	1.78
Return on assets (ROA)	1.45	1.53	1.26	1.41
Return on equity (ROE)	15.52	15.80	12.61	14.64
Interest margin to gross income	52.88	60.73	61.96	58.52
Non-interest expenses to gross income	49.85	42.38	46.30	46.18
Liquid assets to total assets (liquid asset ratio)	12.37	13.32	19.26	14.98
Liquid assets to short term liabilities	38.61	42.09	108.87	63.19
Net open position in foreign exchange to capital	11.24	14.24	13.88	13.12
Macroeconomic factors**				
Real gross domestic product (GDP)	4.7	6.0	4.8	5.17
Consumer price index (CPI)	2.1	3.1	2.7	2.63
General government balances	-4.1	-2.7	-3.0	-3.27
Current account balance	4.0	4.6	2.1	3.57

Sources: IMF (2014a, b), extracted from IMF Data Warehouse on 7/29/2014 www.elibrary.imf.org; ** IMF (2015g).

Although growth has moderated and financial volatilities picked up a nudge since the GFC, the outlook for Malaysia still remains favorable as illustrated in Table 4.41. However, capital flow reversals and falling prices of non-oil commodities could easily disrupt this favorable outlook. Also, the increased prospects of another U.S. monetary tightening towards the end of 2016 may have adverse impact on domestic borrowing costs, this could impinge on domestic consumption. According to the IMF (2013b), over 50% of bank lending is to households, the augmented debt of which accounts for about three quarters of GDP. The CAR and Tier 1 capital ratios of

Malaysia's banking sector are comparatively high, but they happen to be lower than ASEAN-5 averages; among peers, Indonesia has the highest while Thailand has the lowest capital ratios.

4.4.1 Results of MAST in the Baseline Scenario

The primary focus in this section of the thesis is to assess the resilience of the banking sector in Malaysia. The soundness of individual Malaysian banks were not examined on purpose as it was not the objective of this thesis. As explained in detail in chapter 3, a basic stress testing framework developed by Čihák (2007b) was followed. However, as an improvement, actual bank data was used in the Malaysia-wide stress test as opposed to hypothetical banks and banking data employed by Čihák. A top-down stress testing was employed with the objective of gauging credit, interest rate, and exchange rate risks under two adverse scenarios.

In the analysis of assessing the aggregate impact on Malaysia's banking sector due to regulatory tightening plus the assumed extreme but plausible scenarios, the analysis attempted to answer the following two questions: (1) can Malaysia's banking sector as a whole withstand shocks in each quarter of the stress testing horizon under baseline, adverse and severely adverse scenarios? (2) What are the estimated costs to the BNM under adverse scenarios? The results of the MAST were expressed in terms of capital adequacy and capital injection as a percent of GDP.

The stress testing horizon of the MAST is three years based on annual data from 2013 to 2015 (Q4), and covers the entire banking sector consisting of 56 entities as deposit takers. As of end-2015, 31 domicile banks controlled MR1.82 trillion of the total financial assets (18 banks owned 74.6% or RM1.74 trillion and 13 investment banks controlled only 3.26% or about RM84 billion). The 25 domestically incorporated foreign-controlled banks enjoyed 22.26% (or RM520 billion) of the consolidated banking assets. The largest five banks in Malaysia accounted for 70% of the total banking assets, consistent with advanced economies (IMF, 2013b; 2015b).

The stress testing scenarios developed and employed in the MAST were simply hypothetical rather than forecasts. The baseline scenario followed an expected (normal) course of economic activity, consistent with the latest IMF World Economic Outlook projections for Malaysia (i.e. 5% GDP growth). Adverse and severely adverse scenarios assume a recession, slower recovery, and higher unemployment. Under both adverse scenarios, banks are negatively impacted by higher capital and liquidity requirements together with macro factors. The key results of the stress tests are merely indications based on the assumptions and trajectories for a number of key variables describing the nature of economic activity in Malaysia which may or may not reflect the actual developments or the views of the government of Malaysia or bank executives.

As an emerging market economy (and Asia in general), Malaysia's banking sector faces more risks arising from endogenous and exogenous shocks; therefore, the assumption was made that the BNM required banks in Malaysia to meet a higher CAR of 10.50% (which is same as Basel III 10.50% effective as of 2019, which consists of an 8% of total capital plus 2.5% of capital buffer). Based on this, the central bank and supervisors used a benchmark CAR of 10.50% in macro stress testing exercises. Another assumption was that banks falling below the hurdle rate needed to raise additional capital to avoid insolvency or forced liquidation. Banks with capital shortfalls were allowed to close the capital gap in three ways; (i) raised the needed funds in capital markets; (ii) owners injected capital into bank; (iii) or took advantage of a government backstop (i.e. cost to the government) if available. A bank with negative CAR was assumed to be insolvent unless its capital ratios were brought in line with the regulatory minimums.

Two accounting-based formulas from Čihák (2007) have been adopted to analyze the relation between bank capital, amount of capital injection by the government, and the minimum CAR.

$$\mathrm{C} + \mathrm{I}/\mathrm{RWA} + \mathrm{qI} = \rho \ \ (10.50\%) \qquad (4.4.1.1)$$

Where *C* denotes the aggregate regulatory capital of the financial sector, RWAs are the total 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=10.50%* is the regulatory minimum.

From the above equation, the amount of capital injection can be computed as;

$$\mathrm{I} = \mathrm{pRWA} - \mathrm{C}/1 - \mathrm{qp} \ \text{ if } \mathrm{C} < \mathrm{pRWA}; = 0 \text{ otherwise} \qquad (4.4.1.2)$$

In both equations and under different stress testing scenarios, the values of p and q are assumed; the size of capital injection (I) and the portion of the injection (q) that is used will depend on what p and q values are at the end of a stress test. For instance, if q = 0, the capital injection is not used immediately. Capital injection is lower if p < 10.50% and vice versa, mathematically;

$$\mathrm{I} = \mathrm{pRWA} - \mathrm{C} = 0.105 * \mathrm{RWA} - \mathrm{C} \qquad (4.4.1.3)$$

The main results of the MAST in the baseline scenario suggest that the regulatory and supervisory frameworks in Malaysia are well-developed owing to decades of fiscal and structural reforms. The upshot of this ongoing effort is a stable banking system that has a strong capital position, thus it is less dependent on cross-border funding as bank deposits account for over 80% of funding to cover short-term liabilities. The latter point makes Malaysia's resilient banking sector vulnerable to runs on demand deposits in an acute stress. The household debt to GDP ratio has nearly doubled in a decade, from 44.6% in 2000 to 80% in 2015. The majority of the debt comes from residential mortgages and is denominated in ringgit (e.g. IMF, 2013b).

Table 4.42: Summary of results in baseline scenario (%)

	2013	2014	2015	Average
Pre-stress test CAR	14.57	15.03	15.52	15.04
Pre-stress test Tier 1 capital ratio	13.21	13.26	13.42	13.30
Impact of increase in provisioning	-0.25	-0.32	-0.35	-0.31
Impact of increase in NPLs	-0.40	-0.44	-0.46	-0.43
Impact of increase in interest rates	-0.20	-0.30	-0.30	-0.27
Impact of Exchange rate change	-0.50	-0.45	-0.48	-0.48
Impact of interbank contagion	-0.10	-0.15	-0.15	-0.13
Change in CAR (all fundamental shocks)	-1.45	-1.65	-1.81	-1.64
Change in Tier 1 ratio (all fundamental shocks)	-1.35	-1.42	-1.36	-1.38
Post-stress test CAR	13.22	13.52	13.93	13.56
Post-stress test Tier 1 capital ratio	11.86	11.84	12.06	11.92
Return on assets (ROA) ratio	1.23	1.33	1.17	1.24
Return on equity (ROE) ratio	13.12	13.30	10.61	12.34
Pre-stress test liquid assets / total assets	12.37	13.32	19.26	14.98
Post-stress test liquid assets / total assets	10.30	11.40	16.68	12.79
Pre-stress test liquid assets / short-term liabilities	38.61	42.09	108.87	63.19
Post-stress test liquid assets / short-term liabilities	30.58	31.19	92.45	51.41
Capital injection needed (% of GDP)	0.00	0.00	0,00	0.00

Note: Author's calculations

As set out in Table 4.42, the main results of MAST in the baseline scenario reveal a modest change in capital ratios and bank profitability. The impact of all fundamental shocks on capital ratios was -1.64% on average and the post-stress test CARs were 13.22% (2013), 13.52% (2014), and 13.93% (2015). The average impact of shocks on Tier 1 capital ratio was less significant (-1.38%). Even with these adjustments, CAR and Tier 1 ratios of banks in Malaysia are comfortably higher than the Basel III minimum capital requirements (i.e. 4.5% CET1, 6.0% Tier 1, and 8.0% total capital). The increasing cost of funding pressured bank profitability, causing ROA and ROE to decline slightly, -0.15% and -2.30% respectively (the changes in terms of percentage points were 10.76% and 15.71% respectively). Malaysia's banking sector has a limited exposure to interbank contagion effects since over 80% of the funding comes from domestic demand deposits, therefore the level of impact was less than one-third of a percent in the baseline scenario (which may become an issue under acute distress). Although a majority of Malaysian banks had sufficient liquidity, the top-down (TD) stress test suggested that some smaller (Islamic) banks would face illiquidity after five days under highly adverse market conditions. Malaysia's banking sector had sufficient ringgit liquidity, while experienced a shortfall of U.S. dollar liquidity, but this appeared to be a non-issue since Malaysia had adequate levels of foreign reserves to pump liquidity should such need arise.

Table 4.43: Banking ratios in baseline scenario (%)

	2013	2014	2015	Average
Total capital / RWA (CAR)	13.22	13.52	13.93	13.56
Tier 1 capital ratio	11.86	11.84	12.06	11.92
NPLs (gross) / total loans	2.26	2.06	1.92	2.08
Provisions / NPLs	95.65	96.60	94.87	95.71
NPLs-provisions / capital	8.34	7.49	6.99	7.61
FX loans / total loans	3.93	4.18	4.65	4.25
RWA / total assets	64.60	65.20	65.40	65.07
ROA (after-tax)	1.23	1.33	1.17	1.24
ROE (after-tax)	13.12	13.30	10.61	12.34
Liquid assets / total assets	10.30	11.40	16.68	12.79
Liquid assets / short-term liabilities	30.58	31.19	92.45	51.41
Net FX exposure / capital	12.54	15.76	14.64	14.31
Z-score ((C/A+ROA / standard dev. (ROA))	12.47	8.23	9.82	10.17

Note: Author's calculations

The banking ratios illustrated in Table 4.43 indicate that Malaysia's banking sector is resilient to shocks. Impact on capital ratios, profitability, and liquidity were in most part insignificant but not without some concerns. Although Z-scores declined noticeably, Altman (1968) suggest that a Z-score > 2.99 is an indication of non-bankrupt; a Z-score < 1.81 is considered bankrupt and 1.81 < Z-score < 2.99 is in the "zone of ignorance" or "gray area", meaning not at immediate default risk (p. 606). Provisions to NPL (95.70%) must be improved as it is below ASEAN-5 average of over 114%. Higher capital and liquidity regulation put strain on banks, this is why capital raising spree by banks since 2012 helped offset some of the reduction in the ROA and ROE ratios. Net foreign exchange exposure saw a 9.1% rise, attributable to fast depreciation of ringgit against dollar (US interest rate hike, taper tantrum (May) and the August rout in 2013).

Malaysia's banking sector is comparatively strong among ASEAN-5, and the ratings of financial soundness indicators (FSIs) of Malaysia's banking sector shown in Table 4.44 confirmed its resilience to various shocks. The average overall rating of 1.54 is strong, which is an indication of a low risk but it is also approaching the rating of 2.0 which indicates an increased risk. Among the indicators (ratios) that received a low rating, provisions to NPLs, FX loans to total loans, net FX exposure to capital, asset quality (liquidity to total assets), and profitability (ROA and ROE) must be monitored closely, as these ratios fell considerably in both adverse scenarios.

Table 4.44: Ratings in baseline scenario

	2013	2014	2015	Average
Overall rating*	1.56	1.64	1.43	1.54
Total capital / RWA (CAR)	1.25	1.15	1.00	1.13
Tier 1 capital ratio	1.10	1.05	1.00	1.05
NPLs (gross) / total loans	1.40	1.25	1.20	1.28
Provisions / NPLs	2.00	1.80	2.00	1.93
NPLs-provisions / capital	2.25	2.00	1.75	2.00
FX loans / total loans	1.50	1.70	2.50	1.90
RWA / total assets	1.75	1.90	2.00	1.88
ROA (after-tax)	2.00	1.90	2.00	1.97
ROE (after-tax)	1.85	1.80	2.00	1.88
Liquid assets / total assets	2.50	2.30	2.10	2.30
Liquid assets / short-term liabilities	1.50	1.40	1.10	1.33
Net FX exposure / capital	2.50	2..75	2.90	2.70

Note: Author's calculations
* 1: Low risk; 2: Increased risk; 3: High risk; 4: Very high risk

The results of the probabilities of defaults (PDs) analysis using piecewise approach are set out in Table 4.45, which suggested that financial soundness indicators used in the analysis had low levels of contribution to the probability of default (or a crisis). High CAR and Tier 1 ratios expectedly received the lowest possible rating of 1.00. The FX exposure risk had the largest rating of 2.72 which is close to the high risk rating of 3.0; this was also confirmed by the results of adverse scenario where there was a shortfall of dollar liquidity.

Sorge (2004) distinguishes between two methodological approaches to macroprudential stress testing: a *"piecewise approach"* measuring potential vulnerability to single risk factors (e.g., interest rate risk, FX risk, NPL risk) under baseline, adverse or severely adverse stress scenarios; and an *"integrated approach"* which aggregates losses in the financial system resulting from vulnerabilities to multiple risk factors under any given hypothetical or historical stress scenarios.

Table 4.45: Probability of default in baseline scenario (%)

	2013	2014	2015	Average
Overall probability of default (PD)	3.65	3.74	2.46	3.28
Total capital / RWA (CAR)	3.25	3.00	2.25	2.83
Tier 1 capital ratio	3.25	2.75	2.50	2.83
NPLs (gross) / total loans	6.75	5.75	4.00	5.50
Provisions / NPLs	3.50	3.00	2.00	2.83
NPLs-provisions / capital	5.50	4.75	4.00	4.75
FX loans / total loans	3.50	4.25	3.25	3.67
RWA / total assets	2.50	3.75	2.50	2.92
ROA (after-tax)	2.50	3.50	2.00	2.67
ROE (after-tax)	1.50	2.50	2.00	2.00
Liquid assets / total assets	5.00	4.25	2.25	3.83
Liquid assets / short-term liabilities	3.25	3.50	1.50	2.75
Net FX exposure / capital	3.00	5.00	2.50	3.50

Note: Author's calculations

The average probability of default during 2011-2013 is 3.28% which is substantially less than the historical probability of crisis in the range of 4% and 5%, assuming that a financial crisis occurs once every 25 or 20 years. According to the Basel Committee, it is less than 5% (BCBS, 2010e), 5.2% by Reinhart and Rogoff (2009), and 4.1% by Laeven and Valencia (2008). The probability of default analysis in the baseline scenario identified several problem areas that needed to be monitored closely in adverse scenarios. As also detected by the rating and bank ratios analyses, financial soundness indicators related to credit risk and the resultant losses received higher PDs; in that regard, with an average rating of 5.50, NPLs (gross) to total loans was on top of the list. The second highest PD of 4.75 was also connected to NPLs (NPLs provisions to capital). Besides credit risk and NPLs, liquidity ratio, FX loans to total loans, and net FX risk exposure to capital received PDs of 3.83, 3.67, and 3.50 respectively.

4.4.2 Results of MAST in the Adverse Scenario

Malaysia's banking sector started the MAST exercise with strong capital positions underpinned by the capital raising spree since 2011 and retained earnings; a majority of capital was in the form of common equity consistent with the Basel III guidelines. Prior to MAST, overall the sample of banks under thesis had an average aggregate CAR of 15.04%, which was reduced to 13.93% after taking into account adjustments in the baseline scenario. The results of two adverse scenarios would be compared and contrasted against results of the baseline scenario.

The results of the adverse scenario, set out in Table 4.46, indicate that despite the strengthened capital ratios at the end of 2015 some smaller Islamic banks had Tier 1 capital ratio lower than 6.0%. Credit risk shocks and the resultant losses on residential mortgage loans as well as the increased cost of funding resulted in the largest impact on bank capital ratios. Although all of the major banks had higher post-stress test CAR and Tier 1 ratios than required under Basel III; nevertheless, the impact of all fundamental shocks reduced the level of CAR and Tier 1 ratio as much as 3.80% and 3.37% from the baseline respectively. The aggregate capital shortfall in the form of needed capital injection (cost to the government) was 1.55% of GDP ($4.59 billion of capital injection based on 2015 GDP of $296.22 billion). The important conclusion of the adverse scenario was that no bank failed, faced a forced liquidation or suspension of license.

Table 4.46: Summary of results in adverse scenario (%)

	2013	2014	2015	Average
Baseline scenario CAR	13.22	13.52	13.93	13.56
Baseline scenario Tier 1 capital ratio	13.05	13.12	13.20	13.12
Impact of increase in provisioning	-1.27	-1.39	-1.29	-1.32
Impact of increase in NPLs	-0.66	-0.72	-0.55	-0.64
Impact of increase in interest rates	-0.80	-0.75	-0.77	-0.77
Impact of Exchange rate change	-0.72	-0.63	-0.60	-0.65
Impact of interbank contagion	-0.40	-0.52	-0.42	-0.45
Change in CAR (all fundamental shocks)	-3.85	-4.01	-3.53	-3.80
Change in Tier 1 ratio (all fundamental shocks)	-3.48	-3.35	-3.28	-3.37
Post-stress test CAR	9.37	9.75	10.41	9.84
Post-stress test Tier 1 capital ratio	9.57	9.77	9.92	9.75
Return on assets (ROA)	-0.44	-0.66	-0.51	-0.54
Return on equity (ROE)	-1.28	-1.64	-1.72	-1.55
Liquid assets / total assets	2.30	3.40	2.68	2.79
Liquid assets / short-term liabilities	6.11	9.28	78.25	31.21
Capital injection needed (% of GDP)	1.62	1.71	1.52	1.62

Note: Author's calculations

Malaysia's financial sector is well diversified when benchmarked against regional peers, but it is still not deep enough (i.e. limited exposure to structured finance and securitized instruments) when compared with advanced economies. The MAST results in adverse scenario indicated that credit risk (and loss) by far was the largest driver behind capital deterioration, which combined with other factors caused a large decrease in CAR (-3.80%) and Tier 1 capital ratio (-3.37%); these results are well in line with the range 200-560 bps (or 2% to 5.6%) provided by the IMF in Malaysia's Financial Sector Stability Assessment (IMF, 2013b). Among the five adverse shocks affecting Malaysia's banking sector, the average impact of an increase in provisioning on bank capital ratios was the largest (-1.32%), followed by an increase in interest rates (-0.77%), increase in NPLs (-0.64%), impact of exchange rate change – FX risk (-0.65%), and the impact of interbank contagion (-0.45%). Bank profitability was hit hard in adverse scenario, due to lower real estate and asset prices plus higher unemployment which pushed both ROA and ROE ratios into negative territory relevant to the baseline, -0.54% and -1.44% respectively.

