A Financial Stress Index to Model and Forecast Financial Stress in Australia

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ABSTRACT

The series of financial crises that cascaded through and rocked much of the world over the past decade created opportunities to draw meaning from the pattern of countries succumbing to crisis and those who appear to be wholly or partially immune. This thesis examines the case of Australia, a developed country that has seldom experienced an endogenous crisis in the last few decades, but has experienced crisis by contagion. This study designs a financial stress index to measure and forecast the health of the Australian economy and proposes a custom-made stress index to: Gauge the potential for a crisis; and Signal when a timely intervention may minimise fear and contagion losses in the Australian financial market. Financial and economic data is used to design indicators for stress in the banking sector and equity, currency and bond markets. Further, this study explores how movements in equity markets of key trading partners of Australia can be used to predict movements in the Australian equity market. The variance-equal weights (VEW) and principal components approach (PCA) are used to subsume 22 stress indicators into a composite stress index. The VEW and PCA stress indexes were examined to determine monitoring and their forecasting capabilities. It was found that the VEW stress index performed better than the PCA stress index, because it provided more consistent estimates for the level of Australian financial stress. Although, both models show some promise, each model fell short of giving adequate forecasts in financial stress especially at the peak time of the 2007-2009 GFC. Thus, more research is needed to understand the complex nature of financial crisis, how crises develop and the techniques that can be used to predict the onset of financial crises.

STATEMENT OF AUTHORSHIP

I hereby declare that this thesis is my original work. In-text citations have been used within the text to acknowledge all sources used in this study. In order to give due acknowledgement of any sources used, I have also compiled a list of all references used in this study. I further declare that I have not submitted this thesis at any other institution in order to obtain a degree.

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DEDICATION

This thesis is dedicated to my family: To my father, mother and siblings; thank you for your constant encouragement when I was dealing with the challenges of graduate life. To Ben, my fiancé, thank you for your support and the sacrifices you made to help me complete my thesis. Without your help the completion of this thesis would not be possible. To my lovely daughter Abigail, always strive to achieve higher levels of education because education opens the doors to more opportunities, better answers, and even better questions.

PEER REVIEWED PUBLICATIONS AND CONFERENCE PRESENTATIONS

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Mukulu, S., Hettihewa, S. and Wright, C. S. (2013). Financial Stress and Contagion: Developing a Viable Financial Stress Index for Australia. *National Business and Economics Society Thirteenth Annual Conference*, March 6 - 9, 2013, Costa Rica.

Mukulu, S. (2013). An Econometric Analysis on the Relationship between Bilateral Trade Links and Granger Causality: The Case of Australia and Key Bilateral Trade Partners. *The 2013 JKUAT Scientific Technological and Industrialization Conference*, November 14-15, 2013, Nairobi

Local Conferences

Mukulu, S., Wright, C.S. and Hettihewa, S. (2014). Investigating Financial Contagion as a Prelude to its Mitigation: Australia and its Key Trading Partners. *Global Business and Finance Research Conference*, 5-6 May, 2014, Melbourne.

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List of Abbreviations and Acronyms

ABC	Australian Banking Crises
ABS	Australia Bureau of Statistics
ADF	Augmented Dickey Fuller
AFMA	Australia Financial Markets Association
AIC	Akaike information criterion
APRA	Australian Prudential Regulation Authority
AR	Autoregressive
ARCH	Autoregressive Conditional Heteroskedasticity
A-REITs	Australian Real Estate Investment Trusts
ARIMA	Autoregressive Integrated Moving Average
ARMA	Autoregressive Moving Average
ASX	Australian Securities Exchange
ATM	Automated Teller Machine
AUD	Australian Dollar
AUSFTA	Australia-United States Free Trade Agreement
BAB	Bank Accepted Bill
BBA	British Banks Authority
BBSW	Bank Bill Swap
BHP	Broken Hill Propriety
CAPM	Capital Asset Pricing Model
CDO	Collaterised Debt Obligation
CDF	Cumulative Distribution Functions
CEO	Chief Executive Officer

CFA	Chartered Financial Analyst
CMAX	Cumulative Maximum
CNY	Chinese Yuan
CRA	Credit Rating Agencies
DF	Dickey Fuller
DFAT	Department for Foreign Affairs and Trade
DGP	Data Generating Process
DTBB	Dutch Tulip Bulb Bubble
EGARCH	Exponential Generalized Autoregressive Conditional Heteroskedasticity
EMH	Efficient Market Hypothesis
EMPI	Exchange Market Pressure Index
EWS	Early Warning System
EU	European Union
FSI	Financial Stress Index
GARCH	Generalized Autoregressive Conditional Heteroskedasticity
GC	Granger Causality
GDP	Gross Domestic Product
GFC	Global Financial Crisis
H-O	Heckscher-Ohlin
HES	Household Expenditure Survey
HILDA	Household, Income and Labour Dynamics in Australia
ICE	Intercontinental Exchange
IGARCH	Integrated Generalized Autoregressive Conditional Heteroskedasticity
IMF	International Monetary Fund

IOC	Interbank Overnight Cash
JPY	Japanese Yen
KCFSI	Kansas City Financial stress index
KMO-MSA	Kaiser-Meyer-Olkin Measure of Sampling Adequacy
KOSPI	Korea Composite Stock Price Index
LIBOR	London Interbank Offered Rate
LM	Lagrange Multiplier
ln	Natural Logarithm
LP	Lumsdaine and Papell
LS_1	Lee and Strazicich unit root test with one structural break
LS_2	Lee and Strazicich unit root test with two structural breaks
MAIC	Modified Akaike Information Criterion
MBS	Mortgage Backed Securities
MM	Modigliani and Miller
NIKKEI	Nihon Keizai Shinbun
OECD	Organisation for Economic Cooperation and Development
OIS	Overnight Indexed Swap
PCA	Principal Components Analysis
PP	Phillips Perron
RBA	Reserve Bank of Australia
RMSE	Root Mean Squared Error
SARON	the Swiss Average Rate Overnight
SIRCA	Securities Industry Research Centre of Asia-Pacific
SONIA	Sterling Overnight Index Average
S&P	Standard and Poor’s

STEP	Short Term European Paper
TED	Treasury bill and Eurodollar
TONAR	Tokyo Overnight Average Rate
TWI	Trade Weighted Index
UK	United Kingdom
US	United States
USA	United States of America
USD	United States Dollar
VAR	Vector Autoregressive
VEW	Variance Equal Weights
XMM	S&P/ASX 300 metals and mining index
ZA	Zivot and Andrew

CHAPTER 1

INTRODUCTION

Due to the complex and often devastating nature of financial crises, a considerable amount of research has been, and is, devoted to understanding their causes and anatomy. Most studies focus on comprehending one or a few aspects of a financial crisis, because it is difficult to provide a comprehensive analysis of all aspects of a crisis in one study. Specifically, some researchers focus on identifying factors that contribute to the development or spread of financial crises (Kaminsky & Reinhart, 2000; Kriesler, 2009; Liang, 2012; Scott, 2010; Trow, 2010), while others are interested in understanding how financial crises disrupt the normal functioning of different sectors of an economy (Chan, 2010; Ploscaru & Nistorescu, 2010). The detrimental effects of financial crises extend beyond the economic impact on which most studies focus. As a result, some scholars seek to shed light on the non-monetary effects of financial crises. Some studies, for instance, investigate how financial crises can lead to deteriorating mental health among individuals facing financial difficulties or stress resulting from the financial crises (Butterworth, Rodgers, & Windsor, 2009; Lee et al., 2010; Sargent-Cox, Butterworth, & Anstey, 2011). The varied scope of these studies suggests that financial crises are a poorly understood economic phenomena with an expanding body of literature. This is why this study is geared towards developing an anticipatory tool for detecting early stages of financial crises in the Australian context.

This chapter is designed to clarify the scope of this research and explain how this research contributes to existing literature. This chapter and its subsections outline the: Motivation for this research; Research objectives and questions; Theoretical framework of this research;

Challenges faced when conducting this research; and Ethical issues. In this introductory chapter, a brief overview of the research is included in this chapter; a more detailed review of literature is provided in the second chapter of this thesis.

1.1 Brief Overview of the Thesis

The magnitude and timing of financial crises are difficult to predetermine, but financial crises tend to occur roughly in 10-20-year intervals (Ferguson, 2009). Recent historical evidence in support of this notion shows that the global financial market experienced a crash in 1987, an Asian financial crisis occurred in 1997, and a subprime mortgage crisis in the USA ignited a world-wide banking crisis in 2007. Also, other episodes of financial turmoil occurred within this period, including: the 1990 start of the Japanese economic crisis, and the 1994/95 Mexican Peso crisis, and the 1998 Russian default crisis (Chiodo & Owyang, 2002; Kindleberger & Aliber, 2005; Mazumder & Ahmad, 2010). The occurrence and pattern of these crises is renewing debate, among analysts and academics, over extant economic theories and regulatory practices that may exacerbate and/or contribute to the onset of these crises. For example, economists are now challenging widely accepted theories over what influences behaviour in financial markets, such as the efficient market hypothesis (EMH) which considers the relationship between security prices and different types of information available in the financial market. Fama (1991) contends that the EMH has heavily influenced market behaviour, as investors believe that, in an efficient market, it is impossible to 'beat the market' without insider information –which is rarely lawful to be used by an investor. Furthermore, since securities tend to reflect all publicly available information in the long-run, it is impossible for an investor to use prevailing information to consistently make abnormal profits on their investment over a long period. Fox (2010) believes that economists were preoccupied with achieving theoretical ideals proposed in the elusive strong form of efficiency when they should have concentrated on economic analysis that facilitates timely intervention that could prevent financial crises. Ball (2009) offers a contrasting view that the EMH merely predicts that large changes in asset prices can occur and does not suggest that it is possible to predict when future changes in asset prices will occur or help forecast future financial crises; such predications would be more likely in an inefficient market. Essentially, even if the securities were overpriced, investors in the financial markets are still human and not all act in the rational manner proclaimed by neo-classical economists. It is important to note that the human interaction with financial markets can either be in the form of human trading or algorithmic trading. Human traders need to place the trades to buy or sell a security, while algorithmic trades can be placed without human interaction. This is why algorithm trading is regarded as a form of non-human trading. Algorithms can be used to establish the best times to buy or sell a security and have been found to be more efficient than humans in assessing large volumes of information relating to price changes, announcements from the company or media (Gsell & Gomber, 2009). Human behaviour combined with a *laissez faire* ideology that discourages policy makers from intervening when they realise that the market is in distress can create fertile grounds for financial crashes. The key issue is whether crises are inevitable and necessary to how markets function (as some argue), or can authorities (such as politicians and regulators) implement policies that strengthen financial systems to ward-off impending financial crises.

Analysts and policy makers often address the above issue via investigative research aimed at proposing macroeconomic policies to ensure timely intervention that can prevent future episodes of financial crisis or stress. While the notions of *financial stress* and *financial crisis* are closely related, they are not synonyms. Please note: throughout this document, the term stress refers to *financial stress* and crisis/crises refer to *financial crisis/crises*). Specifically, financial stress is often (but not always) a precursor to the much more severe *financial crisis* (Illing & Liu, 2006). It follows that, if rising stress precedes crisis, then economists should design policies to mitigate stress before it progresses to a crisis. Accordingly, macroeconomic stability may be achieved if economists closely monitor the economic environment and implement policies that safeguard against stress and the spill-over effects of a crisis. Economists in countries that have experienced crisis in the last generation are familiar with warning signs associated with past crises and can design and implement policies and other ways and means to forestall the recurrence of similar crises. However, there are always new causes and new twists. As a result, there is always the risk that policy makers will seek expedience, ignore contrary evidence, and enslave their policies to "... some defunct economist" (Keynes, 1936a, Book 6, p. 383).

1.1.1 Australia, Past Crises and the Case for a Financial Stress Index

Deregulation has increased the integration of international financial markets. Essentially, the main objective of deregulation is to encourage the interconnectivity and macroeconomic stability of global financial markets. Along with the many benefits provided by integrating financial markets, the resulting global network also facilitates the spread of financial crisis from one economy to another. The Australian government has been deregulating financial markets for the three decades after 1983 (Dyster & Meredith, 2012). While Australia has not experienced an endogenous financial crisis since the 1980s, it has suffered from financial crises that flowed in from other nations (e.g., the 1987 Black Monday, the 2007 US Sub-Prime Mortgage Crisis and the 2011 European Credit Crunch) and spread to Australian financial markets via trade and interbank linkages. The fact that Australian investors can suffer financial losses due to financial instability experienced in foreign financial markets underscores the need for policy makers to be ever vigilant of endogenous and exogenous risks of financial crisis. Since prevention is better than cure, countries would be better off investing time and resources in preventing economic crises as opposed to bailing out financial institutions as part of an aftermath response. However, in the event that prevention is not possible, economic resilience plays an important role in determining the extent and duration of financial crisis experienced by a country. Economic resilience can be nurtured through the continued improvement of policies and economic tools aimed at reducing financial vulnerability to crises. Minsky (1986) accentuated the need for policy makers to understand what leads to economic instability as a key step in developing adaptive policies to modify or eliminate it.

Unlike other developed countries, Australia has seldom experienced a crisis in the last few decades. Paradoxically, this is an issue of concern because countries that have experienced financial crises are familiar with the steps that need to be taken in order to spearhead economic recovery. Because Australia is a country with limited first-hand experience of financial crises, it is likely that an Australian financial crisis would be more detrimental to Australia in comparison to other countries that have weathered several financial crises before. Thus, Australian economists can only develop economic tools and policies based on factors that led to crisis in other countries and adjust those tools and well-as-possible to the institutions and conditions within Australia. The goal of this research is to add to the available financial economic tools by designing a suitable stress index that signals when a timely intervention may isolate and/or minimise fear and contagion effects which might precipitate losses in Australia. Contagion inspired financial crises occur when financial difficulties spread from one country to another and (in some cases) to the rest of the world. Once investors suspect contagion may lead to losses in the local financial markets, they begin to operate in fear of those future losses and may sell investments or shift to less risky investments. These actions, while prudent for an individual, they can create a self-fulfilling prophecy when competitively pursued by large numbers of investors. If the domestic markets are fundamentally strong, a short and sharp intervention can short-circuit the self-fulfilling prophecy effect. The strength and duration of the intervention will depend on the underlying strength or weakness of the domestic markets. In cases where a market adjustment is needed or might be timely, the regulatory authorities' intervention may be limited to reducing the depth and duration of the downturn. For instance, early intervention was instrumental in reducing the exposure of the Australian economy to the contagion of the 2007 subprime crisis. Notably, the Reserve Bank of Australia (RBA) progressively increased interest rates during 2007 when the "credit bubble entered its most excessive phase" (Trow, 2010, p. 17). In addition, the Australian government bought Residential Mortgage Backed Securities worth $4 billion and "... guaranteed bank deposits up to one million dollars ..." in order to mitigate fears of negative effects from the global financial crisis (GFC). As a result, Australia forestalled a technical recession and fared better than other developed countries during the GFC (Forster, 2010; House of Representatives Standing Committee on Infrastructure Transport Regional Development & Local Government, 2009, p. 2).

This study used empirical and quantitative techniques to examine risk factors that predispose the Australian economy to a financial crisis. The underlying notion is that a combination of factors contributes to the development of a crisis and that in the early stages of a crisis a country experiences episodes of stress. If these episodes of financial stress are dealt with earlier (as opposed to later), a country could save the time and money spent on managing a financial crisis (an extreme form of financial stress). This study explains the nature of stress, how it can mature into a crisis and the role of globalisation and international trade play in the transmission and upsurge of stress. Since financial stress either originates from within the financial system or is a result of financial contagion, the impact of financial contagion on Australian financial markets is considered. At this point, the origin of trade and financial linkages and the role they play in the economic growth and stability of Australia will be discussed. Finally, empirical techniques appropriate for modelling the sources, nature, flow and effects of financial stress are discussed before proposing suitable methodologies for measuring financial stress.

1.2 The Gap in Literature

This section of the chapter provides a brief overview of past studies on Australian financial stress indexes. Three aspects of previous research on Australian stress indexes were examined. The first aspect is the choice of variables that were used to measure financial stress. The choice of variables is important because each variable represents a stress indicator that a researcher deemed as being potentially useful for gauging the level of stress in different sectors of the Australian economy. Data frequency is the second aspect considered. Once a researcher identifies the variables to be used in constructing the composite stress index, they can proceed to collect data at a particular frequency (e.g. at daily, monthly, quarterly or annual intervals). Generally, the data-frequency choice depends on the research questions and the researcher's motivations for constructing the stress index. The third aspect examined is the method of index aggregation used to construct a composite stress index. Additionally, the findings of previous studies were discussed with the aim of identifying avenues for further research that can be addressed by this thesis.

A review of literature identified five studies that constructed a composite financial stress index for Australia (Balakrishnan, Danninger, Elekdag, & Tytell, 2011; Cardarelli, Elekdag,

& Lall, 2011; Duca & Peltonen, 2013; Vašíček et al., 2017; Vermeulen et al., 2015). Table 1.1 summarises the studies with reference to the data frequency, index-aggregation method and variables used to construct the composite stress index. Balakrishnan et al. (2011) estimated composite financial stress indexes for 17 advanced countries and 26 emerging countries. Co-movements in estimated stress indexes were examined in order to establish whether financial crises had spilled over from advanced to emerging countries. Balakrishnan et al. (2011) found that the transmission of stress was faster from advanced to emerging countries especially when there were more financial linkages in the form of bank lending present. Cardarelli et al. (2011) estimated stress indexes for 17 advanced countries in order to examine their trending behaviour over three decades. It was found that countries that experienced crises that were linked to bank stress suffered more detrimental crises. Moreover, countries with asset and credit bubbles were found to be more vulnerable to crises once the rapid rise in credit or asset prices could no longer be sustained. Vašíček et al. (2017) used data from 25 countries to estimate and explore the predictive power of the estimated composite stress indexes. The aforementioned authors found that real estate prices were a better leading indicator of stress than credit. Moreover, forecasting performance of estimated stress indexes was poor especially when performing out-of-sample forecasts for the occurrence of the 2007-2009 Global financial crises. Vermeulen et al. (2015) estimated financial stress indexes for 28 countries. Components of the composite stress indexes and the estimated stress indexes were examined in order to establish their relationship with episodes of crises identified in literature. A weak relationship was found between the stress index components (or the stress indexes) and the onset of crises. Consequently, it was concluded that the stress indexes were suitable for measuring the prevailing level of financial stress but inadequate tools for forecasting the likelihood of stress or crises in the future (Vermeulen et al., 2015).

Table 1.1: Past Studies using an Australian Financial Stress Index

Author	Data frequency (time period)	Index aggregation Method	Variables included in the index
Balakrishnan et al. (2011)	Monthly (1983 M6 to 2009 M4)	Variance-equal weighting of seven variables	i) Banking sector beta ii) TED spread iii) Inverted term spread iv) Equity market returns v) Equity market volatility vi) Exchange market volatility vii) Corporate debt spread
Cardarelli et al. (2011)	Quarterly (1980 Q1 to 2010 Q4)	Variance equal weighting of three subindexes. These are the banking sector, securities market and foreign exchange market subindexes.	Seven variables that are summarised as three subindexes. *Banking subindex:* i) Banking sector beta ii) TED spread iii) Inverted term spread *Securities market subindex:* i) Corporate bond spread ii) Equity market volatility iii) Equity market returns *Foreign market subindex:* i) Exchange rate volatility
Vašíček et al. (2017)	Quarterly 1986 Q1 to 2010 Q1)	Variance-equal weight of five variables	i) Equity market volatility ii) Exchange rate volatility iii) Banking sector beta iv) Long term interest rate v) Inverse yield curve
Vermeulen et al. (2015)	Quarterly (1980 Q1 to 2010 Q4)	Variance-equal weight of five variables	i) Equity market volatility ii) Exchange rate volatility iii) Banking sector beta iv) Long term interest rate v) Inverse yield curve
Duca and Peltonen (2013)	Quarterly (1990 Q1 to 2009 Q4)	Average of variables that were transformed to range from 0 to 3	i) 3-month spread interbank to government bill rate ii) Negative equity index returns multiplied by one iii) Volatility on equity index iv) Volatility of exchange rate v) Volatility of yield on 3-month government bill

Duca and Peltonen (2013) evaluate the performance of composite stress indexes and the components of the stress indexes of 28 countries. The stress index components were assessed individually in order to determine whether the variables correctly signalled the presence or likelihood of a crisis occurring. It was found that consideration of both local and global factors which could contribute to a crisis in a country provides better forecasts of the likelihood of crises in the future (Duca & Peltonen, 2013).

Overall, the following observations were made regarding past studies which included an Australian stress index. All studies used of the same set of variables to estimate stress indexes for several countries over a certain time horizon. This was probably done for ease of comparison of the stress indexes of different countries. The decision of which variables to include in the stress index was determined by: economic plausibility and then whether it was possible to obtain data for the variable for all the countries being studied. Given the second constraint, it is possible that some variables that are useful stress indicators were discarded simply because data for all the countries being studied were not reasonably available. This means that country-specific factors which could contribute to a crisis were not included in the estimated stress indexes (e.g., if agriculture is a mainstay of a country and agricultural exports are a leading source of revenue for that country, then due consideration should be given to the potential impact that a major shock to the agricultural sector could have on the health of the economy). A stress index for an agriculture producing country should include variables which track changes in the prices of the top agricultural exports, so that lower than usual drops in the price of agricultural goods over consecutive periods could signal stress in the agricultural sector. It should be noted that the proposed agricultural variables are country-specific and it is unlikely that if one is examining several countries that all the countries will have comparable variables which are relevant for gauging a country's level of stress. Therefore, it is important to consider factors that are unique to each country in order to identify country-specific factors that are relevant for measuring stress in those countries. In the case of Australia, due consideration should be given to the impact that a shock to the resource sector could have on the Australian economy. This is because mined resources are the leading global exports from Australia (which is primarily a resource-based economy). It follows then that larger than usual drops in the prices of minerals will lead to distress in the mining sector. This study posits that previous studies on Australian financial stress failed to sufficiently account for country-specific factors (such as the mining sector) that could contribute to the development of stress in the economy. Instead of a country-specific stress index (to gauge the specific factors that contribute to financial stress in Australia), previous researcher propose a ‘generic’ stress index that is deemed to sufficiently gauge the level of stress in all the countries being studied. This study proposes the use of country-specific variables that gauge the level of stress in the Australian. In addition to the consideration of the mining sector, this study also examines market co-movements of Australia’s leading trading partners and explores how these movements could be used to predict future patterns of contagion across borders.

With the exception of the study by Balakrishnan et al. (2011) the other studies preferred to use quarterly data. Cardarelli et al. (2011) argue that the using quarterly data, in constructing a composite stress index, makes it is easier to compare the trending of the estimated stress index alongside other macroeconomic variables (which are often reported at quarterly frequency). Moreover, the use of quarterly data allows for data to be obtained for a longer number of periods, which is desirable when estimating stress indexes for several countries, as noted by Vermeulen et al. (2015). Nevertheless, from a policy makers perspective, a stress index that is estimated at a higher frequency (daily, weekly or monthly) could allow for closer monitoring of the level of financial stress and faster response time than indexes which are estimated at a quarterly frequency. In fact higher frequency data could allow for more reliable tracking of stressful events especially since early indications of a crisis are more visible as the timing of crisis draws near (Christensen & Li, 2014). Unfortunately, there are three problems that could arise from using higher frequency data in place of quarterly or monthly data. First, there is no guarantee that a researcher will be able to obtain sufficient historical data to assess the performance of the index over past periods of crisis (Vermeulen et al., 2015). This problem is more common when using daily or weekly data than it is with monthly or quarterly data. Second, using higher frequency data may limit the number of variables available to measure the level of financial stress. Third, very-high-frequency data such as weekly or daily data are more likely to highlight momentary shocks which quickly reverse as being worthy of intervention rather than the more prudent strategy of endurance (Vermeulen et al., 2015). This study gave due consideration to the challenges faced when using weekly or daily data and opted against using these data frequencies. Instead, this study follows Balakrishnan et al. (2011) in the use of monthly data because it is more readily available than higher frequency data, provides a higher frequency of stress monitoring than quarterly interval, and smooths out ephemeral blips. It is believed that a monthly financial stress index is a good tool for close monitoring of the level of Australian financial stress.

With the exception of Duca and Peltonen (2013) who use a simple average of transformed variables, all other studies used the variance-equal weighting technique of index aggregation. The variance-equal weighting technique involves standardising all the stress variables and estimating the average of the standardised stress variables in order to obtain the aggregated index. The use of this technique results in equal weights being allocated to all stress variables (i.e. all are deemed to be equally important). Some critics of the variance-equal-weights method suggest that it can allocate more weight to sectors of the economy with more variables (Oet, Dooley, & Ong, 2015). For example, suppose a composite stress index was constructed using stress variables from the equity, currency, bond and currency markets; now let the number of stress variables that is used to represent each market be equal to five, two, one and one for the equity, currency, bond and currency markets respectively; the Variance-Equal-Weights Approach and nine stress variables can then be used to estimate a composite measure of financial stress in the form of an index. The Variance-Equal-Weights Approach to index aggregation estimates a stress index that deems the equity market as the most important determinant of financial stress simply because, in this case, the equity market makes the highest contribution to the composite stress index overall; with about 55.6 percent (five out of nine variables) of the stress variable components coming from the equity market. However, this problem can easily be resolved by summarising variables from different sectors of the economy and then allocating weights to subindexes of the variables representing sectors of the economy instead of the variables themselves. Accordingly, this study explores the use of the variance-equal weighting method and subindexes. Moreover, this study explores the use of the Principal-Components-Analysis method of index aggregation which has not been used in previous studies highlighted in this section. Further, while earlier studies explore the use of at most seven variables, this study proposes the use of 22 variables, to estimate a composite measure of financial stress for Australia. The number of variables considered in this study is more than triple the number of variables that have been considered in any other study that has attempted to develop a summary measure of financial stress. Thus, this study is likely to provide a greater understanding of the factors contributing to the development of stress in Australian financial markets.

1.3 Contribution to the Literature

This research adopts a broad-spectrum analysis, shifting the focus from the impact of stress at a microeconomic to a macroeconomic level. Initially, this research identifies and assesses factors that may increase Australia's susceptibility to financial crises, with a focus on how that knowledge might contribute to the development of policies directed at avoiding or at least ameliorating the adverse effects of financial crises. This study also explores how increased globalisation has driven changes in the nature and/or extent of Australia's vulnerability to financial stress, including the impact the changes have had on policy strength and development. Key networking relationships within the Australian market are considered, including how they differ from or resemble their counterparts in nations that have experienced financial crises (e.g., the study looks at how Australia's mining boom and its extensive trade with China may have shielded it from the adverse effects of the GFC). While it is likely that the dramatically increased importance of trade with China and other Asian-tiger economies ameliorates Australia's risk from financial crises arising in the USA, Europe, and other developed nations, Australia may (as a result) be more susceptible to financial crises in Asia—particularly, any crises that reduces the purchase of Australian ore by Japan and/or China. This study explores the forecasting performance of the financial index designed using the methodology discussed in Chapter 9. This study suggests why factors, which recently contributed to financial stress/crisis in other developed countries, appear to generate little or no economic harm in Australia.

1.4 Statement of Thesis Intent

This study seeks to understanding the nature of stress in Australia by identifying factors that likely contribute to stress and increased vulnerability to financial contagion. The intent of this study is to design a suitable index that can be used to model, estimate, and forecast stress, so as to provide policy makers/economists with an opportunity to anticipate and forestall or divert a crisis emerging in the Australian economy.

1.5 Objectives of the Study

This thesis examines the concept of financial stress with the intent to determine whether financial indexes can be developed into cost-effective tools that extend and expand the capacity of financial managers to identify, stave-off, and/or mitigate financial crises. A secondary objective of this study is to explore market co-movements of Australia and its key bilateral partners, so as to determine possible pathways of financial contagion via equity markets. An initial step to achieve this objective is to develop a stress index for Australia. The estimated stress index will then be assessed to determine how effective it is as a tool for monitoring and forecasting emerging financial stress in Australia.

1.6 Research Questions

This research seeks to achieve its research objective by answering the following inter-related questions:

A) What are the primary stress indicators in Australia?

B) How can the stress indicators in question A be combined into a composite index for Australian financial stress?

