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A Macro Stress Testing Framework for Assessing Financial Stability: Evidence from Malaysia*

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Abstract
The main results of the macro stress testing exercise in this paper reveal that Malaysia's banking sector is resilient, well diversified, and highly interconnected. Further, Malaysia has a thriving equity market, large bond market and growing private debt securities. Main results of the baseline scenario suggest a modest change in capital ratios; the post-stress test CAR and Tier 1 capital ratio are -1.64% and -1.38% respectively. The impact of all fundamental shocks on capital ratios under both adverse and severely adverse scenarios is significant. The aggregate capital shortfall in the form of needed capital injection (i.e. cost to the government from failed banks) under adverse scenario is 1.55% of the GDP (or $4.59 billion based on 2015 GDP of $296.22 billion). The capitalization needs became more severe in the severely adverse scenario, $10.52 billion (or 3.55% of 2015 GDP). The important conclusion of the macro stress testing is that no bank failed, faced a liquidation or suspension of license.

1. Introduction

Throughout the 1990s global liquidity glut[1] created an asset boom mania worldwide turning ordinary people into avid buyers. This in turn persuaded large banks[2] in advanced countries and emerging market economies to expand credit offering into very risky segment known as the sub-prime via lax and predatory lending (Schwartz, 2009). Subsequently, banks being at the epicenter of financial intermediation became contributors to imbalances and receivers of adverse impact due to severe pro-cyclicality, on-and off-balance sheet exposures, leverage, and shadow banking. After the failure of micro stress tests, used by large private banks and the supervisory community[3] since the late 1990s, the most recent global financial crisis (GFC) marked the birth of macro stress testing[4] as a crisis management tool (see Fed, 2009a; b).[5]

Propagation of financial crises since the late 1990s has made macro stress testing a central focus for the Bank Negara Malaysia (BNM)[6] to test the resilience of Malaysia's banking sector to extreme but plausible scenarios. Although main results of the macro stress testing exercise revealed only a modest change in capital ratios and bank profitability in the baseline scenario, macroeconomic events such as the taper tantrum of May followed by the August rout in 2013 proved that Malaysia's banking sector and its currency (ringgit)[7] were still not immune to exogenous shocks. The domineering lesson of the global financial crisis (GFC) revealed that banks worldwide gravely failed to differentiate various risk dynamics between structured products and bonds. Other important lessons of the GFC have proved that micro stress tests conducted by banks and supervisory authorities failed to capture risks related to short-term funding liquidity, securitization, interbank contagion and counterparty default (BCBS, 2009).

[1] The global savings glut was mainly fostered by the U.S. Federal Reserve's expansive monetary policies (i.e. cheap dollar) in conjunction with the historically low interest rates in the United States and the Euro area (see Bernanke, 2005).
[2] Prior to the GFC (2008), large internationally active 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*.
[3] Basel Committee on Banking Supervision (BCBS) monitors microprudential stress testing in over 100 countries.
[4] Micro and macro stress testing are not standalone tools nor do they supplement other tools in the macroeconomic toolkit.
[5] The foundation of this article is the research and conclusions contained in my PhD (e.g. Taskinsoy, 2018).
[6] Bank Negara Malaysia (BNM) is Malaysia's central bank.
[7] Bouts of shocks since 2013 rattled markets across the world and caused one of the fastest depreciation of ringgit against major currencies in recent memory (since 2012, ringgit has depreciated as much as 50% of its value against the US dollar).

Stress testing is indispensable, but still not failsafe as a standalone tool to measure financial stability. It is effective when complemented by value-at-risk (VaR) or stressed VaR. Financial crises since the 1980s (i.e. Black Monday of 1987 in the U.S.) have unmistakably shown that stress testing is not an early-warning mechanism; to think of it as one would be ill-advised. Stress tests as part of a bank's comprehensive risk management framework can aid bank executives in the decision-making process and central banks in monetary policy decisions.

Macro stress testing was an arcane topic in finance prior to the GFC which markedly unveiled the banking sector's inability to absorb losses in the event of a high-magnitude crisis. As a result, the use of macro stress tests as a crisis management tool has developed rather rapidly since 2009[8]. The forward-looking aspect of macro stress tests has proved a complement to VaR models[9] to help detect underlying risks and quantify innumerable vulnerabilities within the banking sector and assess its resilience to both endogenous and exogenous shocks under highly adverse market conditions mainly triggered by macroeconomic events. The utmost objective of the macro stress test constructed in this paper is twofold; to safeguard financial stability in Malaysia during both benign and malignant economic times, and to aid prudential policy decisions by its central bank (BNM). A top-down macro stress testing framework (e.g. Čihák, 2007) is constructed to assess the solvency of Malaysia's banks and the resilience of banking sector in a forward-looking manner. Malaysia's stress testing experience began with the IMF's Financial Sector Assessment Program (FSAP)[10] in response to the first systemic[11] Asian crisis of 1997-98 (see Blaschke et al., 2001 for the early examples of stress tests).

Against this background, the aim of this paper is to present the main elements of the stress testing framework by Čihák (2007); we extend on the model by adding macroeconomic

[8] The success of the Supervisory Capital Assessment Program (SCAP), undertaken for the first time by the U.S Federal Reserve (Fed) in 2009, spurred the use of macro stress testing as a crisis management tool (a similar program was taken in parallel by the CEBS and EBA in EU). For details, see Fed (2009), CEBS (2010), and EBA (2011).

[9] VaR is not a standalone tool to measure potential vulnerabilities within the banking sector because VaR results are less reliable under extreme but plausible scenarios. Virtually all VaR models focus on the tail-risk which is the lower quantile of the distribution of the profit and loss (P&Ls) and answer the question of the largest loss over a specified time horizon at a given confidence interval. See Jorion (2001) for a survey of VaR models used.

[10] 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 repeated misleading results such as Iceland FSAP (IMF, 2008) caused loss of credibility and left a long lasting scuff on the unblemished reputation of the IMF and the World Bank.

[11] Systemic crisis is not confined to a single country, the contagion of which spreads fast like an epidemic across multiple countries that the consequential prevalent financial instability impairs the normal functioning of a financial system to the point where many segments of the real economy would suffer materially and financial losses can be so unprecedented.

shocks (i.e. unemployment) for conducting macro stress tests. A top-down (TD) stress testing approach is carried out where the aggregated actual bank data is employed to address two critically important questions: (1) is Malaysia's banking sector as a whole able to withstand the assumed shocks under the two adverse scenarios during the stress testing horizon? (2) What would be the potential cost to Malaysia's government for bailing out failed banks? The Malaysia-wide stress test ("MAST") mainly investigates adverse effects of banks' exposures to credit, interest rate, and foreign exchange risk under extreme but plausible scenarios. The MAST exercise primarily attempts to measure the impact on Malaysia's banking sector using one baseline and two adverse scenarios. The outcomes of the analyses are expressed in terms of capital adequacy (CAR) or government intervention as a percent of GDP.

Our empirical work is based on solid foundations. The theoretical and scientific foundation of the study, empirical support, and 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 Malaysia have been published by the BNM and the multilateral organizations such as the IMF and World Bank. We have used reference points for the risk assessment analyses conducted by the U.S. Federal Reserve, Committee of European Banking Supervisors (CEBS), European Banking Authority (EBA), Financial Services Authority of the UK, Basel Committee on Banking Supervision ("the Basel Committee") plus national supervisors for banking regulation and supervision.

The stress testing horizon of the MAST is three years based on actual bank data from 2013 to 2015, and covers the entire banking sector consisting of 56 entities as deposit takers. The benchmark CAR of 10.5% and the hurdle Tier 1 capital ratio of 6.0% were used. The aggregate CAR and Tier 1 capital ratio prior to the start of MAST were comfortably high; 15.04% and 13.30% respectively. A bank falling below either ratio is considered at the risk of insolvency, and would be required to raise fresh capital in order to comply with the regulatory capital minima. The results of the MAST are expressed in terms of independent variables (CAR and capital injection as a percent of GDP). The key results of the MAST indicate that Malaysia's financial sector is well diversified, highly interconnected and its regulatory and supervisory frameworks are consistently resilient to shocks under acute financial stress.

The stress testing scenarios developed and employed in the MAST are hypothetical rather than forecasts. The baseline scenario follows a normal course of economic activity which is consistent with the latest IMF World Economic Outlook projections for Malaysia (i.e. 5% GDP growth). Both hypothetical but plausible adverse and severely adverse scenarios assume a recession, slower economic recovery, and high unemployment. The main results of the MAST are merely indications based on assumptions and trajectories for a number of key variables describing the nature of economic activity in Malaysia which may or may not reflect the views of the BNM, actual developments or market events domestically and globally.