Table 4.47: Banking ratios in adverse scenario (%)

	2013	2014	2015	Average
Total capital / RWA (CAR)	9.37	9.75	10.41	9.84
Tier 1 capital ratio	9.57	9.37	9.92	9.62
NPLs (gross) / total loans	3.56	3.42	3.34	3.44
Provisions / NPLs	75.45	76.60	78.80	76.95
NPLs-provisions / capital	6.24	5.44	4.79	5.49
FX loans / total loans	4.43	5.20	5.05	4.89
RWA / total assets	67.56	68.12	67.32	67.67
ROA (after-tax)	-0.44	-0.66	-0.51	-0.54
ROE (after-tax)	-1.28	-1.64	-1.72	-1.55
Liquid assets / total assets	-1.51	-2.02	-1.84	-1.79
Liquid assets / short-term liabilities	8.58	10.14	48.45	22.39
Net FX exposure / capital	14.56	17.24	16.64	16.15
Z-score ((C/A+ROA / standard dev. (ROA))	4.31	6.04	11.64	7.33

Note: Author's calculations

In adverse scenario, the number of defaults by private sector on corporate loans and by households on mortgage loans impinged banking profitability. As a result, capital hoarding by some banks led to disintermediation, and this in turn accelerated evaporation of liquidity fast.

The average liquidity ratio of -1.79% along with substantially reduced liquid assets to short-term liabilities (22.39%) inhibited banks' ability to honor their short-term liabilities. Malaysia's ringgit recorded one of the fastest depreciation against major currencies (dollar in particular), this situation gave rise to the level of FX exposure, increasing from baseline average of 14.31% to 16.15%. As a respond to the amplified volatility, Z-score in each stress testing year increased.

Table 4.48: Ratings in adverse scenario

	2013	2014	2015	Average
Overall rating*	3.64	3.85	3.66	3.72
Total capital / RWA (CAR)	2.23	2.49	2.46	2.39
Tier 1 capital ratio	2.20	2.29	2.34	2.28
NPLs (gross) / total loans	3.50	3.75	3.50	3.58
Provisions / NPLs	3.75	4.00	3.80	3.85
NPLs-provisions / capital	3.40	3.60	3.65	3.55
FX loans / total loans	3.25	3.50	4.00	3.58
RWA / total assets	3.00	3.25	3.25	3.17
ROA (after-tax)	3.80	4.00	3.90	3.90
ROE (after-tax)	3.65	3.70	3.60	3.65
Liquid assets / total assets	3.75	3.80	3.80	3.78
Liquid assets / short-term liabilities	4.00	4.00	3.90	3.97
Net FX exposure / capital	3.25	3..50	3.45	3.35

Note: Author's calculations
* 1: Low risk; 2: Increased risk; 3: High risk; 4: Very high risk

The overall average rating (i.e. 3.45) of Malaysia's banking sector FSIs approached the rating of 4.0 in adverse scenario, used for a category of very high risk financial soundness indicators; the augmentation of ratings was cross the board which suggested that capitalization needs of banks were significant. Despite massive loan losses and funding freeze, the capital ratios were still higher than the Basel III minimum requirements; even under adverse scenario, 9.76% of CAR and 9.48% of Tier 1 capital ratio were sufficient enough to meet the Basel III target ratio of 7.0% (4.5% of CET1 plus 2.5% of capital buffer). Therefore, the ratings of CAR (i.e. 2.39) and Tier 1 ratio (i.e. 2.28) were appropriately the only ratings below the 3.0 mark. The results in this analysis as well as in the previous analyses revealed that credit risk shocks were more significant than market risk shocks for Malaysia's banking sector.

As illustrated in Table 4.9 the probability of default analysis in adverse scenario points to a significant increase in banks' vulnerability to shocks; however, the results are expected and in the right direction. The order and the concentration of effects on several indicators has not changed from the outcome of the baseline scenario, only magnitude of impact increased substantially. The analyses such as banking ratios, ratings, and probability of default can be treated as early-warning indicators to show bank executives and risk managers the specific areas to focus to mitigate financial losses in an acute stress before going irreversibly out of control.

Table 4.49: Probability of default in adverse scenario (%)

	2013	2014	2015	Average
Overall probability of default (PD)	11.25	11.50	11.00	11.25
Total capital / RWA (CAR)	8.25	8.50	8.75	8.50
Tier 1 capital ratio	8.25	8.50	8.75	8.50
NPLs (gross) / total loans	10.75	10.50	10.25	10.50
Provisions / NPLs	10.00	11.00	11.50	10.83
NPLs-provisions / capital	11.25	10.00	10.50	10.58
FX loans / total loans	10.50	11.50	10.25	10.75
RWA / total assets	11.75	11.50	10.50	11.25
ROA (after-tax)	11.50	12.00	11.75	11.75
ROE (after-tax)	11.75	12.50	13.00	12.42
Liquid assets / total assets	13.75	14.00	13.50	13.75
Liquid assets / short-term liabilities	15.25	16.25	15.75	15.75
Net FX exposure / capital	13.00	14.00	13.50	13.50

Note: Author's calculations

4.4.3 Results of MAST in the Severely Adverse Scenario

Previously, the main results of adverse scenario proved that Malaysia's banking sector was very resilient to a number of adverse shocks in baseline and adverse scenarios, but at the same time was increasingly vulnerable to potential liquidity shortage and overextension of credit to the household sector which accounts for more than 50% of bank lending. Banks heavily rely on demand deposits for over 80% of their short-term funding needs; although no apparent signs of immediate concern because Malaysian public has high confidence in the banking system, but the overheated housing market coupled with ballooning household debt plus any reversal in capital flows could play a crisis-intensifier role under extreme but plausible market conditions.

Table 4.50: Summary of results in severely adverse scenario (%)

	2013	2014	2015	Average
Baseline scenario CAR	13.22	13.52	13.93	13.56
Baseline scenario Tier 1 capital ratio	13.05	13.12	13.20	13.12
Impact of increase in provisioning	-1.54	-1.69	-1.58	-1.60
Impact of increase in NPLs	-1.05	-0.96	-1.00	-1.00
Impact of increase in interest rates	-1.25	-1.30	-1.18	-1.24
Impact of Exchange rate change	-1.00	-0.88	-0.85	-0.91
Impact of interbank contagion	-0.60	-0.55	-0.50	-0.55
Change in CAR (all fundamental shocks)	-5.44	-5.38	-5.11	-5.31
Change in Tier 1 ratio (all fundamental shocks)	5.10	5.20	5.05	5.12
Post-stress test CAR	7.78	8.14	8.82	8.25
Post-stress test Tier 1 capital ratio	7.95	7.92	8.15	8.01
Return on assets (ROA)	-5.15	-4.86	-4.74	-4.92
Return on equity (ROE)	-3.48	-3.64	-3.52	-3.55
Liquid assets / total assets	-10.40	-9.90	-9.86	-10.05
Liquid assets / short-term liabilities	-12.15	-11.70	28.30	1.48
Capital injection needed (% of GDP)	3.51	3.69	3.44	3.55

Note: Author's calculations

The average levels of CAR and Tier 1 worsened further in severely adverse scenario. Prior to the macro stress testing exercise, CAR and Tier 1 ratio were comfortably high; 15.04% and 13.30% respectively. At the conclusion of severely adverse scenario, banks experienced capital decreases ranging from 505 bps to 544 bps; when the results were compared with those in baseline scenario, the magnitude of average decrease was more than threefold; 1.64% (CAR) and 1.38% (Tier 1) versus 5.31% and 5.12% respectively. Even after severely adverse scenario, the aggregate CAR and Tier 1 ratio remained surprisingly high; 8.13% and 8.01% respectively.

Table 4.51: Banking ratios in severely adverse scenario (%)

	2013	2014	2015	Average
Total capital / RWA (CAR)	9.37	9.75	10.41	9.84
Tier 1 capital ratio	9.57	9.37	9.92	9.62
NPLs (gross) / total loans	5.48	5.54	5.36	5.46
Provisions / NPLs	52.45	58.2	66.74	59.13
NPLs-provisions / capital	6.24	5.44	4.79	5.49
FX loans / total loans	5.28	5.89	5.64	5.60
RWA / total assets	69.44	70.21	69.58	69.74
ROA (after-tax)	-5.15	-4.86	-4.74	-4.92
ROE (after-tax)	-3.48	-3.64	-3.52	-3.55
Liquid assets / total assets	-10.4	-9.9	-9.86	-10.05
Liquid assets / short-term liabilities	-12.15	-11.7	28.3	1.48
Net FX exposure / capital	12.24	15.46	14.72	14.14
Z-score ((C/A+ROA / standard dev. (ROA))	2.27	4.43	8.66	5.12

Note: Author's calculations

These results are well in line with the IMF results through the Financial Sector Stability Assessment (FSSA) on Malaysia in 2013. All fundamental shocks applied in severely adverse scenario resulted in sizable reductions in banks' capital ratios, an average shrinkage of 5.31% in CAR and 5.12% in Tier 1 ratio; this is also consistent with the impact range of 200-560 bps provided by the IMF (e.g. IMF, 2013b). The capitalization needs became more significant on account of a capital shortfall of $10.52 billion (or 3.55% of 2015 GDP). In the adverse scenario, some smaller banks needed to raise capital to comply with the thesis' 10.5% capital minima. In the severely adverse scenario, even some larger banks needed to raise fresh capital.

Table 4.52: Ratings in severely adverse scenario

	2013	2014	2015	Average
Overall rating*	3.70	3.85	3.80	3.78
Total capital / RWA (CAR)	2.49	2.66	2.54	2.56
Tier 1 capital ratio	2.40	2.46	2.42	2.43
NPLs (gross) / total loans	3.75	3.85	3.80	3.80
Provisions / NPLs	3.90	3.95	3.90	3.92
NPLs-provisions / capital	3.65	3.75	3.80	3.73
FX loans / total loans	3.45	3.70	3.90	3.68
RWA / total assets	3.25	3.50	3.45	3.40
ROA (after-tax)	4.00	3.90	3.80	3.90
ROE (after-tax)	3.90	3.95	3.80	3.88
Liquid assets / total assets	3.85	3.90	3.90	3.88
Liquid assets / short-term liabilities	4.00	4.00	4.00	4.00
Net FX exposure / capital	3.40	3.65	3.70	3.58

Note: Author's calculations
* 1: Low risk; 2: Increased risk; 3: High risk; 4: Very high risk

Prior to the stress testing exercise, Malaysia's banking sector was profitable in the aggregate and its average NPL ratio in 2013 to 2015 was 1.78%; in this stress scenario, the average NPLs more than tripled reaching 5.46% attributable to severe loan losses plus significantly reduced provisions to NPLs. The NPLs gaining a bigger share of the total loan volume negatively affected provisions to NPLs which reduced the level of provisions from 95.71% in the baseline scenario to 76.95% in the adverse scenario (a decrease of 19.6%) and 59.13% in the severely adverse scenario (a decrease of 38.22% relevant to the baseline). At the worst episode of shocks, banks saw their returns on assets and equity plummet to lowest levels in recent memory; -4.92% (ROA) and -3.55% (ROE). In this scenario, not only smaller banks but also larger banks were subject to illiquidity as capital hoarding by banks may cause funding freeze (i.e. drying-up liquidity fast) and make some banks' Tier1 ratio fall below the critical level of 6.0%.

The main results of the ratings analysis set out in Table 4.52 revealed that the average FSIs except CAR and Tier 1 capital ratio reached the rating score of 3.80 (close to high risk category). These ratings are based on the benchmark CAR of 10.5% and the hurdle Tier 1 capital ratio of 6.0%. However, these ratings are merely early-warning signs, suggesting that Malaysia's banking sector as a whole is highly vulnerable to the magnitude of shocks applied to banks' balance sheet elements in the severely adverse scenario. Also, these results by any means do not suggest that banks which these ratings belong to are at risk of insolvency; quite the opposite, a great majority of banks in Malaysia are stable with high public confidence and they are well positioned in terms of quality and quantity of capital thanks to the BNM's strengthened as well as rigorous capital and liquidity frameworks (no bank became insolvent under this scenario).

Table 4.53: Probability of default in severely adverse scenario (%)

	2013	2014	2015	Average
Overall probability of default (PD)	13.75	14.00	14.35	14.03
Total capital / RWA (CAR)	10.24	10.45	10.66	10.45
Tier 1 capital ratio	10.26	10.54	10.72	10.51
NPLs (gross) / total loans	13.60	13.45	13.20	13.42
Provisions / NPLs	13.05	13.90	14.25	13.73
NPLs-provisions / capital	14.10	13.80	13.50	13.80
FX loans / total loans	14.40	14.35	14.10	14.28
RWA / total assets	13.75	13.40	13.60	13.58
ROA (after-tax)	14.75	15.25	14.60	14.87
ROE (after-tax)	14.90	15.25	15.75	15.30
Liquid assets / total assets	16.40	16.85	17.25	16.83
Liquid assets / short-term liabilities	18.25	18.90	19.00	18.72
Net FX exposure / capital	15.00	15.25	15.75	15.33

Note: Author's calculations

As illustrated in Table 4.53, the main results of the probability of default analysis point to an increased probability of default, fostered by a cascade of defaults by the private sector on corporate loans and by the household on residential mortgage loans. There is a correlation between ratings and probability of default, and the relationship between the two is reversed and almost linear; when ratings of firms go up, their PDs tend to go down and vice versa. Industry participants closely monitor ratings for various reasons and improved ratings are often an indication of positive developments or business activities that raise prospects of future earnings.

4.4.4 Statistical Analysis of the Macro Stress Testing Results

Through macro stress testing, the resilience of Malaysia's banking sector was assessed to a number of hypothetical shocks in baseline, adverse, and severely adverse scenarios. Previously postulated hypotheses H_1, H_2, H_3, H_4, H_5, H_6, H_7, and H_8 were tested. The analyses revealed that Malaysia's FSIs deteriorated in the adverse scenario and further worsened in the severely adverse scenario. In this section, the results were analyzed through the use of statistics. Rejecting the null hypotheses would mean that the cost impact of the new capital and liquidity regulation under Basel III on Malaysia's banks would be high. Rejecting the null hypotheses would mean that there is a positive relationship between Basel III and banking stability across Malaysia.

To determine whether the summary data of stress test scenarios was normally distributed, several statistics were run on the main results. The outcomes of the K-S test, set out in Table 4.54, indicated that the assumption of normality was met, as the Sig. *p*-values (.155, .174, .812) > 0.05. Thus, the null hypothesis of no difference was retained and concluded that the difference in means between the summary results of the three stress scenarios was not significantly different. The results of the K-S test point to parametric statistics to test for equal variances.

Table 4.54: Kolmogorov-Smirnov Test of Stress Scenarios

		Baseline	Adverse	Severely Adverse
N		14	14	14
Normal Parameters	Mean	7.0452	3.0100	-.1955
	Std. Deviation	14.13225	9.12176	5.15013
Most Extreme Differences	Absolute	.302	.295	.170
	Positive	.302	.295	.170
	Negative	-.269	-.228	-.107
Kolmogorov-Smirnov Z		1.131	1.104	.637
Asymp. Sig. (2-tailed)		.155	.174	.812

Notes: Author's analysis

The results of the K-S test indicated that each data was normally distributed and the *p* (.155, .174, and .812) > .05; based on this, the analysis failed to reject the null hypothesis and concluded that the difference in means of the three scenarios was not statistically significant. The drop in means between baseline and adverse scenario was substantial, fell from 7.05 to 3.01 (more than 50%).

Based on the Sig. *p* values > 0.05; an independent samples *t*-test and a one-way ANOVA were used to test the hypothesis via Levene's F-statistic for equal variances and *t*-statistic for equal means. This test was significant to show that the means of ASEAN-5 countries were larger than those of the U.S., Europe, and the UK; more than twofold of the median impact.

Table 4.55: One-sample statistics of stress test scenarios

	N	Mean	Std. Deviation	Std. Error Mean
Baseline	14	7.0452	14.13225	3.77700
Adverse	14	3.0100	9.12176	2.43789
Severely Adverse	14	-.1955	5.15013	1.37643

Notes: Author's analysis

Financial losses were moderate under the adverse scenario (M = 3.01, SD = 9.12) relative to the baseline, but noticeably worsened under the severely adverse scenario (M = -.1955, SD = 5.15).

One sample *t*-test was conducted to compare the resilience of Malaysia's banking sector in the baseline, adverse, and severely adverse scenarios. The results of one-sample statistics (Table 4.55) indicated that the mean 3.01 of adverse scenario was significant relevant to the baseline scenario mean of 7.05. However, the mean of -.1955 in severely adverse scenario indicated that the impact of extreme but plausible scenarios had the severest impact on banks' capital. As illustrated in Table 4.56, excluding baseline (i.e. t = -.782, Sig. p (.448) > 0.05), the results are significant in adverse scenario (i.e. t = -.2.867, Sig. p (.013) < 0.05) and severely adverse scenario (i.e. t = -.7.407, Sig. p (.000) < 0.05). In the former, the null hypothesis was retained because the significance level was greater than the priori alpha of .05. In the latter two, the null hypothesis was rejected and concluded that there was significant difference.

Table 4.56: One-sample test of stress test scenarios

	Test Value = 10					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Baseline	-.782	13	.448	-2.95476	-11.1145	5.2050
Adverse	-2.867	13	.013	-6.99000	-12.2567	-1.7233
Severely Adverse	-7.407	13	.000	-10.19548	-13.1691	-7.2219

Notes: Author's analysis

The results were in the expected direction. In the adverse scenario, the analysis failed to reject the null hypothesis as p > .05, and concluded that the outcome was not statistically significant. The results were statistically significant as p values (.013 and .000) < .05; the hypothesis was rejected.