C) What environmental, structural, institutional, and other key factors can contribute to the emergence and/or severity of an Australian financial crisis?

D) Is a comprehensive stress index for Australia an efficient and effective way to model, predict, and pre-empt or mitigate Australian financial stress?

The following subsidiary questions are directed at assessing the potential value and application of the research outcomes:

A) Potential uses of being able to predict the occurrence, extent and magnitude of future periods of stress in Australia?

B) Limitations and risks of using stress indicators to forecast financial crises?

C) Policy implications of a stress index for Australia?

1.7 Ethical Issues

The use of primary and secondary data sources was considered and the latter source was deemed as more suitable for constructing a financial stress index. Specifically, the credit, macroeconomic and financial market measures required for this study can be obtained from SIRCA and the Reserve Bank of Australia, Australia Bureau of Statistics, Wren Research and Yahoo finance websites. Thus, there is no need to directly involve humans or their personal data in the conduct of this research. Because no primary data is gathered or directly used in this research, the research poses little or no risk of harm via inappropriate disclosure or other breaches of human-rights ethics. Due to the nature of the data required for this research ethical clearance was neither needed, nor sought from the Federation University Human Research Ethics Committee (i.e. no primary-data survey and/or other acquisition of direct data were conducted).

1.8 Chapter Summary

Chapter 1 is an introductory chapter of the subject matter of this thesis. In this chapter, the scope of the study and its importance are discussed and information about the research objectives and questions are outlined.

1.9 Organization of the Thesis

This thesis has ten chapters. The subsequent chapters are organised in the following manner: Chapter 2, provides a literature review of definitions of stress, crises and how contagion of financial crises can occur; Chapter 3, outlines the conceptual framework of this thesis and discusses research approaches and methods used in this study; The gathering and analysis of this data is labour intensive and is discussed in multiple chapters—Specifically, the data and variables used in the construction of the composite stress index are discussed in Chapters 4-8; Financial stress indicators for the equity markets are discussed in Chapter 4; Stress indicators for the bond and money markets are discussed in Chapter 5; Chapter 6 focuses on stress indicators for currency markets and the Australian banking sector; Other Australian-focused stress indicators are discussed in Chapter 7; Chapter 8, proposes foreign-sourced indicators of stress that are important for the monitoring and forecasting of Australian financial stress; The variables developed in Chapters 4-8 are then assembled into an index in Chapter 9—Chapter 9 (also) discusses how the stress indicators developed in previous chapters are aggregated into indexes and the feasibility of use of resultant indexes in monitoring, identifying, and predicting the potential for stress or a crisis; Chapter 10 is the final and concluding chapter of this thesis —it, also, provides a discussion of the results and recommendations for future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter provides a review of literature related to understanding financial crises and financial contagion. First, a discussion of the various notions of financial stress concludes with a definition that is applicable to this research; Second, an analogy for understanding financial stress is provided; Third, a discussion of parties that can contribute to or prevent the occurrence of a financial crisis; Fourth, a similar discussion of how the parties can contribute to the transmission of financial crises across borders, and Finally, the chapter concludes with a discussion of how globalisation and trade or financial links may contribute to the development or spread of financial crises.

2.2 Macroeconomic versus Microeconomic Financial Stress

Financial stress definitions can be classified and evaluated based on whether the perceived impacts tend to occur mostly at the micro- or macro-economic level. While the impacts of micro- and macro-economic stress differ, there is often an interdependent relationship between them — as illustrated in Figure 2.1, micro-economic stress can cause and/or exacerbate stress at the macroeconomic level and vice versa, as shown.

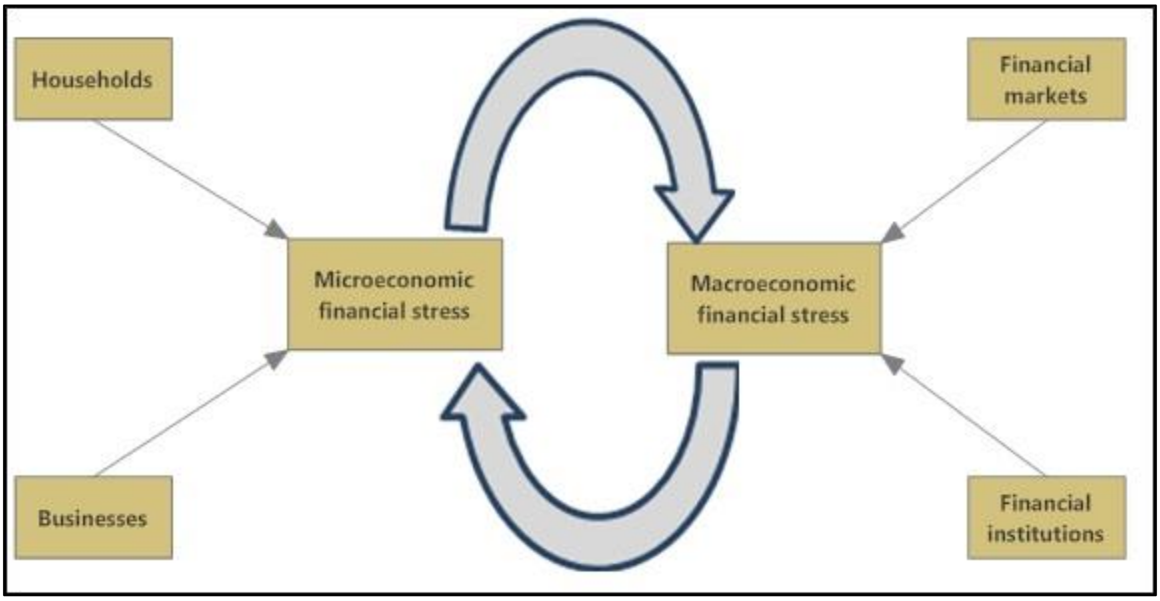

Figure 2.1: The Relationship between Macroeconomic and Microeconomic Stress

2.2.1 Microeconomic Stress

At the microeconomic level, stress can be defined in terms of how it affects households or businesses. Household-related stress is described as:

> "...the adverse economic or social outcomes associated with a household's financial situation, including debt repayment problems, delinquency, bankruptcy and lack of discretionary income" (Worthington, 2006, pp. 2-3).

Researchers usually measure this kind of stress using national or regional surveys. The 1986 Australian Standard of Living survey was the first national survey of financial anxiety in Australia (Marks, 2005). Current examples of national surveys include the 2010 Household, Income and Labour Dynamics in Australia (HILDA) survey conducted by the Melbourne Institute of Applied Economic and Social Research in partnership with the Australian government and the 2003-04 Household Expenditure Survey (HES) conducted by the Australian Bureau of Statistics (ABS) (ABS, 2006; University of Melbourne, 2012). An example of a regional survey is the Wesley Mission (2006) survey of stress in Sydney households.

2.2.2 *Macroeconomic Stress*

In a business context, financial distress occurs when a business undertakes excessive levels of debt beyond the optimal level. The level of debt versus equity financing is determined by a firm's choice capital structure that in turn influences the value of a firm as suggested by fundamental capital structure theories such as Static Trade-Off Theory[1] (Myers, 1984) and Modigliani and Miller (MM) tax adjusted leverage theory (Miller, 1988).[2] According to Fama and French (2002), the optimal level of leverage exists when the marginal benefit of debt just offsets its cost.[3] Beyond the optimum level of debt, a business will begin to experience the costs of financial distress. In the early stages of distress, a business may reject profitable investments because it is illiquid, reduce expenditure on current projects, and/or delay payments to stakeholders. At this stage, various stakeholders may adopt a jump ship mentality with creditors extending less or no credit, shareholders selling all investments, employees seeking employment elsewhere and customers switching to competitor businesses (Petty, Titman, Keown, & Martin, 2012). Extensive episodes of stress often culminate in bankruptcy, receivership or liquidation (Dun & Bradstreet Credibility Corp, 2012). In extreme cases of distress, a business will have to close down and default on its obligations to stakeholders. For this reason, lenders, suppliers and shareholders of a company should regularly monitor the operations of a business so that the potential for default is minimised.

Hakkio and Keeton (2009) suggest that when financial markets are in distress, savers are more reluctant to lend money to borrowers, unless given a premium to offset the increased risk of default. Though the development-stage of a crisis is often accompanied by rising

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[1] Myers (1984) suggests that when an optimum level of debt is maintained the firm's value is maximized.

[2] This theory discussed the tax advantages of debt and the positive relationships between debt and i) a firm's value, ii) risk to ordinary shareholders, and iii) risk of bankruptcy.

[3] The benefits of debt include the tax deductibility of interest while the costs include an increased risk that the firm will not be able to service its debt (Kraus & Litzenberger, 1973).

levels of risk, lenders will continue to extend credit to borrowers as long as the risk of default can reasonably be ascertained. The problem arises during the latter stages of a crisis, when lenders are uncertain about the borrower's capability to repay a debt due to rapidly deteriorating market conditions and the likelihood that the "market will … plummet, carrying the investor's portfolio with it" (Brealey & Myers, 2003, p. 168). In this case, uncertainty at the macroeconomic level can cause a subsequent credit crunch at the microeconomic level. However, Gramlich and Oet (2011) are of the opinion that structural fragility in key-financial markets and regulatory authorities could potentially lead to a crisis as observed in the 2007-2009 subprime mortgage crisis. Edgar (2009) asserts that the abundance of specialized regulatory authorities that set and followed their own set of rules, create a toxic environment where regulators can make decisions aimed at self-preservation as opposed to furthering the common good of society or the financial institutions.[4] In this case, stress experienced by the financial institutions can quickly spread to the macroeconomic level, due to lax macro-prudential regulation.

Macroeconomic definitions of stress focus on the impact of stress on an economy and can be defined in several ways, based on what factors triggered the episode of stress. Since these factors can vary with a country's history and socio-economic characteristics, it is difficult to find one definition that has the capacity to do justice to all the key characteristics, of all historical episodes of stress. Nevertheless, Hakkio and Keeton (2009) maintain that regardless of the origin of macroeconomic stress, stress causes interruption of financial markets. Illing and Liu (2006) define stress as anxiety due to increased uncertainty and changing expectations of economic losses in financial markets and institutions. In this case,

[4] During the GFC, rating agencies such as Moody's engaged in incorrect assessments of mortgage-backed securities (MBS) yet were not held accountable for doing so. Providing favourable ratings for high-risk mortgages translated into higher profits and the agencies' ability to regulate the MBS-market was hampered.

stress develops due to financial fragility[5] and "some exogenous shock"; whereby, vulnerabilities in a financial system cause the shock[6] to develop into stress and facilitate the spread of the shock through the financial system (Illing & Liu, 2006, p. 244). This definition of stress is limited since it fails to account for endogenous causes of financial fragility as highlighted by Minsky (1986).[7] A macroeconomic episode of stress occurs when a country's financial system is under pressure and the country lacks adequate resources to facilitate a quick transition out of an economic slump. Typically, countries under stress experience significant changes in commodity prices, a rapid increase in risk and/or uncertainty, limited liquidity, and fears about the health of the banking system (Balakrishnan et al., 2011).

Microeconomic stress could potentially lower the standards of living of the affected household or business. Macroeconomic stress may culminate in an economic crisis. Given that there is extensive research on the impact of stress at the microeconomic level (Bray, 2001; Breunig & Cobb-Clark, 2004; Commonwealth Department of Family and Community Services, 2003; Marks, 2005; Wesley Mission, 2006; Worthington, 2006); this concentrates on the macroeconomic impact of stress and its possible links to crisis in Australia.

[5] This is often characterised by excessive leverage, reduced lending, and/or poor or inadequate regulation of the system.

[6] Economic shocks result from major devaluation or appreciation of a currency, large changes in prices of commodities such as oil or housing.

[7] Minsky (1986) provides a good description of financial instability arising due to endogenous factors (e.g., government intervention and monetary policy implementation). Notably, Minsky's Financial Instability Hypothesis may explain the development of the 2007-2009 GFC.

2.3 An Analogy of Macroeconomic Crises

In order to address the problem of financial crises, researchers must first understand the nature and anatomy of crises. This research posits that crises are in some way analogous to illness. In that when an individual gets sick, it is in the individual's best interest to consult a doctor in order to determine possible causes of the illness and procure a mode of treatment that suits the patient's needs. Generally, treatment is often more effective when obtained in the early stages of any disease. This is because earlier detection often results in early treatment of the disease and increased probability of a quick recovery. Moreover, doctors are able to obtain an individual's illness history which can be useful in prescribing medication or treatment that is effective and has the least side effects. For example, a patient is better off if cancer is detected in the early stages as the patient has a better chance of getting treatment and beating the cancer. Failure to obtain early treatment could result in the spread of cancerous tumours or growths to surrounding tissues, the rest of the body and eventual death of a patient. Unfortunately, if the patient has waited too long there is often no cure and few treatment options and doctors are left with no option but to manage the symptoms of the cancer as it progresses to a fatal stage. According to Baerheim (2001), the chance of successful treatment of a disease is also dependent on a patient's ability to articulate their symptoms to the doctor so that the doctor can correctly diagnose the patient and recommend suitable treatment. Moreover, it is worth noting that experienced and knowledgeable doctors (as opposed to doctors with less experience and knowledge) are more likely to correctly diagnose an illness based on a patient's history. Now turning to the case of financial crises, some parallels can be drawn between illness and crises as shown in Figure 2.2.

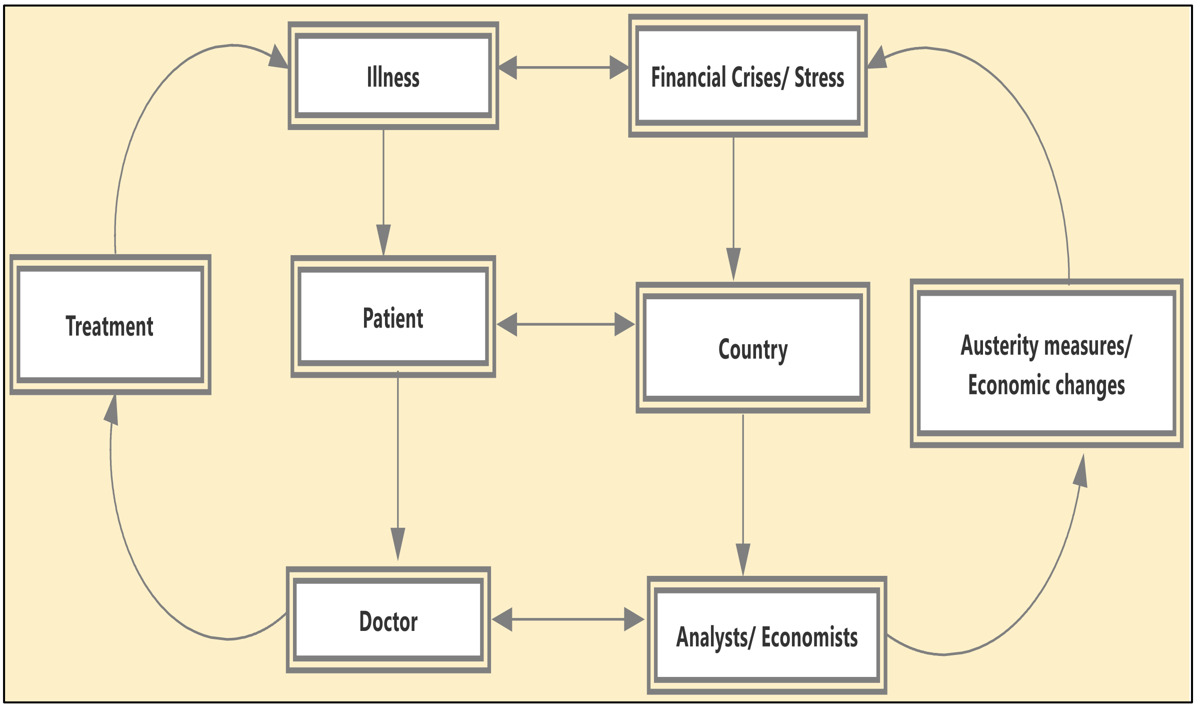


Figure 2.2: An analogy of human illness and financial crises

Two-way arrows are used in Figure 2.2 to show the parallels between treatment of a human illness and addressing crises. The analogous relationships are such that:

- A patient that is ill or diseased is analogous to a country experiencing a crisis,
- Human illness is analogous to financial crises,
- A doctor treating a sick or diseased patient is equivalent to the economists and analysts responsible for monitoring or diagnosing early or late signs of a crisis, and
- Treatment of the illness is equivalent to the austerity measures or changes in economic policies implemented to minimize losses resulting from the crises and initiate economic recovery

Much like a patient's genes, lifestyle and environment may predispose them to certain illnesses; the likelihood of a country experiencing a financial crisis is determined by a combination of factors such as the health and stability of major financial institutions in a country, the state of economy, prevailing regulatory practices and political influence on regulation of financial markets. However, a major difference between doctors and economists is that in most cases the former is able to ask the patient about their symptoms and check for symptoms before diagnosing an illness or disease whereas the latter would only be able to check for symptoms of deteriorating economic health. Besides, the patient can help the doctor to identify early stages of sickness which is not possible in the case of a country that has suffered a financial crisis. In this respect it can be argued that economists face more challenges when trying to identify whether a country is in the early stages of a financial crisis or when trying to pinpoint the best time to introduce more stringent monetary or fiscal policies in order to alleviate or minimize the impact of a crisis.

2.4 Financial Crises Are Here To Stay

In an ideal world, there would be transparent financial systems, no information asymmetry,[8] no greedy investors, and effective regulation of the financial systems which would mean that financial crises would be rare. The prospect of such tranquil financial markets is particularly appealing. Indeed this may be the kind of financial environment of which economists and regulators dream. However, the current world is far from ideal and issues are exacerbated because, as long as humans participate in financial markets, there is a potential for human nature to impact on the efficient functioning of the financial markets. Since the investors and regulators are human it follows that there will always be greedy or over-optimistic[9] investors that underestimate the riskiness of an investment, potential for lax regulation due to political influence on regulatory practices, information asymmetry and inadequate responses to

[8] Information asymmetry in financial markets is due to the fact that all investors will not have the same set of information at any given time and could contribute to the development of asset bubbles

[9] Being overoptimistic is particularly harmful if it leads investors to invest in unprofitable investment because they strongly believe that the 'lemons' will become profitable in the near future. These investors may ignore media reports, the advice of portfolio managers or general pessimism among investors because they believe they are better equipped to assess the riskiness and expected return of an investment.

macroeconomic imbalances.[10] Moreover, as long as there is potential for irrational exuberance, crises are bound to happen somewhere on this planet. Alan Greenspan[11] argued that irrational exuberance was characterized by the rise of asset prices to exorbitant levels, an issue of particular concern because it fosters the development of asset bubbles. If the asset bubble bursts, it is only an issue of concern if it impacts negatively on the normal functioning of the economy (The Federal Reserve Board, December 5, 1996). In this regard an understanding of how bubbles form and why some contribute to the onset of financial crises would be particularly useful. Accordingly, in the discussion that follows is geared towards providing a better understanding of factors that cause bubbles to form, grow and burst.

2.4.1 Bubbles as a Precursor to Financial Crises

More than three centuries after what is probably one of the oldest and most popular asset bubbles, the 1636 Dutch Tulip Bulb Bubble (DTBB), the incidence of similar bubbles in global financial markets is still prevalent. Most bubbles can be categorised into asset-price bubbles and credit bubbles. Generally, bubbles develop naturally over time during the normal operation of an economy and are characterised by a progressive rise in the value of assets, prices of securities or credit over a given period of time (Kindleberger & Aliber, 2005). The rise in the values of assets or credit may be rapid or gradual depending on speculative forces in a financial market. Speculative forces which cause bubbles to develop are also integral to the normal functioning of financial markets. For instance, an investor could invest in shares because he believes that it is currently under- or mispriced. Although the investor does not know whether the price of the shares will go up or down, he has an optimistic outlook on the future movement of prices; he speculates that the price of shares will go up in future. Based

[10] Economists may downplay or fail to respond to the macroeconomic imbalances due to a firm belief in the Keynesian versus the monetarism schools of thought.

[11] These are remarks by the former Federal Reserve chairman in a speech delivered on 5 December 1996.

on this logic, the investor is convinced that purchasing the shares now is a good investment decision, as it would result in a future benefit if the investor chooses to sell off his shares in future. Additionally, in order to capitalize on the upward trend in prices investors often opt to acquire more debt in order to invest more now and enjoy economic benefits in the near future. This is why asset price bubbles are often accompanied by rising levels of credit. Investors justify acquiring more credit now because money borrowed today can be used to purchase an asset that is expected to increase in value in the near future. The investors speculate that the: i) Prices will continue to increase in future; ii) Purchased asset can easily be sold in future; and iii) Proceeds from the sale of the asset will be sufficient to not only finance the repayment of the loan but also to make a profit on the investment. At this point it is important to note that even among optimistic investors there is a broad spectrum of opinions that motivates investment behaviour. For example, optimistic investors will have different opinions about the following: i) whether it is best to make rational or irrational investment decisions, ii) what the true value of a security is, iii) the best time to purchase (or sell) a security, and iv) the best price to pay (or receive payment) for a security. Some factors that contribute to the difference in investor opinion include information asymmetry, varying investor experience and differing investment goals or objectives such as the desire for short versus long term gain from investments. Thaler (1988) states that the nature of financial markets is such that the investor that is willing to pay the highest price for a security is the one that is most likely to gain possession of the security. It is, therefore, likely that investors who eventually obtain a security have probably overestimated the true value of that security and overpaid to obtain it; this is what Thaler (1988) calls the ‘winner’s curse’. Moreover, because it is not always clear whether the investor is acting rationally or irrationally, it is possible for investors to inadvertently nurture the development of an asset bubble by driving the prices of securities up as the try to outbid each other for a security. So far this discussion has focused on the scenario that speculation led the investor to conclude that the investment was worthwhile. However it is also possible other potential investors have opposing views and envisage a possible decline in the price of the security in future. For the pessimistic investor divestment is seen as the best course of action because it safeguards against future losses from a share when the price drops in future. These opposing views ensure that there is a willing buyer and willing seller of a security at any given time, thereby, facilitating trade and the normal functioning of financial markets. It is important to clarify at this point that speculation in itself is not usually problematic. Typically, speculation becomes an issue of concern when there is an overall shift in investor sentiment from an optimistic to a pessimistic outlook, such that commodities or stock that were once viewed as a profitable investment are now viewed as a bad investment –a ‘lemon’. Overall, the investors who are the last to adopt this pessimistic outlook are usually the ones that are stuck with the ‘lemons’ which no one is willing to buy; consequently, these investors bear the financial losses.

Uncertainty and information asymmetry may influence the speculative behaviour of investors in financial markets in the following manner. As long as a bubble is growing, investors with an optimistic outlook can look forward to a good return on investment. However, there is no guarantee that prices will continue rising. Similarly, there is no guarantee that the investor will get a fair return on the money invested in the asset. Nonetheless, this it is a risk that the investor is willing to take. A certain level of uncertainty is present in all financial markets but the degree of uncertainty differs from one investor to another. This is because investors are constantly trying to predict future price movements based on a certain set of information. Due to information asymmetry, some investors tend to have better information compared to others and it is not fully understood which investors possess the superior knowledge about future price trends. In the absence of equal access to information for all market players, information asymmetry and speculation play an important role in the development of asset bubbles. Higher levels of information asymmetry cause more speculation and the subsequent rise or drop in prices. An asset bubble is likely to burst if potential buyers of an asset have generally become convinced that an asset is excessively overpriced and, as a result, refuse to purchase it. Bubbles burst when faith in the continued rise in the prices of the assets can no longer be sustained and it is usually after a bubble bursts that problems begin to emerge in the financial system. For instance, in the case of the 1636 DTBB, investors entered into future contracts for future delivery and payment of tulip bulbs. While there was a general upward trend in the prices of tulip bulbs from 1623 to 1637, Garber (1989) states that it was in January 1637, just a month before the tulip bulb bubble burst, that the bubble was most prominent. In January speculation was rife and prices of bulbs increased at the faster rate than in previous months. Sellers benefitted from investor speculation as long as it exerted upward pressure on the prices of tulip bulbs. Unfortunately, things took a turn for the worse when investor sentiment changed and buyers were unwilling to pay even ten percent of the original price of the bulbs. This made it difficult for sellers to sell the tulip bulbs at a profit or even at breakeven, tulip bulb prices plummeted and sellers were left holding near worthless tulip bulbs. Kindleberger and Aliber (2005) claim that once the tulip bulb bubble burst, Holland households were less eager to spend due to the lower levels of wealth (p. 117). The negative economic effects of an asset bubble bursting are, therefore, evident in the Holland case. From this example, it can be seen that crises arise from a combination of factors, including speculation and changing investor sentiment in financial markets. Figure 2.3 shows the relationship between investor speculation, bubbles and financial crises. It is important to note that Figure 2.3 focuses on the negative impact of a bursting bubble because it is the outcome that this research and analysts are most concerned about. Nevertheless, this research acknowledges that it is possible for a bubble to burst without it adversely affecting an economy; this is in part because a combination of factors contributes to the onset of a financial crisis. This is why the pathway from a bubble to a crisis, in Figure 2.3, is indicated by using an arrow with a dotted line. For example, Mishkin (2009, p. 574) attributed the 2007-2009 GFC to: “the mismanagement of financial innovation, an asset price bubble that burst, and deterioration of financial institution balance sheets”. Schoenbaum (2012, p. 55) provides a total of 15 possible causes of the GFC which can be grouped into the four categories of: “a) failure of oversight and regulation b)private sector abuses c) bad government and policies and d) international monetary imbalances and a lack of preparedness of international economic institutions”.

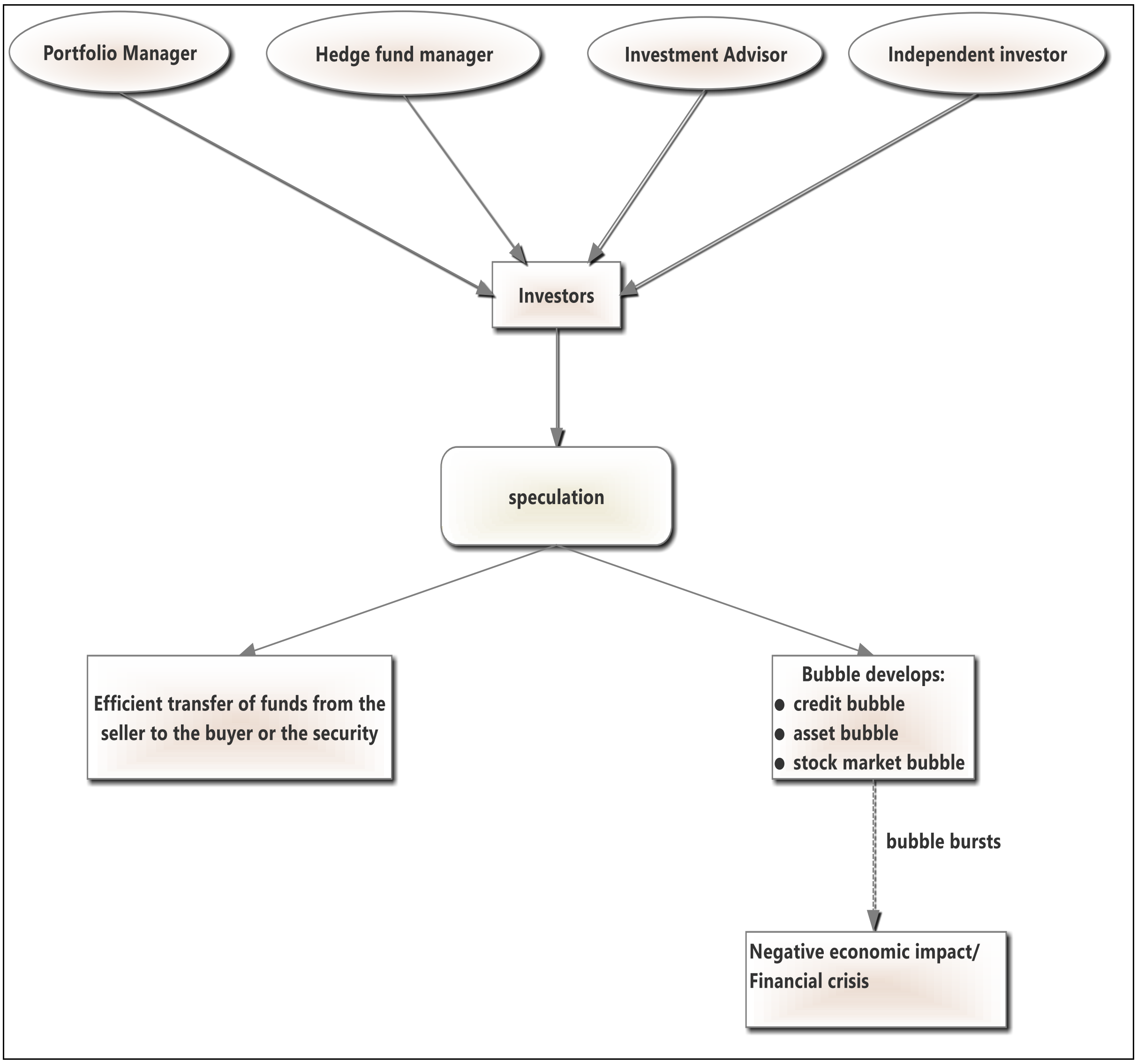


Figure 2.3: How investor behaviour causes financial crises

The fact that several factors may have led to the onset of a financial crisis, implies that in the event of a bubble bursting, policy makers should check for the presence of a combination of factors that may signal increased likelihood of a crisis. Furthermore, by adopting anticipatory policy measures, the negative impacts of a bubble bursting could be lessened.