Malaysia has a thriving equity market, a large bond market (the largest within the Association of Southeast Asian Nations – ASEAN-5), and growing private debt securities. Nevertheless, some restrictions still exist in the financial sector where the Malaysian government has a substantial controlling stake including explicit and implicit guarantees. The BNM must have the utmost responsibility as well as accountability to monitor the levels of private corporate and household indebtedness. Excessive leverage in these two segments put strain on banking sectors and cause unbearable burden on households. It is not alarmingly concerning yet, but Malaysia should work proactively towards reducing the level of foreign claims to avoid a deleveraging process in the event of an acute financial distress. Moreover, Malaysia's banking operation abroad (about one-third of the GDP) should be subject to rigorous monitoring, this may require the BNM to initiate cooperation in the host countries to ensure no escaping from its banking regulation and supervision. Despite a growing criticism, some market distortions still exist (i.e. tax incentives are provided for the Islamic finance); the BNM needs to eliminate such deficiencies and on a regular basis improve both quality and quantity of capital.

1.1 A Historical Perspective on Financial Stability

Financial crises are not instant; on the contrary, they evolve over time via manifestations of protracted (nocuous at times) interactions with linkages between bank intermediation and the broader economy. Financial instability and ensuing crises can stem from a wide spectrum of sources involving an amalgam of high-magnitude events that are complex, multifaceted, and systemic in nature (Claessens & Kose, 2013). Crockett (1997) asserts that monetary and financial stability are the two integral components of a normal-functioning financial system,

Borio (2003) calls it *"twin stability"*. Alternatively, Minsky (1975) strongly argues that cyclical excesses leads to financial instability (i.e. the Fed's expansive monetary stand). Monetarists Friedman and Schwartz (1963), Eichengreen (2002), Bernanke and Gertler (1995) believe that both policy errors and ineffective policy decisions may foster financial instability.

It would be edifying to look at the past century. The world trade (1870-1910), underpinned by the classical gold standard[12], was hugely disrupted by World War-I (WWI) that changed the power structure in Europe and re-defined the pattern of world trade. At the turn of the 19th century (1890s) before the United States entered the scene of dominance, the power structure in Europe was shared by Germany, France, and Britain who were each other's chief enemy. Prolongation of the protectionist policies, currency blocks, and restricted trade zones put in place by each of these major powers elicited constant rivalries among them which are regarded as causal contributors to the sudden eruption of WWI; and severe consequences emanated from the unresolved issues of WWI eventually led to the outbreak of World War II.

The adequate supply of gold, on-and-off, had been a problem in the classical gold standard; as a solution, this was replaced by a gold exchange making the British sterling and the U.S. dollar as reserve currencies for gold shortage (Eichengreen & Irwin, 2010a; Estevadeordal et al., 2003; and Lopez-Cordova & Meissner, 2003). Unresolved issues of WWI culminated in the banking crisis triggered by speculative attacks on British pound subsequently forced Britain to leave the gold standard in 1931. Among many others, Bernanke and James (1991) and Eichengreen (2003) strongly argue that Britain's decision to drop gold arguably contributed to the Great Depression[13] which forced countries (the U.S. in particular) to pass isolationist "*beggar-the-neighbor*"[14] policies that severely disrupted the world trade in the 1930s.[15]

[12] The gold standard was officially inaugurated in 1844 by the British Empire which marked the new beginning in trade where British pound sterling was fully backed by gold. By 1908, most countries adopted gold standard, but after Britain dropping gold standard in 1931, countries in Europe were off-gold by 1936 (see Kindleberger & Alibar 2005).
[13] The Great Depression has been described as "…by far the worst catastrophe of the 20th century" (Wheelock, 2007).
[14] These isolationist policies were passed by countries to resolve their own economic problems at the expense of other nations. The United States passed more policies in this nature in the 1930s than any country (Eichengreen & Irwin, 2010b).
[15] However, Monetarists Friedman and Schwartz (1963) provide a compelling argument that falling money stock in the U.S was the driving force behind the severe contraction in consumption that in turn caused a chain reaction for the steady state output to plummet (more than 30%), prices to free-fall (more than half), unemployment to soar (25% of Americans out of a job), and thousands of banks to fail. These unfolding events actually caused the Great Depression of the 1930s.

In the U.S., the dark and devious side of investment banking activities of commercial banks (e.g. Lardner, 2009) leading up to the Great Depression made investors and the American public lose trust in the entire financial system (Crawford, 2011; Mester, 1996). To restore confidence, the U.S. authorities quickly responded to the outcry by the American public with the passage of the Glass-Steagall Act (or the Banking Act of 1933) which was drafted by US Senator Carter Glass and Representative Henry Steagall.[16] The motivation behind the act was to make the banking system in the United States more resilient through two important objectives; the separation of commercial banking from investment banking to ensure that banks' assets were not used inappropriately by diverting funds into some other speculative purposes (commercial banks were barred from underwriting securities); second, create an independent Federal Deposit Insurance Corp. (FDIC) under the Federal Reserve; previously, the Office of Comptroller of the Currency (OCC) was in charge of national bank liquidations.

After WWII broke out in September 1939, Harry Dexter White (the U.S.) and John Maynard Keynes (the UK) began working on respective monetary plans in the outset of 1940.[17] The Bretton Woods Conference (1944) gave birth to a new monetary system proposed by the U.S. and its decision to establish the International Monetary Fund (IMF) and the World Bank. Although Keynes strongly argued against the use of a fixed exchange rate regime pegged to the U.S. dollar (Helpman 1981), his proposal of a supranational currency and the creation of two watchdog institutions were overwhelmingly rejected (Schumacher, 1943). With the US dollar as the new reserve currency marked the beginning of U.S. hegemony, and many fixed currencies became free-floating (see Ruggie, 1982). In the aftermath of WWII, the U.S. was by far the most dominant[18] industrial power in the world, provided that no competition from the war-devastated Europe and Japan which were completely destroyed by the war.

[16] After the Federal Reserve failed to avoid the Great Depression; the Federal Deposit Insurance Corporation (FDIC) was established and Social Security System was initiated. Also, the first national minimum wage law was ratified, and the federal government spending rose from 3% of GDP then to 10%, now 20% (Wheelock, 2007).

[17] Keynes *("Baron Keynes"*), the distinguished economist and leader of the British delegation at the Bretton Woods Conference in 1944, publicly criticized White's plan for its narrow focus on unresolved issues and immediate postwar problems such as Germany's reparations from WWI, undisrupted world trade, and unrestricted currencies.

[18] The U.S. nearly produced two-thirds of the world's total manufacturing output helped by almost full employment (see Becker, 1964; Keesing, 1966). Extraordinary production capacity and output transformed the U.S. from a net importer (historically) to a net exporter in the late 1940s (Branson et al., 1980).

While different monetary proposals of the Bretton Woods system (e.g. Moggridge, 1980) were being drafted at the onset of 1940, ASEAN-5[19] countries were colonized or occupied by foreign powers. Furthermore, each founding member of the ASEAN-5 was invaded by Japan during WWII (1942-45). For instance, Indonesia was colonized by the Dutch (the 1800s-1945), Malaysia by the British (1824-1946), and the Philippines by the Americans (1898-1946). Interestingly, Thailand had never been colonized but instead faced several military dictatorships for four decades (1932-73). In the post WWII era, ASEAN-5 nations one after another declared independency starting with Indonesia in August 17, 1945; Philippines in July 4, 1946; Malaysia in August 31, 1957.[20]; and Singapore in August 9, 1965.[21]

Economists and historians suggest that the Bretton Woods system was destined to fail due to unrealistic promises and many overlooked issues (governance).[22] The foreseen collapse of the Bretton Woods system resulted in significant volatility in major foreign exchange markets in the 1970s (see Mundell & Swoboda, 1969 for monetary problems). This quickly turned into a worldwide financial turmoil in the wake of two other high-magnitude events causing enormous disruptions to the world trade and financial stability. First was the Yom Kippur War[23] (1973) and ensuing oil crisis (1974-78); the second event was the closure and forced liquidation of Germany's Cologne-based Bankhaus Herstatt (1974).[24] These macro events and their farfetched implications resulted in unprecedented spikes in commodity prices by the mid-1970s during which the prices of both gold and oil broke records.[25] Hazlitt (1984) argues that the instability episodes were the "…consequence of the inherently inflationary institutions set up in 1944" (i.e. the IMF and the World Bank) and the Bretton Woods system

[19] ASEAN-5 stands for the Association of Southeast Asian Nations (the five founding member-nations in alphabetical order are; Indonesia, Malaysia, Philippines, Singapore, and Thailand).
[20] Malaysia was formed in 1963 consisting of one-third of Borneo, Sabah, Sarawak, and Singapore; however, Singapore was forced to withdraw from the federation in 1965, which in the same year declared its independency.
[21] Singapore's decision to separate from Malaysia to become an independent sovereign state was the result of a long lasting political tensions between the two countries' ruling parties. There were also deep economic differences between them.
[22] See Siklos (2013) for issues with the international financial regulation.
[23] This was a follow-up retaliation by the Egyptian and Syrian forces to win back territory lost to Israel during the Arab-Israeli war in 1967. Each side claimed victories but in reality the Yom Kippur war was a disaster for Syria.
[24] The sudden bankruptcy of a small privately-owned Bankhaus Herstatt in June 1974 is a famous as well as a shocking incident that clearly illustrated the settlement risk in foreign exchange payments, plus ignored regulatory issues.
[25] OPEC sharply raised oil prices during 1973-74 to show its strong disapproval of the U.S. aid to Israel during the war. By March 1974, the price of oil rose from $3/barrel to $12/barrel. The price of gold rose from $44/ounce in 1972 to $185 in 1975 (see Kindleberger & Alibar, 2005 for the reasons behind the huge spike).