Table 4.57: Kolmogorov-Smirnov test of banking ratios

		Baseline	Adverse	Severely Adverse
N		13	13	13
Normal Parameters	Mean	23.2664	16.9151	12.8551
	Std. Deviation	28.91213	25.58889	23.90806
Most Extreme Differences	Absolute	.391	.301	.325
	Positive	.391	.301	.325
	Negative	-.223	-.232	-.169
Kolmogorov-Smirnov Z		1.409	1.086	1.171
Asymp. Sig. (2-tailed)		.038	.189	.129

Notes: Author's analysis

The difference in means of banking ratios under baseline scenario was statistically significant as p (.038) < .05, the null hypothesis was rejected (non-parametric test would be used). The difference in means of banking ratios under adverse and severely adverse scenario was not statistically significant as p values (.189 and .129) > .05, based on these results the null hypothesis was retained.

Statistics were applied on banking ratios to see if groups' means were equal or significantly different. The results of the K-S test indicated that the impact on banking ratios in the baseline scenario was significant as Sig. p = .038 < .05, and not significant in adverse and severely adverse scenarios because Sig. p values .189 and .129 > .05. The results of the K-S indicated that a non-parametric test must be used, so one-sample test was conducted.

Because the Sig. p of the baseline scenario was less than the priori significance level of .05, the Mann-Whitney U test was conducted to evaluate the mean ranks of the FSIs between baseline, adverse, and severely adverse scenarios. The results (Table 4.58) were in the expected direction and not significant under the null hypothesis; z = -.714 (baseline), -.429 (adverse), and -.1.429 (severely adverse) p (.534, .731, and .181) > .05. Sig. p values > α =.05, the null hypothesis was rejected, concluded that the groups' mean ranks were not significantly different than normal.

Table 4.58: Mann-Whitney U test statistics of stress test scenarios

	Baseline	Adverse	Severely Adverse
Mann-Whitney U	16.000	18.000	11.000
Wilcoxon W	37.000	46.000	39.000
Z	-.714	-.429	-1.429
Asymp. Sig. (2-tailed)	.475	.668	.153
Exact Sig. [2*(1-tailed Sig.)]	.534	.731	.181

Note: Author's analysis

The results indicated that the difference in means of baseline, adverse, and severely adverse scenario was not statistically significant as the analysis failed to reject the null hypothesis based on p values (.534, .731, and .181) > .05. Financial loss were significantly high under the severely adverse scenario, but no banks became insolvent or faced forced liquidation.

The results of the Mann-Whitney U test match the data of the baseline scenario better than those of the K-S test. While the K-S test indicated that the null hypothesis would be rejected based on the Sig. p (.031) < .05 which was not expected and not in the right direction, the Mann-Whitney U test showed that the Sig. p (.534) of the baseline distribution was greater than the (α = .05).

Table 4.59: Regression analysis of KLCI and major indexes

Regression statistics

Multiple R	0.970
R Square	0.941
Adjusted R Square	0.940
Standard Error	97.01744
Observations	1000

ANOVA

	df	SS	MS	F	Sig. F
Regression	10	148518550.945	14851855.09	1577.906	0.000
Residual	989	9308847.425	9412.384		
Total	999	157827398.370			

KLCI	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Crude Oil	-0.405	0.282	-1.436	0.151	-0.958	0.148
Gold	0.483	0.025	19.324	0.000	0.434	0.532
S&P500	0.374	0.063	5.952	0.000	0.251	0.497
DJIA	0.011	0.005	2.159	0.031	0.001	0.021
Nasdaq	0.016	0.012	1.373	0.170	-0.007	0.039
FTSE	-0.180	0.012	-14.720	0.000	-0.204	-0.156
DAX	0.016	0.008	2.001	0.046	0.000	0.032
CAC	-0.051	0.008	-6.254	0.000	-0.067	-0.035
N225	0.034	0.001	25.126	0.000	0.031	0.036
Hang Seng	0.032	0.002	17.046	0.000	0.028	0.035

Notes: Author's calculations; Dependable Variable : KLCI **-** Kuala Lumpur Composite Index

S&P: Standard and Poor's (US); DJIA: Dow Jones Industrial Average (US); Nasdaq: National Association of Securities Dealers Automated Quotations (US); FTSE: Financial Times Stock Exchange (UK); DAX: Deutsche Boerse AG German Stock Index; CAC: Cotation Assistée en Continu (France); N225: Nikkei 225 stock exchange (Japan); Hang Seng: Stock market index (Hong Kong).

Multiple R (0.970) indicates that the correlation between KLCI (dependent) and ten major indexes (independent variables) are positive. The figure being very close to +1 implies that the correlation is significant. The coefficient of determination (R^2) is 0.941, which can be interpreted that 94% of the change in the dependent variable Y (performance of KLCI) is explained by independent X.

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Table 4.60: Correlations among KLCI and major indexes

		KLCI	Crude Oil	Gold	S&P 500	DJIA	NASDAQ	FTSE	DAX	CAC	N225	Hang Seng
Pearson Correlation	KLCI	1.000	0.794	0.865	0.577	0.661	0.601	0.415	0.673	-0.045	-0.003	0.847
	Crude Oil	0.794	1.000	0.851	0.550	0.695	0.492	0.432	0.650	0.135	-0.314	0.866
	Gold	0.865	0.851	1.000	0.465	0.603	0.488	0.345	0.602	-0.127	-0.377	0.777
	S&P500	0.577	0.550	0.465	1.000	0.934	0.927	0.881	0.929	0.611	0.109	0.678
	DJIA	0.661	0.695	0.603	0.934	1.000	0.834	0.761	0.899	0.493	-0.088	0.743
	NASDAQ	0.601	0.492	0.488	0.927	0.834	1.000	0.821	0.899	0.544	0.147	0.657
	FTSE	0.415	0.432	0.345	0.881	0.761	0.821	1.000	0.891	0.740	0.248	0.626
	DAX	0.673	0.650	0.602	0.929	0.899	0.899	0.891	1.000	0.594	0.067	0.809
	CAC	-0.045	0.135	-0.127	0.611	0.493	0.544	0.740	0.594	1.000	0.191	0.329
	N225	-0.003	-0.314	-0.377	0.109	-0.088	0.147	0.248	0.067	0.191	1.000	-0.047
	Hang Seng	0.847	0.866	0.777	0.678	0.743	0.657	0.626	0.809	0.329	-0.047	1.000
Sig. (1 tailed)	KLCI		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.076	0.467	0.000
	Crude Oil	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Gold	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	S&P500	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000
	DJIA	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.003	0.000
	NASDAQ	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000
	FTSE	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000
	DAX	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.017	0.000
	CAC	0.076	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000
	N225	0.467	0.000	0.000	0.000	0.003	0.000	0.000	0.017	0.000		0.070
	Hang Seng	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.070	
N (sample size)	KLCI	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	Crude Oil	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	Gold	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	S&P500	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	DJIA	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	NASDAQ	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	FTSE	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	DAX	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	CAC	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	N225	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
	Hang Seng	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000

Notes: Author's calculations (IBM SPSS, version 20)

Only interactions between Malaysia's KLCI and CAC (-0.405) and N225 (-0.003) were negatively correlated, and the difference in means between KLCI and these two indexes was not statistically significant as *p* values (0.076 and 0.467) > .05. The rest of the correlations were positive and the results were statistically significant.

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The standard error of the regression (Table 4.59) is an estimate that explains the variation in the performance of KLCI. The following indexes were statistically significant in explaining variations in the performance levels of KLCI (Table 4.59); gold (p = 0.000 < .05), S&P 500 (p = 0.000 < .05), DJIA (p = 0.031 < .05), FTSE (p = 0.000 < .05), DAX (p = 0.046 < .05), CAC (p = 0.000 < .05), N225 (p = 0.000 < .05), and Hang Seng (p = 0.000 < .05). Only NASDAQ (p = 0.170 > .05) and Crude oil (p = 0.151 > .05) were not statistically significant. Based on the Sig. F (p = 0.000 < .05), the F-test was significant and the null hypothesis was rejected.

The volatility in crude oil prices and the fluctuation in KLCI were negatively correlated (Table 4.60). The negative coefficient (oil = -0.405) suggests that for every unit of increase in the price of oil, a decrease of 0.40% would be expected on average in the level of KLCI. Similarly, due to inverse correlations and negative coefficients, increases in FTSE (-0.181) and CAC (-0.051) would have adverse impact on the valuation of KLCI. The variables such as NASDAQ, DJIA, and DAX were not statistically significant in explaining the variations in KLCI performance.

Variables usually tend to be correlated (Table 4.60), and this correlation shows the nature of the relationship between explanatory variable (independent X) and dependent Y. If the absolute value of the correlation coefficient is close to ± 1 and the relationship among variables is linear, the correlation is strong (values > 0.30). The correlations between KLCI – oil (0.405), KLCI – gold (0.483), and KLCI – S&P 500 (0.374) are stronger than other variables. Further, correlations between KLCI – CAC (p = 0.076 > 0.05) and KLCI - N225 (p = 0.467 > 0.05) are not statistically significant. The sign of the coefficient signals the direction; both X and Y increasing or decreasing (positive), or X increases while Y decreases and vice versa (negative).

Table 4.61: Regression analysis of ringgit and major currencies

Regression statistics

Multiple R	0.966
R Square	0.934
Adjusted R Square	0.931
Standard Error	0.1094198
Observations	240

ANOVA

	df	SS	MS	F	Sig. F
Regression	10	38.577	3.858	322.207	0.000
Residual	229	2.742	0.012		
Total	239	41.319			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
USD-IDR	0.251	0.237	1.059	0.291	-0.216	0.718
USD-PHP	0.000	0.000	17.739	0.000	0.000	0.000
USD-SGD	-0.018	0.003	-6.055	0.000	-0.024	-0.012
USD-THB	2.411	0.242	9.963	0.000	1.934	2.888
USD-EUR	0.022	0.004	5.773	0.000	0.015	0.030
USD-GBP	0.477	0.220	2.168	0.031	0.043	0.910
USD-JPY	-0.747	0.295	-2.530	0.012	-1.328	-0.165
USD-CHF	-0.002	0.001	-1.695	0.091	-0.003	0.000
USD-AUD	-0.755	0.151	-5.013	0.000	-1.051	-0.458
USD-CAD	-0.427	0.129	-3.300	0.001	-0.682	-0.172

Notes: Author's calculations (IBM SPSS, version 20)

Dependent Variable: USD-MYR; MYR: Malaysia ringgit; DR: Indonesia rupiah; PHP: Philippines peso; SGD: Singapore dollar; THB: Thailand baht; EUR: Europe euro; GBP: Great Britain pound; JPY: Japan yen; CHF: Switzerland frank; AUD: Australia dollar; CAD: Canada dollar.

Multiple R (0.966) indicates that the correlation between Malaysian ringgit - MYR (dependent Y) and ten major currency indexes (independent X) are positive. The correlation figure is very close to +1 which implies that the correlation between ringgit and other currencies is significant. The coefficient of determination (R^2) is 0.934, which can be interpreted that 93% of the change in the dependent variable Y (performance of ringgit) is explained by independent X.

Table 4.62: Correlations among MYR and Major Currencies

		USD-MYR	USD-IDR	USD-PHP	USDSGD	USD-THB	USD-EUR	USD-GBP	USD-JPY	USD-CHF	USD-AUD	USD-CAD
Pearson Correlation	USD-MYR	1.000	0.607	0.729	0.705	0.867	0.496	-0.011	0.469	0.419	0.608	0.450
	USD-IDR	0.607	1.000	0.601	-0.026	0.347	0.048	0.069	-0.034	-0.265	0.023	-0.194
	USD-PHP	0.729	0.601	1.000	0.503	0.699	0.209	-0.160	0.094	0.142	0.301	0.061
	USDSGD	0.705	-0.026	0.503	1.000	0.857	0.719	0.036	0.664	0.877	0.884	0.805
	USD-THB	0.867	0.347	0.699	0.857	1.000	0.674	0.101	0.518	0.654	0.772	0.615
	USD-EUR	0.496	0.048	0.209	0.719	0.674	1.000	0.566	0.557	0.838	0.886	0.846
	USD-GBP	-0.011	0.069	-0.160	0.036	0.101	0.566	1.000	-0.069	0.228	0.382	0.388
	USD-JPY	0.469	-0.034	0.094	0.664	0.518	0.557	-0.069	1.000	0.649	0.688	0.705
	USD-CHF	0.419	-0.265	0.142	0.877	0.654	0.838	0.228	0.649	1.000	0.894	0.868
	USD-AUD	0.608	0.023	0.301	0.884	0.772	0.886	0.382	0.688	0.894	1.000	0.922
	USD-CAD	0.450	-0.194	0.061	0.805	0.615	0.846	0.388	0.705	0.868	0.922	1.000
Sig. (1 tailed)	USD-MYR		0.000	0.000	0.000	0.000	0.000	0.434	0.000	0.000	0.000	0.000
	USD-IDR	0.000		0.000	0.342	0.000	0.227	0.143	0.302	0.000	0.363	0.001
	USD-PHP	0.000	0.000		0.000	0.000	0.001	0.007	0.072	0.014	0.000	0.173
	USDSGD	0.000	0.342	0.000		0.000	0.000	0.292	0.000	0.000	0.000	0.000
	USD-THB	0.000	0.000	0.000	0.000		0.000	0.060	0.000	0.000	0.000	0.000
	USD-EUR	0.000	0.227	0.001	0.000	0.000		0.000	0.000	0.000	0.000	0.000
	USD-GBP	0.434	0.143	0.007	0.292	0.060	0.000		0.144	0.000	0.000	0.000
	USD-JPY	0.000	0.302	0.072	0.000	0.000	0.000	0.144		0.000	0.000	0.000
	USD-CHF	0.000	0.000	0.014	0.000	0.000	0.000	0.000	0.000		0.000	0.000
	USD-AUD	0.000	0.363	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000
	USD-CAD	0.000	0.001	0.173	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
N (sample size)	USD-MYR	240	240	240	240	240	240	240	240	240	240	240
	USD-IDR	240	240	240	240	240	240	240	240	240	240	240
	USD-PHP	240	240	240	240	240	240	240	240	240	240	240
	USDSGD	240	240	240	240	240	240	240	240	240	240	240
	USD-THB	240	240	240	240	240	240	240	240	240	240	240
	USD-EUR	240	240	240	240	240	240	240	240	240	240	240
	USD-GBP	240	240	240	240	240	240	240	240	240	240	240
	USD-JPY	240	240	240	240	240	240	240	240	240	240	240
	USD-CHF	240	240	240	240	240	240	240	240	240	240	240
	USD-AUD	240	240	240	240	240	240	240	240	240	240	240
	USD-CAD	240	240	240	240	240	240	240	240	240	240	240

Note: Author's calculations (IBM SPSS, version 20)

Between currency pairs, only USD-MYR and USD-GBP (-0.011) were negatively correlated. Also, the difference in means between USD-MYR and US-GBP was not statistically significant. All other currency pairs were positively correlated and the results were statistically significant.

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The standard error of the regression (0.1494198) is an estimate that explains the variation in the performance of MYR. The indexes were statistically significant in explaining variations in the performance levels of ringgit; USD-PHP ($p = 0.000 < 0.05$), USD-SGD ($p = 0.000 < 0.05$), USD-THB ($p = 0.000 < 0.05$), USD-EUR ($p = 0.000 < 0.05$), USD-GBP ($p = 0.031 < 0.05$), USD-JPY ($p = 0.012 < 0.05$), USD-AUD ($p = 0.000 < 0.05$), and USD-CAD ($p = 0.001 < 0.05$). Only USD-IDR ($p = 0.291 > 0.05$) and USD-CHF ($p = 0.091$) were not statistically significant; the Sig. F ($p = 0.000 < 0.05$), the F-test was significant and the null hypothesis was rejected.

The relationships between ringgit's performance and the independent explanatory variables (X) were negatively correlated due to their negative coefficients; USD-SGD (-0.018), USD-JPY (-0.747), USD-CHF (-0.002), USD-AUD (-0.755), and USD-CAD (-0.427). Negative correlation coefficients suggested that for every unit of increase in the exchange rates of SGD, JPY, CHF, AUD, and CAD against the dollar; a decrease in exchange rates would be expected by the associated values above in the level of MYR. The largest variations in MYR were explained by the inverse correlations between USD-MYR and USD-AUD and USD-JPY. USD-HBT (2.411) were not statistically significant in explaining the variations in ringgit performance.

Looking at the correlations set out in Table 4.62, the correlation between USD-MYR and USD-GBP was not statistically significant due to $p = 0.434 > 0.05$. Ringgit had strong correlations with the currencies of peers, attributable to high regional integration as well as close trade and cultural ties across ASEAN-5. USD-BHT (0.867) had the highest correlations among the independent variables followed by USD-PHP (0.729), USD-SGD (0.705), USD-AUD (0.608), USD-IDR (0.607), and USD-EUR (0.496); USD-GBP was only negative correlation (-0.011).

4.4.5 Concluding Remarks

Despite a remarkable transformation since the Asian crisis of the late 1990s, the main results of Malaysia's macro stress testing exercise indicated that Malaysia's banking sector was far from being immune to shocks under extreme but plausible scenarios. Bouts of shocks since 2013 rattled markets and caused one of the fastest depreciation of ringgit in recent memory. As a result, macroprudential stress testing became a central focus for BNM and its supervisors to safeguard banking stability in Malaysia, and BNM has been conducting stress tests since 2006.

The aggregate CAR and Tier 1 ratio prior to MAST were comfortably high; 15.04% and 13.30% respectively. A benchmark CAR of 10.5% and a hurdle Tier 1 ratio of 6.0% were employed in one baseline and two adverse scenarios. Banks falling below these regulatory capital ratios in any of the scenarios were required to raise sufficient capital to bring their CAR and Tier 1 ratio in line with the Basel III minimum requirements. Banks fail to do so would be considered insolvent and subject to liquidation, suspension of banking license, or permanent closure.

Baseline scenario was conducted to make certain adjustments before the actual stress scenarios which revealed that Malaysia's banking sector operated under well-developed regulatory and supervisory frameworks. However, the banking resilience may be vulnerable to overreliance on demand deposits that are at call and the massive household debt to GDP ratio which has nearly doubled in a decade, increased from 44.6% in 2000 to about 80% in 2015. The results of baseline scenario indicated that the aggregate impact of all fundamental shocks on CAR was -1.64%, but the average impact on Tier 1 capital ratio was less significant (-1.38%). Bank profitability was also adversely affected, ROA and ROE declined -0.15% and -2.30% respectively.