It should be noted that bubbles can also play a role in the cross-border transmission of financial crisis. Specifically, if a country (country A) benefits economically from the presence of a bubble in another country (country B) and the benefit is significant,[12] when the bubble bursts in country B it could potentially lead to economic problems in country A. This indirect impact of bubbles depends on the extent to which country A is reliant on the bubble developing in country B. Moreover, the economic resilience of country A may influence the extent and degree of contagion of economic problems from country B. If country A is able to withstand, avoid or recover from economic or financial shocks from country B, it can be regarded as being economically resilient (Candelon, Dumitrescu, & Hurlin, 2012). Policy makers would find the development and implementation of policies that encourage economic resilience desirable because these policies would help to strengthen the financial system.

In summary, this section explained how human involvement in financial markets often results in speculation which in turn can prove both beneficial for and harmful to financial markets. On one hand, speculation is a necessary component for the normal functioning of financial markets while, on the other hand, speculation leads to growth and development of asset bubbles. On bursting, asset bubbles could potentially lead to a decline in economic activity, an issue of particular concern to policy makers and economists alike. Therefore, It follows that, research on how to address the problem of crises is an area of considerable interest as it is hoped that more research will shed some light on why crises occur, how they can be

[12] Significant here refers to the possibility that if a bubble bursts in country B, country A could potentially suffer economic loss, even if a bubble has not burst in country A.

contained or managed, how they spread to neighbouring countries and how to be better prepared for the eventuality of future crises. Accordingly, the subsequent sections (Sections 2.5 to 2.8) focus on the relationship between crises and economic recession, possible channels for contagion of a crisis and investor behavioural factors that contribute to financial contagion.

2.5 Post-Crisis: Who Is To Blame?

In the words of the famous philosopher George Santayana, “Those who cannot remember the past are condemned to repeat it” (Santayana, 1905, p. 284). Likewise, mankind must look to the past to understand how and why financial crises develop and how to prevent future crises. For this reason, it seems almost ‘customary’ that in the aftermath of any financial crisis, researchers, analysts, and policy wonks engage in a finger-pointing exercise in order to establish what went wrong and/or to divert blame. This blame game is perhaps motivated by a belief that once researchers find a party to blame for the occurrence of the crisis, they are one step closer to determining how to address the problem of financial crises. The groups most often identified as having caused or nurtured financial crises include: investors, regulatory authorities, and economists. Investors are blamed for failing to adequately assess the risks of the investment before investing in an asset or commodity or for being too optimistic. Regulatory authorities are deemed to have taken too long to respond to a crisis as it unfolded. For this reason, analysts often try to establish whether regulatory authorities could have prevented a financial crisis. Abolafia (2010) argues that to a certain degree regulatory authorities are able to curb excessive market speculation via improved regulation of financial markets, introducing higher penalties for institutions or investors that fail to comply with the rules and implementing policies that prevent investors from gaining access to easy credit.

Economists, as ‘custodians’ of an economy, are often deemed to have fallen asleep on the job when things go wrong as they should have noticed the deterioration in macroeconomic fundamentals and sounded the alarm in the early stages of a developing crisis. There is some truth in this argument, in so far as the deteriorating macroeconomic fundamentals could have been foreseen before the occurrence of the financial crisis. Even though there will always be certain elements of a crisis that resemble past crises, Taleb (2007) argues that there is always the potential for ‘Black Swan’ events. A ‘Black Swan’ is a massively unexpected crisis that profoundly differs from past episodes of crisis. When policymakers are unfamiliar with such events, they may resort to naïve predictions. For instance, the 1987 stock market crash occurred when least expected, especially because familiar precursors of a crisis were absent. In the immediate aftermath of this crisis, traders erroneously anticipated a repeat of a similar crisis in October of subsequent years (Taleb, 2007, p. 42). It later became apparent that a prediction based on such logic was ill-founded.

It is possible for even the most astute economist to fail to anticipate the incidence of a crisis. According to Megalogenis (2012), “Economists struggle with human beings. Just when they think they have accumulated all relationships in a society within the boundaries of a mathematical model, emotion will overwhelm all logic and create a bust [that] no one sees coming” (p. 60). It can, therefore, be argued that economists can only be blamed to the extent to which they can or should be able to anticipate the occurrence of the crises and opt not to recommend timely implementation of policies to forestall a crisis. If one considers that as financial systems and markets are changing and there is a corresponding change in the anatomy of financial crises. Then it follows that the occurrence of crises that are the same as past crises is unlikely; that is unless regulators failed to address factors that led to past crises.

In general, attributing blame to one party demonstrates an inaccurate and simplistic understanding of the financial crises; especially as it is plausible that several parties played a role in the development and onset of a crisis. For instance, a financial crisis may result from a combination of factors such as lax regulation of financial institutions or inadequate regulation for the trade of certain classes of financial instruments, overoptimism and greed on the part of investors and a prevailing belief among economists that deteriorating macroeconomic fundamentals are not an issue of concern. The fact that several parties may be at fault contributes to the complexity of financial crises especially since the actions by investors, economists or regulators may be based on rational or irrational reasons and the reasons are not always evident until after an action has been taken or a decision has been made. Nevertheless, all parties can learn from past mistakes–investors can try to be less optimistic and greedy in future while economists and regulators can strive to be more vigilant implement more stringent economic policies.

2.6 Financial Stress, Crises and Recessions

Harmful episodes of stress are linked to economic crises and recessions and are of particular interest to policy makers. The main issue of concern for analysts is the origin of the stress. International Monetary Fund (IMF) asserts that the probability of an economic recession depends on the degree to which house prices or aggregate credit rose before an episode of stress (IMF, 2008). There is a positive relationship between stress and large increases in housing prices or credit; the larger the increase in credit and house prices the more the stress and vice versa. Hakkio and Keeton (2009) assert that the degree of subsequent recession will depend on the extent of reduced spending and cost cutting by businesses and households. Moreover, distress from structural weaknesses in the banking sector often results in more severe economic downturns, as compared to securities or foreign market related stress. Illing and Liu (2006) suggest that countries with weak financial systems provide a fertile ground for exogenous shocks to germinate into stress. In extreme cases, if timely corrective action is not taken, stress can spread within local financial systems affecting liquidity in households and financial markets – and culminate in a local crisis. If left unchecked, this could spread to neighbouring economies and eventually affect the global financial market (see Figure 2.4). Cross-border links that exist for trade and financial purposes may provide conduits for the transmission of stress. Specifically, countries with "more-arm's-length financial systems" and "financial innovation" are susceptible to worse periods of recession following an episode of stress compared to countries with negligible financial system integration or linkages (IMF, 2008).

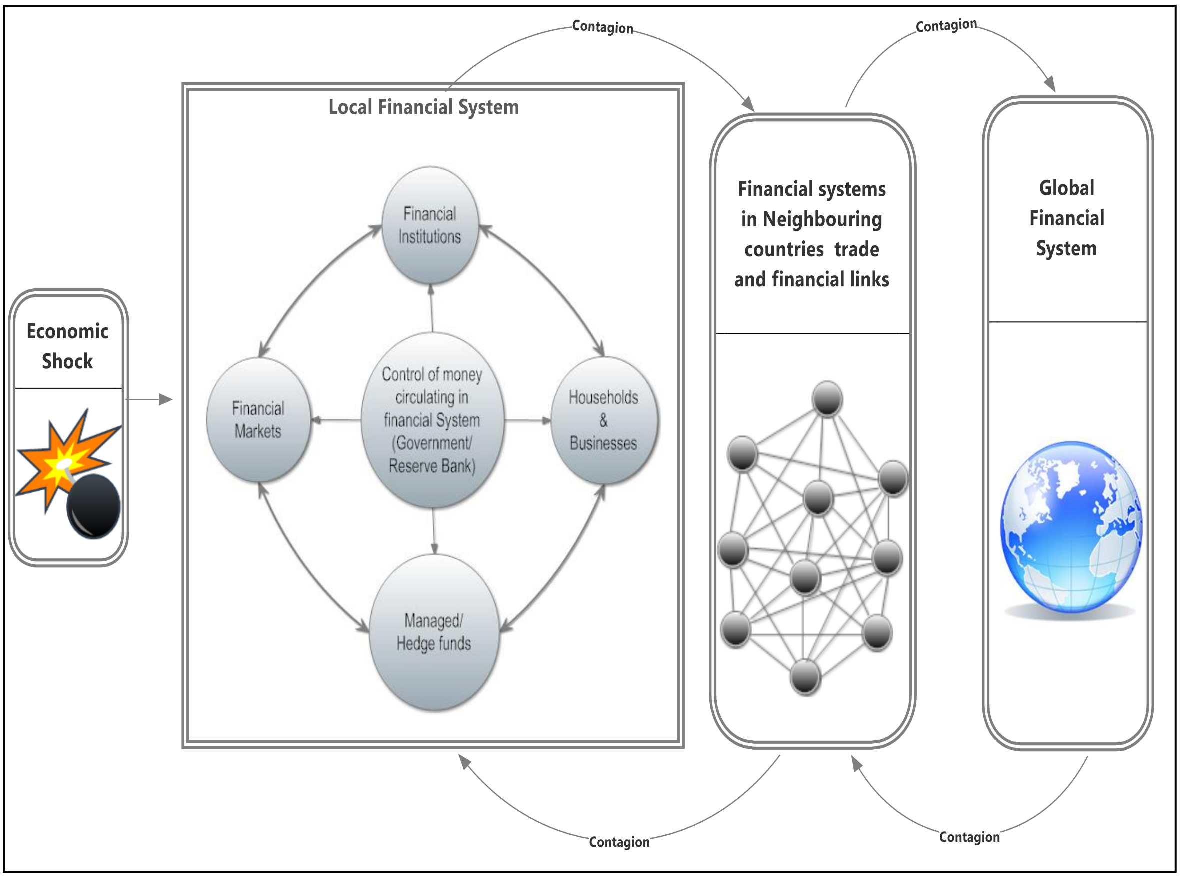


Figure 2.4: Transmission of Financial Stress

2.7 International Trade Theories and Trade Linkages

Stress spreads from one country to another via trade links established to facilitate international trade. It may be argued that reducing trade links that exist between countries reduces financial-contagion risks. However, international trade plays an important role in economic development of Australia and understanding the economic theory relating to international trade could help to explain the importance of trade linkages (Department of Foreign Affairs and Trade, 2012). This discussion of trade theories is a prelude to a more extended examination of contagion that spreads via international or regional trade networks in the following section.

The concept of comparative advantage goes back to the early days of economic theory with Adam Smith, David Ricardo and Eli Heckscher (Heckscher, 1950; Ricardo, 1981; Smith, 1977). The *comparative advantage* concept suggests that when one country specialises in the production of a good, that requires the least number of person-hours and imports the other good from another country, both countries realize increased production of both goods (Czinkota, Ronkainen, Moffett, & Moynihan, 2001). Theoretically, Heckscher-Ohlin (H-O) theory provides valid arguments for why some bilateral trade links are established between countries (Sheng & Song, 2008). However, the empirical performance of the H-O theory in explaining bilateral trade flows has proved problematic in some cases, as first demonstrated by Leontief (1953) and subsequent researchers. Leontief revealed contradictory findings of the H-O theorem using the trading relationship between US and trading partners in the 1950s. Baskaran, Blöchl, Brück, and Theis (2011) offer a plausible explanation for the model's empirical inadequacies by proposing that international trade occurs in a complex network, which is not considered in most tests of the H-O model. If the network relationship of factor differentials that exist between trading countries was examined and incorporated into H-O testing models, empirical findings would favour the H-O theory.[13]

Dornbusch, Fischer, and Samuelson (1977) argued that H-O theory could be ameliorated to account for varying technological predispositions of trading countries by relaxing the technology assumption and subsequently developed a Ricardian model with a continuum of goods. This model is based on the idea that *comparative advantages* mainly reflect differences in technology across different countries and labour is the most relevant factor to consider in the analysis of comparative trade. In this case, trade results due to the disparities in technological endowments. Feenstra and Hanson (1996) used the Ricardian model to explore the relationship between wages and international trade in a capital-based economy (the United States (US)), versus a labour-based economy (Mexico). The study found that outsourcing of labour created more jobs in Mexico and contributed to an increase in wages of the US non-production labour rates by about 31 percent in the 1980s. Overall, trade benefitted parties in both economies and countries establish multilateral trade agreements in order to enjoy similar mutually beneficial relationships.

2.8 Globalization, Contagion and Financial Stress

Financial globalization provides avenues for both economic growth and economic recessions. On one hand, a good mix of policies to reduce trade barriers will provide businesses and individuals with welfare gains (Stiglitz & Charlton, 2007). Reduced trade restrictions can minimize trade costs and businesses that undertake transactions in more than one country can diversify away country specific risk associated with doing business in one country only. On

[13] Baskaran et al. (2011) showed that modified tests yielded better results compared to unmodified versions of H-O model tests using data for trade of goods in about 222 countries/territories.

the other hand, increased inter-linkages across trans-national financial markets make countries more vulnerable to the contagion effect of crises in other nations. Susceptibility to the Greek crisis started as a gross over-surplus of poorly invested funds from Russian oligarchs that spilled into Cyprus, then from Cyprus into Greece, and then into neighbouring European countries (in part) due to the increased structural fragility associated with interbank linkages such as interbank lending relationships, interbank credit lines and solvency (Financial Post, 2013; Gramlich & Oet, 2011; M. Miller, 2013). Financial globalization has developed a network that facilitates quick transmission of economic shocks from one country to another (Stiglitz, 2010). Paradoxically, the increased interconnectivity that facilitates multilateral trade exposes economies to the contagion effects of stress experienced by any trade partner (Lazarides, 2011) and can even create a 'domino effect'.The dilemma that most countries find themselves in is to determine an optimum level of financial integration.

Definitions of contagion can be grouped in to *endogenous, exogenous, negative,* and *positive* contagion (see, Figure 2.5). *Endogenous* definitions of contagion explain how problems originate from within a financial system due to shocks in a particular sector such as the banking or insurance sector. Allen and Gale (2000) state that contagion occurs when small shocks affecting a few financial institutions will (unless contained) spread to the financial sector and then to the rest of the economy. In the banking sector, a shock spreads from one bank to another as banks hold deposits in other banks. The impact of a shock on the banking sector depends on the nature and degree of interconnectedness of financial claims. If a shock affects the liquidity in the banking sector and banks are unable to satisfy the aggregate demand for liquidity, contagion of liquidity problems can spread as banks withdraw holdings in other banks to satisfy demand. The result is *negative contagion* that is characterised by reduced liquidity (a credit crunch) at the regional level and could potentially lead to national crisis. If the regulatory authorities intervene at this point, the spread of the banking crisis could be forestalled. Pericoli and Sbracia (2003) underscore the importance of collaboration between local and foreign institutions in the containment of a local crisis and suggest that this is why the 1999 Ecuador debt crisis did not spread to the global financial market. Conversely, if a shock does not affect the aggregate liquidity of banks, the interbank holdings could prove advantageous. In this regard, the impact of a shock that affects a few banks can be lessened as the shock spreads throughout the banking system.[14] This is an example of *positive contagion* since the banks benefit from reduced risk associated with the reduced shock.

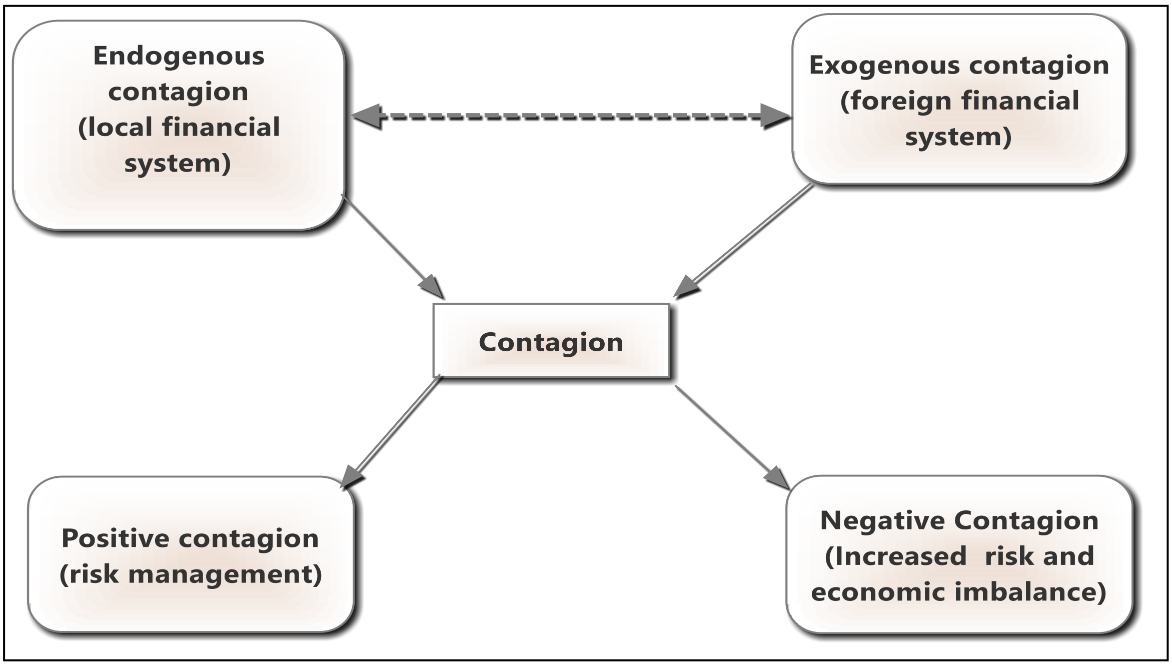


Figure 2.5: Forms of Contagion

There are varying definitions of exogenous contagion but most definitions focus on identifying the cause of a spill-over of crises from foreign countries to the local financial system. Australia is a dual economy that has experienced few episodes of stress originating from within Australia. Indeed most episodes of stress experienced in the Australian economy

[14] This is only possible if each bank has holdings in all other banks and vice versa, a situation Allen and Gale (2000) described as a complete market structure.

have been due to contagion-related stress. The recent GFC originated in the US and affected global markets. Increased co-movement of prices (Hettihewa & Mallik, 2005) in global financial markets due to the occurrence of a crisis in one country could be an indication of contagion. This is a plausible explanation for the steady decline in the US Dow Jones and the Australian All Ordinaries index during the 2007-09 GFC (Figure 2.6).[15] This study shall explore whether a co-integrative relationship between the two stock indexes may explain why contagion of the crisis occurred.[16] Also, an empirical evaluation of the degree of stress transmitted from US to Australia will be examined.

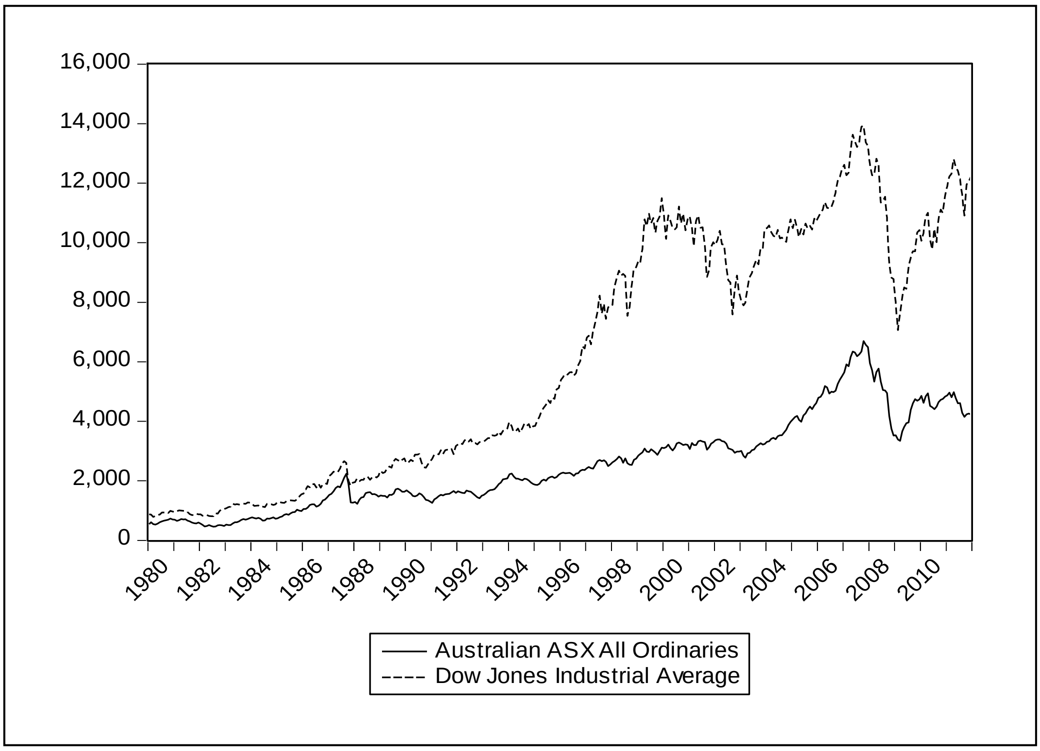


Figure 2.6: Monthly Stock Indexes for Australia and the US (1980-2011)
Data source: Wren Advisers [17]

Analysts suggest that Australia has dealt with contagion-related stress quite well, due to a number of factors. Specifically, Australia had stable financial institutions with prudent regulatory measures (often accused of being passé, pre-GFC) already in place before the

[15] The graph shows monthly averages of stock indexes at the level.
[16] See Hettihewa and Mallik (2005) for details on co-integration
[17] Data retrieved on 25 November, 2012 from: http://www.wrenadvisers.com.au/downloads

onset of the GFC. In addition, the Australian Prudential Regulation Authority (APRA) facilitated strong regulation, close supervision and effective risk management of Australian banks – this nurtured a relatively stable banking sector in Australia.[18] Further, even after the crisis had begun to affect global markets, Australia was enjoying an economic boom owing to the export boom of the mining industries in Queensland and Western Australia (Perlich, 2009). Moreover, the Australian government took pre-emptive measures to ensure Australian banks had sufficient foreign currency at their disposal and money to prevent bank runs and provided a substantial stimulus package to reinvigorate spending confidence by offsetting any declines in perceived wealth (Berg, 2014).

Caramazza, Ricci, and Salgado (2004) define contagion as the process by which "…financial difficulties spread from one economy to another in the same region and beyond…" via trade or financial linkages (p. 51). In this case, stress is not confined to the affected country; rather the impact of stress can affect all countries that trade with the affected country. Pericoli and Sbracia (2003) state that contagion occurs when there is "a significant increase in the probability of a crisis conditional on a crisis occurring in another country" – a definition that explains how the Thai crisis developed into the Asian crisis (p. 574).

Calvo and Mendoza (1998) argue that financial contagion can occur even if linkages are absent or controlled (e.g., if the investment patterns reflect a herding behaviour that may or may not be rational) (Kaminsky & Reinhart, 2000). Unfortunately, irrational decisions made by key market players (e.g., financial institutions, analysts, or respected individuals) can trigger herd behaviour that could destabilize financial markets. Lakonishok, Shleifer, and Vishny (1992) suggest that, although individual investors may herd, it is unlikely they would

[18] See House of Representatives Standing Committee on Infrastructure Transport Regional Development & Local Government (2009).

influence the market unless a group of large investors acted in the same irrational manner, either buying or selling in bulk. From a regulator's point of view, predicting such irrational herding among key market players is impossible. However, historical records of rational herding might be a useful tool for anticipating market imbalances and for planning corrective action (e.g. studies in the United States, by Lakonishok et al. (1992), indicate that fund managers were more likely to engage in herding behaviour when investing in small stocks,[19] due to the limited information in the public domain). Information asymmetry seems to motivate behaviour among fund managers with most managers assuming that competing fund managers have access to better information than they do. Consequently, managers mimic investment behaviour in order to benefit from the potential capital gains that competitor fund managers may receive. Essentially, the fact that herding behaviour exists is proof that financial markets are inefficient (at least in the short run). According to Lakonishok et al. (1992) rational herding by institutions could help counter irrational behaviour by investors and, thereby, stabilize stock prices. However, this does not rule out the possibility that institutions could also contribute to market instabilities if they engage in irrational behaviour. One could test for the overall herding behaviour among money managers in an industry by checking the correlation of trading patterns of different managers. While herding tests can be useful to identify industry specific investment trends and potential for contagion, the focus of this study is on contagion in Australia.

It is difficult to determine whether contagion experienced at the regional level is due mostly to financial links or trade links because countries tend to concurrently establish regional trade agreements and the interbank linkages needed to facilitate the associated trade (Kaminsky & Reinhart, 2000). Nevertheless, trade and/or financial links facilitate the transmission of a

[19] Small stocks include stocks of companies in the bottom two quintiles by market capitalisation (Lakonishok et al., 1992).

crisis from one country to another. An example of regional contagion is the 1997 Asian Crisis that originated in Thailand following the July 2, 1997 announcement that the government could no longer afford to service its foreign debt. The impact of this crisis was increased currency speculation that cost the Thai government $24 billion (USD) in reserve assets. Indonesia, Malaysia and South Korea also suffered the indirect effects of the crisis, spurred on by the speculative forces that convinced foreign lenders to cease all loans denominated in the rupiah, the ringgit and the won respectively – in order to minimize speculative losses. Ultimately, the affected countries were starved of foreign reserves and could not afford to service their foreign debt (Kindleberger & Aliber, 2005).

The vulnerability of a country to contagion of stress depends on, the:

- Degree to which a country depends on trade with other countries,
- Inherent strength of the economies of the trade-partners,
- Nature of the trade and availability of substitutes (e.g. sellers tend to be more vulnerable to buyer problems than vice-versa), and
- Flexibility of the trade (e.g. capacity to shift trade to nations with fewer problems).

In an illustrative example of the above notions, consider a completely insular country that (by definition) has no trade linkages with the rest of the world. In such a country, there is little or no need for financial linkages; since by definition, they would be of little or no use. The government in power need only worry about developing and implementing sound macro-prudential policies that are applicable to its country to avoid *endogenous contagion* of stress. While the absence of trade linkages in this utopian country would seem to make it *safe* from contagion of stress, it also foregoes the benefits of international trade (as highlighted by several economists including Ricardo and Samuelson).[20] Besides, in the real world, no country can be perfectly insular, as this would require the country to operate in isolation. Conversely, excessive dependence on other nations makes a country susceptible to events in those other nations. A more balanced approach is one of inter-dependence, where countries develop bilateral and multilateral trade agreements to the benefit of all, via *mutual-need* synergism. This does not suggest that countries with interdependent relationships are completely safe from contagion. Rather, it implies that there is a positive relationship between dependence and the degree of contagion experienced by a country; higher levels of dependence are associated with increased vulnerability to contagion and vice versa. Moreover, inter-dependent relationships are rooted in "mutual need"; in the absence of mutual need, it is impossible to establish an interdependent arrangement that would benefit both countries — in such a case, unilateral engagements would be more meaningful.