"…not only permits and encourages but almost compels world inflation". Dooley et al. (2004) stress that "Bretton Woods system does not evolve; it just occasionally reloads a periphery".

The severity of financial and political turbulence in the 1970s fostered by the aforementioned instability-inflicting events forced the G-10 Governors[26] to engage in financial collaboration and cooperation, which gave an imminent birth to the creation of the Basel Committee on Banking Supervision in 1974. To converge the existing disparate capital standards across G-10, the Basel Committee published the 1988 Capital Accord (known as Basel I), *"International Convergence of Capital Measurement and Capital Standards"* (BCBS, 1988). Elizalde (2007) and Jones (2000) criticize Basel I for not only ushering riskier lending but encouraging capital arbitrage. Ferguson (2003) emphasizes that "Basel I Accord is too simplistic to adequately address the activities of our most complex banking institutions". Jackson et al. (1999) argue that Basel I is another undue regulatory taxation imposed on banks.[27]

The drawback of Basel I was that it predominantly focused on credit risk while ignoring other important elements such as the supervisory review process and market discipline. To correct the overly criticized flaws of Basel I, and more specifically, to increase the sensitiveness to risk, the Basel Committee published a new revised framework in June 2004 (known as Basel II), fully implemented by the end of 2006: *"International Convergence of Capital Measurement and Capital Standards: A Revised Framework"* (see BCBS, 2004 for details). On the contrary to expectations, Basel II further augmented procyclicality and turned *too-big-to-fail* banks into *bigger-and harder-to-fail* banks. Moreover, Basel II allowed the creation of shadow banking by giving large banks incentives to move assets off their balance sheets. Probably the worst effect of Basel II was to make banks overly rely on the external credit assessment institutions (ECAIs) ratings for decisions on audit frequency, dividend payout, and deposit rates. This last point in turn made banks feel the least urgency to allocate funds to strengthen their existing risk-management frameworks or develop far better ones.

[26] From Belgium, Canada, France, Germany, Italy, Japan, Netherlands, Sweden, Switzerland, the UK, and the United States.
[27] Five arbitrary risk weighting categories and corresponding risk buckets (0%, 10%, 20%, 50%, and 100%) under Basel I for credit risk had adverse effects on financial sectors of the ASEAN-5 prior to the Asian crisis (see BCBS, 1999a;b).

Each milestone in the stress testing evolution has often corresponded with financial crises since the late 1990s, and the introduction of Basel Accords (II and III) followed a similar path during the same period. Once an arcane topic but now a common household name, micro stress testing has gained prominence in the late 1990s, but macro stress testing has become indispensable as a crisis management tool on account of the 2008 credit crisis (GFC). Details of the earlier stress testing practices employed by banks and regulatory supervisors and this paper's topic macro stress testing will be covered in the *Literature Review* section.

2. Literature Review

In the post Second War (WWII) era, financial markets were relatively small and the coverage for pure financial risk was in infancy stages. Insurance policy was predominantly used as a protection against financial losses resulting from work related incidents or environmental catastrophes. The publication of the five seminal papers[28] instigated the evolution of finance to accelerate at a remarkable pace. Prior to the Asian crisis of 1997-98, intensifying financial turmoil by the mid-1990s prompted the Basel Committee to release the 1996 *market risk Amendment* to Basel I (BCBS 1996a; b) requiring large banks to use *backtesting*. However the deficiencies and imperfect signals generated by backtesting (Campbell, 2005), stress testing became a mainstay when banks with substantial trading volumes were required to use stress testing to confirm the accuracy of VaR, Jorion (2001) calls this process "*a reality check*".[29]

The typology of stress testing is categorized along two dimensions: micro-prudential and macro-prudential. Microprudential stress testing[30] (BU: bottom-up) is employed by banks for internal risk management purposes and by regulatory supervisors for *pillar II solvency*. Macroprudential stress testing (both BU and TD: top-down) is employed by central banks and the supervisory community for assessing the entire financial system and by the IMF for country-level surveillance. Starting with the Supervisory Capital Assessment Program of the

[28] Markowitz's (1952, 1959) portfolio theory (mean-variance criterion); Modigliani-Miller's (1958) irrelevance and arbitrage-reasoning; Sharpe's (1964) Capital Asset Pricing Model (CAPM); Black and Scholes' (1973) option pricing formula; and Merton's (1974) pricing of corporate debt (arbitrage-based pricing model).

[29] Interested readers can further read studies such as CGFS (2000, 2001, and 2005) that surveyed major and large financial institutions for their uses of earlier stress testing (i.e. microprudential).

[30] The Basel Committee required banks to use internally designed stress tests in the late 1990s and the use of micro stress testing became mandatory under Basel II; under Basel III, banks are required to use enhanced stress testing approaches.

U.S. 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 stage and not linked to bank solvency.

Greenspan (1998), the US Fed Chairman then, in his testimony to the U.S. Congress on January 26 warned that "…significant mistakes in macroeconomic policy also reverberate around the world at a prodigious pace''. Asian crisis of 1997-98 may have been the inevitable outcome of such policies' adverse effects; Alan Greenspan indicated in 1998 that foreign investors in Asian equities (excluding those in Japan) lost an estimated $700 billion-including $30 billion by American investors (Nanto, 1998). Throughout the 1990s, macro events' massive costs to economies prompted the IMF and the World Bank jointly to initiate the FSAP in 1999.[31] Even though Malaysia now conducts its own micro and macro stress tests, it underwent its first macro stress testing experience via FSAP. The main results of Malaysia's latest FSAP indicate that its economy is robust with a sound financial system helped by a continued flow of funds amid the GFC, but there has been a slow and persistent deterioration since 2013. High levels of public finances, overexpansion of credit and excessive household debt are disquieting, plus the subdued inflation has moved up after the minimum wage law in 2013 (IMF, 2014).

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). 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; (3) an assessment of the existing, laws, rules, codes, regulation, and banking supervision. Although the IMF's 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's 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; IMF & World Bank, 2005a; b for the lessons learned).[32]

[31] 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.
[32] An extensive review of the program's processes was initiated after overhauling of banking systems (i.e. Irish bank system) and collapsing banks (i.e. Belgium's Dexia) shortly after passing FSAPs and EU-wide stress tests in 2010 and 2011.

The contemporaneous financial crises in the new millennium have unmistakably proved that individual banks' micro stress tests for the internal risk management purposes had serious deficiencies; they were both inadequate (not bank-wide) and insufficient (light scenarios generated results by design) to prevent a high-magnitude financial crisis similar to the GFC. The Committee on the Global Financial System (CGFS)[33] investigated the use of stress tests through 424 stress tests performed by 43 large internationally active banks and securities firms from ten countries. The overall conclusion of the CGFS survey reveals the importance of stress testing as a valuable tool to gauge and manage risks (CGFS, 2000). Most frequently used stress testing technique among these institutions in 2000 was the simple sensitivity test to measure the adverse impact of changes in a single risk factor on portfolios or business units. The second popular stress testing technique used was a scenario analysis (i.e. historical or/and hypothetical) to measure risk exposures under extreme but plausible market events. The domineering lesson of the latest global financial meltdown during 2007-08 revealed that banks gravely failed to differentiate common risk dynamics of the modern finance between structured products and bonds; further, micro stress tests conducted by banks and the supervisory authorities failed to capture key risks such as pipeline, securitization, short-term funding liquidity, interbank contagion and counterparty default (see BCBS, 2009 for details).