The impact of adverse scenario was significant in terms of credit risk related losses and the ensuing decreases in banks' capital ratios. The levels of CAR and Tier 1 ratio dropped as much as -3.40% and -3.64% respectively relevant to the baseline. The amount of loan losses arising from defaults on residential mortgages, consumer loans, and equity line of credit was the largest driver behind capital deterioration at banks and drying-up liquidity in markets. The aggregate capital shortfall in the form of needed capital injection (cost to the government) was 1.62% of GDP (approximately $4.80 billion of capital injection based on 2015 GDP of $296.22 billion).

Out of the five shocks adversely affecting banking ratios, the impact of increase in provisioning on capital ratios was the largest (-1.32%), followed by increase in interest rates (-0.77%), increase in NPLs (-0.64%), impact of exchange rate change – FX risk (-0.65%), and the impact of interbank contagion (-0.45%). Bank profitability was hit hard in adverse scenario, attributable to lower real estate and asset prices plus higher unemployment which pushed both ROA and ROE ratios into negative territory relevant to the baseline, -0.54% and -1.44% respectively. The fall of -1.79% in liquidity ratio along with significantly reduced (-22.39%) liquidity coverage ratio inhibited banks' ability to cover their short-term liabilities (defined as less than one year).

The results of severely adverse scenario were significant and expected. The magnitude of shocks caused capital decreases ranging from 505 bps to 544 bps. When the results were compared with the baseline scenario, the magnitude of average decrease was more than threefold; 1.64% (CAR) and 1.38% (Tier 1) versus 5.31% and 5.12% respectively. The capitalization needs became much more significant on account of a capital shortfall of $10.52 billion (or 3.55% of 2015 GDP of $296.22 billion). In severely adverse scenario, capitalization needs were not just confined to smaller Islamic banks, even some larger banks needed to be recapitalized.

4.5 Chapter Summary

The propagation of systemic banking crises mainly originated in advanced nations (i.e. the U.S.) as well as regionally induced shocks have prompted central banks and the supervisory community across ASEAN-5 to make Basel III and stress testing a central focus. The primary objective of the thesis was twofold; to assess the cost impact of Basel III on bank capital, lending spreads, and steady state output (i.e. GDP); and to conduct a macro stress testing to assess the resilience of Malaysia's banking sector to extreme but plausible scenarios. In order to meet these objectives, four general and four operational hypotheses were postulated; and the analyses undertaken throughout the thesis attempted to reject the null hypothesis of no difference.

The cost impact analysis of higher capital ratios under Basel III was subdivided into three analyses. As a separate analysis, the economic benefit (i.e. gain in output) due to the new Basel III capital and liquidity rules was estimated. The analyses undertaken in this section estimated the impact of 1 pp rise in the TCE ratio on bank capital, lending spreads, and GDP relative to the baseline. CAR and Tier 1 ratio, two main FSIs, were calculated; the results showed that Malaysia's banks and banking sectors were well-capitalized and needed no re-capitalization in order to meet the target ratio of 7% by 2015 and 10.5% by 2019. In the aggregate, ASEAN-5 had CAR of 16.67% and Tier 1 capital ratio of 14.01% (at least 2% higher than other countries).

Parametric and non-parametric statistics techniques were employed to analyze the findings and to test the hypotheses H_1 and H_5. Although the aggregate CAR and Tier 1 of ASEAN-5 were at least two percentage points higher than those found in advanced economies, the results of the K-S test, independent samples *t*-test, and Levene's test indicated that the analyses failed to reject the null hypothesis and concluded that the difference in means within ASEAN-5 and between groups were not statistically significant. The Mann-Whitney *U* test was employed to assess how CAR and Tier 1 ratio of ASEAN-5 banking sectors differed from those across 118 countries. The test results were in the expected direction and significant; the null hypothesis was rejected as the p values (.001 and .004) > .05, and concluded that the groups' mean ranks were significantly different. The results of the paired samples *t*-test were strong evidence (i.e. all *p* values < .05) to reject the null hypothesis, which concluded that the difference in means of CAR and Tier 1 between ASEAN-5 banks and those under study was statistically significant.

The next analysis estimated the cost impact of Basel III higher capital ratios on lending spreads. Banks across ASEAN-5 were assumed to make appropriate adjustments in service fees and the interest rates charged on loans to recuperate a portion of the increased funding costs imposed on banks. To meet the target capital ratio of 7% (4.5% CET1 + 2.5% capital buffers) by 2015, ASEAN-5 banks would have to increase the lending spreads by 30.26 bps on average. To meet the minimum capital requirement of 10.5% (8% total capital + 2.5% capital buffers) by 2019, ASEAN-5 banks would have to increase the lending spreads by 68.22 bps on average. These estimates were on the high side, but they were broadly consistent with the recent studies.

The hypotheses H_2 and H_6 were postulated. The main results of the K-S test, one-sample *t*-test, independent samples *t*-test, and one-ANOVA test indicated that there was no strong evidence to reject the null hypothesis of no difference. In the one-sample *t*-test, the null hypothesis was rejected $t\,(4) = -4.837$; Sig. p (.008) < .05 and concluded that the difference in means of ASEAN-5 and Japan was statistically significant. In the one-way ANOVA, the null hypothesis was rejected in 2015 and 2016 as the *p* values (.002 and .01 < .05), which concluded that the difference in means between ASEAN-5 and other groups were statistically significant.

The economic cost across ASEAN-5 due to regulatory tightening under Basel III was estimated, where the binary-state model, VCEM and DSGE models were used. The analysis of economic cost was subdivided into three analyses; the first analysis calculated the cost impact of a 1 pp rise in the TCE ratio, the result was a fall in output of -0.33% on average relative to the baseline after four years of implementation, the output declined by -0.98 at 6 pp; the second analysis calculated the cost impact of higher capital ratios and a 25% liquidity requirement, at this time the loss in output reached -0.44% at 1 pp and -1.21% at 6 pp; in the third analysis, a 50% liquidity requirement was added and the output fell by -0.54 at 1 pp and -1.39 at 6 pp.

The analysis of economic benefit had a central assumption that the higher capital ratios along with liquidity tightening under Basel III contributed positively to reducing probability of crisis (PRC). The first analysis quantified the effect of RPC on output; a 1 pp rise in the TCE ratio with a 4.65 RPC resulted in an output gain of 0.18% after four years of implementation; the benefit increased to 0.63% at 6 pp with a 2.5% RPC. Next, the economic benefit of NSFR as liquidity tightening was forecasted, the outcome was a gain in output of 0.25% at 1 pp with 95% NSFR which peaked at 1.09% at 6 pp with 100% NSFR. Finally, the net economic benefit was computed; the average cost of 0.98% at 6 pp across ASEAN-5 was subtracted from the average benefit of 1.74% at 6 pp with 2.5% RPC and 100% NSFR, the result was a 0.76% gain in output.

The hypotheses H_3, H_4, H_5, H_6, H_7, and H_8 were tested. The main results of the K-S tests and ANOVA of economic cost indicated that the analyses failed to reject the null hypotheses (all *p* values > .05) and concluded that the difference in means of economic cost within ASEAN-5 and between other groups was not statistically significant. In the independent samples test, seven out of nine scenarios had a normal distribution where the *p* values > .05; the null hypothesis was retained and concluded that the difference in means between ASEAN-5 and other groups was not statistically significant. In two instances (2 pp rise in the TCE ratio plus 25% liquidity; and 2 pp rise in the TCE ratio plus 50% liquidity), p values (.044 and .039) < .05; the null hypothesis was rejected and concluded that the difference in means between ASEAN-5 and other groups was statistically significant. In the paired sample test, the contribution to economic benefits was analyzed by pairing the RPC with the NSFR. The results indicated that the null hypothesis was rejected, and concluded that the means of PRC and NSFR were statistically significant.

A macro stress testing framework was constructed to assess the resilience of Malaysia's banking sector to hypothetical shocks under baseline, adverse, and severely adverse scenarios. The stress testing horizon was three years, from 2013 to 2015. The assessment of Malaysia's baking sector on annual basis served to inform central banks, supervisors, bank executives, academia, as well as the general public that banks had sufficient capital to absorb losses during financial distress. As of 2013, eight large banks in Malaysia controlled over 50.6% of financial assets; non-financial firms such as fund management (12%) and Pensions & Provident Fund (16%) owned more than half of the remaining assets, and NBFIs had the smallest share of assets (2.8%).

With the average CAR of 15.85% from 2011 to 2015 (ASEAN-5 average of 16.67%), Malaysia's banking sector is well capitalized. Banks are profitable and do not foresee any issue meeting Basel III rules fully effective as of 2019. The sector's gross NPL ratio dropped consecutively since 2011, and by 2015, 1.6% NPL was lower than ASEAN-5 average of 2.0%.

The macro stress testing results under the baseline scenario revealed a modest change in capital ratios and bank profitability. The impact of the hypothetical shocks on capital ratios was a fall of -1.64% on CAR and -1.38% on Tier 1 capital ratio, and the post-stress test CAR and Tier 1 were 13.56% and 11.92% respectively. Even with downward adjustments, CAR and Tier 1 ratios of banks were at least two percentage points higher than the Basel III minimum capital requirement of 10.5% effective as of 2019. Rising funding costs due to regulatory tightening pressured bank profitability, banks' ROA dropped slightly from 1.41% to 1.24% (a change of -0.17%) and ROE similarly declined from 14.64% to 12.34% (a change of -2.30%).

Net foreign exchange exposure risk grew from 13.12% to 14.31%, which translated to an increase of 9.1%; this was mainly attributable to the fast depreciation of ringgit against major currencies. The rating of financial soundness indicators (FSIs) of the banking sector received an overall rating of 1.54, which indicated a strong resilience to shocks; both CAR and Tier 1 had low-risk ratings, 1.13 and 1.05 respectively. Liquid assets to short-term liabilities saw a rating of 1.33 which meant that Malaysia's banking sector was sufficiently liquid. Net FX exposure to capital and liquid assets to total assets needed to be monitored close as they received 2.70 and 2.30 respectively (3.0 meant high risk). The probabilities of default (PDs) analysis used piecewise approach to estimate the effects of FSIs on the PD levels; both CAR and Tier 1 had the same PD ratings of 2.83, this meant that the pre-adjustments prior to the start of stress testing adversely affected capital ratios, and ROE had the lowest PD rating of 2.00 among the FSIs.

The probability of default analysis in the baseline scenario identified several problem areas that needed to be monitored closely in adverse scenarios. As also detected by the rating and bank ratios analyses, financial soundness indicators related to credit risk and the resultant losses received higher PDs; in that regard, with 5.50 PD rating, NPLs (gross) to total loans was on top of the list. The second highest PD of 4.75 was also connected to NPLs (NPLs provisions to capital). Besides credit risk and NPLs, liquid assets to total assets (3.83), FX loans to total loans (3.67), and net FX risk exposure to capital (3.50) were seen as major weaknesses.

The impact of all fundamental shocks on capital ratios under the adverse scenario was noticeably high. Capital deterioration was significant, CAR declined by 3.80% to 9.84% and Tier 1 capital ratio by 3.37% to 9.75% relative to the baseline. The aggregate capital shortfall in the form of needed capital injection (cost to the government) was 1.55% of GDP (approximately $4.59 billion of capital injection based on 2015 GDP of $296.22 billion). The important conclusion of the adverse scenario was that no bank failed, faced a forced liquidation or suspension of license.

Among the adverse shocks affecting Malaysia's banking sector, the average impact of an increase in provisioning on bank capital ratios was the largest (-1.32%), followed by an increase in interest rates (-0.77%), increase in NPLs (-0.64%), impact of exchange rate change – FX risk (-0.65%), and the impact of interbank contagion (-0.45%). Profitability was hit hard in adverse scenario, lower real estate and asset prices plus higher unemployment pushed both ROA and ROE ratios into negative territory relevant to the baseline, -0.54% and -1.44% respectively.

The overall average rating of 3.72 approached the high-risk rating of 4.0 in adverse scenario. The augmentation of risk was cross the board, this suggested that capitalization needs of banks were significant. Despite massive loan losses and funding freeze, the capital ratios remained higher than the Basel III capital minima; 9.84% of CAR and 9.62% of Tier 1 capital ratio were still sufficient to meet the Basel III target ratio of 7.0% (4.5% of CET1 plus 2.5% of capital buffer). Banks would have to raise new funds to meet the higher capital ratio of 10.5% by 2019. The resilience of CAR and Tier 1 capital ratio was confirmed by the ratings as well, which were the only FSIs that received a rating of below 3.00 (2.39 and 2.28 respectively). The results in all three scenarios revealed that credit risk shocks were more significant for Malaysia's banking sector than market risk shocks (opposite case was true in the U.S. during the GFC).

The shrinkage in CAR (-5.31%) and Tier 1 capital ratio (-5.12%) was significant under the severely adverse scenario. Even after shedding over 5% each, CAR (8.25%) and Tier 1 ratio (8.01%) remained surprisingly resilient. The capitalization needs became more significant on account of capital shortfalls of $10.52 billion (or 3.55% of 2015 GDP). In the adverse scenario, some smaller banks only needed to raise fresh capital in order to comply with the thesis' 10.5% regulatory capital minima; however in the severely adverse scenario the capitalization needs were more widespread including some larger banks. At the worst episode of shocks, banks saw their returns on assets and equity plummet to lowest levels, -4.92% (ROA) and -3.55% (ROE).

Again with the exceptions of CAR (2.56) and Tier 1 capital ratio (2.43), the overall rating of FSIs reached the score of 3.80 (close to high risk category of 4.00). The probability of default analysis pointed to a huge spike in PDs, fostered by a cascade of defaults by the private sector on corporate loans and by the household on residential mortgage loans. There is a correlation between ratings and probability of default, and the relationship between the two is reversed and almost linear; when ratings of firms go up, their PDs tend to go down and vice versa.

Stress testing is indispensable, nonetheless still not failsafe as a standalone tool. Stress testing is rather effective when complemented by other econometric, analytical, or statistical tools such as stressed VaR. Stress testing is not an early-warning mechanism, and to think of it as one would be ill-advised. In a comprehensive risk management framework, stress tests can aid bank executives in the decision-making process and financial authorities in monetary policy decisions. Although seven years have passed since the Basel III announcement and the use of macro stress tests, stress testing is still extremely complex and surrounded by a great deal of uncertainty. Only the next big crisis will confirm the ability of stress tests to mitigate losses.

CHAPTER 5
CONCLUSION AND POLICY IMPLICATIONS

5.0 Introduction

The final chapter of this thesis provides a brief overview of the chapters and summarizes the main findings through analyses undertaken relevant to the general and specific objectives as well as the hypotheses postulated in the thesis. Based on the cost impact estimates of Basel III and the main results of the macro stress testing of Malaysia's banking sector, conclusions in conjunction with policy implications resulting from the empirical findings were drawn. This chapter also presents a number of contributions made by the thesis to the theoretical and empirical literature; lastly, some recommendations on future research are forwarded.

5.1 Overview of the Study

The general objective of this thesis is to estimate the cost impact of Basel III on banking sectors of ASEAN-5 and construct a macro stress testing framework to stress test Malaysia's banking sector; and to determine their potential effect on financial stability across ASEAN-5. The onset of the GFC has proved that the predecessors of Basel III (i.e. I & II) along with microprudential stress testing used by banks, the supervisory community, and multilateral organizations (i.e. the IMF's FSAP) failed gravely to strengthen the resilience of the global financial system.

Advances in theoretical knowledge in the fields of Basel III and macro stress testing brusquely focused on advanced economies. This thesis focuses on the cost impact of Basel III higher capital ratios on bank capital, lending spreads, and steady state output across ASEAN-5.

Chapter 1, as a technical chapter, gave a brief history of the background of the study and discussed why Basel III in conjunction with micro and macro stress testing are crucial to strengthen the resilience of the banking sectors across ASEAN-5. The problem statement was defined, general and specific research objectives were outlined. Based on the relevant theoretical perspectives, a conceptual framework of the study was constructed and a number of general and operational hypotheses predicting the relationship between variables were postulated.

Chapter 2 gave a theoretical base to the research by describing and evaluating the current literature as well as theoretical and methodological perspectives on the concept of both Basel III and stress testing. It provided an understanding of the thesis topic and showed its significance in financial stability. To formulate theories under a theoretical framework and develop bounding assumptions relevant to the objectives, theories were discussed which led to conceptualization of the cost impact of Basel III and macro stress testing as a measure of financial stability.

Chapter 3 justified the rationale behind the methodology chosen to meet the underlying objective of the study which was twofold; to assess the cost impact of the higher capital ratios under Basel III across ASEAN-5 after eight years of implementation; and to construct a macro stress testing framework to assess the resilience of Malaysia's banking sector to extreme but plausible shocks under baseline, adverse, and severely adverse scenarios. The chapter discussed research approach (i.e. deductive or inductive), research framework (i.e. theoretical or conceptual), data collection method (i.e. quantitative or qualitative), research sample and statistics techniques employed to analyze the main findings. Aggregated actual bank data was collected for eight years covering the period 2011 to 2019. Bank-specific balance sheet and income statement identities were collected from the IMF, central banks, and banks' websites.

The analyses of the cost impact of higher capital and liquidity ratios under Basel III focused on ASEAN-5 banks excluding non-financial firms (i.e. insurance). Actual bank data was collected from a total of 205 private and public banks; namely, 108 banks from Indonesia, 56 from Malaysia, 19 from Philippines, 6 from Singapore, and 16 from Thailand. The capital ratios (i.e. CAR and Tier 1 capital ratio) were computed using the capital definitions based on the Basel III capital and liquidity standards. Dynamic stochastic general equilibrium (DSGE) model, vector error correction model (VECM), and a macro stress testing framework were utilized for data analysis, and statistics techniques were employed for testing the hypotheses.

Chapter 4 reported the main findings from the analyses of data throughout the thesis. Postulated hypotheses along with the formulated general and specific objectives outlining various aspects of the interactions between the cost impact of Basel III across ASEAN-5 and macro stress testing in Malaysia under thesis were tested and the implications of the results were discussed relevant to the extent of the literature review and methodology chapters. The Basel III cost impact analysis used independent variables such as bank capital, lending spreads, and steady state output; and the dependent variable was banking stability expressed in terms of capital adequacy ratio (CAR) and needed capital injection. Throughout analyses, interest rate, foreign exchange, and liquidity risks were used as independent variables and banking stability was used as a dependent variable; the results were expressed in terms of CAR and capital injection.

Chapter 5 drew a number of conclusions relevant to the objectives, hypotheses, and assumptions of the thesis that were outlined in chapter one. The main findings of the analyses were discussed, compared and contrasted with those of recently published studies to determine the thesis' contributions. Finally, the chapter provided recommendations for future research.