2.9 Concluding Remarks

In conclusion, this chapter discussed the definitions of financial stress that were applicable for this study. While financial stress can be experienced at the micro and macro level, the primary focus of this study is on understanding the macroeconomic kind of stress. Consequently, subsequent chapters focus on the impact of stress on the Australian economy and examine how market dynamics and investor behaviour could contribute to the spread of financial stress if irrational exuberance is left unchecked by regulators. The next chapter presents the conceptual framework, research methods and approaches that were used in this study.

[20] Moreover, the country is not safe from the (true) contagion that occurs even if linkages are absent.

CHAPTER 3

RESEARCH APPROACH AND METHODS

3.1 Introduction

This chapter is designed to explain why this study adopts certain research approaches and methods to answer the research questions outlined in Section 1.6 of Chapter 1. The conceptual framework for this study is outlined in Section 3.2 before exploring the best approaches and methods to conduct this study. Section 3.3 outlines the research process for this study. This is followed by a discussion of the research philosophy underpinning this study (Section 3.4), the research approaches (Section 3.5), research strategies (Section 3.6) and the choice of research methods (Section 3.7). The time horizon for this research and data frequency concerns are discussed in Sections 3.8 and 3.9 respectively. Section 3.10 focuses on the review of the literature on how to measure financial stress and financial contagion; the main focus will be on providing arguments for the methods which are applicable to the Australian case. Section 3.11 provides a brief discussion of the aggregation methods used in the design of composite financial stress indexes. Towards the end of this chapter, Section 3.12 and 3.13 focus on: the justification of the research methodology employed in this study and the concluding remarks of this chapter respectively.

3.2 Conceptual Framework

The conceptual framework of this study is developed based on the literature from finance, econometrics and economics (see Figure 3.1). In this study the types of stress/crises, the theoretical aspects (EMH, asymmetric information, herd behaviour and trade theory) will be considered in identifying the trade relationship and its influence and importance to the objectives of this study. Based on the literature, this study investigates the internal and external factors that contribute to financial stress. It is common for price movements of assets or securities of countries with financial or economic ties to follow a similar trend, but the reasons for the common trends are still a source of academic debate. Accordingly, market integration was examined and evaluated in order to identify the possible links between financial integration and stress/crises. There are two main arguments offered for increased market integration with the arguments based on either an explanation of 1) contagion or 2) interdependence. Both arguments are examined in order to identify suitable ways of measuring contagion of financial stress. Moreover, the impacts of stress/crises were discussed in order to identify possible indicators of stress in the Australian context.

This study uses the variables identified in Chapters 4 to 8 and index building techniques in Chapter 9 to construct a composite index for stress in Australia. Specifically, variables that measure the level of stress in the Australian mining sector, banking industry and financial markets[21] were subsumed into composite measures for stress using the principal component analysis and variance-equal weights methods.[22] The estimated stress variables and stress indexes were assessed to determine if they were sufficient tools for monitoring and forecasting Australian financial stress. Moreover, the framework was used to test the following hypotheses:

1. There exist bilateral short-term movements between Australia and its key trading partners that can be used to gauge the potential for stress in Australian financial markets,

[21] These include the Australian equity, bond, money, currency and property markets

[22] The researcher assessed four index aggregation methods before opting for the use of these two methods for index aggregation. Chapter 9 of this thesis provides a detailed discussion the aggregation methods which include the principal components analysis, variance-equal weights, transformation by cumulative distribution functions and the credit weights techniques.

2. The choice of index aggregation method affects the performance of the composite stress index, and
3. A significant decline in exports of the mining industry for a prolonged period will translate to increased vulnerability to stress in the Australian mining sector.

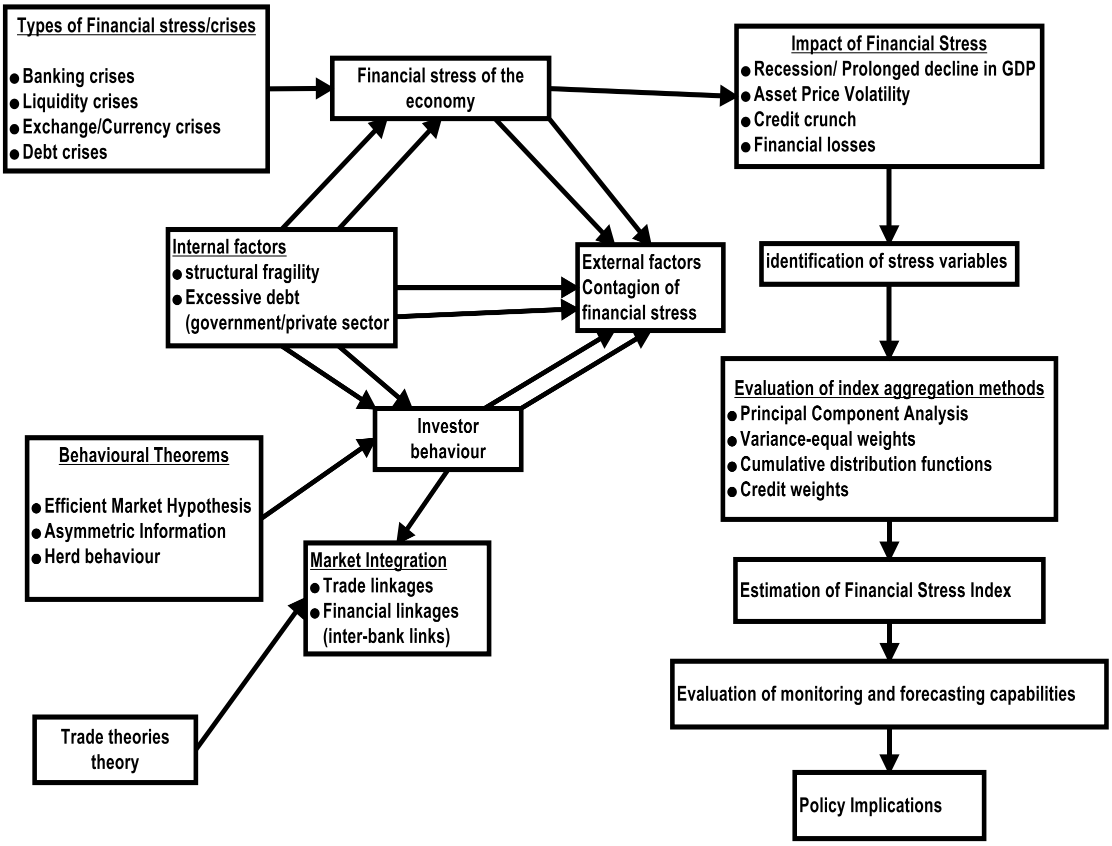


Figure 3.1: Conceptual Framework

While the conceptual framework outlines the theoretical requirements of this research, it does not explain how this research was conducted. An understanding of how this study was done is important not only for the purpose of this research but for future researchers who may wish replicate and extend the work in this study. To illustrate this point consider the case of an automobile manufacturer that has declining levels of revenue due to decreasing demand for the cars produced by the company. The Chief Executive Officer (CEO) of the automobile company thinks that introducing a new car model to suit the customers’ changing needs combined with strategic marketing of the new model would result in increased demand for the company's cars. As a result, the CEO hires a marketing research consultant to conduct a research on the customer preferences when buying a car. At this point, the marketing researcher is aware of the problem at hand and can identify the information that must be obtained from potential car buyers in order to solve this problem. However, the manner in which the research will be conducted must be clearly outlined. In particular, the marketing researcher would need to develop a research design to specify, among other things: 1) how data will be collected (through phone interviews, questionnaires-posted versus face to face interviews), 2) what kind of data is required (quantitative versus qualitative or both), how long should the research take (the time line based on an anticipated completion time). This means that the researcher would need to come up with a detailed plan for the research before the study was conducted. This plan should detail the research process and explain the design of the whole research; ideally it should act as a 'road map' and provide guidelines to different parties involved in the research process from the start to finish. This plan can be used by the automobile company to replicate a similar research in future should the need arise. The research design proposed in this chapter aims to provide clear guidelines on how the researcher conducted this study, in the hope that this information will be a useful guide for future researchers who wish to extend the work done in this thesis. Accordingly, the discussion in the section that follows turns to the explanation of various aspects of the research process.

3.3 Research Process

This section of the study outlines the research process that was adopted. The research process used in this study draws from the concept of the 'research onion' as proposed by Saunders, Lewis, and Thornhill (2009). In this approach to research design, the researcher starts from the outer layers of the research onion and progressively peels each layer away until reaching the centre of the research ‘onion’. Each layer represents an aspect of research process that must be consider in order to set out a plan for how to conduct a research. In particular, the research ‘onion’ has five layers that represent important elements of research including the: 1) Research philosophy; 2) Research approach; 3) Research strategies; 4) Choice of research method; and 5) Time horizon. Once the first five aspects of research have been addressed, the researcher can more effectively tackle the central component of the research ‘onion’ which is the identification of methods and procedures for collecting data. The subsequent sections give a more general discussion of the five aspects of the research design. Figure 3.2 shows the adapted version of research onion applied in this study.

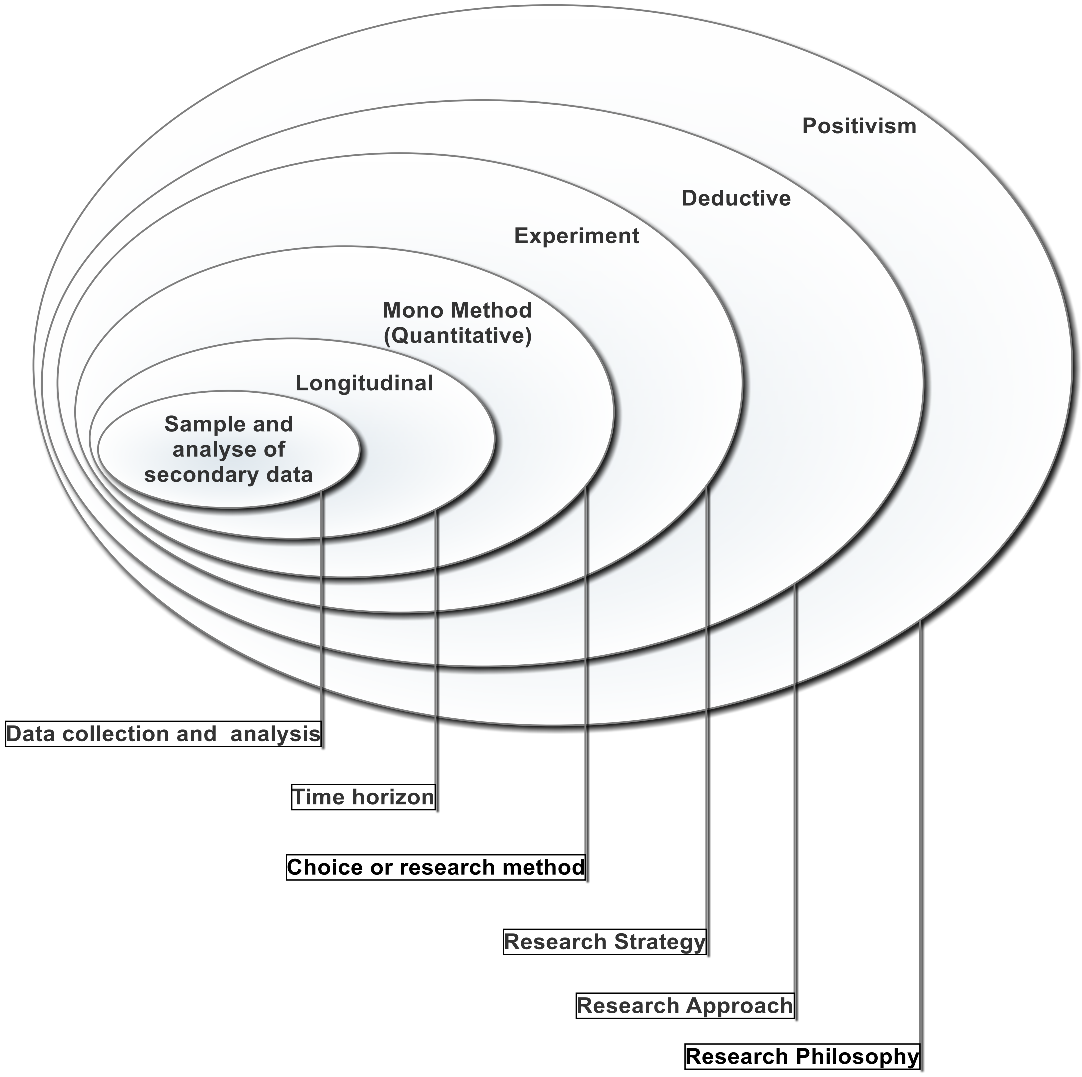


Figure 3.2: The Research Process for this study
Source: Adapted from Saunders et al. (2009, p. 108)

3.4 Research Philosophy

3.4.1 Brief Overview of Research Philosophies

A research philosophy can be understood as how the researcher views the world around him or her (Saunders et al., 2009). Every researcher perceives the world around them differently depending on their individual: i) Upbringing; ii) Life experiences; iii) Education; iv) Personal beliefs or value-system; v) Customs; and vi) Societal values. The extent to which a research is or is not influenced by the researcher's values depends on research philosophy adopted by the researcher. The selected research philosophy permeates the choice of research approaches and methodologies. Saunders et al. (2009) document four main research philosophies that explain different world views of researchers; these are: *positivism*, *realism, interpretivism*, and *pragmatism*. The following subsections discuss these four research philosophies and then highlight the research philosophy used in this study.

3.4.1.1 Positivism

Positivism refers to the world view that a researcher can examine the environment around them, collect some data and analyse the data to check for trends or patterns that can be generalized and used for forecasting (Saunders et al., 2009; Saunders & Tosey, 2012). This approach is more suited to the collection and analysis of quantitative data. Consider for example, a researcher who is interested in the effect of financial crises on stock prices. The researcher may hypothesize that the prices of shares decline at a faster rate during in-crisis periods as opposed to out-of-crisis periods. An assessment of the historical trends of end-of-day prices of different shares in the pre-crisis, during crisis and after-crisis periods could help to test this theory. In particular, past episodes of financial crises in the US such as the 1987 Black Monday and the 2007-2009 subprime mortgage crisis could be examined in order to test the researcher's hypothesis. By examining data for US share prices in periods before, during and immediately after these two episodes of crisis, the researcher could check whether the prices declined at a faster rate during crisis period than in non-crisis periods. Based on the findings of the research, a generalized conclusion can be made on the effect of a crisis on the prices of US stocks. This generalisation can be useful for designing models that explain the potential losses for investors during a crisis as opposed to out-of-crisis periods. Moreover, it can help investors to hedge against large losses during periods of crisis. While, positivism is the oldest research philosophy it is far from perfect. According to Cavana, Delahaye, and Sekaran (2001) the positivist approach fails to consider aspects that cannot be quantified such as nonmonetary motivations for human behaviour and it ignores the subjective influence of a researcher on a study. Due to these weaknesses, alternative philosophies such as the *realism* approach have been developed to address the weaknesses of the positivist approach. Accordingly, the subsection that follows provides a discussion of the realism approach to research philosophy.

3.4.1.2 Realism

Unlike the positivist approach which focuses on understanding objects (respondents or phenomenon) and ignores the interaction between the researcher and object being studied, the *realism* philosophies focus on understanding the interactive relationship between the researcher and the object of study. In particular, *realism* philosophies are based on the premise that the world exists independent of the researcher and that the researcher understands the world around them by what they perceive via their senses. Saunders et al. (2009) identifies two main categories of realism namely *direct realism* and *critical realism*. *Direct realism* argues that the senses provide the researcher with the most accurate understanding of the world. Conversely, *critical realism* argues that the researcher's understanding of the world is subjective and that what is perceived by the senses must then be interpreted or understood by the mind. Saunders and Tosey (2012) state that *critical realism* focuses on understanding what is experienced by the senses as well as the underlying factors such as the complex "structures and relationships that lie beneath" (p. 58). Cavana et al. (2001, p. 10) provides the following criticisms for the critical realist approach: "it assumes that laws of social order are out there waiting to be discovered, it may force change on people before they are ready" and "it focuses on destroying current reality without providing processes for building new reality." Based on these criticisms the aforementioned author proposed the use of the interpretivist research philosophy. For this reason, the section that follows will now turn to the discussion of the *interpretivism* research philosophy.

3.4.1.3 Interpretivism

Cavana et al. (2001) asserts that the *interpretivism* philosophy is based on the idea that man's experience of social and physical reality is subjective. This philosophy focuses on the understanding human behaviour which is influenced by a variety of factors such as emotions, intellect, education, experience, religion, social norms and customs. The focus on human attributes means that interpretivist researchers often collect qualitative data (Saunders et al., 2009). It is important to note that even though a researcher may be interested in understanding a phenomenon or an object, the scope of his or her research will be limited to collecting information on human experiences in relation to the phenomenon or object of interest. In this case the focus is not on understanding the phenomenon or object in isolation but on understanding the respondent's experience of phenomenon. Cavana et al. (2001) argues that a researcher adopting this philosophy is interested in understanding the environment of the people being studied.

3.4.1.4 Pragmatism

Pragmatism is based on the idea that multiple realities may exist and adopting of a single viewpoint could mean that the researcher fails to understand the whole problem (Saunders & Tosey, 2012). This research philosophy is flexible in that it is structured in a manner that helps the researcher to answer the research questions asked and gain a comprehensive understanding of the problem at hand. Saunders et al. (2009, p. 119) suggest that researcher may adopt a mixed methods approach and examine qualitative and quantitative data in order to understand "observable phenomena and subjective meanings". This approach to research aims to provide a holistic understanding of a problem using several techniques to examine the subparts (of the problem) as are deemed fit.

3.4.2 The Research Philosophy used in this Study

When deliberating on the research philosophy that is most suitable for a study, it is important for a researcher to bear in mind the overall objective of their study. The main objective of this study is to gain an understanding of factors that contribute to the occurrence of crisis and use that information to propose a quantifiable measure of financial stress or crisis in Australia. This study acknowledges that financial crises are complex and are caused by a combination of factors including social, financial and economic factors. The social aspect of a financial crisis is due to the fact that financial markets comprise of investors who are interested in buying or selling a commodity. Investor behaviour in financial markets has led to past crises characterised by bank runs or divestment by a large group of investors in financial markets. Financial aspects relate to the stability of major financial institutions operating in a country. For instance countries that suffer from poor management of the financial institutions, lax regulation and/ or excessive lending may be at higher risk of financial instability and crisis. Economic factors relates to prevailing economic policies that may have worsened the episode of crisis. All these factors interact and combine in a manner that produces financial stress and ultimately financial crisis when financial systems are subjected to high levels of financial stress (Illing & Liu, 2006). Several studies have shown that the macroeconomic and financial impact of crises can be quantified and analysed in order to gain a deeper understanding of the phenomenon of financial crises (Corbet, 2014; Dahalan, Abdullah, & Umar, 2016; Ekinci, 2013; Illing & Liu, 2006; Louzis & Vouldis, 2012; Oet et al., 2015; Siņenko, Titarenko, & Āriņš, 2013). Therefore, this study uses the *positivist* approach to identify and obtain numerical data for indicators for stress and/or crisis in Australia. The stress indicators are subsequently used to develop a composite stress index.

3.5 Research Approaches

Once the research philosophy has been identified, the researcher can proceed to identify the research approach that will address the research problem. A researcher can choose between two research approaches; the *deductive* versus the *inductive* approach to research. Cavana et al. (2001) consider deductive process as a top-down approach where the researcher: a) Develops a theory; b) Formulates hypotheses; c) Collects and analyses data; and d) Performs hypothesis tests in order to determine whether to accept or reject the hypotheses. Moreover, the same authors view the inductive process as a bottom-up approach where researchers: a) Examine objects, social behaviour or phenomena; b) Identify patterns or themes in the data; c) Suggest relationships based on what was observed in data; and d) Develop a theory about the object, nature of the phenomenon. Weathington, Cunningham, and Pittenger (2012) argue that the inductive approach is more suited to qualitative research as the researcher uses data as a starting point for analysis and ends by developing a theory based on the research findings. Conversely, the deductive approach is more suited for quantitative research as the researcher starts off with a hypothesis which is tested via the analysis of data collected. The deductive approach focuses on performing research to confirm a predetermined hypothesis while the inductive approach leads to the development of a hypothesis or theory. This implies that the researcher's choice of either approach depends on whether the researcher is interested in finding evidence to support a hypotheses or developing a theory about a phenomenon, object or human behaviour. Saunders et al. (2009) argue that a combination of the approaches could prove advantageous, if it enables the researcher to address the research questions asked and complete the research within a reasonable time frame.

This research uses the inductive approach due to the sequence of research process followed in this study. First, the researcher identified two hypotheses of interest for this study; these hypotheses are discussed in Section 3.2. Second, economic and financial data was collected and analysed in order to determine whether Australian data supports the chosen hypotheses. Third, the data is used to construct stress variables. Last, the selected variables are used to construct a composite stress index which is used to formulate a theory as to when Australia is experiencing financial distress or is at risk of a financial crisis.

3.6 Research Strategies

The research strategy used in this study is the experimental strategy. Neuman (2014) states that the experimental strategy is suitable for research that use the positivist approach because it allows a researcher to hypothesize about relationships that may exist between variables, collect data and analyse it to see if the hypothesis is true quantitative evidence. Moreover, Saunders, Lewis, and Thornhill (2015) argues that experimental design is useful for exploratory or explanatory research mainly because these research tend to focus on 'what', 'how', and 'why' questions. The experimental research is suitable for this research because this study examines how past crises developed and spread with the aim of identifying relevant stress variables that signal the worsening of financial health in an economy to crisis levels. It also explores how the variables can be combined to form an aggregate measure of stress in Australia. This study presents hypothesis on the conditions that could precipitate distress in the Australian mining sector and the potential effect of using different index aggregation techniques. Since Australia has had limited experience with financial crises, the study draws on the experience of other developed countries (that have suffered more financial crises) in order to determine Australia's likelihood of crisis in future.

3.7 Choice of Research Methods

This research considered the use of a *mono method* versus a *mixed methods* technique for this study. The *mono method* techniques use either a predominantly quantitative or qualitative method. The quantitative methods focus on obtaining numerical data while qualitative methods focus on obtaining non-numerical data. The choice of either technique influences the data collection technique chosen in the final stage of the research design process. Proponents of the *mixed methods approach* often utilise quantitative and qualitative methods in data collection and analysis stages of their research design (Saunders et al., 2009, 2015). The procedure for data collection and analysis in this study is consistent with a *mono method* technique. In particular, this study mainly collected and analysed quantitative data before presenting a quantifiable measure of financial stress for Australia. Consequently, the quantitative aspects of this study are discussed in Section 3.7.1 of this chapter.

3.7.1 Quantitative Approach

The quantitative aspect of this research focused on providing quantitative measures of stress. This involved examining historical financial trauma events with the intent of identifying stress indicators that can contribute to designing a composite stress index for Australia. A good starting point for developing quantitative measures is an evaluation of financial and economic variables that reflect the performance or health of the Australian economy over time. For the purposes of this study, variables were selected based on four main criteria:

1) Desirability, as evidenced by use in similar studies (e.g., focused on other countries) or in theory papers from the literature review.[23]
2) Availability, timing structure (e.g., weekly, monthly, quarterly, annual), range (years covered), and nature (scope),
3) Quantity; to ensure that statistical tests are robust and that the research findings are statistically significant/valid, this study uses variables with at least 100 data points, and
4) Availability of appropriate proxies, where a variable is highly desirable but sufficient, reliable, and/or appropriate historical data is unavailable.

Once suitable variables were identified, the researcher assessed the degree of variable responsiveness during past episodes of stress (i.e., the variables show statistically different behaviour during stressful periods, as compared to non-stressful periods). This implies that variables that exhibit the same kind of trending behaviour or movement regardless of the incidence or absence of a crisis provide insignificant information when measuring the level of stress. Variables that signal financially traumatic periods were deemed fit for index-construction purposes.

The index-construction phase of the study considers where, and as appropriate, incorporates extant-research methodologies and recommended index-building techniques. Section 3.11 contains a brief discussion of the index aggregation methods used in this study. A detailed discussion of these methods and the index building procedure are provided in Chapter 9. The econometric packages to be used for variable analysis and index construction are Regression Analysis of Time Series (*RATS*), *Eviews* (7 and 8), and *IBM SPSS Statistics 19* econometric

23 Studies indicate that changes in asset prices and credit measures could prove useful in designing early warning indicators of financial stress (Borio & Lowe, 2002; Misina & Tkacz, 2009; Sorge, 2004).

packages (Estima, 2017; IBM, 2015; Quantitative Micro Software, 2015). The estimated indexes were assessed to verify that they are suitable forecasting and monitoring tools.

Forecasting of stress involved splitting the dataset into two halves and using historical values in one-half to forecast observations in the other half and robustness of the forecasting model will be checked. This study also explored how financial-and-trade networks that link the Australian market to other parts of the world might be potential conduits of stress (contagion) to Australia. The study concludes with a discussion of the limitations and policy implications of the stress index.

3.8 Time Horizons

The time horizon is an important aspect of research that should be specified before data is collected or analysed. There are two main categories of time horizons: The *longitudinal*; and *cross-sectional* time horizons (Saunders et al., 2009). The *longitudinal* studies examine a phenomenon over an extended period of time and data is collected from one observation. It is common for the extended period of time to be divided into a regular time interval such as weekly, monthly, quarterly or yearly. By examining the trends of data the researcher can identify weekly, monthly, quarterly, or annual trends; or seasonality in quantitative data. Cross-sectional studies focus on the understanding a phenomenon at a specific point in time. Data is collected at a point in time across several observation points. The difference between the two categories of time horizon can be better understood if an example is considered. Therefore, consider inflation as a variable of interest for illustrative purposes. The quarterly inflation rate in Australia from 1980 to 2014 is an example of a longitudinal variable while the inflation rate of the G20 countries in the last quarter of 2014 is an example of a cross-sectional variable. In the case of the longitudinal time horizon, Australia is the single observation and data relating to inflation is obtained in each quarter from 1980 to 2014.

Conversely, the cross sectional variable focuses on the rate of inflation at one point in time (the last quarter or 2014) and more than one observation is considered (e.g., Australia, Japan, the USA, and the UK). This study has a longitudinal time horizon—it is focused on designing an index for Australia using historical data for the economic and financial variables. Now that it has been established that a longitudinal time horizon is most applicable for this study, the next issue is the data frequency that is most suitable for this study. Therefore, the section that follows discusses the data frequency that was used in this study.

3.9 Data Frequency

For the purposes of this study, time series of monthly frequency is preferred to the daily frequency since data for macroeconomic variables is more readily available at the monthly frequency. Opting for data at the daily frequency would limit the choice of variables to those available on daily frequency only (Holló, Kremer, & Duca, 2012; Illing & Liu, 2006). In most cases, the daily frequency is suitable for financial data but it is not suitable for macroeconomic data. Moreover, due to non-synchronous trading it is difficult to generate a synchronous dataset using daily data especially when the economic or financial variables are obtained from different countries. Given that this study considers the inclusion of foreign variables in the composite stress index, obtaining a synchronous dataset is an issue of considerable concern. Often, security markets remain closed on public holidays and different countries often observe public holidays on different dates. As a result, there is no trading of securities and consequently there is no trading data on public holidays. For instance, daily data for Australian may not be available for Australia day, ANZAC day, and the Queen's Birthday because the Australia Securities Exchange (ASX) remains closed on those days. It should be noted any of these holidays fall on a weekend, the trading calendar would not be affected; however, this is rarely the case. Even though the Australian markets remain closed during Australian public holiday, other markets will continue trading and trading data would be available. This means that when comparing trading data for Australia and other countries, data will be available for trades in other countries and no trading data will be available for Australia. With regard to estimation of the composite financial stress index this means that, missing values of certain variables could lead to incorrect estimates of the level of financial stress. Brown and Warner (1985) highlight other problems with daily data as identified by Fama (1976). These include the tendency of daily data to deviate more from the normal distribution than monthly data would. This is an issue of concern as a common assumption for many statistical analysis techniques assume an approximately normal distribution in the data. Allayannis and Ofek (2001) prefer the use of monthly data when dealing with exchange rates indices instead of daily or weekly data because monthly data tends to be less noisy. This study also considered the use of either quarterly or annual data instead of data at a monthly frequency. However, the use of either quarterly or annual data presents two problems. Firstly, lowering the frequency of data reduces the number of data points available for performing empirical analysis. Secondly long periods will lapse (a year or a quarter) before the data necessary for estimating the financial stress index is available. As a result, there will be a delayed monitoring of the economic health, late detection of the onset of a crisis, and delayed implementation of the steps to curb a developing crisis in Australia. Since the focus of this research is to provide tools for timely intervention the use of annual data was altogether avoided; rather the use of variables that are available at the monthly frequency are preferred. As a last resort, when monthly data is unavailable, quarterly data is converted to monthly series via interpolation.