Another shortcoming of the earlier micro stress tests was that they had a narrow focus in scope and the health of the financial system as a whole or the buildup of systemic risk was never a concern. 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 stress testing literature vividly illustrates that micro stress tests prior to the GFC had weaknesses under extreme market conditions and the not have the sufficient capacity to cope with the subsequent unfolding events. According to the Basel Committee, this huge oversight on the part of financial authorities contributed to the intensity of the GFC (e.g. BCBS, 2009). In the post-GFC (since 2009), macro stress testing as a crisis management tool is used virtually by all central banks to measure financial stability

[33] 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.

and systemic risk. To date, IMF has completed about 130 of 188 member-FSAPs, but it is a slow-moving process. As an improvement, the IMF has expanded its initial goal of one FSAP per month to 24 FSAPs per year, but the current rate is still 17 to 19 per year (IMF, 2004).

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. On that note, the US, Indonesia, and Malaysia did not undergo nor requested to participate in an FSAP prior to the GFC. Malaysia initially refused to participate in the IMF administered program due to its resentments towards the IMF's policy responses handling the Asian crisis. A widely perceived belief suggests that interest rate hikes along with inappropriate fiscal measures of the IMF during and in the aftermath of the Asian crisis acted as a crisis' intensifier role causing further turmoil in Malaysia's economy. Many argue 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. IMF defended its actions by arguing that policy choices were limited without alternatives.[34]

The success of the Supervisory Capital Assessment Program (SCAP), undertaken for the first time by the Fed in 2009 spurred the use of macro stress testing by central banks as a crisis management tool (see Fed, 2009a for design and implementation; 2009b for results details). In stark contrast to the US, Europe bungled with its first two macro stress tests designed and conducted by the CEBS (2010) and its successor EBA (2011). The SCAP was informative, which provided credible and market-demanded information regarding the projected post-stress losses (Bernanke, 2013). However, results of the EU-wide stress tests conducted by the CEBS and the EBA were widely perceived as insufficiently granular. According to Ellahie (2012), the stress test conducted by the CEBS, in most part, was uninformative and its partial disclosure caused a decline in equity values in Europe (CEBS, 2010). Beltratti (2011) believes that the EBA's macro stress test in 2011 had issues as well but it was nonetheless informative in terms of methodologies and scenarios used. 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

[34] The GFC has proved that the predecessors of Basel III (i.e. I & II) along with microprudential stress testing used by banks, supervisors, and multilateral organizations failed gravely to strengthen the resilience of the global financial system.

attributes of the SCAP was a backstop (i.e. temporary financial relief) provided by the U.S. Treasury which enabled the regulatory supervisors to identify the tail risks better.

Bernanke (2013) states 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, 2010). 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). 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). The Basel Committee stresses that both BU and TD approaches should be used to capture second-round liquidity and systemic effects (BCBS, 2013).

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 has escaped the severe consequences of the GFC with a minor dent in its economy. Malaysia's financial sector went through great transformation since the Asian crisis. Asia's systemically induced home-grown crisis in the late 1990s forced Malaysia to initiate widespread micro and macro-prudential reforms. The end result of the relentless efforts is a strengthened financial sector complemented by a rigorous regulatory and supervisory frameworks. The stress tests conducted by both BNM and IMF indicate that Malaysia's banking system is well capitalized, therefore it is resilient to withstand economic and market shocks, but not absent from risks. Malaysian banks' heavy reliance on demand deposits increases liquidity risk, rising household debt increases default risk (IMF, 2013).

Despite a decade-long highly praised micro and macroprudential reforms introduced by BNM and other government authorities, the farfetched implications of the GFC clearly proved that Malaysia is still disquietingly susceptible to developments in G-2 (the U.S. and EU). 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 Malaysia's equity market and made its currency (ringgit) plummet against the dollar, in fact ringgit's depreciation against dollar was the fastest in 17 years. Other macro events such as the slow-growth path of China, global imbalances, accommodative monetary policies and reemerged weaknesses in the Euro area contribute to the volatility.

Malaysia's well-diversified economy is expected to experience a noticeable decline; low oil and gas prices will keep inflationary pressures subdued and cause a sizable reduction in the current account surplus. However, revenue loss due to lower commodity prices is expected to be offset by the elimination of the oil subsidies and manufacturing exports favored by a weaker exchange. Surging house prices and fast rising household debt in Malaysia remain to pose a threat to financial stability, this may even lead to the formation of a real estate bubble. Although rising real interest rates globally will curb the growth of financial risks eventually, enhanced stress tests along with macroprudential measures may be necessary (IMF, 2015).

3. Research Method

Since the banking operation is at the epicenter of any financial intermediation, there is no perfect substitute for it in capital markets; thus, the broader economic activity is adversely affected during financial turmoil. In the aftermath of the most unprecedented global financial crisis of 2007-08, the BNM has used macro stress testing as a measure of financial crisis. Malaysia-wide stress test ("MAST") is based on a top-down (TD) stress testing approach consisting of one baseline (not a real stress scenario, mostly used for adjustment purposes) and two adverse scenarios; the main results of all three stress scenarios are informative to central banks, supervisors, bank executives, and academia.

This paper focuses on the macro stress testing of Malaysia's banking sector to assess its resilience to extreme but plausible scenarios (see Figure 1 for the stress testing framework). Some of the main research methods have been utilized; as such, the analysis and synthesis methods, induction, deduction, and analogy. Also, research methods such as factorial and comparative analysis, statistical and mathematical methods are used. For the purpose of an econometric study, specific macroprudential banking data was compiled from various

sources including but not limited to bankscope, central bank databases, World Bank, the IMF FSAPs, Eurostat, the Basel Committee, and individual banks' websites (Taskinsoy, 2018).

The paper follows the stress testing model developed by Čihák (2007); as an improvement, actual bank data is used in the Malaysia-wide stress test 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 of measure is on 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 capital adequacy and capital injection as percentage 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 owned 3.26% or RM84 billion). Domestically incorporated foreign-controlled banks (25) enjoyed 22.26% (or RM520 billion) of the consolidated banking assets. Malaysia's five largest banks account over 70% of the total financial assets, consistent with that in advanced economies (IMF, 2013; 2015).

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;

$$E\left(\tilde{x}_{t+1}\right) = g_1\left\{X^t, Z^t\right\}$$

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;

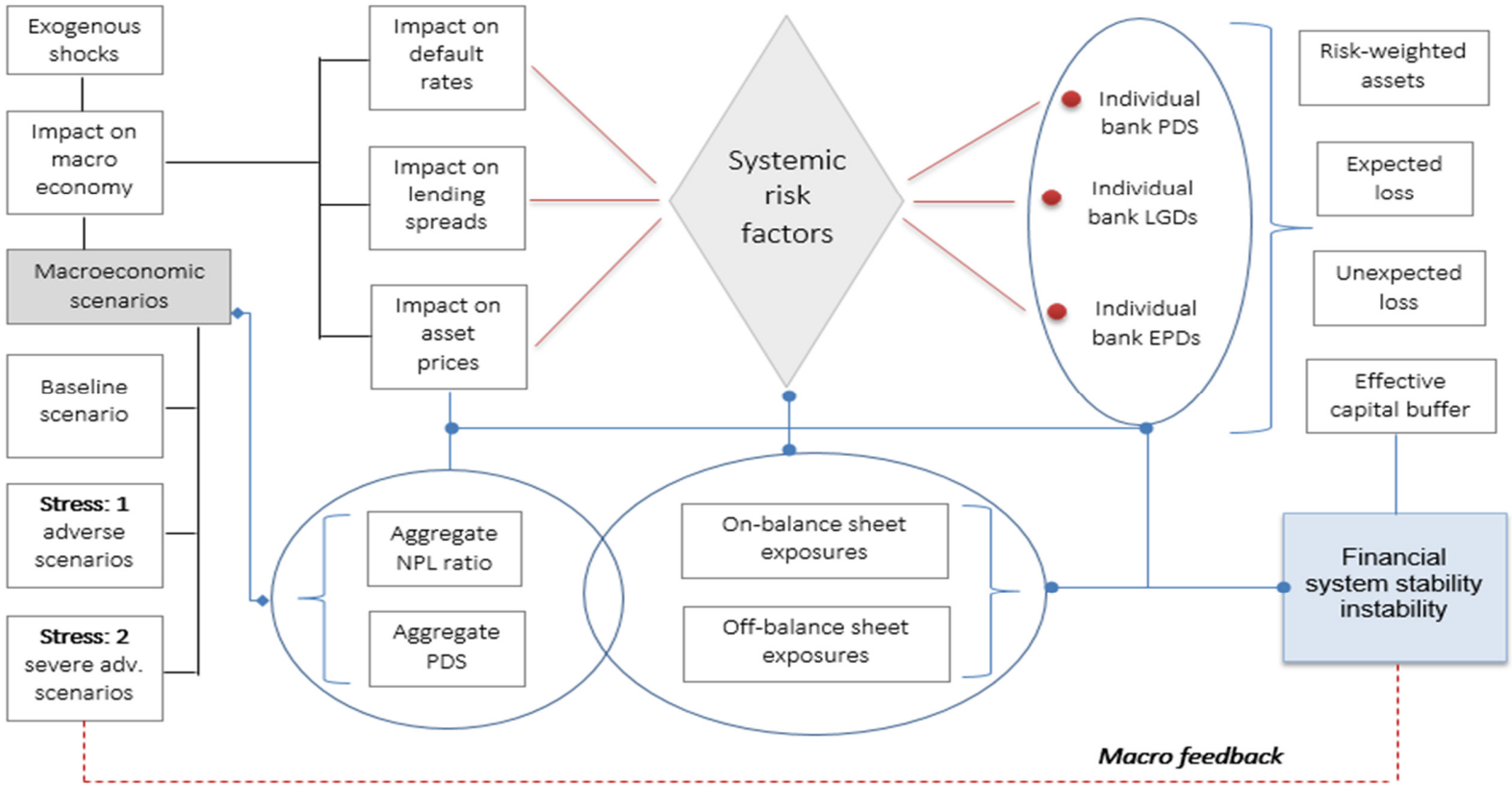
$$P\left(\tilde{x}_{t+1} \geq \bar{x}\right) = g_2\left\{X^t, Z^t\right\}$$