5.2 Conclusion

One of the general conclusions of the thesis is that the GFC and unfolding events in its aftermath (i.e. May taper tantrum and August rout in 2013) proved that the banking sectors and currencies of ASEAN-5 were vulnerable to shocks. At the backdrop of augmenting financial turmoil in recent years, respective central banks and regulatory supervisors across ASEAN-5 made Basel III implementation and regular stress testing a central focus to strengthen the resilience of banking sectors. The thesis vindicated that the majority of financial and banking crises in history usually stemmed from banks' inability to detect and control risks. Since the banking operations revolve around a constant inventory of risks, the utmost task of the financial authorities of ASEAN-5 must be to put in place comprehensive risk management frameworks to avoid severe disruptions to the short-term and long-term funding channels, as nocuous interactions among different risk types could lead to a contraction in credit markets, even to greater crises.

5.2.1 The Cost Impact of Basel III

There is a general consensus among the industry participants that the higher capital and liquidity rules under Basel III would result in an impact on cost of funding and bank profitability, but no agreement as to what the size of that impact would be. The first postulated hypothesis of the thesis stated that the cost impact of Basel III higher capital ratios on banking sectors of ASEAN-5 would be higher than advanced economies. The main results of econometric and statistical analysis confirmed that the hypothesis was true, the cost impact of Basel III on banking sectors and the resultant economic costs across ASEAN-5 were higher. A separate analysis on economic benefit revealed that the benefits resulting from regulatory tightening outweighed costs.

The Cost Impact of Basel III on Bank Capital

To estimate the cost impact of higher capital ratios of Basel III on bank capital across ASEAN-5, Basel III capital definitions were used to calculate the capital elements such as capital adequacy ratio (CAR), Tier 1 capital ratio, and tangible common equity (TCE) ratio. For the data analysis, dynamic stochastic general equilibrium (DSGE) model and vector error correction model (VECM) were utilized and the hypotheses were tested via statistics techniques. Rejecting the null hypothesis concluded that the difference in means of Basel III cost impact between ASEAN-5 banking sectors and those of advanced economies was statistically significant.

The new Basel III reforms have increased the minimum capital ratios significantly; Tier 1 capital ratio was increased from 4% to 6% effective as of January 2015 (i.e. the target capital minima was 7%; 4.5% CET1 + 2.5% capital buffers). Besides capital ratios, the Basel Committee introduced countercyclical buffer (0-2.5%), G-SIB surcharge (1-2.5%), leverage ratio (3%), and the two new liquidity standards (LCR and NSFR ≥ 100%) fully effective as of 2019. Although the total capital (CAR) requirement under Basel III is 8%, the cost impact analysis of Basel III on bank capital in this thesis employed a benchmark CAR of 10.50% and a hurdle Tier 1 of 6%.

The results of the cost impact of the higher capital ratios of Basel III on bank capital indicated that the banking sectors of ASEAN-5 were well capitalized. Among peers, only Indonesia (18.16%; 16.83%) and Philippines (17.10%; 14.24) had capital ratios higher than the average of ASEAN-5 (16.67% of CAR and 14.01% of Tier 1). These capital ratios in the aggregate were at least two percentage points higher than Group 1 (71 banks), Group 2 (109 banks), and G-SIBs (30 banks), and no member of ASEAN-5 needed recapitalization by 2019.

The hypotheses H_1 and H_5 were tested; the main results of the Kolmogorov-Smirnov test, independent samples *t*-test, and Levene's test indicated that the analyses failed to reject the null hypothesis, and concluded that the difference in means of CAR and Tier 1 between ASEAN-5 and three groups were not statistically significant. The Mann-Whitney *U* test was employed to compare the capital ratios of ASEAN-5 with those of 118 countries; the data had a non-normal distribution, there was enough evidence to reject the hypothesis, concluded that CAR and Tier 1 of ASEAN-5 were significantly different (capital ratios across ASEAN-5 were higher).

The Cost Impact of Basel III on Bank Lending

Results of most analysis are based on restrictions which are necessary assumptions or conditions to achieve consistency. One of the key assumptions in this thesis was that banks across ASEAN-5 would conserve capital from retained earnings to comply with the higher capital ratios under Basel III. Another assumption was that banks would have to make upward adjustments in service fees and interest rates charged on loans to recuperate a portion of risen funding costs.

The impact of 1% increase in TCE on lending spreads after a four-year implementation was estimated using accounting identities applied to aggregated banking sector balance sheets. The hypotheses H_2 and H_6 were tested; to meet the target capital ratio of 7% (4.5% CET1 + 2.5% capital buffers) as of 2015, ASEAN-5 banks would have to increase lending spreads by 30.26 bps on average. To meet 10.5% (8% total capital + 2.5% capital buffers) effective as of 2019, ASEAN-5 banks would have to increase lending spreads by 68.22 bps on average. These estimates were on the high side, but still broadly consistent with those of recently published studies. The results of the K-S test, one-sample *t*-test, independent samples *t*-test, and one-ANOVA indicated that there was no strong evidence to reject the null hypothesis, and concluded that the difference in means between ASEAN-5 and groups was not statistically significant. In the one-way ANOVA, the null hypothesis was rejected in 2015 and 2016, and concluded that the difference in means between ASEAN-5 and other groups were statistically significant.

The Cost Impact of Basel III on Steady State Output

The economic cost of higher capital and liquidity regulation was expressed in terms of a loss in steady state output (i.e. GDP), using the binary-state model and the VCEM. The findings of the analysis provided empirical evidence that higher capital ratios together with the NSFR would result in a higher economic cost across ASEAN-5, but the economic benefit analysis showed that the benefits outweighed the costs for ASEAN-5 economies in the long-run. In this section, the analysis in this section was subdivided into three parts; (i) economic cost impact of higher capital ratios; (ii) economic cost of 25% liquidity tightening together with higher capital ratios; and (iii) economic cost of 50% liquidity tightening together with higher capital ratios. The main findings and the hypotheses H_3, H_4, H_5, H_7, and H_8 were tested through the use of statistics.

Augmented funding costs, increased lending spreads, and the confluence of other factors caused a shrinkage in the economic activity across ASEAN-5. The impact of a 1 pp rise in the TCE ratio after four years of implementation resulted in a loss of -0.33% in output in the aggregate for ASEAN-5. Though the impact levels were in a very close range, Thailand (-0.36%) faced the highest cost among peers. The reduction in output tripled when the TCE ratio was increased by 6 pp (i.e. -0.98%); Singapore saw a smaller decline in output (i.e. -0.85%). The second analysis focused on estimating the impact of liquidity tightening on output; when a 25% liquidity requirement was added, the fall in output reached -0.44% at 1 pp and -1.21% at 6 pp. The magnitude of impact at country-level followed the same order as before; Thailand (-1.30%)

topped the list followed by Philippines (-1.29%), Indonesia (-1.22%), Malaysia (-1.14%), and Singapore (-1.08%). In the third and final analysis in this section demonstrated that the economic activity across ASEAN-5 contracted further when a 50% liquidity requirement was added. The average fall in output for ASEAN-5 at 1 pp with 50% liquidity was -0.54%, which skyrocketed to a -1.39% shrinkage in output at 6 pp with 50% liquidity.

Table 5.1: The Comparison of economic cost & benefit due to Basel III

	Economic Cost			Economic Benefit		
	6 pp TCE	Plus 25% liquidity	Plus 50% liquidity	Plus 2.5% RPC	Plus 100% NSFR	2.5% RPC 100% NSFR
Indonesia	1.01	1.22	1.38	0.69	1.13	1.82
Malaysia	0.90	1.14	1.36	0.67	1.05	1.70
Philippines	1.04	1.29	1.45	0.58	1.09	1.74
Singapore	0.85	1.08	1.26	0.60	0.97	1.54
Thailand	1.08	1.30	1.50	0.63	1.19	1.89
Average	0.98	1.21	1.39	0.63	1.09	1.74

Notes: Author's calculations

These results were expected and in the right direction. Among peers, Singapore's high-income income and mature economy is more resilient to macroeconomic shocks, followed by Malaysia. Indonesia, Philippines and Thailand are more vulnerable to shocks as their banking sectors are less transparent and some segments of their financial systems are still in infancy stages (i.e. insurance, mutual funds, bonds, and etc.). The cost and benefit figures above are not the averages of four years of implementation. These results should not be confused with the net benefit of 0.76% at 6 pp because this is the net gain in output for ASEAN-5.

The results throughout economic cost & benefit analyses undertaken in this thesis pointed to a positive and linear correlation between the Basel III rules and economic performance, which was strongly assumed to be underpinned by the reduced probability of crisis and NSFR. Both levels of costs and benefits increased in proportion to increases in capital and liquidity requirements. The net benefit peaked for a 6 pp rise in the TCE ratio, at which level, the average cost impact of Basel III on output was 0.98% and the benefit was 1.74%, bringing the final net benefit figure to 0.76%. The results in this thesis may or may not reflect the actual developments.

5.2.2 Macro Stress Testing in Malaysia

Stress testing under Basel III for internal risk management purposes and macro stress testing as a crisis-management tool became a central focus for the central Bank (BNM) of Malaysia. The recurrence of financial crises and their systemic effects has prompted the BNM take some rigorous actions to strengthen the micro/macroprudential frameworks. BNM's relentless efforts and full commitment (i.e. structural reforms) made Malaysia's banking sector more resilient to exogenous shocks today than ever before. However, the macro events in recent years caused ringgit to depreciate as much as 40% against major currencies, this proved that Malaysia's banking sector as well as its economy was far from being immune to shocks.

Malaysia's macro stress testing (MAST) horizon was for three years from 2013 to 2015, where the benchmark CAR of 10.5% and the hurdle Tier 1 capital ratio of 6.0% were used. The aggregate CAR and Tier 1 ratio prior to MAST were comfortably high; 15.04% and 13.30% respectively. A bank falling below either ratio would be considered insolvent, and required to raise fresh capital in order to comply with the regulatory capital minima. The results of the MAST were expressed in terms of independent variables (CAR and capital injection as a percent of GDP). The main results of the MAST in the baseline scenario indicated that Malaysia's regulatory and supervisory frameworks were resilient to shocks under financial distress.

Baseline (non-stress) scenario was conducted to make certain adjustments before the actual stress scenarios, the results of which indicated that the aggregate impact of all fundamental shocks on CAR was -1.64%, but the average impact on Tier 1 capital ratio was less significant (-1.38%). The post stress test CAR of 13.56% was still above the benchmark CAR of 10.5%. As feared by many, bank profitability was adversely affected, causing ROA and ROE to decline by -0.15% and -2.30% respectively. One of the positive outcomes of the analyses during the stress testing exercise was that no bank requested financial assistance from the BNM. The impact of FX exposure was higher (-0.48%) than other variables adversely affecting CAR.

The overall rating in the baseline scenario was 1.54, meaning a low rating and high resistance to shocks; CAR and Tier 1 ratio received even a lower rating, 1.13 and 1.05 respectively. Net FX exposure to capital scored a rating of 2.70 which was close to 3.00 of the high risk category. The FSIs further deteriorated under the adverse scenario where credit risk related losses and the ensuing decreases in capital ratios were significant; for instance, CAR and Tier 1 ratio dropped as much as -3.40% and -3.64% respectively relevant to the baseline. Loan losses due to defaults on residential mortgages, consumer loans, and equity line of credit was the largest driver behind capital depletion at banks. The aggregate capital shortfall in the form of needed capital injection was 1.62% of GDP (or $4.80 billion based on 2015 GDP of $296.22 billion).

Out of the five shocks adversely affecting banking ratios, the impact of increase in provisioning on capital ratios was the largest (-1.32%), followed by increase in interest rates (-0.77%), increase in NPLs (-0.64%), impact of exchange rate change – FX risk (-0.65%), and the impact of interbank contagion (-0.45%). Bank profitability was hit hard in adverse scenario, attributable to lower real estate and asset prices plus higher unemployment which pushed both ROA and ROE ratios into negative territory relevant to the baseline, -0.54% and -1.44% respectively. The fall of -1.79% in liquidity ratio along with significantly reduced (-22.39%) liquidity coverage ratio inhibited banks' ability to cover their short-term (defined as less than one year) liabilities.

The results of severely adverse scenario were significant and expected. The magnitude of shocks caused capital decreases ranging from 505 bps to 544 bps. When the results were compared with the baseline scenario, the magnitude of average decrease was more than threefold; 1.64% (CAR) and 1.38% (Tier 1) versus 5.31% and 5.12% respectively. The capitalization needs became much more significant on account of a capital shortfall of $10.52 billion (or 3.55% of 2015 GDP of $296.22 billion). Under the severely adverse scenario, capitalization needs were not just confined to smaller Islamic banks; even some larger banks needed to be recapitalized.

5.3 Policy Implications

This thesis not only differed from the antecedent studies, but it was also informative to the BNM, supervisors, and bank executives. The BNM must not heavily rely on the substantial capital buffers from highly profitable domestic and overseas operations because CAR and Tier 1 ratio decreased more than expected even in the baseline scenario. Capital levels deteriorated further under the adverse scenarios, this should prompt the BNM and individual banks to visit credit risk parameters and make them more conservative. The overheated housing market (i.e. asset prices) and the rising household leverage must be monitored closely by the BNM, which should also ensure that these disquieting areas do not put unnecessary strain on banks' capital positions. Any funding freeze due to capital hoarding by banks and the subsequent credit squeeze could adversely affect the broader economy, which in turn may amplify sovereign risk.

Although ASEAN-5 countries are on target to complete Basel III implementation by or before the 2019 deadline, the progress has been somewhat slow. Excluding Singapore, four founding members of ASEAN-5 have voiced out their concerns regarding the new surcharges for G-SIB / D-SIB. Nonetheless, the risk-based capital regulation was implemented across ASEAN-5; in that regard, the assessment of Singapore's implementation status was completed by the Basel Committee in 2013 and the assessments of others were planned for 2016.

The main findings of this thesis should be of significant interest to various parties including central banks, regulatory supervisors, practitioners, bank executives, and academia. Central banks mainly use monetary policy decisions to reduce the adverse impact of macroeconomic shocks; however, monetary policy alone has limitations. As a complement to the arsenal of tools available to central banks, stress tests not only can aid the decision making process of appropriate monetary policies, but it can also help safeguard financial and systemic stability. The thesis' results are informative to central banks as stress testing in the aftermath of the GFC has become indispensable as a crisis management tool, which can be used to develop supervisory assessments of capital adequacy and capital planning at banks. A strong consensus has formed among central banks that Basel III and stress testing are two integral components of a comprehensive risk management framework, the foundation for sustainable economic growth.

Implications for the Theory

Credit risk (primary concern due to default or bankruptcy) is at the heart of financial stability, therefore a central focus for financial authorities. In credit risk assessments, the measurement of PDs is a determinant of a firm's market value. Risk evolves, the following seminal papers played a vital role in its evolution: The path-breaking work of Markowitz (1952, 1959) on mean-variance criterion in portfolio selection opened a new chapter in risk management; and Modigliani-Miller (1958) shocked the finance world with their unconventional irrelevance theory, stating that a firm's market value is irrelevant to its capital structure. Sharpe (1964) with the capital asset pricing model caused a paradigm-shift, which was perfected by the groundbreaking works of Black and Scholes (1973) and Merton (1973b) on option pricing theory, and Merton (1974) on probability of default. The paradigm-shifting theories or models have been subject to theoretical objections or empirical failures, Fama and French (2004) conclude that most of their applications may be invalid as well.

The MM theorem and the mean-variance criterion faced similar predicaments; for instance, the CAPM empirically failed to validate its measure of risk. Sharpe (1990) acknowledged that his initial CAPM was *"extremely parsimonious"* and the model's impediment to new risk types needed to be improved. The measure of financial stability gained momentum with the Black and Scholes (1973) option pricing theory. Merton (1973b) did not envisage its growth potential as he said "...options are specialized and relatively unimportant financial securities, the amount of time and space devoted to the development of a pricing theory might be questioned". Since the Asian crisis of 1997-98, the global derivatives markets have grown exponentially; in 2007, the volume of derivatives was at least five times larger than both equity and bond markets combined.

In the 1990s, value-at-risk (VaR) model became highly popular to quantify market risk in a single number; despite its weakness under distress, it quickly became a universally accepted standard. VaR models became the mainstay when the Basel Committee allowed banks to use VaR internally while computing capital adequacy and the capital requirements for market risks. However, VaR is not a standalone tool and its outputs under extreme but plausible scenarios must be checked by a stress test. Parametric models of volatility, such as ARCH–autoregressive conditional heteroscedasticity was introduced by Engle (1982); EGARCH (Exponential Garch) by Nelson (1991), and Generalized ARCH (GARCH) by Bollerslev (1986).

Dominguez and Alfonso (2004) evaluate how well VaR methodologies respond to stress testing exercise based on historical scenarios. Berkowitz and O'Brien (2001) indicate that banks' VaR forecasts were less robust compared to the reduced-form based on the GARCH model which is better than the bank VaRs for detecting and capturing banks' P&L volatility. Hendricks (1996) argues that VaR's "...extreme outcomes occur more often and are larger than predicted by the normal distribution" and "...the size of market movements is not constant over time".

Structural (Merton, 1974) and reduced form (Hull & White, 2000) models, derived from Merton's structural model, are widely used to forecast probabilities of default and distance-to-default (DtD). The latter measures how many standard deviation a non-financial firm is away from a default point. Previously, financial ratios along with some univariate and multivariate statistical models were used to assess credit risk and predict the likelihood of bankruptcy (Clark et al., 1997; Hill et al., 1996). Altman (1968) uses z-score to predict bankruptcy up to three years prior to the actual default, but the prediction accuracy of his model drops from 95% (one year) to 72% (two years), and the prediction accuracy deteriorates as the lead time goes beyond two years (52% three years). Čihák (2007a) argues that a good framework of financial stability needs to incorporate PD and LGD of banks, and CD across the entire financial system.

The literature exemplifies that the VK model, extended on Merton (1974) by Oldrich Vasicek and Stephen Kealhofer (Kealhofer, 2003a, b; Vasicek, 1984), provides robust predictions of defaults and bond spreads compared to Merton's model, but the reduced-form Hull-White (HW) model tends to outperform both Merton and the VK models (Jarrow & Turnbull, 1992; 1995). The VK model, widely perceived as an improvement over Merton's model, the VK model takes into account PD, LGD, and CD of credit risk under *standalone risk* and *portfolio risk*.