3.10 Measuring Financial Stress and Contagion

The incidence of financial crises is an issue of global concern whether a country is directly affected by a crisis, indirectly affected by a crisis or not affected at all. Ideally, the scenario of a country that is unaffected by a crisis is most favourable. However, this is not a perfect world. It seems that somewhere on this planet market dynamics often culminate in countries suffering from either the direct or indirect impact of a crisis. In regards to the direct impact of a crisis, the post-crisis season is characterised by a sort of 'clamour' among regulators to be more vigilant, to introduce more stringent monetary or fiscal policies and to examine the anatomy of the crisis that led to financial disarray. The notion is that a better understanding of this crisis will aid in predicting and averting or ameliorating the effects of future crises. However, a plausible reason why economists fail to anticipate financial crises until it is too late is that for the most part, financial crises can only be anticipated if history repeats itself. By no means does this mean that economists should give up on the quest for early warning indicators of financial stress. Rather, it is an admonition to analysts to avoid making rush and simplistic conclusions.

3.10.1 An analogy for financial crisis

This study suggests that the reader consider an analogy between a financial stress and human cancer in order to understand the complex nature of financial crises. Suppose that the idea of the various stages of cancer is similar to the notion of development of a crisis along a continuum from financial stress to a crisis. In the case of cancer, a combination of factors including genetics and lifestyle choices such as alcohol consumption, smoking habits, an aversion to fruits and vegetables and a high body mass index predispose an individual to developing cancer (Danaei, Hoorn, Lopez, Murray, & Ezzati, 2005). Understanding the factors that increase one's risk of developing a cancer can be useful in adopting preventative healthcare. For instance, a non-smoker has less likely to develop lung cancer than a smoker. However, this does not mean that non-smokers will never develop lung cancer. Indeed, the phenomenon of rising lung cancer among non-smokers has been documented (Sagawa, Nakayama, Tanaka, Sakuma, & Sobue, 2012; Wise, 2008). While doctors continue their research on the combination of factors that predispose the non-smokers to develop cancer, it is apparent that the incidence of lung cancer does not develop solely due to the smoking of cigarettes. Moreover, in some cases genetics provides some smokers with some protection against cancer such that they never develop this terrible disease in their lifetime. If one was to take a simplistic view of cancer for instance and focus on addressing one risk factor such as a change in diet to include more fruits and vegetables but neglect the consideration of the other issues raised (i.e. drinking, and smoking), then the individual would be just as likely to develop cancer. Similarly, a combination of factors such as macroeconomic imbalances, structural fragilities and financial contagion lead to the onset and/or development of a crisis. Attributing the onset of a crisis to one factor alone would be considered as failing to appreciate the complex nature of financial crises. After all, if the answer were that simple, then analysts would not waste time mulling over each incident of a financial crisis. This study asserts that crises like cancer develop over time and can be dealt with if caught in the early stages. Consider the stress index as a screening or biopsy procedure that helps to assess the early stages stage of a crisis. By using the stress index, analysts are not saying financial crises will never occur. Rather that if a stress index indicates high levels of financial stress then intervention is advisable in order to manage effectively a potential crisis.

Regarding the indirect impact of financial crisis, it is often said when a neighbour’s house is on fire, then you are prudent to help them put the fire out before it spreads to your house. When considering houses it is clear to see when the danger is nearby. However, with global economies it is less evident. Researchers are concerned about the manner in which financial crises spread from one economy to another while other countries remain unaffected by the contagion of crisis. Scholars have varying opinions on factors that make countries vulnerable to contagion. Glick and Rose (1999) assert that currency crises are often experienced by countries within the same geographical area and spread via bilateral trade links. However, being in close proximity to another country does not guarantee that a country with suffer from contagion. Park and Song (2001) confirm the importance of trade links but stress that herding behaviour, speculative attacks among investors and common macroeconomic practices contributed to the contagion of the 1997 Asian Crisis. Kaminsky and Reinhart (2000) posit that in addition to trade links, financial links via banks or financial markets can help explain channels of contagion. From the literature, it is clear that the consideration of financial and trade links is equally important in explaining a country's risk of contagion and that the consideration of either of the links in isolation is unwise. Consequently, this study considers the role that trade and financial links play in the contagion of financial stress to Australia.

3.11 Aggregation Methods for Composite Indexes

When developing a composite index for measuring stress, researchers try several aggregation methods before adopting a comprehensive measure of stress. Generally, the index should provide the best fit for the data, provide reasonable estimates for stress and be relatively easy to interpret. Common aggregation methods include the principal-components analysis (PCA), transformation to cumulative distribution functions (CDFs) and the variance-equal weights method. The subsections that follow provide a brief summary of what each aggregation technique involves.

3.11.1 Principal Component Analysis

PCA is a well-accepted method of index construction that was implemented in the: Canadian stress index, Kansas City Financial Stress Index (KCFSI), St Louis Financial Stress Index (STLFSI), Greek Financial Stress Index, and European Central Bank's Composite Indicator of Systemic Stress (CISS) (Federal Reserve Bank of St Louis, 2010; Hakkio & Keeton, 2009; Holló et al., 2012; Illing & Liu, 2006; Louzis & Vouldis, 2011). According to Vyas and Kumaranayake (2006), the PCA is a "... multivariate statistical technique used to reduce the number of variables in a data set into a smaller number of *dimensions*." It uses a set of correlated variables to create uncorrelated indices/components. The resulting index is expressed in linear form, via the sum of each variable multiplied by its corresponding weight. Conversely, if the variables were standardized, the covariance matrix should be used to estimate the respective weights (Vyas & Kumaranayake, 2006). Critics of the PCA method argue that it lacks a clear technique for choosing the number of components and variables to include in empirical analysis (Oet, Eiben, Bianco, Gramlich, & Ong, 2011). Moreover, the computed index weights are vulnerable to peculiarities entrenched in the data, such as extreme values or outliers. The PCA methodology computes a fixed set of weights for all time periods that are applicable for the data, but have no real existence. This problem can be overcome by conducting expert surveys, as demonstrated by Illing and Liu (2006) to select alternative weighting schemes so as to adequately capture the episodes of stress as (and when) they occur.[24]

[24] Illing and Liu (2006) distributed 40 questionnaires to economists and analysts working in Canadian banks, financial institutions, and policymaking roles. The questionnaires highlighted perceived episodes of historical crisis from 1981-2001 and asked experts to give their professional opinion on whether they believed Canada experienced financial stress at a particular time.

3.11.2 Transformation to Cumulative Distribution Functions

The transformation of variables to cumulative distribution functions (CDFs) method involves converting all variables to their sample CDFs before constructing the index (Illing & Liu, 2006). Each variable is expressed in terms of a rank percentile that ranges from one to 100. The lowest values of a particular variable are assigned the value 1.0 and the highest the value 100.0. This means that all variables range from 1.0-100.0. The composite index is computed by taking the arithmetic mean of the transformed variables. An intuitive interpretation of this index is that lower values of the stress index indicate lower levels of stress and vice versa.

3.11.3 Variance-Equal Weights

The variance-equal weights technique converts all stress indicators to a standardized normal variable that can be positive, negative, or zero. This is done using the mean and standard deviation to calculate the standardized a variable in the following manner: First the mean and sample standard deviation of a variable are calculated; Then standardised values of the variable are obtained by subtracting the mean from the value of a variable at a given time; and Then dividing the difference by the standard deviation of the variable. It is important to note that in the variance-equal-weights approach, variables being considered for the index are assumed to be normally distributed with equal variances such that no variable dominates the others in the designed stress index. The equal-weight approach is flawed as it penalizes variables with high volatility or better indicators of stress by assigning smaller weights to them and assigns larger weights to variables with lower volatility and less crisis predictive power higher weights (Das, Iossifov, Podpiera, & Rozhkov, 2005; Sachs, Tornell, & Velasco, 1995, p. 159). This implies that a consideration of variable weights would be more applicable as it apportions higher weights to variables that are more volatile or better indicators of stress and apportion lower weights to variables which are less accurate predictors of stress or crises.

3.12 Justification of Research Approach and Methods

This research uses a *mono methods* approach (i.e. a quantitative approach). Proponents of quantitative methods argue that findings of a quantitative study can easily be replicated and verified using the same data set and techniques employed by a researcher; something that is often difficult to achieve with qualitative techniques (Gray, Williamson, Karp, & Dalphin, 2007). From a policy perspective, estimation of stress indices for several countries using the same quantitative method can help in setting benchmarks of optimal stress levels (e.g. those that best foster economic development). Moreover, standard measures of financial contagion can be developed to assess the presence and intensity of contagion. Quantitative methods are useful for identifying what caused stress and evaluating whether stress contagion has occurred and/or its intensity. An example of a quantitative study by Hanschel and Monnin (2005) adopted the variance-equal weight technique after the PCA technique failed to yield meaningful results. Different variable combinations were used to evaluate the robustness of the resulting stress index and the forecasting ability of index was assessed using data from 1987 to 2003. Although the variance-equal-weight-stress index is easy to estimate, that estimation technique assumes that variables included in the index are normally distributed, something that is not always the case with stock index data which exhibit a fat tailed distribution.[25]

Key limitations of quantitative techniques include the inability to identify and explain policy implications of the stress index and/or to explain why stress contagion occurs in some situations and not in other often seemingly identical ones. Such insights can often be gained by using qualitative methods, which are more suited to selecting, and answering why questions. According to Gray et al. (2007), qualitative methods can contribute to the

[25] Please note: There are well-accepted techniques for normalizing many types of non-normal-data distributions (e.g., use of log functions for lognormal distributions).

understanding of important aspects of stress that are not conveyed in the stress index. Thus, theoretical models may explain why contagion occurs and suggest policy implications of measuring and acting on stress indicators. For instance, using theoretical explanations Allen and Gale (2000) and Pericoli and Sbracia (2003) offer models of contagion and propose containment strategies based on those employed in other countries. Given that theories are developed based on a combination of a researcher's convictions and the review of literature, it is possible for several researchers to arrive at different explanations for the same phenomenon. Hence, replication of qualitative research can prove problematic.

This study chose to use a quantitative methods approach because, in the researcher's opinion, it would facilitate the design of a stress index that could be replicated by various stakeholders in order to assess the level of stress. For example, policy makers could make use of the stress index to evaluate the prevailing level of stress and recommend policy measures in response to current conditions in Australian financial markets. A possible limitation of this research is that the indicators of stress will be developed using historical data. Specifically, such data reflects causes of stress/crisis in the past and will only forecast stress if the future (that it seeks to forecast) mimics the pattern of past economic imbalances. In economics, that assumption is highlighted with the *ceteris paribus* phrase and accounting recognises with the adage that in the absence of evidence to the contrary, the best predictor of the future is the past. In any event, use of the index to provide insights into potential stress or contagion must come with the caveat that it must be adjusted to take into consideration financial innovations and trade agreements that did not exist at the time of the index was created. Future research will need to continuously update the indices to incorporate new risks posed by recent financial innovation and trade relationships.

3.13 Concluding Remarks

This chapter provides the conceptual foundation for designing the Australian financial stress index and assessing its effectiveness for policy implementation and prediction of future crises in Australia. This chapter also outlined the research process used in this study. Overall, the researcher found that a positivist philosophy, deductive strategy and an experimental research method were most suited for this study. The justification for the research approach proposed was also discussed in this chapter. This chapter deliberated on the data frequency that was most appropriate for this research. It was decided that obtaining data at a monthly frequency was most desirable as it would allow for close and regular monitoring of the level of stress in Australian financial markets. It was not possible to contain a discussion of the data and variables in one chapter because this research is data intensive. Therefore, a detailed discussion the data collected and the stress variables constructed in this study are provided in Chapters 4 to 8. Ultimately the variables presented in these chapters and the aggregation methods discussed Chapter 9 was used to construct the stress index for Australia. The following chapter discusses the stress variables that indicate financial stress in the Australian equity markets.

CHAPTER 4

FINANCIAL STRESS IN EQUITY MARKETS

4.1 Introduction

The main purpose of this chapter is to propose indicators of financial stress or crisis in the Australian equity market. The chapter commences with a brief overview of the importance of equity markets. It then proceeds to delve into the subject matter of the characteristics of an equity market crisis. At this point, four indicators of equity market stress are discussed and subsequently estimated. The warning indicators proposed in this chapter are subsequently incorporated into the composite financial stress index in order to measure financial stress in the Australian market as a whole.

4.2 Indicators of stress in equity markets

An understanding of what equity markets are and how they function during in-crisis periods and out-of-crisis periods could prove useful in identifying the indicators of stress. Equity markets facilitate the transfer of funds from investors with surplus funds to investors with a shortage of funds (Petty et al., 2012). Usually, the transfer occurs via the trading of shares listed on the Australian Securities Exchange (ASX). Once a public company is listed on the ASX, it can issue and sell shares in order to raise equity for business operations. Investors purchase a company’s shares in the hope that the shares will appreciate in future and subsequent resale of shares will result in a capital gain. It is common for share prices to move upwards or downwards as shares continue to trade on a stock exchange. During out-of-crisis periods, it is expected that equity markets are tranquil exhibiting low volatility and less fluctuations in share prices. Conversely, during in-crisis periods, there is higher volatility and oscillation of share prices. More specifically, stock market crashes are characterised by rapid drops in share prices and a general decline in the prices of shares traded in an equity market, which may signal problems in the financial system. For instance, during the 1987 Black Monday share prices in the New York Stock exchange fell by about 33.33 percent over five trading days in October (Patel & Sarkar, 1998). Generally, speculative forces intensify during financial crises suggesting that a country can never be immune to large drops in the share prices regardless of whether a country is an emerging economy or developed country such as Australia. Nonetheless, share prices in emerging markets tend to be more fragile and bound to experience larger share price losses compared to developed countries.

Most scholars recognize increased volatility in stock markets as an indicator of stress in equity markets. Accordingly, indicators that measure volatility in equity markets have been incorporated in many financial stress indexes. A popular approach to estimating time varying volatility in equity markets is based on the Generalized Autoregressive Conditional Heteroskedasticty (GARCH) approach developed by Bollerslev (1986). In most cases a GARCH (1, 1) process is applied to returns of the composite stock index of a country; this process has been deemed sufficient by many researchers. Nonetheless, some authors estimate more than one GARCH model to assess the suitability of the model. Although, Illing and Liu (2003) explored the use of other GARCH models such as the GARCH (2, 1) and GARCH (1, 2) models. It was found that the other models provided similar results to the GARCH (1, 1) model. This study shall explore the use of the other GARCH models if the GARCH(1,1) is found to be inadequate.

GARCH models have been used in studies of emerging and advanced countries and for different time frequencies. The following are a few examples of the studies that utilize this approach. Illing and Liu (2006) use this approach to estimate volatility in daily returns on the Canadian stock market. Vermeulen et al. (2015) uses this approach in a study of 28 Organisation for Economic Cooperation and Development (OECD) countries to estimate equity market volatility using quarterly data from 1980 to 2010. Using data of the same frequency and quarterly data from the first quarter of 1992 to the last quarter of 2012, Park and Mercado (2014) estimate volatility measures for 25 emerging and 15 advanced countries. Balakrishnan et al. (2011) also use a similar approach for estimating volatility for 26 emerging countries using monthly returns on composite stock indexes. The time span for the study by the aforementioned authors varied from country to country with the earliest starting date being January 1997 and the latest ending date being January 2009. Hakkio and Keeton (2009) proposed an alternative measure of implied volatility that attempts to forecast volatility in S&P 500 by checking monthly movements in the Chicago Board Options Exchange volatility index (VIX). These authors argue that this is a good indicator of stress as it gauges uncertainty about investor behaviour and about asset values.

With regard to large drops in stock prices, four measures are often incorporated in stress indexes. First, Duca and Peltonen (2013) and Balakrishnan et al. (2011) propose the use of a negative equity returns variable using quarterly and monthly data respectively. This variable is estimated using returns of a composite stock index. The equity returns are transformed to signal stress in the following manner. Zero replaces positive returns in the final variable. Negative returns are then converted to positive values by multiplying the values by negative one. As a result, large drops in equity prices result in higher values in the negative returns variable and indicate higher values of stress in the equity market and vice versa. Second, simpler indicators of stress focus on the use of returns on a composite stock index. Park and Mercado (2014) use returns on composite stock indexes to measure stress. Although, the aforementioned authors fail to provide criteria for identifying in-crisis periods, it is likely that a long period of successive negative returns on shares could signal an equity market crash. Third, percentage changes in the returns of an equity index have been used to signal periods of equity market stress. Edison (2003) used the percentage change in a stock index from a year ago to measure stress in 20 countries in developed and emerging markets. In this case, large declines in value of the variable would indicate episodes of stress or crises. Last, the CMAX variable which was developed by Patel and Sarkar (1998) has been utilized in several studies some of which include research by Holló et al. (2012), Illing and Liu (2006) and Park and Mercado (2014). Illing and Liu (2003, p. 6) refer to this as a “hybrid volatility-loss measure” that can be used to identify large drops in share prices.

This study estimates four viable variables to measure equity stress in the Australian market. All variables are constructed using monthly data for the All Ordinaries index since this data is readily available from Wren Advisers (2015). The variables of interest for measuring equity market stress are: 1) an inverted CMAX equity variable 2) percentage change from a year ago, 3) a negative equity returns variable and 4) a GARCH volatility model. Sections 4.2.1 to 4.2.5 discuss the procedure used to estimate each variable.

4.2.1 Inverted CMAX Equity Index

Illing and Liu (2006) propose the use of a CMAX variable to measure share volatility in a financial market. The CMAX was originally designed by Patel and Sarkar (1998) and it compares the level of a share index to the maximum value over a historical time window which could be expressed in terms of years. Following Illing and Liu (2006), this research adopts a CMAX measure for a period of 2 years (24 months) since it is not expected that the share price of stock indexes in developed countries would vary by much during a two-year period. The CMAX calculation can be expressed as shown in Equation 4.1.

$$CMAX_t = \frac{I_t}{\max[I \in (I_{t-j} | j=0,1,2 \ldots T)]} \quad (4.1)$$

Where I_t is the value of the share index at time t. T defines the moving time window being considered and was set to 2 years. When dealing with monthly data, the CMAX calculation for the All Ordinaries index would compare the value of the index at time t with to the maximum value over the past 24 months. The researcher is of the opinion that the 12 month window would be as sufficient in the estimation of the CMAX variable. Consequently, a 12-month window is considered in addition to the 24-month window. Historical data of monthly averages of the Australian All Ordinaries index from January 1980 to December 2014 was used to estimate the CMAX variable using a 1 year and 2 year window. A graphical representation of the resultant CMAX series is shown in Figure 4.1.

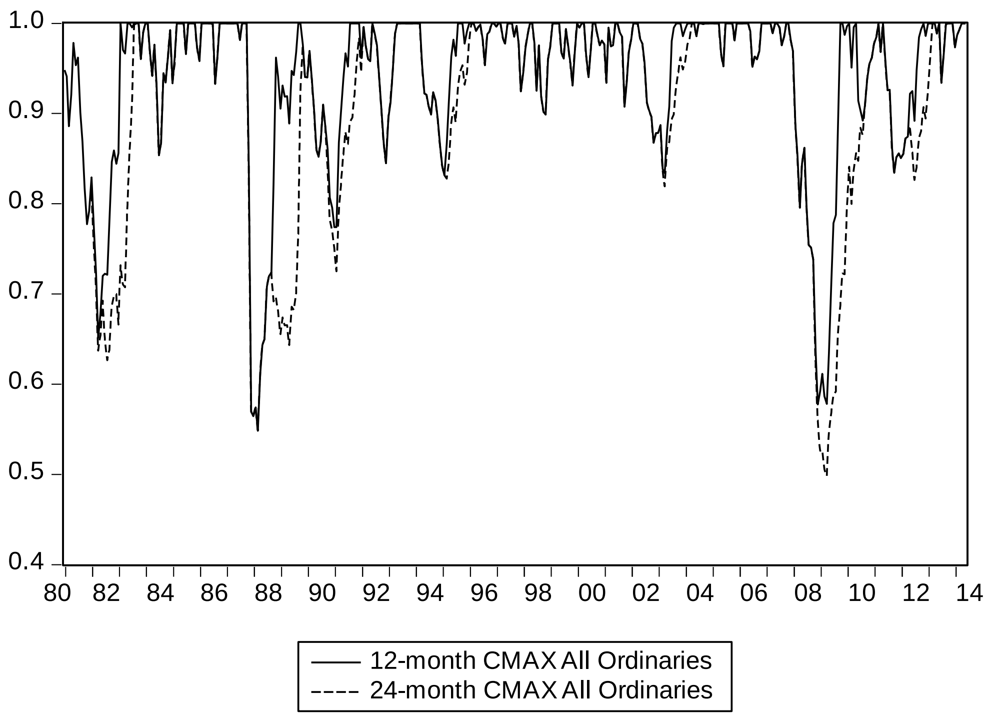


Figure 4.1: The 12-month and 24-month CMAX Graphs for All Ordinaries Index
Source: Authors calculations based on Wren Advisers (2015) data

It appears that the use of either the 12-month or 24-month window is sufficient as there is not much difference in the estimated CMAX series, with both indicating that Australian equity markets experienced high levels of financial stress in 1982-1983, 1988-1989 and 2008-2009. The indicated periods of stress correspond to periods of financial stress or crisis in Australia. Notably, the CMAX series correctly highlight the 1982-1983 recessions, 1989-1992 Australian Banking Crises[26] (ABC) and the 2007-2009 Global Financial Crises (GFC).

Australia experienced an economic recession from 1982 to 1983. Siriwardana (1998) argues that the recession was particularly made worse because of a number of factors including an oil shock, rising real wages, a severe drought and contractionary monetary policy. Moreover, this author states that Australia's recession had probably originated in the US and/or Europe which experienced recessions before Australia. Given a consideration of two episodes of stress, the 1982-1983 recession and 2007-2009 GFC, it could well be argued that Australia is particularly vulnerable to financial contagion from the American financial markets.

In the lead up to the 1989-1992 Australian Banking Crises, there was extensive deregulation of the financial sector. From December 1980 to September 1988 comprising of floatation of the Australian dollar in December 1983, elimination of controls on bank deposits in August 1984, elimination of interest rate ceilings on bank deposits in December 1980 and house loans in April 1986 and reduced restriction of foreign banks entry into the Australian market (Kriesler, 1995). Naturally, banks made some mistakes when trying to operate in the new yet unfamiliar financial system. In anticipation of increased competition from foreign banks, Australian banks engaged in risky lending practices while requiring less collateral. This strategy was unsustainable in the long-run as it negatively impacted the banks' profitability. As a result, Australian banks that engaged in rapid expansion or increased lending of risky

[26] Kovzanadze (2010) identifies this as the only systemic banking crisis in Australia from the 1970s to 1990s.

loans subsequently required bailouts or mergers. In particular, the South Australian government bailed out the Bank of South Australia when it failed in 1991 while in Victoria the state had to merge Tricon with Commonwealth bank when it ran out of funds to bail it out (Stanford, 2010, p. 23). Overall, it would appear that Australia learned from the 1989-1992 banking crisis, as the banking industry fared much better during the 2007-2009 GFC. Nonetheless, Australia like other developed countries, suffered the contagious impact of the GFC, albeit to a lesser degree.

4.2.1.1 Transformations to the CMAX index

In order to include the CMAX index in the composite financial stress index, this study proposes the use of the inverse form of the CMAX index. The inverse CMAX differs from the CMAX measure developed by Patel and Sarkar (1998) with respect to the interpretation of the index. With respect to the CMAX index, an increase in the index indicates a lower stress in the equity market while a decrease in the index indicates higher levels of stress in the equity market. Conversely, the rationale for the transforming the CMAX index is based on the notion that rising levels of the inverted CMAX would signal rising levels of financial stress and vice versa. Therefore, a mathematical representation of the inverted CMAX is as shown in Equation 4.2.

$$\text{Inverted } CMAX_t = \frac{\max\left[I \in (I_{t-j} | j = 0,1,2 \ldots T)\right]}{I_t} \tag{4.2}$$

While, either CMAX index is suitable for use in the final index, the 24-month CMAX index used in the final index. Figure 4.2 is a graphical representation of the transformed CMAX index. The highest spikes in the inverted CMAX series in February 1988 and March 2009 correspond to periods of the Australian banking and the Global financial crises. Therefore, the inverted CMAX index is deemed an adequate indicator of equity market stress, which results in large drops in the value of the All Ordinaries index. However, a shortcoming of the inverted CMAX index is that it fails capture changes in volatility of the All Ordinaries index, which is also an important measure of equity markets stress. In order to address this shortcoming of the variable, an alternative measure is proposed in Section 4.2.2.