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;

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

Where $\tilde{Y}_{t+1} / \tilde{x}_{t+1} \geq \bar{x}$ is the aggregate measure of the distress of the financial system ($\tilde{Y}_{t+1}$) 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.



Source: Taskinsoy (2018); 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 paper. 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: Overview of Macroprudential Stress Testing Framework

3.1 Measure and Scale of Variables

The macro-financial parameters must meet two conditions of properties (see Table 1); (1) in assessing the soundness of a banking sector, variables should be measurable/quantifiable, interpretable as well as comparable with other variables; (2) variables should be linked to a number of different risk factors so that econometrics, analytical, and statistical analyses can be performed. A list of commonly used variables is adopted from Čihák (2007).

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 viewed as 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:

$$\begin{aligned}&\text{CET1 Ratio} = \text{CET1 Capital} / \text{RWAs} = 4.5\%\\&\text{Tier 1 Capital Ratio} = \text{Total Tier 1 Capital} / \text{RWAs} = 6\%\\&\text{Total Capital Ratio} = (\text{Tier 1 Capital} + \text{Tier 2 Capital}) / \text{RWAs} = 8\%\end{aligned} \quad (3.1.1)$$

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

The capital adequacy ratio (CAR) is used as a key variable and calculated as;

$$\text{CAR} = \text{RC} / (\text{CRWA} + \text{MRWA} + \text{ORWA}) = \text{p (i.e. } 10.5\%) \quad (3.1.2)$$

Where RWA denotes risk-weighted assets (i.e. $\text{RWA} = \sum \text{W}_i\text{A}_\text{i}$); 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 (see Table 2), and p is the minimum CAR used in the paper. The constituents of capital changed significantly from Basel II to Basel III (see Table 3 for the Basel III phase-in arrangements). Capital adequacy and Tier 1 capital ratios are critically important financial stability indicators (FSIs). 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;

$$\text{RWA} = \text{p } (10.50\%) \ * (\text{CRWA} + \text{MRWA} + \text{ORWA}) + \sum \text{W}_\text{i}\text{A}_\text{i} \quad (3.1.3)$$

Table 1: 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.

Table 2: 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.

Table 3: 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, 2010)

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.

Another important variable used in the macro stress testing is the capital injection expressed as a percentage of GDP. When a bank falls below the hurdle rate (i.e. CAR of 10.5% or 6% of Tier 1 capital ratio), 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.

$$\rho = \frac{C + I}{RWA + qI} \tag{3.1.4}$$

Where C denotes the bank's current regulatory capital, RWAs are the existing risk-weighted assets (i.e. RWA = 8% * (market risk + operational risk) + $\sum W_i A_i$), 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 = 10.5% of RWAs).

$$I = \frac{\rho\ RWA - C}{1 - q\rho} \qquad \text{If } C < \rho\ RWA;\ I = 0 \text{ otherwise} \tag{3.1.5}$$

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.

3.2 Credit Risk in the MAST

At the heart of the traditional banking business lies credit risk, which is the primary risk of default by firms and counterparties. Four stress shocks are applied to assess credit risk; ***credit shock 1*** is in the baseline scenario. 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 of 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 (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. The following is based on (Ieda et al., 2000);

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

$$L = \sum_{i=1}^{n} D_i v_i (1 - r_i) \qquad D_i = \begin{cases} 1 & (\text{Probability } P_i) \\ 0 & (\text{Probability } 1 - P_i) \end{cases} \tag{3.2.1}$$

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. If the loss is an indiscrete value, the expected value for L;

$$E[L] = \sum_{i=1}^{n} P_i v_i (1 - r_i) \tag{3.2.2}$$

Where E denotes the expected value for L; differently than in equation (3.2.1), 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:

$$\text{Exposure at default under SA} = \text{EAD} = \text{alpha} * (\text{RC} + \text{PFE}) \tag{3.2.3}$$

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 to satisfy margin call (BCBS, 2014).

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

$$AE(c,t) = \max\{0, V(c,t)\} \quad (3.2.4)$$

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), at time τ which is between t and maturity (T):

$$PE(c,t) = max\{0, max_{t<\tau\leq T}\{PV_t[V(c,\tau)]-V(c,t)\}\} \quad (3.2.5)$$

Where $PV_t(*)$ 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;

$$TE(c,t) = AE(c,t) + PE(c,t) \quad (3.2.6)$$

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

3.3 Interest Rate Risk in the MAST

The paper uses *"gap"* and *"duration"* techniques from (Čihák, 2007) to measure the direct interest rate risk arising from maturity and repricing mismatches. 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.

$$\frac{\Delta A(r_A)}{A(r_A)} \cong \frac{-D_A \Delta r_A}{(1+r_A)} \quad , \frac{\Delta L(r_L)}{L(r_L)} \cong \frac{-D_L \Delta r_L}{(1+r_L)} \quad (3.3.1)$$

Where D_A and D_L represent duration, $A(r_A)$ and $L(r_L)$ are the values of assets and liabilities of the banking sector, and r_A and 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;

$$\frac{\Delta[C(r_A, r_L)/A_{RW}(r_A)]}{\Delta r_A} \cong -\frac{(L/A_{RW})}{1+r_A} \left(D_A - D_L \frac{1+r_A}{1+r_L} \frac{\Delta r_L}{\Delta r_A}\right) \frac{1 - \frac{\Delta A_{RW}}{A_{RW}} \frac{C}{\Delta C}}{1 - \frac{\Delta A}{A} \frac{C}{\Delta C}} \quad (3.3.2)$$

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 3.3.2 can be simplified as;

$$\frac{\Delta[C(r_A, r_L)/A_{RW}(r_A)]}{\Delta r_A} \cong -\frac{(L/A_{RW})}{1+r_A} GAP_D \quad (3.3.3)$$

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

$$GAP_D = D_A - D_L \frac{1+r_A}{1+r_L} \frac{\Delta r_L}{\Delta r_A} \quad (3.3.4)$$

Banks make money by moving low-interest short-term liabilities into long-term higher interest rate assets. 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 $GAP_A > 0$.

3.4 Foreign Exchange Risk in the MAST

As in Čihák (2007), 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 (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: $\Delta e/e = \Delta F/F$, where $F \neq 0$ and $\Delta C/\Delta F = 1$

$$\frac{\Delta[C(e)/A_{RW}(e)]}{\Delta e} \cong \frac{\frac{F}{e}A_{RW} - C\frac{\Delta A_{RW}}{\Delta C}\frac{F}{e}}{A_{RW}^2} \cong \frac{1}{e}\frac{F}{C}\frac{C}{A_{RW}}\left(1 - \frac{\Delta A_{RW}}{\Delta C}\frac{C}{A_{RW}}\right) \quad (3.4.1)$$

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

$$\Delta[\mathrm{C(e)/A_{RW}(e)}] \cong \frac{\Delta e}{e}\frac{F}{C}\frac{C}{A_{RW}}\left(1-\frac{\Delta \mathrm{A_{RW}}}{\Delta \mathrm{C}}\frac{\mathrm{C}}{\mathrm{A_{RW}}}\right) \quad (3.4.2)$$

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 ($\mathrm{C/A_{RW}}$). This is a linear approximation, 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. The BNM imposes 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, indirect foreign exchange risk can arise from a depreciation or appreciation in corporations' assets and liabilities in foreign currencies.