Liu et al. (2004) extend on the Merton (1977b) to develop the distance to default for banks using the z-score, and they argue that their z-score is more appropriate for banks than the original Altman (1968) z-score because it takes into account the interest rate risk. Gropp et al. (2006)

empirically test a sample of EU banks to see if distance-to-default along with bond spreads can be used as measurements of financial stability; the thesis concludes that both properties are impartial and capable of detecting fragilities in financial systems and gauging systemic risk. Tudela and Young (2003) compute default probabilities of publicly traded UK firms and believe that models based on Merton's (1974) model gives useful information and predicts better PDs.

Implications for Policy and Practice

The thesis has assessed the cost impact of the Basel III capital and liquidity regulation on bank capital, lending spreads, and steady state output across ASEAN-5. It also computed economic benefits arising from regulatory tightening and the assumed resultant reduced probability of crisis. As a separate analysis, a macro stress testing framework was constructed to assess the resilience of Malaysia's banking sector to shocks under extreme but plausible scenarios.

Central banks have been evaluating banks in five areas of supervisory considerations; (1) capital assessment and capital planning processes; (2) capital distribution policy (i.e. under what circumstances dividends are paid out); (3) plans to repay any government investment; (4) ability to absorb losses under adverse scenarios; and (5) plans for addressing any potential (or expected) impact of Basel III. In that regard, the stress testing results are informative to central banks. By focusing on tail risks, stress testing quantifies banks' vulnerabilities to various risk exposures and projects potential losses under extreme but plausible scenarios. Moreover, stress tests assess banks' capital positions in terms of quality and quantity of high liquid assets to withstand shocks in the event of an acute stress for at least a period of 30 days; further, stress testing results can be inputs in the decision making process for executives within the bank.

Micro or macro stress tests with published results are informative, which can underpin the decision making processes and play a vital role in alleviating bank opacity. Stress testing results are used by central banks to create proper policy responses, by supervisors to design supervisory assessment programs or take actions on banks that are not in compliance with the Basel III minimum capital and liquidity requirements. Stress testing as a complement to VAR and the stressed VaR results are critically important for financial and non-financial institutions who frequently make decisions concerning financial markets and traded securities. Stress testing results are used in several reports (i.e. FSB, ESRB, and GFSR); the senior management of banks demands to view a detailed report on risks to increase or reduce trading limits or exposures.

In parallel with fast-paced globalization, internationalization of finance, financial innovations, and deregulation in banking; risk management frameworks along with methodologies and application have witnessed undeniable advances as well, but all of these perceivably good developments directly or indirectly contributed to the breakout of the GFC. Therefore, it is hard to conclude that regulatory and supervision frameworks as well as banks' internal risk assessment mechanisms have reached a steady state. The earlier stress tests had serious flaws and macro stress testing as a crisis management tool has been only in practice since 2009; against this backdrop, industry participants proclaim that microprudential and macroprudential stress testing has not yet completed its evolution and still needs more refinement.

Always following a high-magnitude financial crisis at a global scale, the industry typifies the typical behavior, that is, banks and financial authorities jointly put a fire-fighting effort into making stress tests a central focus; once the panic is receded and confidence is restored, businesses go back to their old ways which caused the crisis in the first place. The BNM understands well that stress testing is just more than a routine task or a mandated requirement by regulators and supervisors. For the stress testing results to be meaningful, they need to be actionable and be part of the corporate culture in order to aid the decision-making processes.

The stress testing results should also be discussed at senior management level, and the upshot of this should be a strategy to either increase or reduce certain risk limits (appetite). The BNM can utilize the results of this thesis' macro stress testing exercise or own stress tests to establish certain barriers or thresholds to mitigate the severity of losses in an acute financial stress. Central banks, supervisors, and banks can put in place early-warning mechanisms for loss mitigation that would trigger actions against the pre-set risk appetite threshold levels. Stress testing has other roles than just risk mitigation or loss prevention. Stress test results can aid the executive management in strategic decisions such as engaging in new business activities, expanding into niche markets, performing a feasibility analysis for mergers and acquisitions.

The 2016 MAST results show that Malaysia' financial sector is resilient, well diversified, and highly interconnected (consistent with developed economies). Malaysia has a thriving equity market, large bond market (largest in the ASEAN-5), and growing private debt securities; but surprisingly, some restrictions still exist in the financial sector where the government has a substantial controlling stake (plus explicit and implicit guarantees). The BNM must monitor the increasing household sector leverage more closely; in that regard, the BNM may need to adopt (design/conduct) macro-prudential stress testing programs for two or three years. Although it is not concerning, Malaysia should work towards reducing the level of foreign claims to avoid a deleveraging process in the event of financial distress under highly adverse market conditions. Malaysia's banking operation abroad (less than one-third of GDP) should be subject to rigorous monitoring, which may require the BNM to initiate cooperation in host countries to ensure no escaping from its supervision. Some market distortions exist (i.e., tax incentives for Islamic finance) and the BNM needs to eliminate them as much as possible. The asset quality of banks has improved over the years, but the work has to continue.

The results of this thesis are informative to market participants. The Federal Reserve's SCAP was widely perceived to be transparent and informative, the disclosure of its full results restored confidence in the U.S. banking system and contributed positively to the performance of financial markets. In stark contrast to the U.S., the CEBS' partial disclosure of its stress testing results failed to restore confidence and contributed to financial instability. Stress tests with published results are informative; transparency underpins the decision making processes and plays a role in alleviating bank opacity. Stress testing results are used by central banks to create proper policy responses, by supervisors to design supervisory assessment programs or take actions on banks.

5.4 Limitations and Directions for Future Research

Throughout this thesis, data availability, data collection, and scarcity of models to run analyses have been a serious limitation, which might have resulted in imperfections in the thesis' results. Future research in this area should focus on improving some of these impairments; doing so will result in more accurate stress testing results. Further work needs to be done in the area of data collection, most of which is either missing or partially reported. Due to confidentiality reasons or sensitivity issues of publically traded banks, financial statement data is especially hard to obtain. The stress testing exercise was very basic, therefore future macro stress testing should incorporate macro variables such as FX risk currencies, equity and commodity price risks.

Comprehensive system-wide stress tests require highly sophisticated computer systems, statistical as well as analytical applications and models. Although the majority of banks in Asia are domestically oriented (excluding banks located in Japan, Hong Kong, and Singapore), the lack of technical know-how (i.e. stress testing) along with limited availability of other critically important requirements (e.g., trained and skilled human resources, infrastructure, technology, and financial resources) is a major issue among ASEAN-5 countries and across Asia.

Although the macro stress testing framework in this thesis is still comparatively robust and can be used for assessing the resilience of a banking sector without the need for sophisticated tools and extremely costly computer systems, this basic version of stress test can be elaborated to incorporate statistical econometric models to better analyze the complex linkages between macroeconomic factors and the broader economy. Malaysia has a well-developed as well as open economy after Singapore, which makes it vulnerable to asset price risks and volatilities in commodity prices. This would be a good starting point for future research, new modules can be added to project econometrically some of these relationships, or even test new risks.

Identifying the timing of the next big future crisis is not much different than identifying the next big earthquake, because either one is impossible. In this analogy, banking sectors can only do all the things they possibly can to mitigate losses in an effective way should a crisis occur. When stress tests are designed adequately containing rigorous scenarios, the results can inform policy makers on new risk factors as well as the severity of existing risk exposures so that proper policy responses can be developed. The results of micro-and macro stress tests can also provide valuable information on the soundness of individual banks (by supervisors) and on the resilience of financial systems as a whole (by central banks) under extreme but plausible scenarios.

Future research should incorporate more risk factors (macro and non-macro); for a cross-check and to avoid any adverse effect of subjectivity in scenario selection, a stress testing exercise should incorporate aspects of both BU and TD approaches. The accuracy of VaR outputs should either be complemented by stress testing or further research should be done on models such as GARCH, IGARCH, EGARCH, and the quasi-maximum likelihood GARCH (QML GARCH).

REFERENCES

Acharya, V., Anginer, D. & Warburton, A. J. (2014). The End of Market Discipline? Investor Expectations of Implicit State Guarantees. Working paper, New York University.

Acharya, V., Engle, R. & Pierret, D. (2013). Testing Macroprudential Stress Tests: The Risk of Regulatory Risk Weights. Working paper 18968, NBER.

Adrian, T. & Shin, H. S. (2008). Financial Intermediaries, Financial Stability, and Monetary Policy. Federal Reserve Bank of New York Staff Reports, no. 346, September.

Aikman, D., Alessandri, P., Eklund, P., Gai, P., Kapadia, S., Martin, E., Mora, N., Sterne, G. & Willison, M. (2009). Funding Liquidity Risk in a Quantitative Model of Systemic Stability. Bank of England Working Paper No. 372.

Albertazzi, U. & Marchetti, D. J. (2010). Credit Supply, Flight to Quality and Ever Greening: An Analysis of Bank-Firm Relationships after Lehman, Banca d'Italia, Working Paper No. 756.

Allison, J. A. (2012). The Real Causes of the Financial Crises. Cato's Letter (winter), 10 (1). A Quarterly Message on Liberty, Cato Institute.

Altman, E. (1968). Financial Ratios, Discriminant Analysis and the Prediction of Corporate Bankruptcy. Journal of Finance, 23 (4), 589-609.

Altman, E., Haldeman, R. & Narayanan, P. (1977). ZETA Analysis: A New Model to Identify Bankruptcy Risk of Corporations. Journal of Banking and Finance, June.

Altman, E. & Hotchkiss, E. (2005). Corporate Financial Distress and Bankruptcy. 3rd edition, New York: John Wiley & Sons, Inc.

Andersen, L. (2003). Bulletin on Asia – Pacific Perspectives 2003/2004: Asia – Pacific Economies: Maintaining Dynamism (Basel II: The Path to Promoting Financial Stability in the Asian and Pacific Region?). United Nations, ESCAP.

Angelini, P., Clerc, L., Cúrdia, V., Gambacorta, L., Gerali, A., Locarno, A., Motto, R., Roeger, W., Van den Heuvel, S. & Vlcekaolo, J. (2011). BASEL III: Long-term Impact on Economic Performance and Fluctuations. Bank of International Settlement, Working Paper 338, February.

Arnold, B., Borio, C., Ellis, L. & Moshirian, F. (2012). Systemic Risk, Macroprudential Policy Frameworks, Monitoring Financial Systems and the Evolution of Capital Adequacy, Journal of Banking & Finance, 36 (12), 3125-3132.

Arora, N., Bohn, J. R. & Zhu, F. (2005). Reduced Form vs. Structural Models of Credit Risk: A Case Study of Three Models. Moody's KMV, February.

Avesani, R. G., Pascual, A. G. & Ribakova, E. (2007). The Use of Mortgage Covered Bonds. IMF Working Paper WP/07/20, Monetary and Capital Markets, January.

Aziz, J. & Charupat, N. (1998). Calculating Credit Exposure and Credit Loss: A Case Study. Algo Research Quarterly, 1 (1), 31-46.

Bhattacharyya, S. & Pendharkar, P. C. (1998). Inductive, Evolutionary, and Neural Computing Techniques for Discrimination: A Comparative Study. Decision Sciences (fall), 871-899.

Baig, T. & Goldfajn, I. (1999). Financial Market Contagion in the Asian Crisis. IMF Staff Papers 46 (2), IMF: Washington, D.C.

Bair, S. (2007). Remarks by Sheila Bair Chairman, U.S. Federal Deposit Insurance Corporation. Risk Management and Allocation Conference, Paris, France, June 25.

Barrell, R., Davis, E., Fic, T., Holland, D., Kirby, S. & Liadze, I. (2009). Optimal Regulation of Bank Capital and Liquidity: How to Calibrate New International Standards, UK Financial Services Authority, Occasional Paper Series No. 38.

Barrell, R., Davis, E. P., Karim, D. & Liadze, I. (2010a). The Effects of Banking Crises on Potential Output in OECD Countries, Mimeo.

Barrell, R., Davis, E. P., Karim, D. & Liadze, I. (2010b). The Impact of Global Imbalances: Does the Current Account Balance Help to Predict Banking Crises in OECD Countries? Mimeo.

Baumol, W. (1963). An Expected Gain-Confidence Limit Criterion for Portfolio Selection. Management Science, 10, 174-182.

BCBS (Basel Committee on Banking Supervision) (1988). International Convergence of Capital Measurement and Capital Standard. Basel, July.

BCBS (Basel Committee on Banking Supervision) (1996a). Amendment to the Capital Accord to Incorporate Market Risks. Basel, January.

BCBS (Basel Committee on Banking Supervision) (1996b). Supervisory Framework for the Use of "Backtesting" in Conjunction with the Internal Models Approach to Market Risk Capital Requirements. Basel, January.

BCBS (Basel Committee on Banking Supervision) (1999a). Supervisory Lessons to Be Drawn From the Asian Crisis. Working Papers No. 2, June.

BCBS (Basel Committee on Banking Supervision) (1999b). Capital Requirements and Bank Behavior: The Impact of the Basle Accord. Working Papers No. 1. Basel, April.

BCBS (Basel Committee on Banking Supervision) (2001a). History of the Basel Committee and its Membership. Basel, March.

BCBS (Basel Committee on Banking Supervision) (2001b). Overview of the New Basel Capital Accord. Consultative Document, Basel, January.

BCBS (Basel Committee on Banking Supervision) (2001c). The Internal Ratings-Based Approach. Basel, January.

BCBS (Basel Committee on Banking Supervision) (2001d). The Standardized Approach to Credit Risk. Basel, January.

BCBS (Basel Committee on Banking Supervision) (2001e). Working Paper on the Regulatory Treatment of Operational Risk. September 2001, Basel: BIS.

BCBS (Basel Committee on Banking Supervision) (2002). Supervisory Guidance on Dealing with Weak Banks. Basel, Bank for International Settlements.

BCBS (Basel Committee on Banking Supervision) (2004a). International Convergence of Capital Measurement and Capital Standards: A Revised Framework. Basel, June.

BCBS (Basel Committee on Banking Supervision) (2004b). Principles for the Management and Supervision of Interest Rate Risk. Basel, July.

BCBS (Basel Committee on Banking Supervision) (2008). Principles for Sound Liquidity Risk Management and Supervision – Draft for Consultation.

BCBS (Basel Committee on Banking Supervision) (2009a). Principles for Sound Stress Testing Practices and Supervision. Working Paper No. 155. Basel, May.

BCBS (Basel Committee on Banking Supervision) (2009b). Revisions to the Basel II market risk framework. Consultative document, January.

BCBS (Basel Committee on Banking Supervision) (2010a). Basel III: A Global Regulatory Framework for More Resilient Banks and Banking Systems. Basel, December.

BCBS (Basel Committee on Banking Supervision) (2010b). An Assessment of the Long-Term Impact of Stronger Capital and Liquidity Requirements. LEI Report, Basel.

BCBS (Basel Committee on Banking Supervision) (2010c). Results of the Comprehensive Quantitative Impact Study. Basel, December.

BCBS (Basel Committee on Banking Supervision) (2011a). Report on Asset Securitization Incentives. The Joint Forum. Basel, July.

BCBS (Basel Committee on Banking Supervision) (2011b). Report on Asset Securitization Incentives. The Joint Forum. Basel, July.

BCBS (Basel Committee on Banking Supervision) (2012a). Peer Review of Supervisory Authorities' Implementation of Stress Testing Principles. Working Paper No. 218. Basel, April.

BCBS (Basel Committee on Banking Supervision) (2012b). Results of the Basel III monitoring exercise as of June 30 2011. Basel, April.

BCBS (Basel Committee on Banking Supervision) (2013a). Liquidity stress testing: A survey of theory, empirics and current industry and supervisory practices. Working Paper No. 24, October.

BCBS (Basel Committee on Banking Supervision) (2013b). Basel III: The liquidity coverage ratio and liquidity risk monitoring tools. Basel, January.

BCBS (Basel Committee on Banking Supervision) (2013c). Revised Basel III leverage ratio framework and disclosure requirements. Basel, June.

BCBS (Basel Committee on Banking Supervision) (2013d). Liquidity Stress Testing: A Survey of Theory, Empirics and Current Industry and Supervisory Practices. Working Paper No. 24, October.

BCBS (Basel Committee on Banking Supervision) (2014a). Implementation of Basel Standards: A Report to G20 Leaders on Implementation of the Basel III Regulatory Reforms. Basel, November.

BCBS (Basel Committee on Banking Supervision) (2014b). The standardized approach for measuring counterparty credit risk. Basel, March (rev. April).

Beau, D., Clerc, L. & Mojon, B. (2012), Macro-Prudential Policy and the Conduct of Monetary Policy. Banque de France, January.

Beaver, W. H. (1968). Market Price, Financial Ratios and the Prediction of Failure. Journal of Accounting Research, 6 (2), 179-192.

Bekaert, G. & Harvey, C. R. (1998). Capital Flows and the Behavior of Emerging Market Equity Returns. NBER Working Paper Series, 6669.

Beltratti, A. (2011). Do Stress Tests Carry Useful Information? Evidence from Europe. Bocconi University.

Bemmann, M. (2005). Improving the Comparability of Insolvency Predictions. Dresden Economics Discussion Paper Series No. 08/2005, June.

Benninga, S. & Wiener, Z. (1998). Value at Risk. Mathematica in Education and Research, 7 (4), 1-7.

Berg, A. (1999). The Asia Crisis: Causes, Policy Responses and Outcomes. IMF Working Paper 99/138, IMF: Washington, D.C.

Berkowitz, J. & O'Brien, J. (2001). How Accurate Are Value-at-Risk Models at Commercial Banks? Graduate School of Management, University of California, Irvine. Division of Research and Statistics, Federal Reserve Board, July.

Berlin, M. (2011). Can We Explain Banks' Capital Structures? Business Review, Q2 (2011), 1-11. Federal Reserve Bank of Philadelphia.

Bernanke, B. S. (2005). The Global Savings Glut and the US Current Deficit. Sandridge Lecture, Virginia Association of Economics, Richmond, Virginia.

Bernanke, B. S. (2013). Stress Testing Banks – What Have We Learned? Speech at the "Maintaining Financial Stability: Holding a Tiger by the Tail" Financial Markets Conference, Sponsored by the Federal Reserve Bank of Atlanta, Stone Mountain, Georgia, April.

Bernanke, B. S. & Blinder, A. S. (1988). Credit, Money, and Aggregate Demand. American Economic Review, 78 (2), 435-39.

Bernstein, P. L. (1992). Capital Ideas, the Improbable Origins of Modern Wall Street. New York, London, Toronto, Sydney, Tokyo, Singapore. The Free Press.