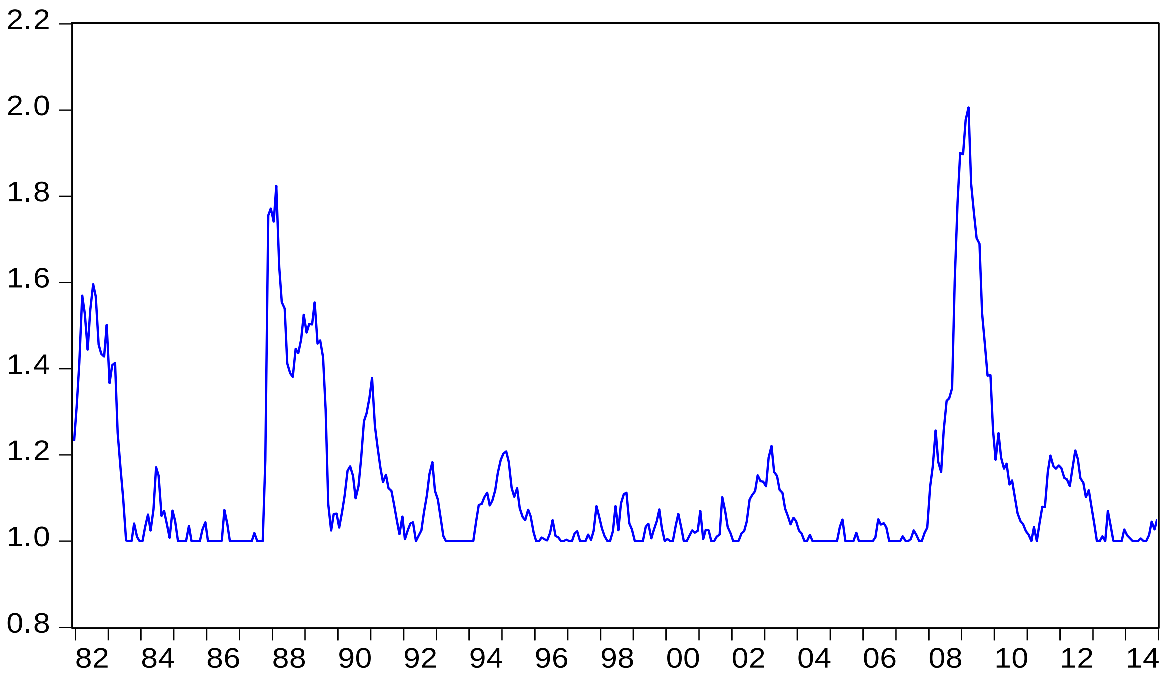


Figure 4.2: Inverted 24-month CMAX index
Source: Authors calculations based on Wren Advisers (2015) data

4.2.2 Percentage change in the equity index from a year ago

The percentage change in the value of the All Ordinaries index from a year ago is estimated using the formula shown in Equation 4.3. Where Y_t represents the value of the stock index today and Y_{t-12} represents the value of the stock index 12 months ago. The values of the index from January 1979 to December 2014 were used to obtain a series of values from January 1980 to December 2014. A graphical representation of the resulting series is provided in Figure 4.3.

$$\%\Delta\ in\ equity\ index\ from\ a\ year\ ago = 100 * (Y_t - Y_{t-12})/Y_{t-12} \qquad (4.3)$$

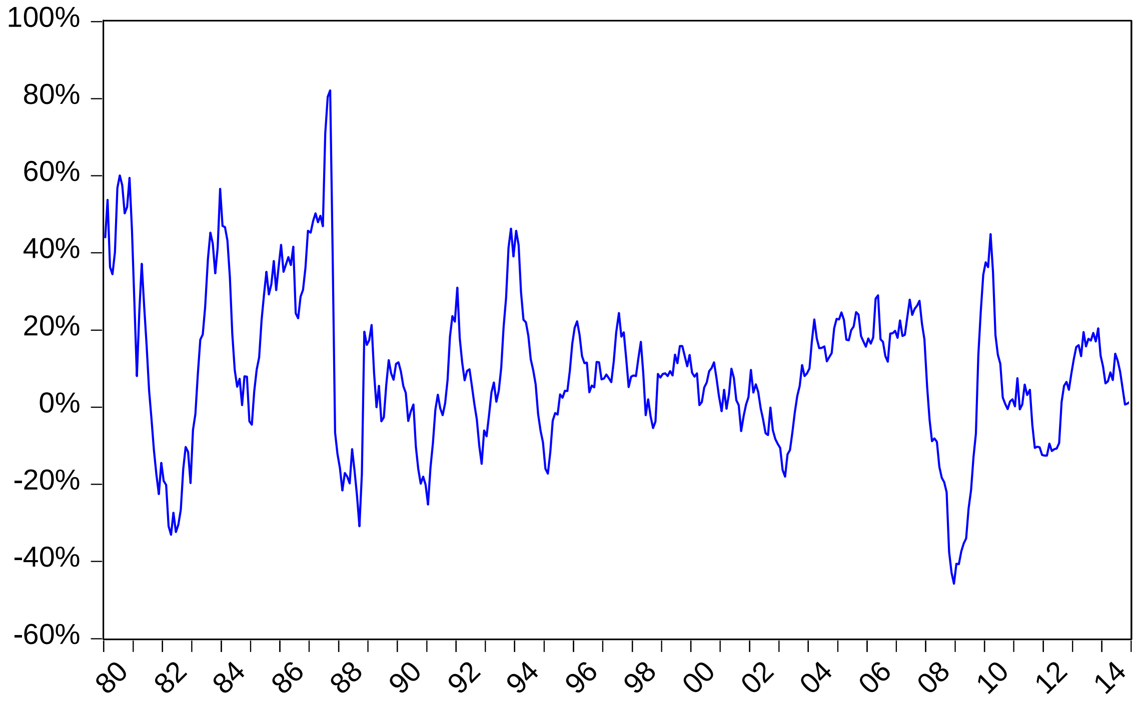


Figure 4.3: Percentage Change in the All Ordinaries Index from a year ago
Source: Authors calculations based on Wren Advisers (2015) data

Negative values of the series are indicative of stress in the Australian stock market. The largest drop in the index (in comparison to previous year) occurred in April 1982 (-33%), June 1982 (-32%), September 1988 (-31%) and December 2008 (-46%). Coincidentally, the last two points in Figure 4.3 correspond to times of financial crises namely the 1989-1992 Australian Banking Crises (ABC) and the 2007-2009 Global Financial Crisis (GFC). Therefore, it can be deduced that smaller negative values indicate the presence of stress.

4.2.3 Transformations to percentage change in equity index

An examination of Figure 4.3 shows that the lowest points in the graph are signalling the presence of stress. For ease of interpretation, this study aims to design a stress index where rising levels in the stress variables indicate rising levels of stress. Therefore, a modified expression of the percentage change in the All Ordinaries index is estimated as shown in

Equation 4.4 before incorporating it into the composite stress index. The resulting series is shown in Figure 4.4.

$$Modified\ \%\Delta\ in\ equity\ index\ from\ a\ year\ ago = 100 * (1 - \frac{(Y_t - Y_{t-12})}{Y_{t-12}}) \quad (4.4)$$

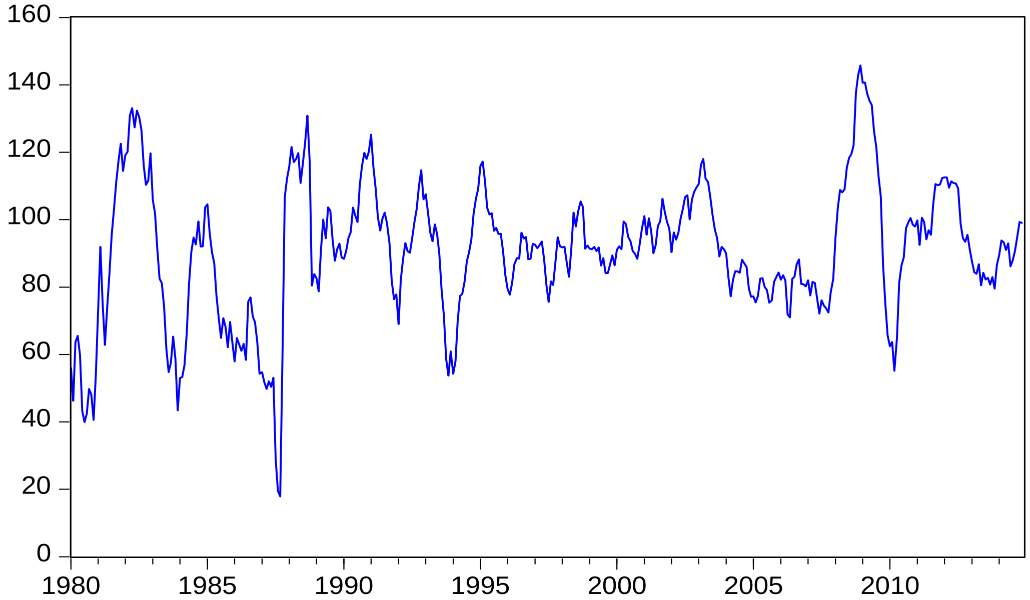


Figure 4.4: Modified Percentage Change in the All Ordinaries Index from a year ago
Source: Authors calculations based on Wren Advisers (2015) data

4.2.4 Negative equity returns variable

The negative equity returns variable is estimated using the procedure outlined by Duca and Peltonen (2013) and Balakrishnan et al. (2011). The variable was estimated using four steps. First, the monthly averages of the index from December 1979 to December 2014 were expressed in natural logarithmic terms. Second, the logarithmic values of the index were used to calculate the continuously compounded return on the index as shown in Equation 4.5, where R_t is the logarithmic return on the All Ordinaries index at time t, P_t is the value of the All Ordinaries at in month t and P_{t-1} is the value of the index in month t-1. Therefore, the return is estimated by comparing the value of an index in a particular month with the value of the index in the previous month.

$$R_t = ln(P_t) - ln(P_{t-1}) \qquad (4.5)$$

Third, the returns of the index were examined to check for negative returns on the index. Since it is a requirement that positive returns on the index be ignored and negative returns be transformed to positive numbers, a dummy variable(D_t) was created that takes on the value of negative one when the returns on the index are negative and zero when the returns on the index are positive. More formally, the mathematical expression for this binary variable would be as shown in Equation 4.6.

$$D_t = \begin{cases} -1 & if\ R_t < 0 \\ 0 & if\ R_t \geq 0 \end{cases} \tag{4.6}$$

Fourth, the negative equity returns series was obtained by multiplying the dummy variable at time t by the corresponding returns on the All Ordinaries index at time t. The formula for estimating the series can, therefore, be written as shown in Equation 4.7 and the graph of the final series is shown in Figure 4.5. The most prominent spikes in the series occur in November 1987 and October 2008, which corresponds to the approximate timing of two US crises, namely the 1987 Black Monday and 2007-2009 GFC.

$$Negative\ equity\ returns = D_t R_t \tag{4.7}$$

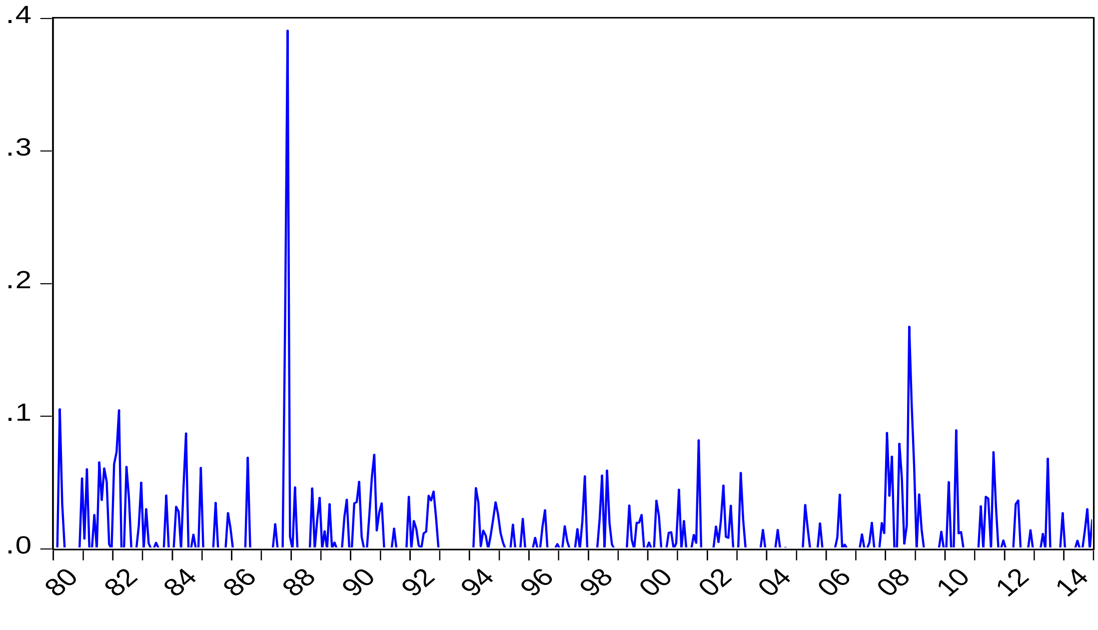


Figure 4.5: Negative equity returns (January 1980 to December 2014)
Source: Authors calculations based on Wren Advisers (2015) data

4.2.5 Volatility in the equity markets

Volatility in share prices is an inherent aspect in the operations of global financial markets. When examining trading of stocks over long periods, it is common to observe that certain periods are characterized by small fluctuations in the price of shares while others are characterized by large fluctuations in share prices. Small fluctuations in the share price indicate low volatility while large fluctuations indicate high volatility in the price of a share. Brooks (2008, p. 380) argues that "volatility clustering" is a common phenomenon in financial markets that is characterized by periods of high volatility whereby large increases (or decreases) in share returns are followed by large changes in share returns and vice versa. With respect to financial crises, stock prices and exchange rates tend to fluctuate more during periods of crisis compared to out-of-crisis periods. For instance, in 2008, Gujarati (2011) asserted that the US Dow Jones Index oscillated due to rising oil prices and the 2007 subprime mortgage crisis. More specifically, on 29 September 2008, the Dow Jones lost 777.7 points and subsequently swung upwards and downwards by more than 300 points for most of October 2008 (p. 238). Such volatility in stock prices can be incorporated into a financial-stress index using a GARCH process (Bollerslev, 1986). In this study, GARCH[27] models are used to capture volatility clustering exhibited in equity and foreign exchange markets. Therefore, the formulas and procedure for estimating GARCH models discussed in this chapter were applied to subsequent measures of volatility used in this study.

Time series data of the All Ordinaries for the months of December 1983 to December 2014[28] was sourced from Wren Advisers (2015). Figure 4.6 graphs the values of the All Ordinaries

[27] An ARCH test was performed on the All Ordinaries index. The F-statistic and the LM statistic for this test is 9271.06 and 357.72 respectively. Both statistics have a p-value of 0. Thus, the null hypothesis for no ARCH effect in the series is rejected at any level of significance. The estimation of the GARCH models is justified.

[28] In order to ensure that all GARCH models have the same number of data points, the starting date of data used in all GARCH volatility models is set to the last starting point of all data collected for stock indexes and exchange rates. The starting date is set to December 1983 because the Reserve Bank of Australia only reports data for the exchange rates of the Australian Dollar to the Chinese Yuan Renminbi from December 2013 onwards.

expressed in natural logarithmic terms and Table 4.1 shows the descriptive statistics for the sampled range of the All Ordinaries index. The index is negatively skewed and the test statistic for Jarque-Bera test indicates that the null hypothesis for normality can be rejected even at the 1% level of significance. This suggests that the data is not normally distributed.

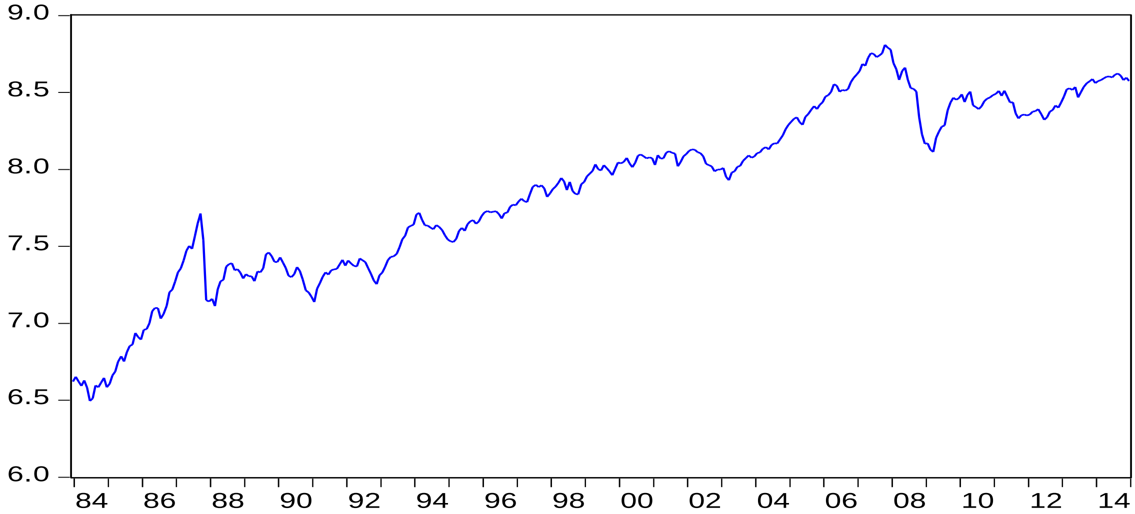


Figure 4.6: All Ordinaries index (December 1983 to December 2014)
Source: Wren Advisers (2015)

Table 4.1: Descriptive statistics for the All Ordinaries

Mean	Maximum	Minimum	Standard deviation	Skewness	Kurtosis	Jarque-Bera	Observations
7.867	8.810	6.495	0.561	-0.417	2.332	17.765***	373

Note: *** indicates that Jarque-Bera test statistic is significant at the 1% *** level.

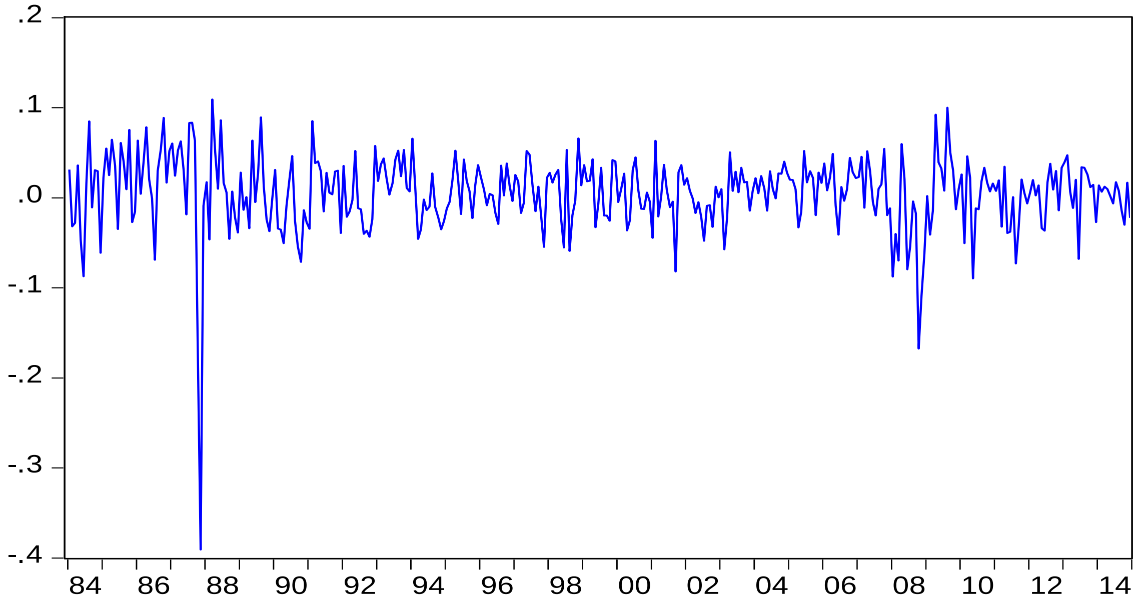


Figure 4.7: Returns on the All Ordinaries index (January 1984 to December 2014)
Source: Authors calculations based on Wren Advisers (2015) data

The logarithmic values of the index are used to estimate the returns of the series using the procedure discussed in Section 4.2.4 and Equation 4.5. The estimated series of logarithmic returns series is presented in Figure 4.7. Figure 4.6 and Figure 4.7 gives the visual representation of the logarithmic All Ordinaries index which appears to be non-stationary while the logarithmic returns on the All Ordinaries seems to be is stationary. To confirm this suspicion, the Augmented Dickey Fuller (ADF) tests developed by David Dickey and Wayne Fuller were performed on both series (Dickey & Fuller, 1979, 1981). Because the All Ordinaries index series trend upwards, a trend term is included in the ADF tests for these series. Therefore, the estimating regression for the ADF test[29] is as shown in Equation 4.8.

$$\Delta y_t = \alpha + \beta t + \rho y_{t-1} + \gamma_1 \Delta y_{t-1} + \cdots + \gamma_p \Delta y_{t-p} + e_t \qquad (4.8)$$

Where: Δy_t = the 1st difference of the stock index (or returns of the stock index),
α = a constant term,
β = coefficient of the trend term,
t = trend term,
ρ = coefficient of the lagged stock index (or lagged returns on the stock index),
γ_1= coefficient of the 1st difference of the first lag of the stock index,
γ_p = coefficient of the 1st difference of the p^{th} lag of the stock index,
e_t = error term.

A trend component appears to be lacking in the returns on the All Ordinaries index. Therefore, the equation for conduction the ADF tests for the returns series excludes the trend term in Equation 4.8, the modified equation is as shown in Equation 4.9:

$$\Delta y_t = \alpha + \rho y_{t-1} + \gamma_1 \Delta y_{t-1} + \cdots + \gamma_p \Delta y_{t-p} + e_t \qquad (4.9)$$

The number of lags (p) in Equations 4.8 and 4.9 were determined using the Modified Akaike Information Criterion (MAIC) as proposed by Ng and Perron (2001). Table 4.2 contains the results of the ADF tests. As expected, ADF test results confirm that the All Ordinaries series is non-stationary at the level as the series contains a unit root. By contrast, the return on the

[29] The null hypothesis for the ADF test is that y_t has a unit root. In which case ρ would be equal to zero. The null is rejected if the series does not contain a unit root or is stationary.

All Ordinaries series that is equivalent first difference of series proves stationary at any level of significance. Therefore, the return on the All Ordinaries series was used to estimate the GARCH models using the GARCH process developed by Bollerslev (1986).

Table 4.2: Unit root tests using ADF tests for the All Ordinaries

Variables	Level	First difference
All Ordinaries Index	-3.056	-14.686***
Returns on the All Ordinaries index	-14.686***	-26.398***

Note: * indicates that the Dickey-Fuller tau statistic is significant at the 10% (*), 5% (**) or 1% (***) level.

To initiate the GARCH process, a simple AR (1)-GARCH (1, 1) model is estimated before considering alternative GARCH models. The estimated AR (1)-GARCH (1, 1) model can be written in equation form as shown in Equation 4.10 a and 4.10 b.

$$y_t = \hat{\phi}_0 + \hat{\phi}_1 y_{t-1} + \hat{e}_t \qquad (4.10\text{ a})$$

$$\hat{\sigma}_t^2 = \hat{\alpha}_0 + \hat{\alpha}_1 \hat{e}_{t-1}^2 + \hat{\beta}_1 \hat{\sigma}_{t-1}^2 \qquad (4.10\text{ b})$$

Table 4.3 shows the estimated coefficients for the AR (1)-GARCH (1, 1) models for returns on the All Ordinaries index using the maximum likelihood technique. The AR (1)-GARCH (1, 1) model proves sufficient as indicated by the highly significant GARCH parameter estimates.[30] Moreover, the estimated coefficients satisfy the two criteria outlined by Bollerslev (1986). The first criteria is that $\alpha_0 > 0, \alpha_1 \geq 0$ and $\beta_1 \geq 0$. This requirement is met as all values of the coefficients are non-negative. The second requirement is that the sum of the ARCH and GARCH coefficients must be less than unity ($\alpha_1 + \beta_1 < 1$) so that the unconditional variance is well defined and constant; when $\alpha_1 + \beta_1 > 1$ the unconditional variance is defined (Brooks, 2008). If the sum of the coefficients is equal to one ($\alpha_1 + \beta_1 = 1$) then the use of an integrated GARCH (IGARCH) model is often utilized instead of a GARCH model. In practice, researchers often estimate an IGARCH model if the sum of α_1 and β_1 is close to one. In this case, the sum of the coefficients is 0.9548 which is relatively

[30] The ARCH Lagrange Multiplier test for the series indicates that no ARCH left in the standardized residuals. Hence there is no need to estimate a GARCH(1,2) or GARCH(2,1) model.

high and indicative of highly persistent volatility in the Australian stock markets. For this reason, an AR(1)-IGARCH(1,1) model was estimated by excluding the constant term (α_0) from Equation 4.10 b and restricting the sum of α_1 and β_1 to one. The estimated model is reported in Table 4.3.

Table 4.3: GARCH and IGARCH models for the All Ordinaries index

	AR(1)-GARCH (1, 1)	AR(1)-IGARCH (1, 1)
ϕ_0	0.0051***	0.0044***
	(0.0017)	(0.0012)
ϕ_1	0.1811***	0.1854***
	(0.0475)	(0.0409)
α_0	0.0001**	n.a
	(0.00004)	n.a
α_1	0.1960***	0.1362***
	(0.0309)	(0.0173)
β_1	0.7588***	0.8638***
	(0.0453)	(0.0173)

Note: Robust standard errors are reported in parentheses. The coefficient is significant at the 10% (*), 5% (**), or 1% (***) level. All estimated values are reported to 4 decimal places.

Figure 4.8 plots the time varying variance for the AR (1)-IGARCH (1, 1) process which was utilized in the composite stress index. There are two noticeable peaks in the conditional variance which indicate two periods of high volatility in the Australian financial markets; one in December 1987 and the other in November 2008. As expected the periods of high volatility coincide with the periods of past global financial crises; namely the 1987 stock market crises and the 2007-2009 GFC.

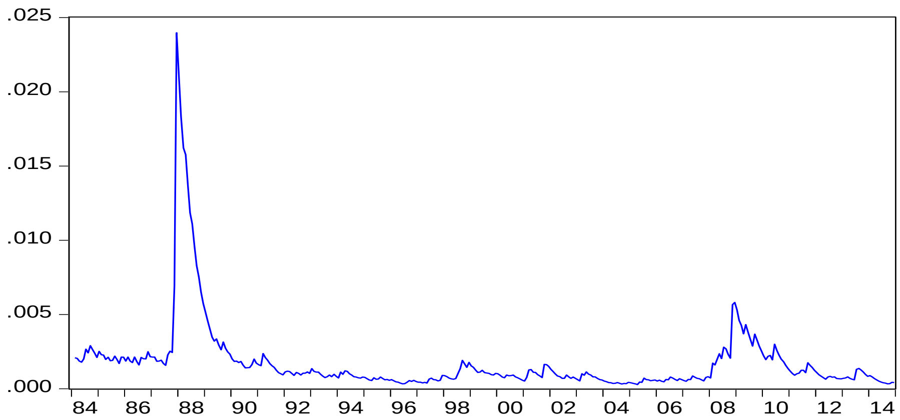


Figure 4.8: Estimated AR (1)-IGARCH (1, 1) model for All Ordinaries index
Source: Authors calculations based on Wren Advisers (2015) data

4.3 Conclusion

This chapter explores the use of four indicators of equity markets stress over approximately three decades (1980 to 2014). The four variables are used to gauge two characteristics of equity market stress which included increased volatility in stock prices and larger than usual drops in the stock prices. The inverted CMAX, percentage change in the All Ordinaries from a year ago and the negative equity returns variables proved useful in measuring very large drops in stock prices in the Australian Market. While increased volatility in the Australian markets was measured using a GARCH volatility model. At this juncture, it is worth noting that these variables are suitable for measuring the specified characteristics of equity market stress (volatility and large price drops). Hence, it is possible that a symptom of equity market stress that is not measured by the four variables may be overlooked. While this study deemed the four variables as good indicators of stress in the equity markets, the variables identified in this chapter are not exhaustive and there is potential for future research to address this limitation by proposing variables that gauge other symptoms of equity market stress. Indeed it would be prudent of analysts to incorporate the additional measures of equity stress; should future researchers reveal other important precursors of equity market crash other than the ones discussed in this chapter.

CHAPTER 5

FINANCIAL STRESS IN BOND AND MONEY MARKETS

5.1 Introduction

The main purpose of this chapter is to propose indicators of financial stress in the Australian bond and money markets. In order to understand how a crisis develops in the bond and money markets, it is important to consider the risks associated with the instruments that are traded in those markets. Thus, it was deemed necessary to explain the risks associated with purchasing of debt securities such as bonds. This chapter commences with an overview of default and credit risks before discussing the role of credit ratings as a means of assessing the riskiness of debt securities such as bonds—of particular interest is the role that credit ratings, credit rating agencies and moral hazard played in the nurturing and development of past crises. It is against this backdrop that this study examines the usefulness of yield spreads with different maturities and credit rating as indicators for stress in bond and money markets. The yield spreads that were identified as the most suitable indicators of stress in bond and money markets are later incorporated into the composite stress index measure for Australia.

5.2 Default or Credit Risk

Generally, an investor assesses the riskiness of an investment before investing in any security. As a rule of thumb, investors expect to be compensated for higher levels of risk via higher returns on an investment. The notion of receiving high returns is particularly appealing. However, higher levels of risk are often linked to higher uncertainty and increased risk of default especially when a borrower has liquidity problems. Financial crises can increase the likelihood of default on loan repayments especially when a borrower's liquidity is adversely affected by a crisis as it unfolds. Therefore, global investors often consider the creditworthiness of the borrower[31] and the state of economy of the borrower's country when assessing the riskiness of an investment. In bond markets, investors may prefer to use of credit ratings to assess a country's probability of default. This is primarily because credit ratings are easy to understand and readily available for different countries. There are three Credit Rating Agencies (CRAs) that dominate the global financial market (i.e. Fitch, Moody's and Standard & Poor). CRAs provide ratings for countries, insurance companies, funds, stocks, bonds and money market securities. The credit rating criteria for long-term securities such as corporate bonds is shown in Table 5.1.