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

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

$$\frac{\Delta[\mathrm{D_c(e)/E_c(e)}]}{\Delta \mathrm{e}} \cong \frac{\frac{\Delta \mathrm{D_c}}{\Delta \mathrm{E_c}}\frac{\mathrm{F_c}}{\mathrm{e}}\mathrm{E_c}-\mathrm{D_c}\frac{\mathrm{F_c}}{\mathrm{e}}}{\mathrm{E_c^2}} \cong -\frac{1}{\mathrm{e}}\frac{\mathrm{F_c}}{\mathrm{E_c}}\left(\frac{\mathrm{D_c}}{\mathrm{E_c}}-\frac{\Delta \mathrm{D_c}}{\Delta \mathrm{E_c}}\right) \quad (3.4.3)$$

The corporate sector's leverage increases if it is in short position and the exchange rate depreciates. 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;

$$\Delta(\mathrm{NPL/TL}) \cong \mathrm{a}\Delta[\mathrm{D_c(e)/E_c(e)}] \cong -\frac{\Delta \mathrm{e}}{\mathrm{e}}\frac{\mathrm{F_c}}{\mathrm{E_c}} \quad (3.4.4)$$

Where $\Delta(\mathrm{NPL/TL})/\Delta(\mathrm{D_c/E_c}) = \mathrm{a} > 0$ when $\Delta \mathrm{D_c}/\mathrm{E_c} = 0$ 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

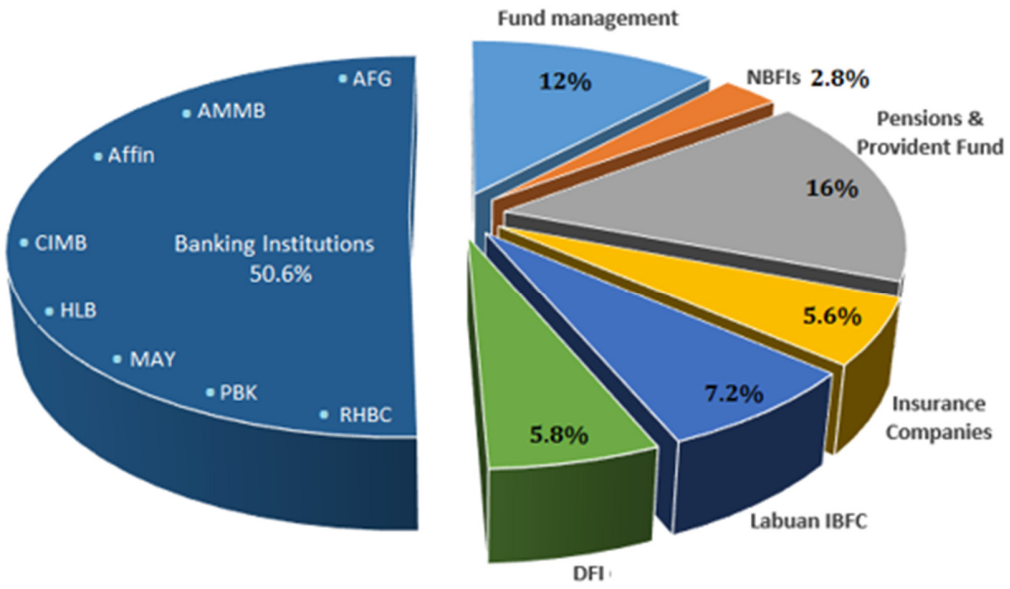
potential of moving the existing performing loans into non-performing category, and to assess the impact on capital, differentiate C/A_{RW} by substituting for NPL/TL in 3.4.4;

$$\Delta\left(\frac{C}{A_{RW}}\right) \cong \frac{\Delta e}{e}\frac{TL}{A_{RW}}\left(1-\frac{C}{A_{RW}}\frac{\Delta A_{RW}}{\Delta C}\right)\pi\frac{F_c}{E_c}\,a\left(\frac{D_c}{E_c}-\frac{\Delta D_c}{\Delta E_c}\right) \quad (3.4.5)$$

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.

4. Results and Discussion

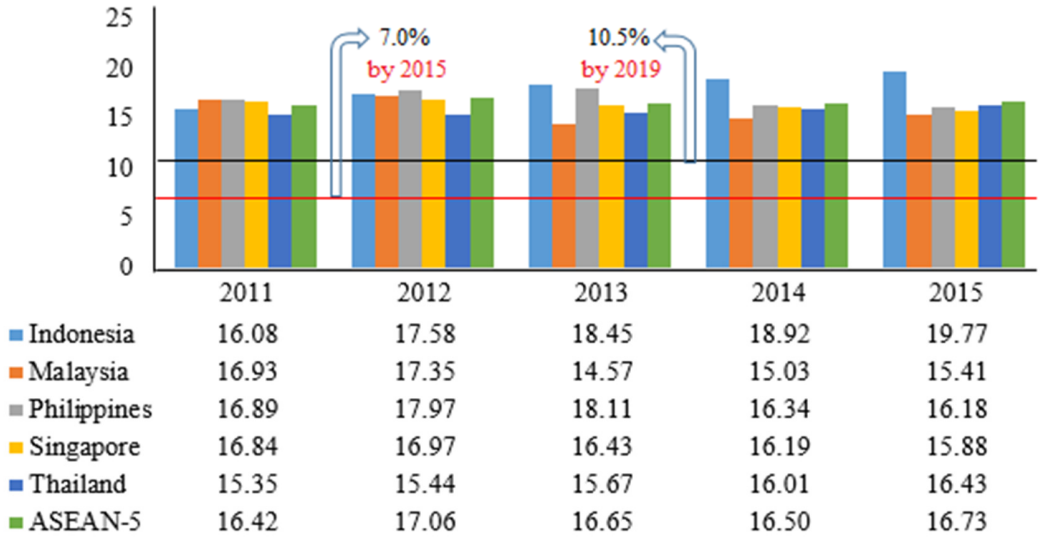
Malaysia's banking sector, in terms of domicile commercial banking groups, is only about one-third of what it was in 1986; after a banking overhaul, the number has been reduced to 8 from 22 in the 1980s (see Figure 2). The banking consolidation was not just confined to banks; other financial and non-financial institutions also underwent consolidation.



Source: Author's analysis; data is from BNM and IMF (2013)

Figure 2: Malaysian Banking Sector Structure (by asset share)

Malaysia's banking sector is well capitalized; the aggregate risk-weighted CAR of 15.41% is an indication that banks are profitable and committed to meeting the Basel III capital minima of 10.5% (8% total capital plus 2.5% capital buffer) before the 2019 deadline (see Figure 3).

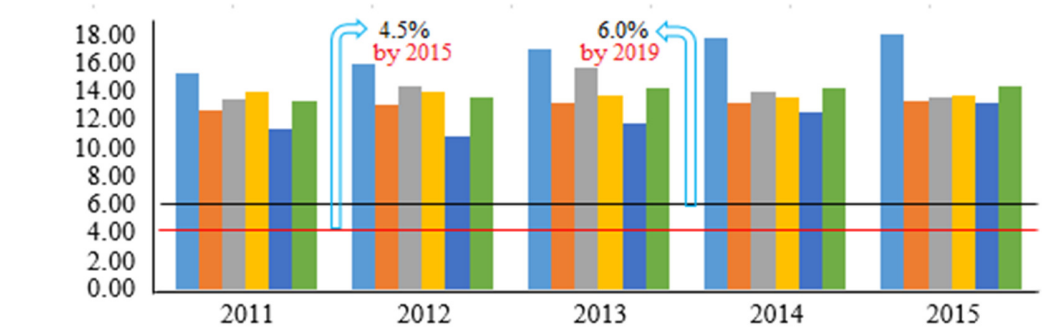


	2011	2012	2013	2014	2015
Indonesia	16.08	17.58	18.45	18.92	19.77
Malaysia	16.93	17.35	14.57	15.03	15.41
Philippines	16.89	17.97	18.11	16.34	16.18
Singapore	16.84	16.97	16.43	16.19	15.88
Thailand	15.35	15.44	15.67	16.01	16.43
ASEAN-5	16.42	17.06	16.65	16.50	16.73

Source: Author's analysis; data is from BNM and IMF (2013)

Figure 3: Pre-Stress Testing Capital Adequacy Ratio (CAR %)

The average CAR of Malaysia's banking sector from 2011 to 2015 is 15.41%. Although this is below the ASEAN-5 average of 16.73%, it is nevertheless at least two percentage points higher than those of banking sectors in advanced economies.