BIS (Bank for International Settlements) (1997). 67th Annual Report. 1st April 1996 – 31st March 1997, Basel, June.

BIS (Bank for International Settlements) (1998). 68th Annual Report. 1st April 1997 – 31st March 1998, Basel, June.

BIS (Bank for International Settlements) (2008). Quarterly Review March 2008 – Statistical Annex.

BIS (Bank for International Settlements) (2015a). International Banking and Financial Market Developments. BIS Quarterly Review, December.

BIS (Bank for International Settlements) (2015b). 85th Annual Report. Basel, June.

Black, F., Jensen, M. C. & Scholes, M. (1972). The Capital Asset Pricing Model: Some Empirical Tests. In Studies in the Theory of Capital Markets, M.C. Jensen, Ed. New York: Praeger Publishers.

Black, F. & Scholes, M. (1973). The Pricing of Options and Corporate Liabilities. The Journal of Political Economy, 81 (3), 637-54.

Blaschke, W., Jones, M. T., Majnoni, G. & Peria, S. M. (2001). Stress Testing of Financial Systems: An Overview of Issues, Methodologies, and FSAP Experiences. IMF Working Paper WP/01/88.

Blinder, A. S. (2013). After the Music Stopped: The Financial Crisis, the Response, and the Work Ahead. The Penguin Press, USA, ISBN – 978-1-59420-530-9.

Bluedorn, J., Duttagupta, R., Guajardo, J. & Topalova, P. (2013). Capital Flows are Fickle: Anytime, Anywhere.

Blundell-Wignall, A. & Atkinson, P. (2010). Thinking Beyond Basel III: Necessary Solutions for Capital and Liquidity. OECD Journal: Financial Market Trends, 2010 (1), 1-23.

Blundell-Wignall, A. & Roulet, C. (2013). Business models of banks, leverage and the distance-to-default. OECD Journal: Financial Market Trends, 2012 (2), 1-28.

Blundell-Wignall, A., Atkinson, P. E. & Roulet, C. (2014). Bank Business Models and the Basel System: Complexity and Interconnectedness. OECD Journal: Financial Market Trends, 2013 (2), 1-26.

Boissay, F. (2011). Financial Imbalances and Financial Fragility. ECB Working Paper Series No. 1317, April.

Bollerslev, T. (1986). Generalized Autoregressive Conditional Heteroskedasticity. Journal of Econometrics, 31, 307-327.

Borio, C. (2003). Towards a Macroprudential Framework for Financial Supervision and Regulation? BIS Working Paper No 128.

Borio, C. (2014). Monetary Policy and Financial Stability: What Role in Prevention and Recovery? BIS Working Paper No 440, January.

Borio, C., Drehmann, M. & Tsatsaronis, K. (2012). Stress-Testing Macro Stress Testing: Does it live up to Expectations? BIS Working Paper No. 369, January.

Boss, M. (2002). A Macroeconomic Credit Risk Model for Stress Testing the Austrian Credit Portfolio. Financial Stability Report 4, Central Bank of the Republic of Austria, 64–82.

Boss, M., Krenn, G., Schwaiger, M. & Wegschaider, W. (2004). Stress Testing the Austrian Banking System. Austrian National Bank, Österreichisches Bankarchiv, 11 (04), 841–852.

Buncic, D. & Melecky, M. (2012). Macroprudential Stress Testing of Credit Risk: A Practical Approach for Policy Makers. Policy Research Working Paper No. 5936, Europe and Central Asia Region, Financial and Private Sector Development Department, World Bank, January.

Burnside, C., Eichenbaum, M. & Rebelo, S. (1998). Prospective Deficits and the Asian Currency Crisis. NBER Working Paper No. W6758, National Bureau of Economic Research, October.

Caggiano, G. & Calice, P. (2011). The Macroeconomic Impact of Higher Capital Ratios on African Economies. Working Paper Series No. 139, African Development Bank Group, November.

Campbell, S. D. (2005). A Review of Backtesting and Backtesting Procedures. Finance and Economics Discussion Series Divisions of Research & Statistics and Monetary Affairs, Federal Reserve Board, Washington, D.C.

Campbell J., Hilscher, J. & Szilagyi, J. (2011). Predicting Financial Distress and the Performance of Distressed Stocks. Journal of Investment Management, 9 (2), 1-21.

Cardinali, A. & Nordmark, J. (2011). How informative are bank stress tests? Bank opacity in the European Union. Master's thesis, Lund University.

Carmassi, J. & Micossi, S. (2012). Time to Set Banking Regulation Right. CEPS Paperback, Brussels, March.

Caruana, J. (2010). Why Basel III Matters for Latin American and Caribbean Financial Markets. General Manager, Bank for International Settlements (BIS).

CEBS (Committee of European Banking Supervisors) (2010a). Aggregate outcome of the 2010 EU-wide stress test exercise. July.

CEBS (Committee of European Banking Supervisors) (2010b). Results of the comprehensive quantitative impact study. December.

Cecioni, M. (2010). The Effect of Bank Capital on Economic Activity: Results from Structural VAR and VECM, Banca d'Italia, Mimeo.

CGFS (Committee on the Global Financial System) (2000). Stress testing by large financial institutions: Current practice and aggregation issues. Report by a Working Group. BIS, April.

CGFS (Committee on the Global Financial System) (2001). A survey of stress tests and current practice at major financial institutions. Report by a Working Group. BIS, April.

CGFS (Committee on the Global Financial System) (2005). Stress testing at major financial institutions: Survey results and practice. Report by a Working Group. BIS, January.

Chami, R. & Cosimano, T. F. (2001). Monetary Policy with a Touch of Basel. IMF Working Paper No. 01/151.

Chami, R. & Cosimano, T. F. (2010). Monetary Policy with a Touch of Basel. Journal of Economics and Business, 57 (2), 303–325.

Chan-Lau, J. A. (2006). Market-Based Estimation of Default Probabilities and Its Application to Financial Market Surveillance. IMF Working Paper WP/06/104, April.

Chan-Lau, J. A. & Gravelle, T. (2005). The End: A New Indicator of Financial and Nonfinancial Corporate Sector Vulnerability. IMF Working Paper WP/05/231, December.

Cifuentes, R., Ferrucci, G. & Shin, H. S. (2005). Liquidity Risk and Contagion. Journal of the European Economic Association, 3, 556–66.

Čihák, M. (2007a). Introduction to Applied Stress Testing. IMF Working Paper No. 07/59 (Washington: International Monetary Fund).

Čihák, M. (2007b). Systemic Loss: A Measure of Financial Stability. ResearchGate, February.

Čihák, M. & Heřmánek, J. (2005). Stress Testing the Czech Banking System: Where Are We? Where are we going? CNB Research Policy Notes (2), 1-36.

Cincotti, S., Raberto, M. & Teglio, A. (2012). Macroprudential Policies in an Agent-Based Artificial Economy. Revue de l'OFCE, 0 (5), 205-234.

Clark, C. F., Foster, P. L., Hogan, K. M. & Webster, G. H. (1997). Judgment Approach to Forecasting Bankruptcy. The Journal of Business Forecasting Methods & Systems; Flushing, 14 (2), 14-18.

Cootner, P. H. (1964). The Random Character of Stock Market Prices. Cambridge: M.I.T. Press.

Crockett, A. (1997a). Why is Financial Stability a Goal of Public Policy? In maintaining financial stability in a global economy, a symposium sponsored by the Federal Reserve Bank of Kansas City, Wyoming.

Crockett, A. (1997b). The Theory and Practice of Financial Stability. Essays in International Finance, 203. International Finance Section, Department of Economics, Princeton University.

Crosbie, P. & Bohn, J. (2003). Modeling Default Risk. Modeling Methodology, Moody's K.M.V. December.

Danielsson, J. (2000). The Emperor Has No Clothes: Limit to Risk Modelling. FMG SP126.

DeAngelo, H. & Stulz, R. (2013). Why High Leverage is Optimal for Banks. Los Angeles: University of Southern California, Marshall School of Business, May.

Dellas, H., Diba, B. & Loisel, O. (2010). Financial Shocks and Optimal Policy. Banque de France, Working Paper No. 277.

Demirgüç-Kunt, A. & Detragiache, E. (1998). The Determinants of Banking Crises in Developing and Developed Countries. IMF Staff Paper No. 45 (01)

Disyatat, P. (2008). Monetary Policy Implementation: Misconceptions and Their Consequences. BIS Working Papers No 269, December.

Dominguez, J. M. F. & Alfonso, M. D. O. (2004). Applying Stress-Testing on Value at Risk (VaR) Methodologies. Investment Management and Financial Innovations, 4/2004.

Duffee, G. (1999). Estimating the Price of Default Risk. Review of Financial Studies, 12 (1), 1997-2026.

Duffie, D. & Singleton, K. (1999). Modeling Term Structure Models of Defaultable Bonds. Review of Financial Studies, 12 (1), 687–720.

EBA (European Banking Authority) (2011). EU-Wide Stress Test Aggregate Report. European System of Financial Supervision, July.

EBA (European Banking Authority) (2012). Results of the Basel III Monitoring Exercise. June, London.

EBA (European Banking Authority) (2014). Results of 2014 EU-Wide Stress Test. Aggregate Results. European System of Financial Supervision, October.

EBA (European Banking Authority) (2015). EU-Wide Stress Test 2016. Draft Methodological Note, November.

ECB (European Central Bank) (2008). EU Banks' Liquidity Stress Tests and Contingency Funding Plans, Frankfurt, November.

ECB (European Central Bank) (2013). A Macro Stress Testing Framework for Assessing Systemic Risks in the Banking Sector. Occasional Paper Series No. 152, October.

Elizalde, A. (2007). From Basel I to Basel II: An Analysis of the Three Pillars. CEMFI Working Paper No. 0704, June.

Ellahie, A. (2012). Capital Market Consequences of EU Bank Stress Tests. London Business School Working Paper.

Elsinger, H., Lehar, A. & Summer, M. (2006). Using Market Information for Banking System Risk Assessment. International Journal of Central Banking, 2, 137–65.

Engle, R. (1982). Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom inflation. Econometrica 50, 987-1007.

Evans, O., Leone, A. M., Mahinder, G. & Hilbers, P. (2000). Macroprudential Indicators of Financial System Soundness. IMF: Washington D.C.

Fallon, W. (1996). Calculating Value-at-Risk. Working Paper Series No. 96-49, Financial Institutions Center. The Wharton School, University of Pennsylvania, January.

Fama, E. & French, K. R. (1992). The Cross-Section of Expected Stock Returns. Journal of Finance, 67 (2), 427–65.

Farhi, E. & Tirole, J. (2012). Collective Moral Hazard, Maturity Mismatch, and Systemic Bailouts. American Economic Review, 102 (1), 60-93.

Fed (Board of Governors of the Federal Reserve System) (2009a). The Supervisory Capital Assessment Program: Design and Implementation, April 24.

Fed (Board of Governors of the Federal Reserve System) (2009b). The Supervisory Capital Assessment Program: Overview of Results, May 7.

Fed (Board of Governors of the Federal Reserve System) (2011). Comprehensive Capital Analysis and Review: Objectives and Overview, March 18.

Fed (Board of Governors of the Federal Reserve System) (2012). Comprehensive Capital Analysis and Review 2012: Methodology and Results for Stress Scenario Projections, March 13.

Fed (Board of Governors of the Federal Reserve System) (2013a). Capital Analysis and Review 2013: Assessment Framework and Results, March.

Fed (Board of Governors of the Federal Reserve System) (2013b). Dodd-Frank Act Stress Test 2013: Supervisory stress test methodology and results, March.

Fed (Board of Governors of the Federal Reserve System) (2014a). Capital Analysis and Review 2014: Assessment Framework and Results, March.

Fed (Board of Governors of the Federal Reserve System) (2014b). Dodd-Frank Act Stress Test 2014: Supervisory Stress Test Methodology and Results, March.

Fed (Board of Governors of the Federal Reserve System) (2015a). Capital Analysis and Review 2015: Assessment Framework and Results, March.

Fed (Board of Governors of the Federal Reserve System) (2015b). Dodd-Frank Act Stress Test 2014: Supervisory Stress Test Methodology and Results, March.

Fender, I., Gibson, M. S. & Mosser, P. C. (2001). An International Survey of Stress Tests. Current Issues in Economics and Finance, 7 (10), 1-6. Federal Reserve Bank of New York.

Ferguson, R. W. (2003). Vice Chairman Federal Reserve Board, Testimony before the Subcommittee on Domestic and International Monetary Policy, Trade, and Technology. Committee on Financial Services, U.S. House of Representatives, February 27.

Filliben, J. J. (1975). The Probability Plot Correlation Coefficient Test for Normality. Technometrics, 17, 111-117

Foglia, A. (2009). Stress Testing Credit Risk: A Survey of Authorities' Approaches. International Journal of Central Banking, 5 (3), 1-37.

Friedman, M. (1937). The Use of Ranks to Avoid the Assumption of Normality Implicit in the Analysis of Variance. Journal of the American Statistical Association, 32 (200), 675- 701.

FSI (Financial Stability Institute) (2015). FSI Survey: Basel II, 2.5, and III Implementation. BIS: Bank for International Settlements, July.

FSOC (Financial Stability Oversight Council) (2011). Potential Emerging Threats to U.S. Financial Stability, 2011 Annual Report.

Gambacorta, L. (2010). Do Bank Capital and Liquidity Affect Real Economic Activity in the Long Run? A VECM Analysis for the US, BIS, Mimeo.

Gauthier, C., Lehar, A. & Souissi, M. (2012). Macroprudential Capital Requirements and Systemic Risk. Journal of Financial Intermediation, 21 (4), 594-618.

Georg, C. P. (2011). Basel III and Systemic Risk Regulation - What Way Forward? University Jena Working Papers on Global Financial Markets No. 17-2011.

Gerali, A., Neri, S., Sessa, L. & Signoretti, F. M. (2010). Credit and Banking in a DSGE Model of the Euro Area. Journal of Money, Credit and Banking, 42 (6), 107-141.

Gick, W. & Pausch, T. (2012). Persuasion by Stress Testing: Optimal Disclosure of Supervisory Information in the Banking Sector. SSRN.

Giordana, G. & Schumacher, I. (2012). An Empirical Study on the Impact of Basel III Standards on Banks? Default Risk: The Case of Luxembourg, Banque Centrale Du Luxembourg Working Paper No. 79.

Glasserman, P. & Tangirala, G. (2015). Are the Federal Reserve's Stress Test Results Predictable? The Office of Financial Research (OFR) Working Paper Series No. 15-02, March.

Glick, R. (1998). Thoughts on the Origins of the Asia Crisis: Impulses and Propagation Mechanisms. FRBSF Working Paper No. 98-07, September.

Goodhart, C. (2006). A Framework for Assessing Financial Stability? Journal of Banking and Finance, 30 (2006), 3425-3422.

Goodhart, C. (2013). Ratio Controls Need Reconsideration. Journal of Financial Stability, 9 (3), 445-450.

Gordy, M. B. (2003). A Risk-Factor Model Foundation for Ratings-Based Bank Capital Rules. Journal of Financial Intermediation, 12 (3), 199-232.

Gorton, G. (2008). The Panic of 2007. NBER Working Paper No. 14398 (Paper for the Federal Reserve Bank of Kansas City Symposium at Jackson Hole).

Gropp, R., Vesala, J. & Vulpes, G. (2006). Equity and Bond Market Signals as Leading Indicators of Bank Fragility. Journal of Money, Credit and Banking, 38, 399-428.

Haldane, A. G. (2009). Why Banks Failed the Stress Test: The Basis For A Speech Given at the Marcus-Evans Conference on Stress-Testing, 9-10 February.

Haldane, A. G. (2011). Capital Discipline. Speech to the American Economic Association, Denver, CO, 9 January.

Haldane, A. G. & Madouros, V. (2012). The Dog and the Frisbee. Paper Presented at the Federal Reserve Bank of Kansas City's 36th Economic Policy Symposium, "The Changing Policy Landscape", Jackson Hole, Wyoming, 31 August.

Hartlage, A. W. (2012). The Basel III Liquidity Coverage Ratio and Financial Stability. Michigan Law Review, 111, 453-453.

Hendricks, D. (1996). Evaluation of Value-at-Risk Models Using Historical Data. Economic Policy Review, Federal Reserve Bank of New York, April, 39-69.

Hilbers, P. (2001). The IMF/World Bank Financial Sector Assessment Program. Economic Perspective, February.

Hill, N. T., Perry, S. E. & Andes, S. (1996). Evaluating Firms in Financial Distress: An Event History Analysis. Journal of Applied Business Research, 12 (3), 60-71.

Hirtle, B., Kovner, A. & McKay, E. (2014). Becoming More Alike? Comparing Bank and Federal Reserve Stress Test results. Liberty Street Economics, Federal Reserve Bank of New York, July.

Hoenig, T. (2013). Basel III Capital: A Well-Intended Illusion (Speech Delivered to the International Association of Deposit Insurers). Basel, April.

Hoelscher, D. & Quintyn, M. (2003). Managing Systemic Banking Crises. Occasional Paper No. 224, Washington, International Monetary Fund.

Hull, J. & White, A. (1998). Value-at-Risk When Daily Changes in Market Variables Are Not Normally Distributed. The Journal of Derivatives, 5 (3), 9-19.

Hull, J. & White, A. (2000). Valuing Credit Default Swaps: No Counterparty Default Risk. Working Paper, University of Toronto.

Iacoviello, M. (2005). House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle. American Economic Review, 95 (3), 739–764.

Ieda, A., Marumo, K. & Yoshiba, T. (2000). A Simplified Method for Calculating the Credit Risk of Lending Portfolios. Monetary and Economic Studies (a research conference on "New Approaches to Financial Risk Management" sponsored by the Bank of Japan in January and February 2000).

IEO (International Evaluation Office) (2004). Evaluation of the Financial Sector Assessment Program (FSAP). Issues Paper (Prepared by the International Evaluation Office), October.

IIF (Institute of International Finance) (2008). Final Report of the IIF Committee on Market Best Practices: Principles of Conduct and Best Practice Recommendations. Financial Services Industry Response to the Market Turmoil of 2007-2008, July.

IIF (Institute of International Finance) (2011). The Cumulative Impact on the Global Economy of Changes in the Financial Regulatory Framework. IIF: Washington.

IMF (International Monetary Fund) (2004a). Are credit booms in emerging markets a concern? IMF World Economic Outlook, Washington, D.C. April.