Table 5.1: Credit Agency Ratings for long-term securities

Moody's	Fitch	Standard & Poor	Credit Quality	Default or credit risk
Aaa	AAA	AAA	Highest	Unlikely
Aa	AA	AA	↑	↓
A	A	A		
Baa	BBB	BBB		
Ba	BB	BB		
B	B	B		
Caa	CCC	CCC		
Ca	CC	CC		
C	C	C		
	D	D	Extremely low	Very likely

Data source: Fitch Ratings (2014), Moody's Investors Service (2015) and Standard & Poor (2012)

Table 5.1 shows that Moody's credit rating system differs from those of Fitch and Standard & Poor; however, the latter two rating agencies have a similar rating system. Corporate bonds of high quality and a low probability of default receive an A rating; these include all bonds rated as AAA, AA, A, Aaa or Aa. The top quality bonds are the triple A rated bonds, which have the lowest probability of default. The risk of default increases as one moves down Table 5.1 from A rated bonds to C or D rated bonds. C or D rated corporate bonds have the highest

[31] The term borrower refers to the case of an individual, company or a government.

default and credit risk with little prospects of recovering the initial investment. A corporate bond is rated D if the bond issuer defaults on bond repayments and it is unlikely that any payments will be forthcoming in the near future. For example if the bond issuer files for bankruptcy, it is expected that the issuer is more likely to default. Consequently, the rating of the bonds issued by a bankrupt bond issuer will be downgraded from a higher rating to a D rating in the case of Standard & Poor and a C rating in the case of Fitch and Moody's. In this case, there is little hope of an investor recovering the funds invested in bonds that receive this rating (Fitch Ratings, 2014; Moody's Investors Service, 2015; Standard & Poor, 2012). It is important to note that ratings for junk bonds range from Baa to C based on Moody's rating system and BBB to D based on Fitch and Standard and Poor rating systems (Ross, Westerfield, & Jaffe, 1996). In this case, the risk of default among junk bonds would be lowest for the Baa or BBB rated bonds and increase as one moves further down Table 5.1 to lower rated bonds; whereby C or D rated junk bonds would have the highest risk of default.

CRAs may downgrade corporate bonds from a higher to a lower class if the ability of bond issuer to service the debt is in doubt. From an investors point of view, bond buyers who are risk averse prefer higher ranked (A or B rated corporate bonds) to lower ranked bonds (C or D rated corporate bonds) when making investment decisions. Large changes in the rating of a corporate bond may signal increased likelihood of default and could cause panic among investors holding assets that are perceived to be of lower value or worthless. For example, investors would be more concerned about a B rated bond being downgraded to a C or D rated bond than a review in a corporate bond's rating from A to BBB. The former case indicates increased likelihood of default on future payments or loss of the invested funds. Conversely, the latter indicates a slight increase in credit risk; default on payments is less probable.

So far, this section has discussed the credit ratings and not the credit ratings agencies. Moreover, the reliability of the credit ratings and their usefulness in predicting crisis has not been questioned. A failure to address these issues would make this study incomplete. Therefore, this discussion now focuses on the role that credit rating agencies have played in past crises. Ideally, credit rating agencies should be objective, providing an accurate and unbiased assessment of the risk associated with investing in a particular asset or security. Risk averse investors could then rely on credit ratings in order to safeguard investments and minimize the risk on a portfolio of investment. Theoretically, inaccurate ratings would expose investors to higher levels of risk than they would be willing to bear. Studies show that in the lead up to the 2007-09 GFC, American financial institutions, regulators and rating agencies operated in a manner that nurtured moral hazard and facilitated the transfer to 'toxic assets' to unsuspecting investors (Crotty, 2009; Edgar, 2009).

Kotowitz (1989, p. 207) provides a comprehensive definition of moral hazard that is relevant for this study:

> "Moral hazard may be defined as actions of economic agents in maximizing their own utility to the detriment of others, in situations where they do not bear the full consequences or, equivalently, do not enjoy the full benefits of their actions due to uncertainty and incomplete information or restricted contracts which prevent the assignment of full damages (benefits) to the agent responsible."

Figure 5.1 illustrates how the different agents facilitated the creation and flow of 'toxic assets' from financial institutions to investors. During the GFC, 'toxic assets' mainly consisted of mortgage backed securities (MBSs) and collaterised debt obligations (CDOs). MBSs and CDOs are financially engineered securities that are derived from loans via a securitisation process. An explanation of the sequence of the securitisation process of both assets follows. Mortgage and commercial banks loaned money to homeowners and individuals respectively. The banks sold loans to investment bankers and mortgage financiers, thereby transferring the risks and rewards of the transacted loans to these parties. With regard to risk, investment banks (or mortgage financiers) would incur a loss if the homeowner (or borrower) failed to make payments on their mortgage loan (or bank loan), thereby defaulting. If however, the loan payments were made by the due dates, investment banks would be rewarded with a steady stream of cash flows. The investment banks and mortgage financiers repackaged portfolios of loans into securities; this part of the process is commonly referred to as securitisation.

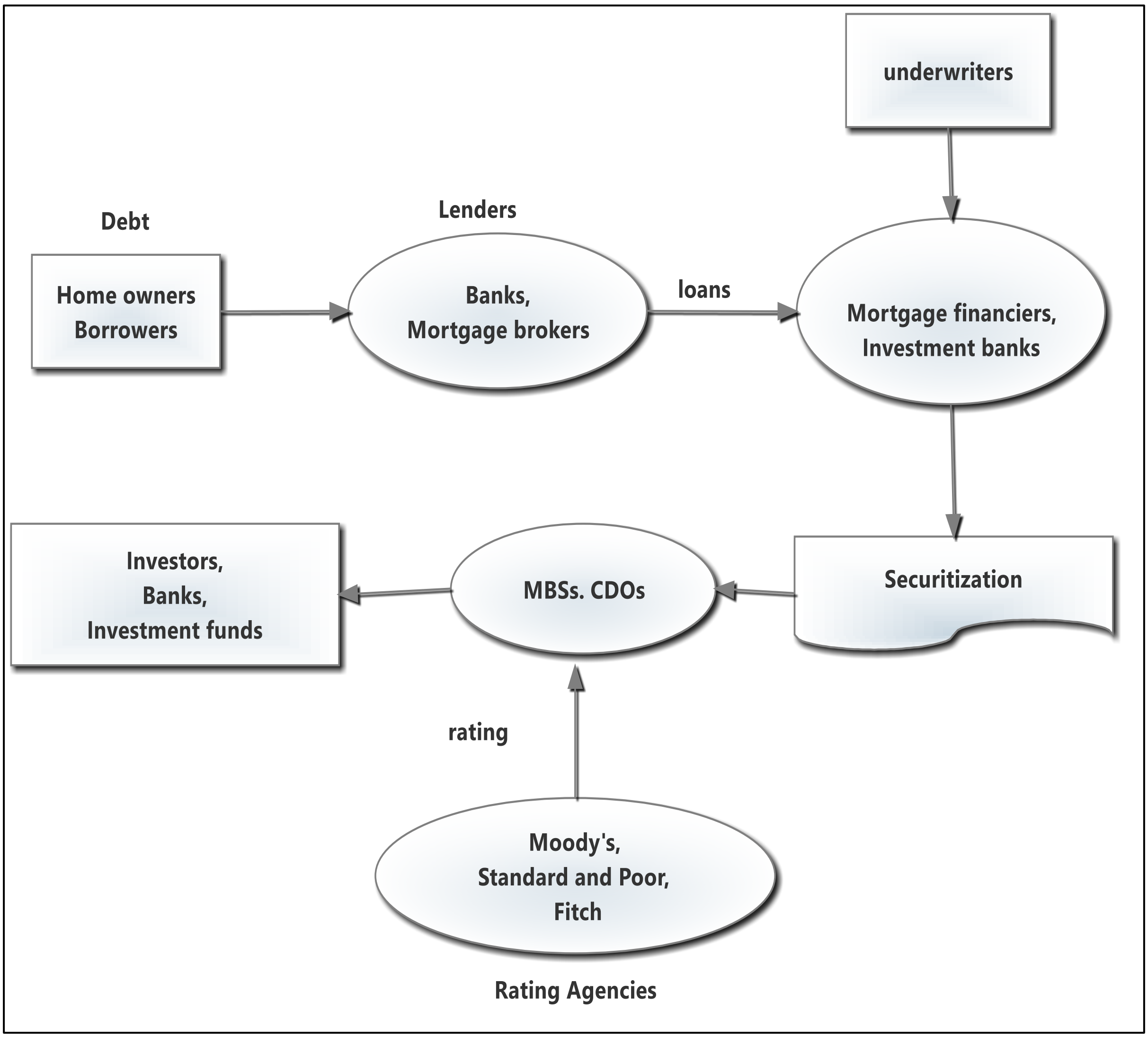


Figure 5.1: The Securitization process for MBSs and CDOs

A MBS was created by pooling together mortgage repayments from a group of mortgage holders (homeowners). The pooled mortgage repayments were repackaged and issued in the form of MBSs. CRAs rated the MBSs and investment banks and mortgage financiers subsequently sold the MBSs to investors. Consequently, a buyer of a MBS expected to receive a stream of mortgage loan repayments when they fall due and bore the risk of default. Similarly, a CDO pools a portfolio of different kinds of loans. The pooled loans are then issued in the form of CDOs that are rated by rating agencies and subsequently sold to investors. Investors in CDOs were paid in a sequential manner depending on the investor's risk preference. The risk preference was reflected via credit rating and/or a 'tranch system' such that the owners of CDOs in the top tranch bore the least risk and owned A-rated securities. Conversely, buyers of CDOs in the third tranch bore the most risk, no rating was provided for these securities. There was a preferential system of payment for CDO holders. Holders in the first (top) tranch are paid before the holders of CDOs in the second and third (or equity) tranch; thereafter the second tranch holders are paid before the third tranch holders. Hence, if there were insufficient funds to make payment to owners of all tranches, holders of CDOs in the third tranch risked receiving no payment (Kolb, 2011). Buyers of CDOs were paid different yields such that owners of CDOs in the equity tranch bore the higher risk and received the highest yield compared to the other tranches.

MBSs and CDOs proved particularly beneficial for three reasons. First, these securities were easier to trade than the individual mortgages or loans. Second, the pooling of repayments ensured that a default risk was spread among a group of investors. Third, both types of securities were theoretically designed to ensure that if some mortgage or loan holders failed to make payments while others did, the investor would receive some income. However, Crotty (2009, p. 566) argues that the manner in which the securities were designed rendered them "complex and opaque". Due to the involvement of several intermediaries such as investment bankers, mortgage financiers, commercial bankers, mortgage brokers and rating agencies the problem of information asymmetry was amplified. It was more difficult for investors to know the true value of the MBSs and CDOs, since the information relating to the creditworthiness of homeowners and borrowers was more readily available to intermediaries (e.g. commercial banks and mortgage brokers) than it was to investors. This made the involvement of the credit rating agencies in the risk assessment process necessary.

Crotty (2009) argues that the GFC resulted from a combination of factors that weakened the American financial system. Notable factors included lax regulation of intermediaries, excessive risk-taking behaviour among intermediaries, loss of objectivity among credit rating agencies and excessive leverage in financial institutions. There was inadequate regulation of banks especially large banks that were allowed to perform internal risk assessments and determine minimum capital requirements. Moreover, financial institutions were allowed to keep off-balance-sheet records of financially engineered securities such as CDOs. Since, off-balance-sheet assets and liabilities were unregulated; there was no need for banks to set aside any capital against these securities. These conditions allowed banks to acquire high levels of liabilities in the form of CDOs, thereby becoming highly leveraged. Moreover, because CDOs were off-balance-sheet liabilities the true extent of leveraging was often understated, especially if banks held a large portions of liabilities in the form of CDOs.

Treatment of moral hazard among the different intermediaries stems from the notion that the risk associated with loans or mortgages can always be passed on to the next party. While Mortgage brokers were aware of increased possibility of default (especially when selling mortgages to homeowners that would struggle to make loan repayments—subprime mortgages), the credit worthiness of homeowners was disregarded and brokers were paid higher commissions for selling more subprime mortgages. Similarly, investment bankers were encouraged to participate in more risky investments and rewarded for doing so via bonuses or commissions. CRAs received a large portion of revenue from the institutions that issued MBSs and CDOs. According to Crotty (2009), these securities accounted for over two fifths of Moody's revenue in 2005. CRAs strove to satisfy the most valued customers that mainly consisted of large investment banks (Lehman Brothers and Bear Stearns) and mortgage loan financiers (Fannie Mae and Freddie Mac). Consequently, MBSs and CDOs issued by these key customers were rated favourably in order to maximise customer satisfaction, retain customers and maximise revenue of the rating agencies. It was feared that an unfavourable rating would result in customer dissatisfaction, loss of a customer to a competitor-rating agency and loss of revenue. With this in mind, it is unlikely that any rating agency was acting in the best interest of the investor in the lead up to the GFC. The objectivity of the rating agencies was compromised and it was only a matter of time before the credit bubble in the housing market would implode affecting several sectors of the American financial system.

The events of the GFC showed how a reliance on the ratings provided by credit rating agencies could expose an investor to credit and/or default risk, especially when financially engineered securities are involved. This is because engineered securities tend to be more 'opaque' than other financial securities and the increased information associated with these securities makes investors especially reliant on the ratings issued by CRAs. Hence, prudent investors should consider the use of the ratings in conjunction with other tools for assessing a country's risk. This study explores the use of yield spreads as a viable alternative to the use of credit ratings.

5.3 Yield Spreads

A yield spread is calculated by taking the difference between the yields of two debt securities. The higher the yield spread, the greater the difference between the yields offered by each instrument. Klepsch and Wollmershäuser (2011) posit that yield spread, theoretically, mainly gauges two things: an investor's risk aversion and the borrower's risk of default (credit risk). Lenders or investors tend to be more risk averse and prefer to be compensated for additional risk with higher yields on traded securities during financial crises periods than they would be in out-of-crisis periods (pre- or post-crisis periods). From an anticipatory point of view, the credit rating of a country proves inefficient in anticipating a crisis. Rather a downward credit rating is often the provided after a country is already experiencing negative effects of a financial crisis; Kaminsky and Schmukler (2002) provide three evidential examples from 1997 to 1998 in the cases of Thailand, Korea, and Russia. Furthermore, the same authors assert that in a transparent market, most investors would expect a downgrade rating in light of weakening economic fundamentals, reduced liquidity among key financial institutions or governments and slow or lax regulation. However if investors are in the dark about deteriorating fundamentals and information is not readily available the downgrade would result in more pronounced financial instability.[32]

The consensus is that yield spreads can provide valuable insights into the financial health of the borrower's country; where a widening of yield spreads may signal a developing crisis and serve as an early indicator of a financial crisis. For example, Manconi, Massa, and Yasuda (2012) noted that mutual fund owners were the primary holders of corporate bonds in the lead up to the 2007-2009 GFC. In the early stages of the crisis, mutual fund holders with MBSs opted to sell off corporate bonds (especially junk or lower rated bonds) in order to cater for their rising liquidity needs as it became apparent that bonds which received a high rating in the pre-crisis period were actually low quality bonds with a higher risk of default. As a result, the widening of spreads was more pronounced in lower-rated bonds compared to higher rated

[32] For purposes of this thesis, Australia is considered as more of a transparent than opaque economy. Thus, credit ratings would simply reflect prevailing investors' sentiments of an impending downgrade in rating of Australian securities should Australia experience a crisis or contagion of a crisis.

bonds during the GFC. Candelon et al. (2012) argue that yield spreads could aid in early detection of currency crises which are often preceded by credit growth, since rising yield spreads indicate rising levels of credit and higher probability of balance of payment problems in the near future. To assess the importance of yield spreads in forecasting financial stress, the aforementioned authors used data for six South-Asian countries and six Latin-American countries to construct two kinds of early warning system (EWS) models;[33] one model included a yield-spread variable while the other excluded it. The results of this experiment found that yield spreads improved EWS measures for about 83.33 percent of the South Asian countries studied. Unfortunately, no benefits were obtained from the inclusion of yield spreads in the Latin-American cohort. Nevertheless, it is clear that general trending of yield spreads differs in pre-crisis, in-crisis, and post-crisis periods and generally affects the level of a country's indebtedness. For instance, the 10-year government bond spreads for 11 European countries were found to be identical prior to the GFC. In July 2007, spreads begun to diverge with the highest spreads recorded in September 2008. Moreover, the yield spreads of heavily indebted countries such as Greece and Ireland were about 300 basis points greater than those Germany (Klepsch & Wollmershäuser, 2011, p. 171). The findings of past studies suggest that yield spreads possess some predictive power. Accordingly, Section 5.3.1 focuses on the behaviour of various Australian yields spreads during the GFC; since the 2007-2009 GFC negatively affected global financial markets including the Australian one.

5.3.1 *Corporate, Government and Corporate to Government spreads*

This section discusses the use of interest rates on government and/or corporate bonds in estimating viable yield spreads for different combinations of government and/or corporate

[33] Both types of EWS models included a common set of economic variables that were deemed important for early detection of financial crisis, namely the first difference of the ratio of lending to deposits, the first difference of the industrial production index and growth rates for: a) international reserves, b) exports, and c) domestic credit over Gross Domestic Product (GDP).

bonds of different durations. As a starting point for this analysis, the A-rated and BBB-rated corporate bond spreads from January 2005 to December 2014 as reported by the Reserve Bank of Australia (RBA)[34] were examined. The RBA provide two kinds of yield spreads at monthly frequency, namely credit spreads to Australian Dollar swap rates and credit spreads to commonwealth government securities of similar time to maturity and credit-rating. The graphical representations of the reported spreads are provided in Figures 5.2 to 5.5, where the shaded region corresponds to the United States recession as a result in the GFC. As expected, there is a general rise in all spreads especially after the Lehman Brothers filed for bankruptcy in September 2009.

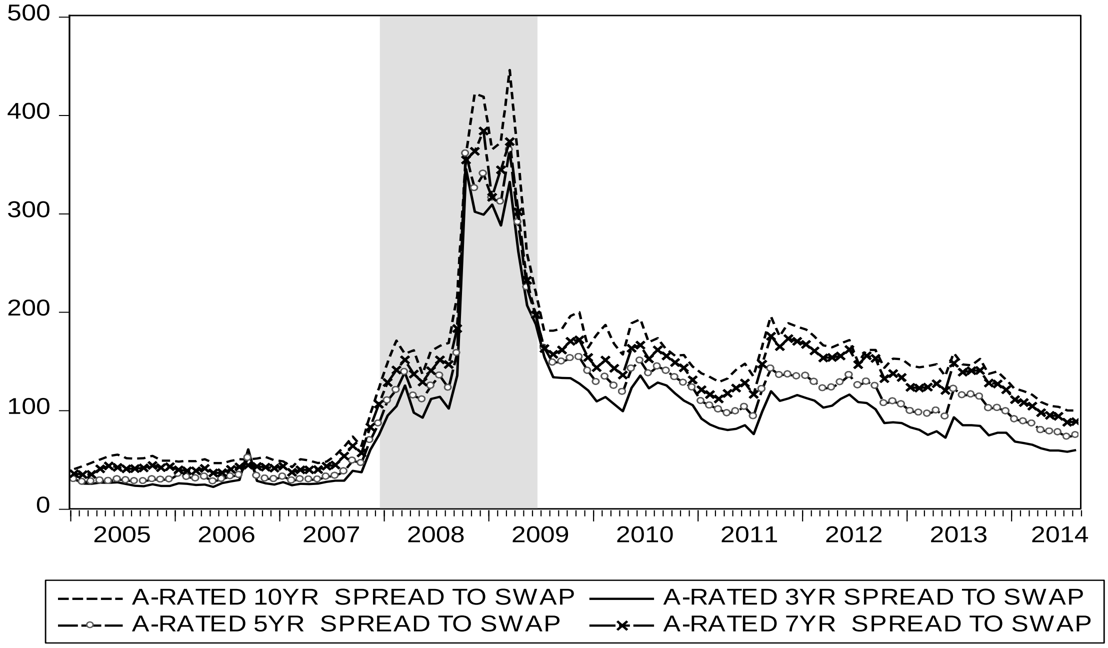


Figure 5.2: A-rated Credit Spread to A-rated Australian Dollar Swaps
Source: Reserve Bank of Australia (2017)

[34] The yield spreads are sourced from the F3 spreadsheet for Aggregate Measures of Australian Corporate Bond Spreads and Yields: Non-financial Corporate (NFC) Bonds. Data is provided from 2005 onwards.

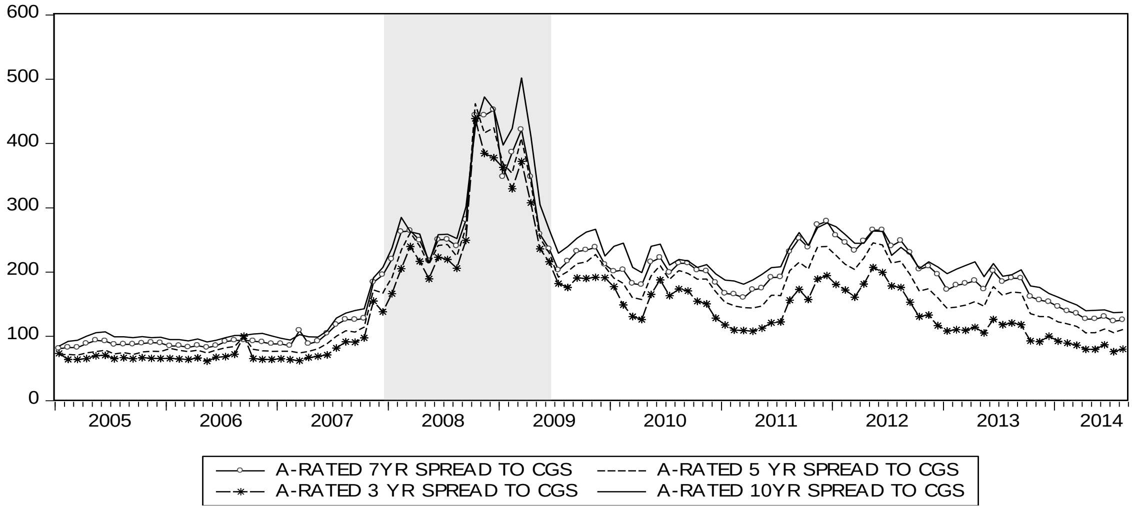


Figure 5.3: A-rated Credit Spread to Commonwealth Government Securities
Source: Reserve Bank of Australia (2017)

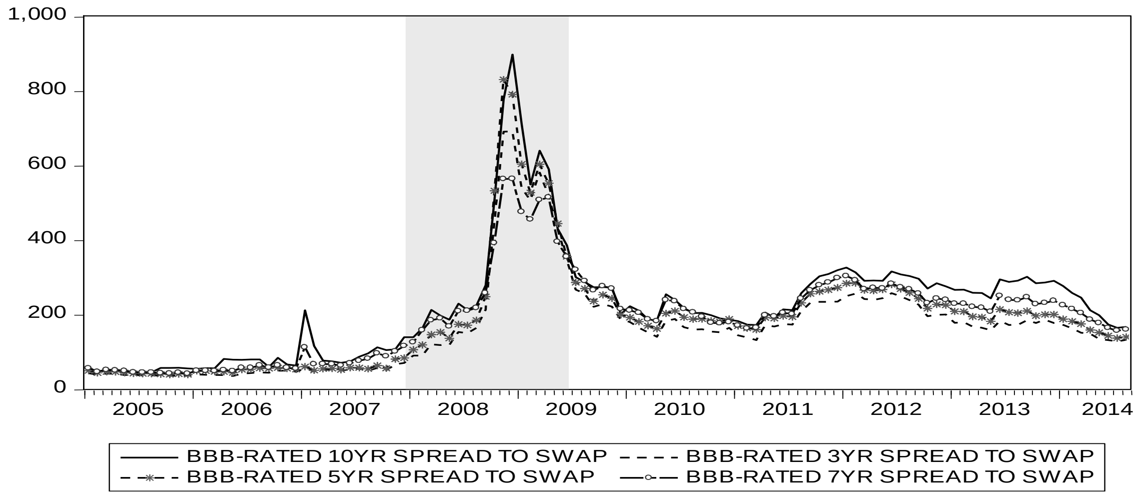


Figure 5.4: BBB-rated Credit Spread to BBB-Australian Dollar Swap
Source: Reserve Bank of Australia (2017)

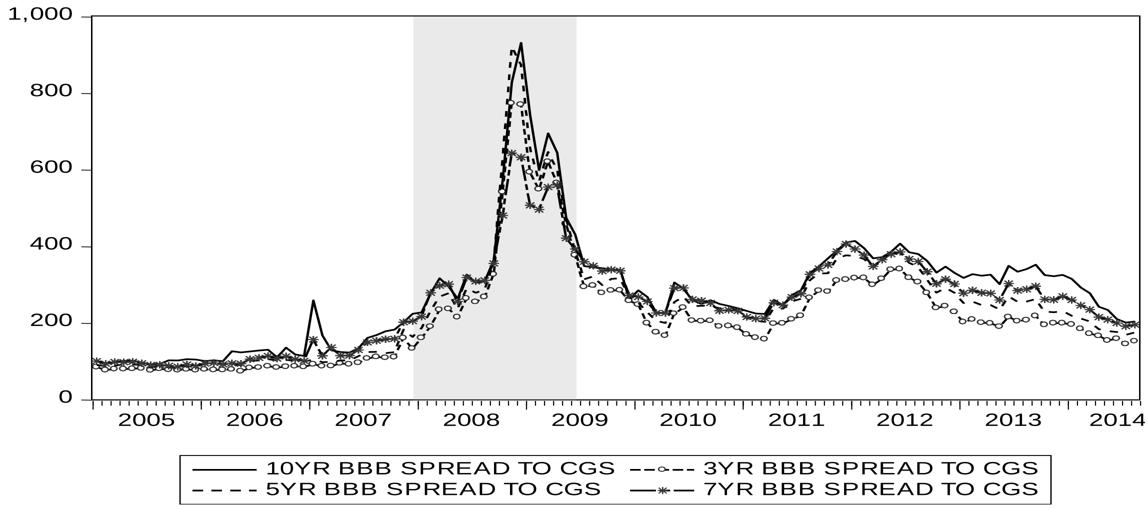


Figure 5.5: BBB-rated Credit Spread to Commonwealth Government Securities Spread
Source: Reserve Bank of Australia (2017)

Using the yields for Australian resident non-financial corporate bonds as provided by the RBA, the BBB to A yield spread was estimated as the difference between the yields on the BBB and A corporate bonds for similar times to maturity; 3, 5, 7, and 10 years. The graphical representation of the resulting spreads in Figure 5.6 shows that all estimated spreads peak in November 2008 during the GFC. The BBB to A yield spreads seem to provide an earlier warning of financial distress in the Australian financial system than the RBA yield spreads.

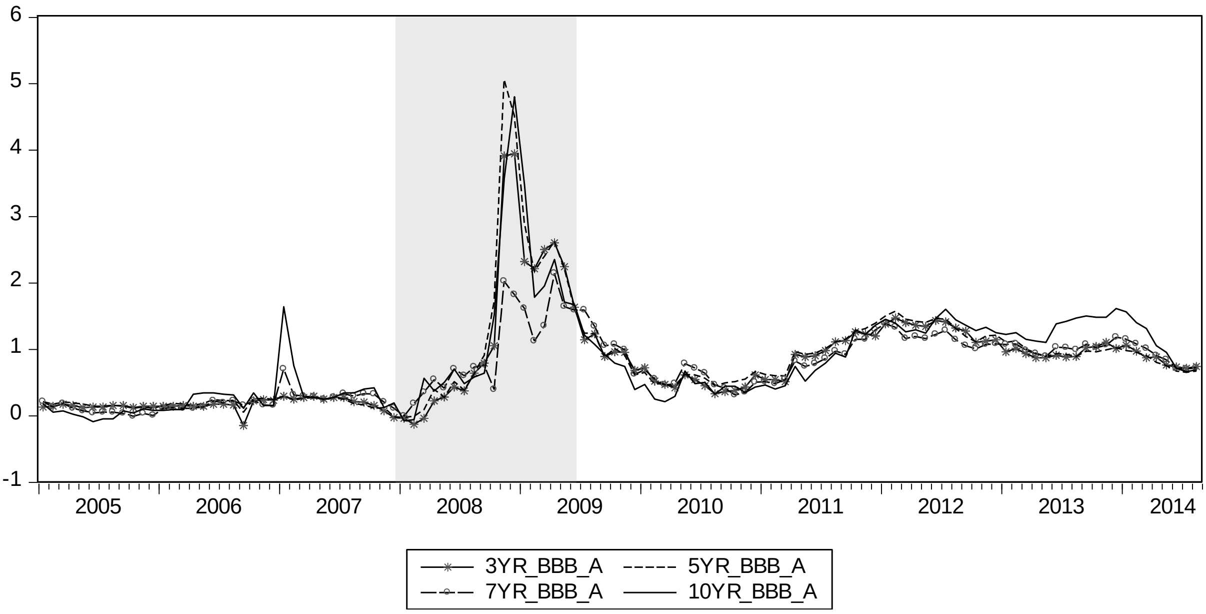


Figure 5.6: BBB to A Corporate Bond Yield Spreads
Source: Reserve Bank of Australia (2017), Authors calculations based on RBA data

The study seeks to estimate various combinations of yield spreads of different ratings and different levels to maturity. These included 3 to 10 year spreads, the 5 to 10 year spreads and 7 to 10 year spreads for A-rated securities and BBB-rated securities. With the exception of the 7 to 10 year spread for the A-rated bonds, all other spreads performed poorly in detecting the incidence of the 2007 crisis via a spike in the spreads during the crisis period. Figure 5.7 shows that the A-rated 7 to 10 year yield spread has similar trending behaviour to the other spreads; therefore, the study opted to exclude this yield spread from the final stress index as it does not provide any additional information. In summary, the final index will include the estimated BBB to A yield spreads; these yield spreads appear to be the most useful from an anticipatory perspective.