	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 (2013)

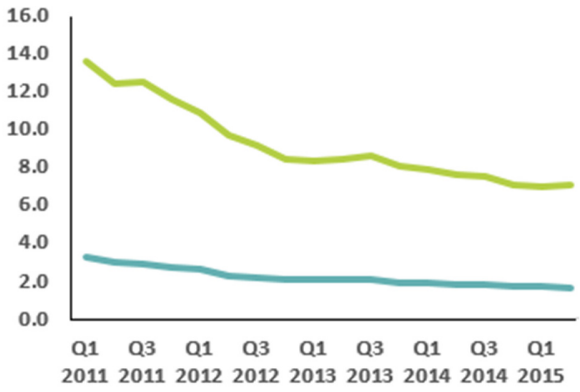
Figure 4: Pre-Stress Testing Tier 1 Capital Ratio (%)

Higher CAR and Tier 1 capital ratio underpinned by the BNM's strong regulation and banking supervision helped Malaysia to escape the GFC with a minor dent in its economy.

Table 4: 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 (2015).



Malaysia's banking sector's gross NPL ratio has dropped consecutively since 2011 (14%), and by 2015, 1.6% NPL is lower than ASEAN-5 average of 2.0%. Any uncovered portion of the NPLs are covered by the collaterals in banks' possession in the event of a default.

The taper tantrum of May and August rout in 2013, the 5th wave[35], have adversely affected Malaysia's financial and macroeconomic indicators and proved that both Malaysia's banking

[35] Asian crisis (1st wave); mortgage debacle of 2006 in the U.S. (2nd wave); the GFC of 2008 (3rd wave); sovereign debt crisis in the euro zone (4th wave).

sector and its currency (ringgit) are still not immune to exogenous shocks. During the past two decades, Malaysia has become ever more susceptible to macro shocks arising from rapid boom-and-bust cycles, excessive corporate leverage, household debt, monetary tightening by the U.S., asset price volatility, and capital flight to safety (i.e. reversal of capital flows).

4.1 Results in the Baseline Scenario

The main results of the MAST in the baseline scenario reveal that Malaysia's regulatory and supervisory frameworks are well-developed. As set out in Table 5, the main results suggest a modest change in capital ratios and bank profitability.

Table 5: Summary of Results in Baseline Scenario (%)

Financial soundness indicators (%)	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

The impact of all fundamental shocks in the post-stress test CAR and Tier 1 capital ratio are -1.64% and -1.38% respectively. Even with these adjustments, CAR and Tier 1 ratios of banks in Malaysia are still higher than the Basel III minimum capital requirements (i.e. 4.5% CET1, 6.0% Tier 1, and 8.0% total capital). The rise in funding costs puts strain on bank profitability, causing ROA and ROE to decline slightly, -0.15% and -2.30% 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. Although a majority of Malaysian banks had sufficient liquidity, the top-down (TD) stress test suggested that some smaller (Islamic) banks may face illiquidity after five days under highly adverse market conditions.

Table 6: Banking Ratios, Ratings, and PDs in Baseline Scenario

All figures are on average covering the stress testing horizon (2013-2015)

Financial soundness indicators	Ratios %	Ratings*	PDs %
Overall	N/A	1.54	3.28
Total capital / RWA (CAR)	13.56	1.13	2.83
Tier 1 capital ratio	11.92	1.05	2.83
NPLs (gross) / total loans	2.08	1.28	5.50
Provisions / NPLs	95.71	1.93	2.83
NPLs-provisions / capital	7.61	2.00	4.75
FX loans / total loans	4.25	1.90	3.67
RWA / total assets	65.07	1.88	2.92
ROA (after-tax)	1.24	1.97	2.67
ROE (after-tax)	12.34	1.88	2.00
Liquid assets / total assets	12.79	2.30	3.83
Liquid assets / short-term liabilities	51.41	1.33	2.75
Net FX exposure / capital	14.31	2.70	3.50

Note: Author's calculations

* 1.00: Low risk; 2.00: Increased risk; 3.00: High risk; 4.00: Very high risk; PD: Probability of default

The banking ratios illustrated in Table 6 indicate that Malaysia's banking sector is resilient to shocks. The capital raising spree by banks since 2012 has helped offset some of the decline in the ROA and ROE ratios. Net foreign exchange exposure saw a 9.1% rise, attributable to fast depreciation of ringgit against the US dollar. The average overall rating of 1.54 is strong, which is an indication of a low risk. The probability of default (PD) analysis using piecewise approach suggests that the financial soundness indicators used in the analysis had low levels of contribution to the probability of default. CAR and Tier 1 ratios are robust, as a result they receive close to the lowest possible rating of 1.00 (1.13% and 1.05% respectively). The FX exposure risk has the largest rating of 2.72, its increased risk is also confirmed by the results of the adverse scenario where Malaysia banking sector runs into shortfall of dollar liquidity. As expected, credit risk and the resultant losses receive higher PDs; with an average rating of 5.50, gross NPL to total loans tops the list. The second highest PD of 4.75 is again related to

NPLs provisions to capital. Besides credit risk and NPLs, liquidity ratio, FX loans to total loans, and net FX risk exposure to capital have received PDs of 3.83, 3.67, and 3.50 respectively.

4.2 Results in the Adverse Scenario

The results of adverse and severely scenarios are compared and contrasted against the main results of the baseline scenario. The MAST results in adverse scenario indicate that credit risk by far is the largest driver behind financial losses. As a result, CAR and Tier 1 capital ratio saw significant decreases, -3.80% and -3.37% respectively. These results are well in line with the range of 200-560 bps (or 2% to 5.6%) shrinkage in capital ratios provided by the IMF's FSAPs. The five adverse shocks affecting Malaysia's banking sector, the average impact of an increase in provisioning on bank capital ratios is the largest (-1.32%), 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 pushing both ROA (-0.54%) and ROE (-1.55) ratios into negative territory relevant to the baseline.

Table 7: 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

The aggregate capital shortfall as in the needed capital injection (cost to the government) is 1.55% of GDP ($4.59 billion of capital injection based on 2015 GDP of $296.22 billion). The

most important conclusion of the adverse scenario is that no bank failed (even smaller Islamic banks), faced a forced liquidation or suspension of license.

Table 8: Banking Ratios, Ratings, and PDs in Adverse Scenario
All figures are on average covering the stress testing horizon (2013-2015)

Financial soundness indicators	Ratios %	Ratings*	PDs %
Overall	N/A	3.72	11.25
Total capital / RWA (CAR)	9.84	2.39	8.50
Tier 1 capital ratio	9.62	2.28	8.50
NPLs (gross) / total loans	3.44	3.58	10.50
Provisions / NPLs	76.95	3.85	10.83
NPLs-provisions / capital	5.49	3.55	10.58
FX loans / total loans	4.89	3.58	10.75
RWA / total assets	67.67	3.17	11.25
ROA (after-tax)	-0.54	3.90	11.75
ROE (after-tax)	-1.55	3.65	12.42
Liquid assets / total assets	-1.79	3.78	13.75
Liquid assets / short-term liabilities	22.39	3.97	15.75
Net FX exposure / capital	16.15	3.35	13.50

Note: Author's calculations
* 1.00: Low risk; 2.00: Increased risk; 3.00: High risk; 4.00: Very high risk; PD: Probability of default

The number of defaults by private sector on corporate loans and by households on mortgage loans impinged banking profitability. Consequently, intentional capital hoarding by banks led to disintermediation, 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.

Despite the overall average rating of 3.72 (i.e. very high risk), massive loan losses and funding freeze, CAR (9.84%) and Tier 1 capital ratio (9.75%) are still higher than the Basel III capital minima of 7.0% effective by 2015. Strong capital position of Malaysia's banking sector is also confirmed by the ratings of CAR (i.e. 2.39) and Tier 1 ratio (i.e. 2.28), which are the only ratings below the 3.0 mark. 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 analyses such as banking ratios, ratings, and probability of default can be viewed as early-warning indicators to show bank executives and risk managers what areas to focus to mitigate losses in an acute stress before going irreversibly out of control.

4.3 Results in the Severely Adverse Scenario

The average levels of CAR and Tier 1 worsened further in severely adverse scenario. At the conclusion of severely adverse scenario, banks experienced capital decreases ranging from 505 bps to 544 bps. When the results are compared with those in the baseline scenario, the magnitude of average decrease is 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 9: 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 main results of the severely adverse scenario are 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. Large banks' capitalization needs become 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 10.5%; in the severely adverse scenario, even some larger banks needed to raise fresh capital.