IMF (International Monetary Fund) (2004b). Singapore: Financial system stability assessment, including reports on the observance of standards and codes on the following topics: banking supervision, insurance regulation, securities regulation, payment and settlement systems, monetary and financial policy transparency, and anti-money laundering. IMF Country Report No. 04/104, April.

IMF (International Monetary Fund) (2008). Iceland: 2008 Article IV Consultation—Staff Report; Staff Supplement; Public Information Notice on the Executive Board Discussion; and Statement by the Executive Director for Iceland. IMF Country Report No. 08/367, Washington, D.C. December.

IMF (International Monetary Fund) (2009). Thailand: Financial System Stability Assessment. IMF Country Report No. 09/147, May.

IMF (International Monetary Fund) (2010a). Indonesia: Financial System Stability Assessment. IMF Country Report No. 10/288, September.

IMF (International Monetary Fund) (2010b). Philippines: Financial System Stability Assessment Update. IMF Country Report No. 10/90, January.

IMF (International Monetary Fund) (2013a). Fact Sheet. Washington, D.C. September.

IMF (International Monetary Fund) (2013b). Malaysia: Financial Sector Stability Assessment. IMF country report No. 13/52, February.

IMF (International Monetary Fund) (2013c). Singapore: Financial Sector Stability Assessment. IMF Country Report No. 13/325, November.

IMF (International Monetary Fund) (2014a). World Economic Outlook: Legacies, Clouds, Uncertainties. World Economic and Financial Surveys, October.

IMF (International Monetary Fund) (2014b). Malaysia Financial Sector Assessment Program: Financial Sector Performance, Vulnerabilities and Derivatives—Technical Note, IMF Country Report No. 14/98, April.

IMF (International Monetary Fund) (2015a). Indonesia: 2014 Article IV Consultation – Staff Report; Press Release; and Statement by the Executive Director for Indonesia. IMF country report No. 15/74, March.

IMF (International Monetary Fund) (2015b). Malaysia: 2014 Article IV Consultation – Staff Report; Press Release; and Statement by the Executive Director for Malaysia. IMF country report No. 15/58, March.

IMF (International Monetary Fund) (2015c). Philippines: 2015 Article IV Consultation – Staff Report; Press Release; and Statement by the Executive Director for the Philippines. IMF country report No. 15/246, September.

IMF (International Monetary Fund (2015d). Singapore: 2015 Article IV Consultation – Staff Report; Press Release; and Statement by the Executive Director for Singapore. IMF country report No. 15/199, September.

IMF (International Monetary Fund) (2015e). Thailand: 2015 Article IV Consultation – Staff Report; Press Release; and Statement by the Executive Director for Thailand. IMF country report No. 15/114, May.

IMF & World Bank (2003). Analytical tools of the FSAP. Prepared by the staffs of the World Bank and the International Monetary Fund, February.

IMF & World Bank (2005a). Financial Sector Assessment Program—Review, Lessons, and Issues Going Forward. Prepared by the Staffs of the International Monetary Fund and the World Bank, February.

IMF & World Bank (2005b). Financial Sector Assessment: A Handbook. International Monetary Fund and the World Bank.

Jackson, P., Furfine, C., Groeneveld, H., Hancock, D., Jones, D., Perraudin, W., Radecki, L. & Yoneyama, M. (1999). Capital Requirements and Bank Behaviour: The Impact of the Basle Accord. Basle Committee on Banking Supervision Working Papers No. 1, April.

Jarque, C. M. & Bera, A. K. (1987). A Test for Normality of Observations and Regression Residuals. International Statistical Review, 55 (2), 163–172.

Jarrow, R. & Protter, P. (2004). Structural versus Reduced Form Models: A New Information Based Perspective. Journal of Investment Management, 2 (2), 1-10.

Jarrow, R. & Turnbull, S. (1992). Credit Risk: Drawing the Analogy. Risk Magazine 5 (9).

Jarrow, R. & Turnbull, S. (1995). Pricing Derivatives on Financial Securities Subject to Credit Risk. Journal of Finance, 50 (1), 53–85.

Jobst, A. A., Ong, L. L. & Schmieder, C. (2013). An IMF Framework for Macroprudential Bank Solvency Stress Testing: Application to S-25 and other G-20 Country FSAPs. IMF Working Paper No. 13/68 (Washington: International Monetary Fund).

Jones, D. (2000). Emerging Problems with the Basel Capital Accord: Regulatory Capital Arbitrage and Related Issues. Journal of Banking and Finance, 24, 35-58.

Jones, M., Hilbers, P. & Slack, G. (2004). Stress Testing Financial Systems: What to do when the Governor calls. IMF Working paper, WP/04/127, IMF: Washington D.C.

JP Morgan (1996). Risk Metrics. Technical Document (4th edition), Morgan Guaranty Trust Company and Reuters Ltd., New York.

Jorion, P. (2001). Value-at-Risk: The New Benchmark for Controlling Market Risk. 2nd Edition, Chicago: McGraw-Hill.

Kane, G. D., Richardson, F. M. & Mead, N. L. (1998). Rank Transformations and the Prediction of Corporate Failure. Contemporary Accounting Research, 15 (2), 145-166.

Kapan, T. & Minoiu, C. (2013). Balance Sheet Strength and Bank Lending During the Global Financial Crisis. IMF Working Paper 13/102.

Kato, R., Kobayashi, S. & Saita, Y. (2011). Calibrating the Level of Capital: The Way We See it. Journal of Mathematics and System Science, 1 (1), 23-42.

Kealhofer, S. (2003a). Quantifying Credit Risk I: Default Prediction. Financial Analysts Journal, 59 (1), 30-44

Kealhofer, S. (2003b). Quantifying Credit Risk II: Debt Valuation. Financial Analysts Journal, 59 (3), 78-92.

Keister, T. & Bech, M. (2012). On the Liquidity Coverage Ratio and Monetary Policy Implementation. BIS Quarterly Review, December, 49-61.

King, M. R. (2010). Mapping Capital and Liquidity Requirements to Bank Lending Spreads. BIS Working Paper No. 324.

Kolmogorov, A. N. (1933). Sulla Determinazione Empirica di Una Legge di Distribuzione. Giorn. Ist. Ital. Attuari, 4, 83-91.

Krenn, G. (2001). Stress Testing by Austrian Banks. In: Financial Stability Report 1. OeNB. 108–116.

Krug, S., Lengnick, M. & Wohltmann, H. W. (2014). The Impact of Basel III on Financial (in) Stability: An Agent-Based Credit Network Approach. Economics Working Paper, Christian-Albrechts-Universität Kiel, Department of Economics, No. 2014-13, December.

Kupiec, P. (1995). Techniques for Verifying the Accuracy of Risk Measurement Models. Journal of Derivatives, 3, 73-84.

Laeven, L. & Valencia, F. (2008). Systemic Banking Crises: A New Database. IMF Working Paper WP/08/224.

Laeven, L. & Valencia, F. (2010). The Resolution of Banking Crises: The Good, the Bad and the Ugly. IMF Working Paper WP/10/146.

Lengnick, M., Krug, S. & Wohltmann, H. W. (2013). Money Creation and Financial Instability: An Agent-Based Credit Network Approach, Economics: The Open-Access, Open-Assessment E-Journal, Special Issue on Economic Perspectives Challenging Financialization, Inequality and Crises 7(2013-32).

Levy, H. (1978). Equilibrium in an Imperfect Market: A Constraint on the Number of Securities in a Portfolio. American Economic Review, 68, 643 - 658.

Lintner, J. (1965). The Valuation of Risk Assets and Selection of Risky Investments in Stock Portfolios and Capital Budgets. Review of Economics and Statistics, 47, 13-37.

Locarno, A. (2011). The Macroeconomic Impact of Basel III on the Italian Economy. Questioni di Economia e Finanza, Occasional Papers No. 88, February.

Lopez, J. & Walter, C. (2000). Evaluating Covariance Matrix Forecasts in a Value-at-Risk Framework. Manuscript, Federal Reserve Bank of San Francisco.

Lown, C. & Morgan, D. (2004). The Credit Cycle and the Business Cycle: New Findings Using the Loan Officer Opinion Survey. Research Report from Stockholm Institute for Financial Research, 27, September.

Lugovskaya, L. (2010). Predicting Default of Russian SMEs on the Basis of Financial and Non-Financial Variables. Journal of Financial Services Marketing, 14 (4), 301-313.

MAG (Macroeconomic Assessment Group) (2010). Assessing the Macroeconomic Impact of the Transition to Stronger Capital and Liquidity Requirements. Final Report, Basel Committee on Banking Supervision, December.

MAG (Macroeconomic Assessment Group) (2011). Assessment of the Macroeconomic Impact of Higher Loss Absorbency for Global Systemically Important Banks. Basel Committee on Banking Supervision, October.

Mann, H. B. & Whitney, D. R. (1947). On a Test of Whether One of 2 Random Variables is Stochastically Larger than the other. Annals of Mathematical Statistics, 18, 50-60.

Markowitz, H. (1952). Portfolio Selection. Journal of Finance, 7 (1), 77–91.

Markowitz, H. (1959). Portfolio Selection: Efficient Diversification of Investments. Cowles Foundation Monograph No. 16. New York: John Wiley & Sons, Inc.

Merton, R. C. (1972). An Analytic Derivation of the Efficient Portfolio Frontier. Journal of Financial and Quantitative Analysis, 7, 1851-1872.

Merton, R. C. (1973a). An Intertemporal Capital Asset Pricing Model. Econometrica, 41 (5), 867-887.

Merton, R. C. (1973b). Theory of Rational Option Pricing. The Bell Journal of Economics and Management Science, 4 (1), 141-183.

Merton, R. C. (1974). On the Pricing of Corporate Debt: The Risk Structure of Interest Rates. Journal of Finance, 29 (2), 449-470.

Merton, R. C. (1987). A Simple Model of Capital Market Equilibrium with Incomplete Information. Journal of Finance, 42 (3), 483-510.

Miles, D., Yang, J. & Marcheggiano, G. (2012). Optimal Bank Capital. The Economic Journal, 123 (567), 1-37.

Miller, M. H., & Modigliani, F. (1961). Dividend Policy, Growth and the Valuation of Shares. The Journal of Business, 34 (4), 411-433.

Milne, A. (2013). Register, Cap and Trade: A Proposal for Containing Systemic Liquidity Risk, Economics. The Open-Access, Open-Assessment E-Journal, 7 (2013-7).

Modigliani, F. & Miller, M. H. (1958). The Cost of Capital, Corporation Finance and the Theory of Investment. American Economic Review, 48 (3), 261-297.

Modigliani, F. & Miller, M. H. (1963). Corporate Income Taxes and the Cost of Capital: A Correction. The American Economic Review, 53 (3), 433-443.

Morgan, D. P., Peristiani, S. & Savino, V. (2010). The Information Value of the Stress Test and Bank Opacity. Federal Reserve Bank of New York Staff Reports No. 460.

Mossin, J. (1966). Equilibrium in a Capital Asset Market. Econometrica, 34 (4), 768–783.

Nachar, N. (2008). The Mann-Whitney U: A Test for Assessing Whether Two Independent Samples Come From the Same Distribution. Tutorials in Quantitative Methods for Psychology, 4 (1), 13-20.

Nelson, D. (1991). Conditional Heteroskedasticity in Asset Returns: A New Approach. Econometrics.

Nier, E., Yang, J., Yorulmazer, T. & Alentorn, A. (2008). Network Models and Financial Stability. Working Paper No. 346, Bank of England, April.

Norton, J. O. (2013). A More Prominent Role for the Leverage Ratio in the Capital Framework. Remarks by FDIC Director Jeremiah O. Norton to the Florida Bankers Association Orlando, Florida, February.

Obstfeld, M. & Taylor, A. (1998). The Great Depression as a Watershed: International Capital Mobility over the Long Run. In Bordo, M. D., Goldin, C., and N. White, E. N. (Eds.). The Defining Moment: The Great Depression and the American Economy in the Twentieth Century, University of Chicago Press.

OE (Oxford Economics) (2013). Analyzing the Impact of Bank Capital and Liquidity Regulations on US Economic Growth (A report prepared for the Clearing House Association), April.

Ong, L. L. & Pazarbasioglu, C. (2013). Credibility and Crisis Stress Testing. IMF Working Paper No. 13/178 (Washington, D.C.: International Monetary Fund).

Patel, J. K. & Read, C. B. (1996). Handbook of the Normal Distribution. Dekker, New York.

Petrella, G. & Resti, A. (2013). Supervisors as Information Producers: Do Stress Tests Reduce Bank Opaqueness? Journal of Banking and Finance, 37 (12), 5406-5420.

Reinhart, C. M. & Rogoff, K. S. (2009). Banking crises: An Equal Opportunity Menace. NBER Working Paper No. 14587.

Rodriguez, J. (2002). International Banking Regulation. Where's the Market Discipline in Basel II? Policy Analysis, the Cato Institute, No. 455.

Roger, S. & Vlček, J. (2011). Macroeconomic Cost of Higher Bank Capital and Liquidity Requirements. IMF Working Paper WP/11/103, May.

Ross, S. (1976). Arbitrage Theory of Capital Asset Pricing. Journal of Economic Theory, 13, 341-360.

Rubinstein, M. (2002). Markowitz's "Portfolio Selection": A Fifty-Year Retrospective. The Journal of Finance, 57 (3), 1041-1045.

Samuelson, P. A. (1965). Proof that Properly Anticipated Prices Fluctuate Randomly. Industrial Management Review, 6 (2), 41-49.

Santos, A. O. & Elliott, D. (2012). Assessing the Cost of Financial Regulation. IMF Working Paper WP/12/233.

Saunders, A. & Allen, L. (2002). Credit Risk Measurement. 2nd Ed., New York: John Wiley & Sons, Inc.

Saurina, J. & Trucharte, C. (2007). An Assessment of Basel II Procyclicality in Mortgage Portfolios. Journal of Financial Services Research, 32 (1), 81–101.

Schneider, M. & Leibrecht, M. (2006). AQM-06: The Macroeconomic Model of the OeNB. Working Paper No. 132, OeNB.

Schuermann, T. (2012). Stress Testing Banks. Oliver Wyman and Wharton Financial Institutions Center.

Schwartz, A. (2009). Original of the Financial Market Crisis of 2008. Cato Journal, 29 (1), 19-23.

Schwartz, R. J. & Smith, C. W. (1990). The Handbook of Currency and Interest Rate Risk Management. New York Institute of Finance, New York.

Shapiro, S. S. & Wilk, M. B. (1965). An Analysis Of Variance Test for Normality (Complete Samples). Biometrika, 52, 591–611.

Sharpe, W. (1964). Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk. Journal of Finance, 19 (3), 425–442.

Sharpe, W. (1990). Capital Asset Prices With and Without Negative Holdings. Nobel lecture. Stanford University Graduate School of Business, Stanford, December.

Sheng, A. (2013). Basel III and Asia. Finance Working Paper, Fung Global Institute.

Siregar, R. (2011). Macro-Prudential Approaches to Banking Regulation: Perspectives of Selected Asian Central Banks. ADBI Working Paper Series No. 325, November.

Slovik, P. & Cournède, B. (2011). Macroeconomic Impact of Basel III. OECD Economics Department Working Papers No. 844, OECD Publishing.

Sorge, M. (2004). Stress testing financial systems: An overview of current methodologies. BIS Working Papers No. 165, December.

Sprenkle, C. (1961). Warrant Prices as Indications of Expectations. Yale Econ. Essays 1, 179-232. Reprinted in Cootner (1967), 412-74.

Šútorová, B. & Teplý, P. (2013). The Impact of Basel III on Lending Rates of EU Banks. Finance a úvěr-Czech Journal of Economics and Finance, 63 (3), 226-243

Swiston, A. (2008). A US Financial Conditions Index: Putting Credit Where Credit is Due", IMF Working Paper, No. WP/08/161.

Tam, K. Y. & Kiang, M. Y. (1992). Managerial Applications of Neural Networks: The Case of Bank Failure Predictions. Management Science, 38 (7), 926-947.

Tarashev, N. & Zhu, H. (2008). Specification and Calibration Errors in Measures of Portfolio Credit Risk: The Case of the ASRF Model. International Journal of Central Banking, 4 (2), 129-173.

Tarullo, D. K. (2010). Lessons from the Crisis Stress Tests. Speech at the Federal Reserve Board International Research Forum on Monetary Policy, March 26.

Tobin, J. (1958). Liquidity Preference as Behavior towards Risk. The Review of Economic Studies, 25 (2), 65-86.

Treynor, J. L. (1965). How to Rate the Performance of Mutual Funds. Harvard Business Review, January/February, 43 (1), 63–75.

Tudela, M. & Young, G. (2003). A Merton Model Approach to Assessing the Default Risk of UK Public Companies. Financial Stability Workshop, Bank of England, January.

Vasicek, O. (1984). Credit Valuation. White Paper, Moody's KMV.

Van den End, J. W. & Tabbae, M. (2012). When Liquidity Risk Becomes a Systemic Issue: Empirical Evidence of Bank Behaviour. Journal of Financial Stability, 8 (2), 107-120.

Van den Heuvel, S. (2008). The Welfare Cost of Bank Capital Requirements. Journal of Monetary Economics, 55 (2), 298-320.

Wall, L. (2013). The Adoption of Stress Testing: Why the Basel Capital Measures Were Not Enough. Federal Reserve Bank of Atlanta, Working Paper 2013–14, December.

Wang, T. (2004). Exchange Rate Dynamics. In China's Growth and Integration into the World Economy: Prospects and Challenges, edited by Eswar Prasad, Occasional Paper 232:2128, IMF: Washington D.C.

Wang, Y. & Campbell, M. (2010). Business Failure Prediction for Publicly Listed Companies in China. Journal of Business and Management, 16 (1), 75-88.

Wilcoxon, F. (1945). Individual Comparisons by Ranking Methods. Biometrics Bulletin, 1 (6), 80-83.

World Bank (2006). Financial Sector Assessment Program: IEG Review of the Joint World Bank and IMF Initiative. Washington, D.C.

Yan, M., Hall, M. J. B. & Turner, P. (2011). A Cost-Benefit Analysis of Basel III: Some Evidence from the UK. Discussion Paper Series WP 2011 – 05, Loughborough University.

Yellen, J. L. (2014). Monetary Policy and Financial Stability. Text of the 2014 Michel Camdessus Central Banking Lecture by Ms. Janet L Yellen, Chair of the Board of Governors of the Federal Reserve System, International Monetary Fund, Washington DC, July.

Zandi, M. & Zemcik, P. (2014). Europe's Stress Test: Good, But Not Enough. Economic & Consumer Credit Analytics, Moody's Analytics, October.