The average levels of CAR and Tier 1 worsened in the severely adverse scenario; 8.25% and 8.01% respectively. The level of non-performing loans more than triples reaching 5.46%, attributable to severe loan losses plus significantly reduced provisions to NPLs (from 95.71% in baseline scenario to 76.95% in adverse scenario, and 59.13% in the severely adverse scenario). During the worst episode of shocks, banks saw their returns on assets and equity plummet to their lowest levels; -4.92% (ROA) and -3.55% (ROE). In this scenario, not only smaller banks but also larger banks are subject to illiquidity as some banks' capital hoarding is believed to cause funding freeze (i.e. drying-up liquidity fast) and make some banks' Tier1 ratio fall below the critical benchmark rate of 6.0%.

Table 10: Banking Ratios, Ratings, and PDs in Severely Adverse Scenario

All figures are on average covering the stress testing horizon (2013-2015)

Financial soundness indicators	Ratios %	Ratings*	PDs %
Overall	N/A	3.78	14.03
Total capital / RWA (CAR)	9.84	2.56	10.45
Tier 1 capital ratio	9.62	2.43	10.51
NPLs (gross) / total loans	5.46	3.80	13.42
Provisions / NPLs	59.13	3.92	13.73
NPLs-provisions / capital	5.49	3.73	13.80
FX loans / total loans	5.60	3.68	14.28
RWA / total assets	69.74	3.40	13.58
ROA (after-tax)	-4.92	3.90	14.87
ROE (after-tax)	-3.55	3.88	15.30
Liquid assets / total assets	-10.05	3.88	16.83
Liquid assets / short-term liabilities	1.48	4.00	18.72
Net FX exposure / capital	14.14	3.58	15.33

Note: Author's calculations

* 1.00: Low risk; 2.00: Increased risk; 3.00: High risk; 4.00: Very high risk; PD: Probability of default

The overall rating in the severely adverse scenario approaches the very high risk mark of 4.0 (i.e. 3.78), however the ratings of CAR (2.56) and Tier 1 (2.43) are still below the high risk mark of 3.0, this is an indication of banks' strong capital positions. Therefore, these ratings by any means do not suggest that some banks might be at risk of insolvency; conversely, a great majority of Malaysia' banks are stable with high public confidence. The main results of the probability of default analyses point to an increasing level of defaults, mainly fostered by a cascade of defaults taken place in the private sector on corporate loans and by households on residential mortgage loans (i.e. no bank has become insolvent or faced liquidation).

4.4 Statistical Analysis of the Macro Stress Testing Results

The analyses reveal that the banking sector's FSIs noticeably deteriorate in adverse scenario and worsen further in the severely adverse scenario. The main outcomes of the Kolmogorov-Smirnov Test (K-S test) indicate that the assumption of normality is met, as the Sig. p-values (.155, .174, and .812) > 0.05; the null hypothesis[36] would be retained and concluded that the difference in means between the three stress scenarios is not significantly different.

Table 11: 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

As illustrated in Table 12, excluding the baseline (t = -.782, Sig. p (.448) > 0.05), the results are statistically significant in adverse scenario (t = -.2.867, Sig. p (.013) < 0.05) and severely adverse scenario (t = -.7.407, Sig. p (.000) < 0.05). In the former, we fail to reject the null hypothesis because the significance level is greater than the priori alpha of .05. In the latter two, the null hypothesis is rejected and concluded that the difference is significant.

Table 12: 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

[36] H_0: There is positive relationship between macro stress testing and financial stability.

We analyzed macro factors to assess their impact on financial stability of Malaysia's banking sector. Except crude oil (p = 0.151 > .05) and NASDAQ (p = 0.170 > .05), all other indexes are significant in explaining variations in the performance of KLCI. Based on the Sig. F (p = 0.000 < .05), the F-test is significant and the null hypothesis is rejected. Multiple R (0.970) indicates that the correlation between KLCI (dependent) and major indexes (independent variables) are positive. The figure being very close to +1 implies that the correlation is significant. The coefficient of determination (R2) is 0.941, which can be interpreted that 94% of the change in the dependent variable Y (performance of KLCI) is explained by independent variable X.

Table 13: 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	148518550.9	14851855.0	1577.906	0.000
Residual	989	9308847.4	9412.384		
Total	999	157827398.3			

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).

Table 14: 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)

As illustrated in Table 14, 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 are not statistically significant in explaining the variations in KLCI performance. Only interactions between Malaysia's KLCI and CAC (-0.405) and N225 (-0.003) are negatively correlated, and the difference in means between KLCI and these two indexes is not statistically significant as the p values (0.076 and 0.467) > .05. The rest of the correlations are positive and the results are statistically significant.

Table 15: 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.

Table 16: 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)

The results of the regression analysis of Malaysia's ringgit and ten major currencies are set out in Table 15. Multiple R (0.966) indicates that the correlation between ringgit - MYR (dependent Y) and ten major currency indexes (independent X) are positive. The correlation figure is close to +1 which implies that the correlation between ringgit and other currencies is significant. The coefficient of determination (R^2) is 0.934 can be interpreted that 93% of the change in the dependent Y (performance of ringgit) is explained by independent X.

The standard error of the regression (0.1094198) is an estimate that explains the variation in the performance of MYR. The indexes are statistically significant in explaining variations in the performance 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.

Between the currency pairs (as shown in Table 16), only USD-MYR and USD-GBP (-0.011) are negatively correlated, therefore not statistically significant. The remaining currency pairs are positively correlated and the results are statistically significant. The 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 in the level of MYR. Looking at the correlations, 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). The largest variations in MYR are explained by the inverse correlations between USD-MYR and USD-AUD and USD-JPY. USD-HBT (2.411) are not statistically significant in explaining the ringgit's performance.

5. Conclusion

The macro stress testing results under the baseline scenario (i.e. not a real stress scenario) revealed a modest change in the aggregate capital ratios and bank profitability. Impact of the extreme but plausible and hypothetical shocks on capital ratios was a fall of -1.64% on CAR and -1.38% on Tier 1 capital ratio; post-stress test CAR and Tier 1 were 13.56% and 11.92% respectively. Even taking downward adjustments into account, CAR and Tier 1 ratios of banks are 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 in the aggregate 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 in the baseline scenario surprisingly grew from 13.12% to 14.31% (an increase of 9.1%); this was mainly attributable to the fast depreciation of Malaysian ringgit against other major currencies (USD and EUR in particular). The rating of financial soundness indicators (FSIs) of the banking sector received an overall rating of 1.54, which indicates 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 had sufficient liquidity. The probability of default analysis in the baseline scenario identified some issues; net foreign exchange exposure to capital and liquid assets to total assets received 2.70 and 2.30 respectively (3.0 meant high risk). Despite strong CAR and Tier 1, their PD rating of 2.83 meant that the pre-adjustments in the baseline scenario prior to the start of adverse scenarios negatively affected capital ratios. Credit risk and the resultant losses received higher PDs; in that regard, gross NPLs to total loans with the PD rating of 5.50 was on top of the list (4.0 meant very high risk).

The impact of all fundamental shocks on capital ratios in the adverse scenario was noticeably higher. Namely, capital deterioration was significant; CAR and Tier 1 capital ratio declined significantly, by -3.80% and -3.37% respectively. The aggregate capital shortfall in the form of needed capital injection (the cost of insolvent banks to the government) was 1.55% of GDP (approximately $4.59 billion of capital injection based on $296.22 billion). Nevertheless, the

important finding of the adverse scenario was that no bank failed, faced a forced liquidation or suspension of banking license. Among the adverse shocks affecting the banking sector, the average impact of 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 due to lower real estate and asset prices plus higher unemployment; as a result, ROA and ROE ratios were pushed 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, which 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.

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 Islamic banks only needed to raise fresh capital in order to comply with the paper's 10.5% regulatory capital minima; however in the severely adverse scenario the capitalization need was more widespread including larger banks. Banks saw their returns on assets and equity plummet to lowest levels, -4.92% (ROA) and -3.55% (ROE).

This paper differs from the antecedent studies, therefore it is informative to the BNM, the supervisory community, and bank executives. BNM must not heavily rely on the substantial capital buffers from highly profitable domestic and overseas operations because CAR and

Tier 1 capital ratios of banks decreased more than expected in the baseline scenario. Capital levels deteriorated further under the two adverse scenarios, this should prompt the BNM and individual banks to re-visit their 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, the resultant contraction in spending in turn may amplify the risk of a sovereign debt crisis.

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