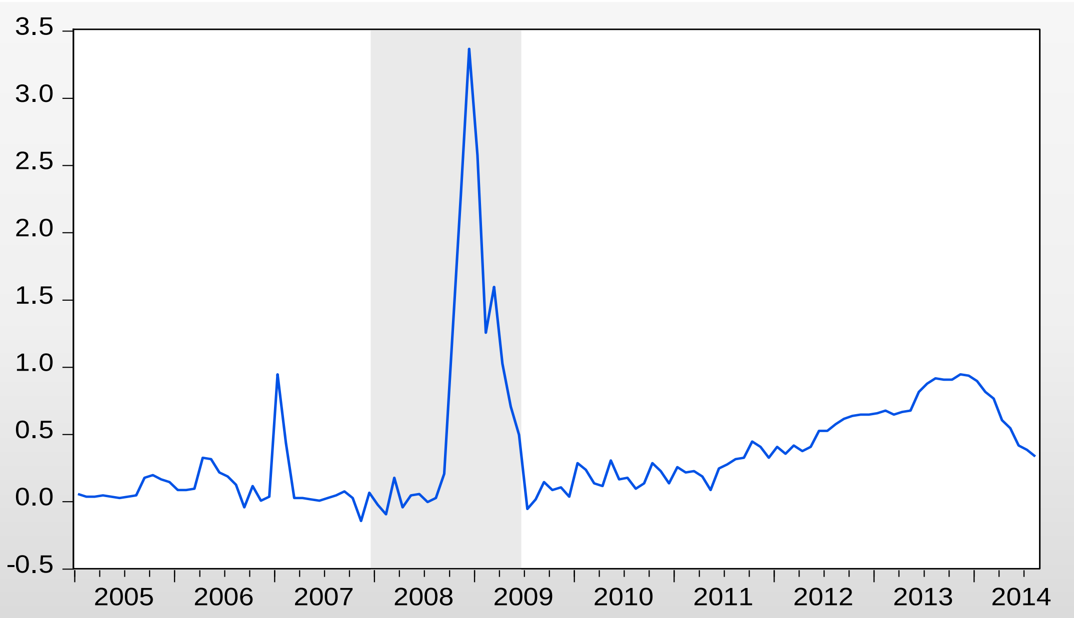


Figure 5.7: 10 to 7 Year Corporate Bond Yield Spread for A-rated securities
Source: Reserve Bank of Australia (2017), Authors calculations based on RBA data

5.4 Conclusion

This chapter examines the use of yield spreads as a proxy for measuring stress in bond and money markets over nine years (2005 to 2014). The RBA does not provide data prior to 2005. Therefore, the dataset range used in this chapter is smaller (under a decade), compared to the range of datasets used to estimate the equity stress variables (where over three decades of data was available). Overall, the BBB to A yield spreads were found to provide the earliest indication of stress in the Australian debt and money markets; especially in the lead up to the 2007-09 GFC. Unfortunately, due to data limitations it was not possible to evaluate the performance of this variable during the 1989-1992 Australian Banking Crises. To this end, future researchers could propose variables with more historical data that can be used to provide early indications of distress in the Australian bond and money markets.

CHAPTER 6

FINANCIAL STRESS IN CURRENCY MARKETS AND THE BANKING SECTOR

6.1 Introduction

This chapter focuses on developing early indicators of stress in the banking sector and the currency market based on the experiences of other countries that have suffered either or both crises. Several studies on past financial crises have found that currency and banking crises can occur concurrently with more devastating effects than either crisis in isolation (Ariccia, Detragiache, & Rajan, 2008; Bordo, Eichengreen, Klingebiel, Soledad Martinez Peria, & Rose, 2001; Hutchison & Noy, 2005; Kaminsky & Reinhart, 1999, 2000). The fact that both crises can occur at the same time suggests that there may be a relationship between the two kinds of crisis and that this relationship should be considered when developing measures of stress in either the currency market or banking sector. For this reason, this chapter focusses on the indicators for three forms of financial crises (i.e. currency crises, banking crisis and twin crises—the incidence of both crises).

This study posits that a greater understanding of how currency markets operate could provide valuable insight as to why currency crises occur and how to prevent future currency-market crashes. Similarly, it is important to understand the role that banks play in the Australian economy and how weaknesses in the banking sector may lead to a banking crisis. Moreover, factors that make a country more vulnerable to the incidence of both crises are of interest. This chapter is structured as follows. To begin with, a brief overview of the role that the currency markets play in the Australian economy is provided in Section 6.2. Thereafter, Section 6.3 explores the extant literature on currency crises. This sets the stage for a discussion of the empirical measures of crises in the currency markets in Section 6.4. The chapter then turns its attention to the subject matter of the potential for a crisis in the Australian banking sector. In this regard, a brief overview of the Australian banking sector in Section 6.5 is followed by a discussion of banking crises in Section 6.6. Thereafter, Section 6.7 proposes empirical measures of banking crises. The chapter comes to a close with a discussion of the twin crises in Section 6.8. The indicators of currency and banking stress developed in this chapter are eventually incorporated into the composite financial stress index for Australia.

6.2 The Currency Market

Currency (or the foreign exchange) markets mainly facilitate the conversion of a domestic currency to foreign currencies at a rate referred to as an exchange rate. According to Rose (2000), there are three main markets that exist in the foreign exchange markets, the: 1) Spot market; 2) Forward market; and 3) Currency-futures-and-options market. In spot markets, dealers buy and sell foreign currencies at a spot rate and the transaction is finalised within two trading days. Because Australia has had a floating exchange rate system in operation since the 1983, the spot rate is determined by forces of demand and supply in the currency market (Reserve Bank of Australia, 2015a). In the forward market, dealers enter into forward currency contracts, which require a seller to exchange foreign currency at a predetermined exchange rate at a future date. Common durations for forward currency contracts are 30, 90, and 180 days. The futures market is similar to the forward market in that both markets provide a means for hedging against unfavourable changes in the exchange rate. There are three main differences between the two markets. First, the futures market offers more standardized contracts for the exchange of currencies while the forward currency contract tend to be customized to suit the buyer's needs. Second, while futures currency contracts are traded on the ASX, forward currency contracts need not be transacted via the ASX. Third, an initial payment is required for futures currency contract while none is required for forward currency contracts. In general, futures contracts tend to be more standardised and less risky than forward contracts. As a result, futures are often preferred to forward currency contracts (Petty et al., 2012; Rose, 2000).

In options markets, dealers pay a fee in order to obtain a currency-option contract that gives them the right, but not the obligation, to buy/sell a foreign currency at a given exchange rate within a certain time. Brealey, Myers, and Allen (2011) state that options are often used to hedge against downside risk; buyers of currency options hedge against unfavourable changes in the currency that would lead to loss of investment or revenue. A dealer is said to have exercised an option if he or she chooses to buy/sell a foreign currency at the specified exchange rate. Dealers usually exercise an option if currency option offers a better exchange rate than the spot rate. Otherwise, the dealer would choose not to exercise the option because the spot exchange rate is better than the option exchange rate; in this case the option would lapse and the dealer would only lose the fee paid to obtain the currency option. In summary, the spot markets cater for a dealer's immediate foreign currency needs while the forward, futures and option markets cater for a dealer's future foreign currency needs.

By and large, global currency markets are dominated by large commercial and investment bankers who use futures, forward, and option contracts to hedge against currency risk (Brealey et al., 2011). Currency risk is defined as the likelihood that a lender to a foreign country or an investor in assets in foreign country will suffer a loss because of changes in currency prices (Rose, 2000). Countries affected by currency crises are often perceived to have higher levels of currency risk in comparison with countries that are not experiencing a currency or financial crisis. This is because currency crises generally result from successful speculative attacks on the value of a currency. In the event of a currency crash, the affected countries may resort to currency devaluation or default on foreign loans. For example, Chiodo and Owyang (2002) cite the case of the 1998 Russian crises that resulted from a combination of factors. Rising levels of foreign reserves and debt against a backdrop of declining revenue and a fixed exchange rate regime made the Russian rouble vulnerable to speculative attacks. The rouble begun to falter in November 1997 soon after the speculative attacks that followed the 1997-1999 Asian crisis; consequently, Russia's foreign reserves were depleted to the tune of six billion US dollars. Moreover, fears of possible devaluation of the rouble drove foreign investors to enter into forward and futures currency contracts with the Russian central bank and commercial banks. By May 1998, the global prices of oil (a key export of Russia) were on a steady decline and participants in the oil industry begun to advocate for the rouble to be devalued. Ultimately, the weakening of bond, currency and stock markets forced the government to bow to pressure to float the Russian rouble. Floatation of the rouble caused the currency to lose value. At the same time the Russian government defaulted on loans to foreign countries while commercial banks were unable to meet financial obligations to foreign banks (Chiodo & Owyang, 2002).

The 1998 Russian crisis was similar to the 1997 Thailand crisis, which subsequently led to the 1997-1999 Asian crises. Much like Russia, the Thailand government implemented a fixed exchange rate regime with the Thai baht prior to the currency crisis. Corsetti, Pesenti, and Roubini (1999) state that from 1990 to 1997, the fixed rates of the Thai baht to the American dollar ranged from 25.2 to 25.6. Currency speculation forced the Thai government to use about 93 percent of its foreign reserves[35] in forward contracts in defence of the Thai baht. Foreign reserves were dwindling fast, speculative attacks finally took their toll and the Thai

[35] Corsetti et al. (1999, p. 349) state that 28 out of 30 billion US dollars in Thai foreign reserves were used to defend the Thai baht against speculative attacks.

government was forced to float the baht on 2 July 1997. What ensued was the contagion of the Thai crisis to neighbouring countries, including Indonesia, Malaysia and South Korea.

Because currency markets are dominated by banks, speculative attacks from banks are bound to have a more devastating impact on the value of a currency especially if most of the bankers anticipate a major devaluation in a foreign currency. Since, bankers form a large proportion of the dealers in the foreign exchange markets, increased speculation of the value of a currency is accompanied by reduced or immediate cessation of lending to the country experiencing a currency crash. This would result in depletion of the affected country's foreign reserves as was seen in case of Thailand. Kaminsky and Reinhart (2000) argue that foreign banks play a crucial role in the exacerbation and the spread of currency crisis. The aforementioned authors explain a mechanism for the spread of the 1997 Thailand crisis via common lender banks located in Japan. In this case, Japanese banks had extended loans to five countries affected by the crisis including Thailand. Some 54 percent of Thailand's foreign debt was sourced from Japan and when Thailand banks begun to go bankrupt, it seemed like a domino effect ensued in the banks of other Asian countries, including Philippines, Malaysia, Korea and Indonesia. Sadly, the Asian banks could have prevented the Asian crises if adequate steps had been taken to hedge against currency risk (Kaminsky & Reinhart, 1999, 2000).

6.3 Currency Crises

Several authors have proposed theoretically and empirically definitions of currency crises. Mainly, theoretical definitions focus on designing models to explain why and when currency crises occur. There are generally three categories of models used to explain currency crises (i.e. first, second, and third generation models).

First generational models of currency crises are an extension of work by Salant and Henderson (1978) that focus on the impact that government policy and speculative attacks have on the pricing of gold and the level of gold reserves held by the government. Instead of focusing on the pricing of gold, first generation models focus on the price of a currency that is expressed in the form of an exchange rate. Kaminsky (2006) argues that first generation models were developed in response to the Latin America crises of 1960s and 1970s. These models explain how the prevailing government policy and the level of foreign reserves held by the central bank can make a currency vulnerable to speculative attacks and possible currency collapse. These models focus on how a crisis can occur in a country that has a pegged exchange rate regime.[36]

An example of a first generation model is the one proposed by Krugman (1979) which focusses on the role that government reserves and investor sentiment play in incidence of a balance-of-payments (or currency) crisis. The main premise of the model is that investors have a self-maximising behaviour that influences their investment decisions and would change the composition of holdings in foreign currencies or assets in order to achieve maximum yield on investments. If investors begin to question the validity of the exchange rate regime they may speculate that the regime will soon become obsolete and need to be replaced. Consequently, the currency will suffer a speculative attack. If a country experiences successful speculative attacks, investors expect that the government to use its foreign reserves to defend the value of its currency.

Krugman (1979) argues that government actions to defend the currency only temporarily restore confidence in the value of the local currency. Eventually, increased uncertainty about

[36] The pegged exchange rate system replaced the Bretton Woods system where the value of a country's currency was determined by the amount of gold reserves a country had. In the case of the pegged exchange rate system the value of a country's currency was linked to the value of another country's currency or a basket of other currencies. For instance, the value of the Australian dollar was pegged to the UK pound for 40 years until 1971 when it was pegged to the US dollar (Blundell-Wignall, Fahrer, & Heath, 1993).

the government's commitment to the fixed exchange rate regime would contribute to more investor speculation and increased potential of a currency crisis. A series of subsequent speculative attacks on a country's currency will lead to the progressive erosion of foreign assets. After several speculative attacks on the currency, the government will have used a large portion of its foreign reserves to defend its currency. Ultimately, it is expected that the government will runout of resources to defend the pegged currency, even if a government resorted to borrowing from other countries or purchasing currency forward contracts. Besides a country can only borrow so much and buy so many contracts before the pegged exchange rate regime becomes unsustainable. Rising levels of debt, depleted foreign reserves and the emergence of a fiscal deficit would limit the options that the government has available. It is against this backdrop that a government will have to abandon a pegged system in favour of a floating exchange rate system. In an effort to minimise future losses from the change in exchange rate regimes, investors begin incorporating foreign currency-denominated assets or securities in lieu of local currency-denominated assets and currencies in their portfolios or shift to physical assets (land, buildings, heavy equipment, etc.). If the reserves are severely depleted, this would place additional pressure on the limited resources of foreign currency and lead to the collapse of the currency. Another example of a first generation model is the one designed by Flood and Garber (1984) who extended the work by Krugman (1979). The alternative model estimates the timing of the collapse of a fixed exchange rate regime by examining factors such as market fundamentals, levels of foreign reserves, investor speculation and the level of domestic debt. These authors use linear and stochastic models to assess the likelihood and timing of currency crises. Overall, the first generational models seem to provide an explanation of how speculative attacks are necessary as they facilitate the transition from a fixed to floating exchange rate regime.

Second generation currency-crisis models are mainly influenced by the work of Obstfeld (1986), who agrees with Krugman (1979) in that a crisis may be necessary if a country is forcibly transitioned out of a fixed exchange regime. While, first generation models are based on the notion of an unsustainable exchange rate regime, second generation models consider the collapse of a sustainable exchange rate regime due to successful speculative attacks on a currency. Obstfeld (1986) argues that there exist several equilibria that influence investor expectations that a currency will collapse (e.g. prevailing level of foreign reserves and domestic debt held by the government). Growing levels of domestic debt are seen as another indicator that a fixed exchange rate regime will soon be abandoned. Future expectations of a collapse in a currency would cause investors to switch the composition of a portfolio from domestic to foreign currency-denominated assets. If many investors become pessimistic and engage in this behaviour, there will be a run on a country's foreign reserves and a self-fulfilling crisis is likely to ensue. It is important to note that second generation models primarily focus on investor speculation, thus, adverse herding behaviour among investors can still result even in countries with sound economic policies. Chiodo and Owyang (2002) state that spread of a second generation currency crises is best explained in a study by Eichengreen, Rose, and Wyplosz (1997). According to Eichengreen et al. (1997), trade links are a better indicator, than macroeconomic similarities, of the likelihood that a country will suffer speculative attacks on its currency. Therefore, if a country suffered a speculative attack on the value of its currency, it is likely that its key trading partners will suffer a similar fate. However, it is important to note that trade links only explain in part the manner in which currency crises spread to other countries. Other country specific factors such as high levels of inflation, government debt and unemployment can render a country more vulnerable to a speculative attack (Eichengreen et al., 1997). In fact, the Glick and Rose (1999) assertion that currency crises affect countries in the same region with similar macroeconomic features lends credence to the argument that a combination of factors predispose a country to speculative attacks and eventually currency crises.

Third generational models were developed to explain the factors that led to the 1994 Tequila Crisis and the 1997-1999 Asian Crisis (Eichengreen, 2003; Kaminsky, 2006). Proponents of third generational models are motivated by the idea that the first and second generational models provide inadequate explanations for the dynamics of these crises. Scholars provide diverse hypotheses and models in order to explain how and why the two (and other similar) crises occurred. Nonetheless, followers of this school of thought argue that third generation currency crises result from a combination of problems in the banking sector and financial markets (Chiodo & Owyang, 2002; Eichengreen, 2003; Glick & Hutchinson, 2011; Kaminsky, 2006). A combination of factors precedes and leads to the incidence of a third generational currency crisis. These include large declines in foreign direct investment, high levels of domestic debt, government revenue that is declining, depleted foreign reserves, an overvalued currency and rising expectations that a currency will be devalued in the near future (Chiodo & Owyang, 2002; Frankel & Rose, 1996). Kaminsky (2006) states that these crises mainly result from moral hazard and information asymmetry in both sectors that nurture excessive borrowing by various market participants in the financial market. In particular, this author highlights the dangers of excess; countries that enjoy economic booms and the corresponding asset bubbles are doomed to suffer when the bubbles eventually burst and lending reaches unsustainable levels. A recent example of a third generation currency crises is the Eurozone crises that have affected countries like Cyprus, Greece, Ireland, Italy, Portugal, and Spain since 2009. Kaminsky (2006) measures third generation currency crises by assessing the level of borrowing in an economy at a given time; these include the ratio of domestic credit to GDP, the ratio of M2 to foreign reserves, the M2 multiplier, the level of bank deposits, the stock prices and the incidence of banking crises. According to this study, countries that suffer a banking crisis have a higher chance of also suffering a currency crisis; a twin crisis. Overall, it is important to note that even though third generation models offer good explanations for how currency crises can result from a combination of factors, there is a need for policy makers to monitor financial systems in order to identify new factors that could potentially cause currency crisis. By doing so, policy makers would ensure that problems that are not identified by the third generation models are still addressed.

Besides the theoretically definitions for currency crises, scholars have proposed empirical definitions of currency crises. Here are a few examples of empirical definitions of currency crises. Frankel and Rose (1996) identify a currency crisis using two criteria. The first criterion is the depreciation of a country's exchange rate by 25 percent or more in a particular year. The second criterion is an increase in the rate of depreciation by 10 percent or more. Stanford (2010) argues that the fulfilment of the first criterion is sufficient to conclude that a currency crisis has occurred. Consequently, this author offers a more lenient definition of a currency crisis based on the first criterion only. Some authors recommend the use of an index to identify episodes of currency crisis. For example, Eichengreen et al. (1997) developed an exchange market pressure index (EMPI) which measures the weighted average changes in three variables, namely a country's exchange rate relative to a reference country, interest rate and foreign reserves. The mean value and standard deviation of the EMPI are calculated and extreme values of the EMPI are used to identify crisis periods. These authors define a crisis as a period when the estimated EMPI is more than 1.5 standard deviations above the mean. Other researchers modified the EMPI measure proposed by Eichengreen et al. (1997) by omitting the interest rate variable from the index. Consequently, the modified EMPIs are a function of a country's exchange rate and the foreign reserves only. Two authors who modify the EMPI in this manner are Balakrishnan et al. (2011) and Kaminsky and Reinhart (1999;

2000). Balakrishnan et al. (2011) found the modified version of the EMPI performed well since it failed to identify past episodes of currency crises only 20 percent of the time. This author follows the approach of Kaminsky and Reinhart (1999) who propose a different way of interpreting the modified EMPI. According to Kaminsky and Reinhart (1999) the measure of 1.5 standard deviations above the mean would result in several warnings that a crisis has occurred even if there was actually no currency crisis. In order to avoid such false positives, these authors argue that two standard deviations from the mean value of the EMPI should be interpreted as currency turbulence and only three standard deviations of the EMPI above the mean should be classified as a currency crisis.

6.4 Indicators of Stress in Currency Markets

This section discusses the indicators of stress in currency markets. A review of literature suggests that the collapse of a currency is associated with high levels of government debt, low foreign reserves, increased expectation of a currency devaluation, currency speculation, depleted foreign direct investment, and the incidence of a banking crisis (Chiodo & Owyang, 2002; Frankel & Rose, 1996; Kaminsky, 2006; Kaminsky & Reinhart, 1999, 2000). Accordingly, the empirical measures of stress discussed in this section consist of variables that assess the level of debt, foreign reserves, exchange rates and foreign direct investment reserves. In addition, this study posits that increased volatility in an exchange rate is a suitable proxy for currency speculation. The reasoning for this is based on the work by Black (1976) on volatility of stock prices. According to this study, poor performance of a publicly listed company is generally followed by a drop in stock prices and increased volatility of the prices of the shares. Conversely, good performance of the company would result in a rise in the company's share prices and less volatility in the prices. The same logic can be extended to currency markets such that increased uncertainty in the foreign exchange markets causes more currency speculation and increased fluctuation in an exchange rate. Volatility in the foreign exchange markets can be measured using a GARCH (1, 1) model of the nominal effective exchange rate, this approach is similar to those adopted in other studies (Cardarelli et al., 2011; Illing & Liu, 2006; Vermeulen et al., 2015). This study explored the suitability of the GARCH (1, 1) model to measure volatility in Australian exchange markets. A detailed discussion of this analysis is included in Section 6.4.1. Besides exchange market volatility, distress in the foreign exchange market is also measured using an EMPI and an inverse CMAX variable of the Australian trade weighted index; a discussion of these variables is included in sections 6.4.2 and 6.4.3 respectively.

6.4.1 *Volatility in currency markets*

This study uses four GARCH models to measure exchange market volatility in the Australian market. Following Illing and Liu (2003, 2006), one GARCH model is based on a trade weighted index (TWI) of exchange rates of the Australian dollar to currencies of Australia's leading trading partners as reported by the Reserve Bank of Australia (RBA). The TWI incorporates exchange rates of 90 percent or more of Australia's bilateral traders and the weight of currencies in the TWI are reviewed every year in October (Baker, 2004). The TWI is a useful indicator of Australia's competitiveness internationally. Moreover, when the bilateral exchange rates of the Australian dollar to other currencies show diverging trends, the TWI can help to assess whether the Australian dollar is on average weaker or stronger than currencies of the leading bilateral partners (RBA, 2002). The other three variables are selected based on data of Australia's top three bilateral trading partners for the past five years as indicated by Department for Foreign Affairs and Trade (DFAT, 2011, 2012, 2013, 2014). In order of rank, the top three bilateral traders are China, Japan and the USA. Accordingly, three GARCH models were estimated using exchange rates for China, Japan and the USA.

Monthly data was sourced for all four variables from the Reserve Bank of Australia website. Figure 6.1 plots the four sampled series from December 1983 to December 2014 and as expressed in natural logarithmic terms. The GARCH (1, 1) model could capture the volatility clustering that is exhibited in all series. The descriptive statistics for the sampled data is shown in Table 6.1 and the distributions of the four series are plotted in Figure 6.2.

Table 6.1: Descriptive statistics for the TWI and exchange rates

	AUD to CNY	AUD to JPY	AUD to USD	TWI
Mean	1.534	4.494	-0.284	4.108
Maximum	1.957	5.394	0.091	4.433
Minimum	0.580	4.027	-0.715	3.850
Standard deviation	0.363	0.262	0.173	0.138
Skewness	-1.011	1.362	-0.117	0.414
Kurtosis	2.881	5.595	2.889	2.327
Jarque-Bera	63.746***	220.065***	1.0400	17.696***
Observations	373	373	373	373

Note: * indicates that the Jarque-Bera test statistic is significant at the 10% (*), 5% (**) or 1% (***) level. TWI, AUD to CNY, AUD to JPY and AUD to USD stand for the Trade Weighted Index, the exchange rate of the Australian dollar to the Chinese Yuan Renminbi, the exchange rate of the Australian dollar to the Japanese Yen and the Australian dollar to the US dollar respectively.

It is customary to perform an ARCH test before estimating an ARCH or GARCH model. Therefore, hypotheses tests are performed on the level of each series. The null (H_o) and alternative hypothesis (H_a) for each ARCH test are as follows: H_o: there is no ARCH effect in the series and H_a: there is an ARCH effect. Table 6.2 provides a summary of the results of the ARCH-LM tests. The null hypothesis was rejected at all levels of significance for all series. Consequently, the estimation of GARCH models is justified.

Table 6.2: The test results for the presence of ARCH

	LM statistic	Probability of LM-statistic
TWI	329.139	0
AUD to CNY	358.789	0
AUD to USD	334.923	0
AUD to JPY	364.773	0

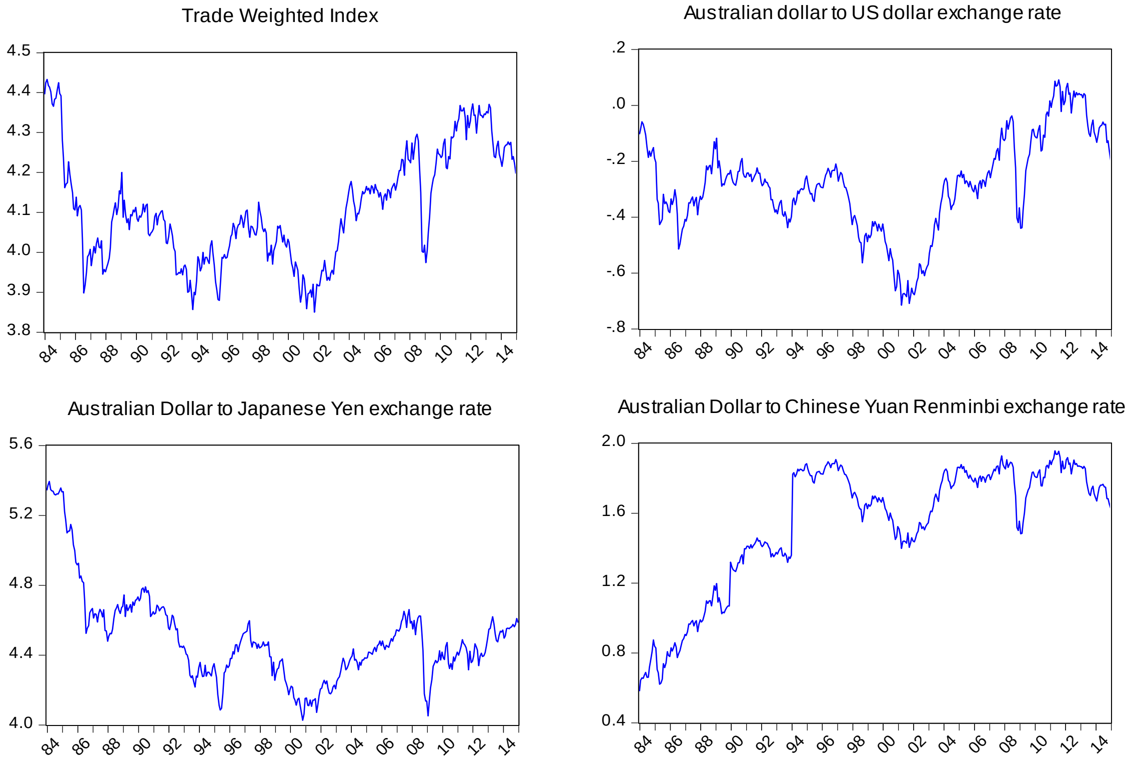


Figure 6.1: Exchange Rates & Trade-Weighted Index (Dec/83-Dec/14)

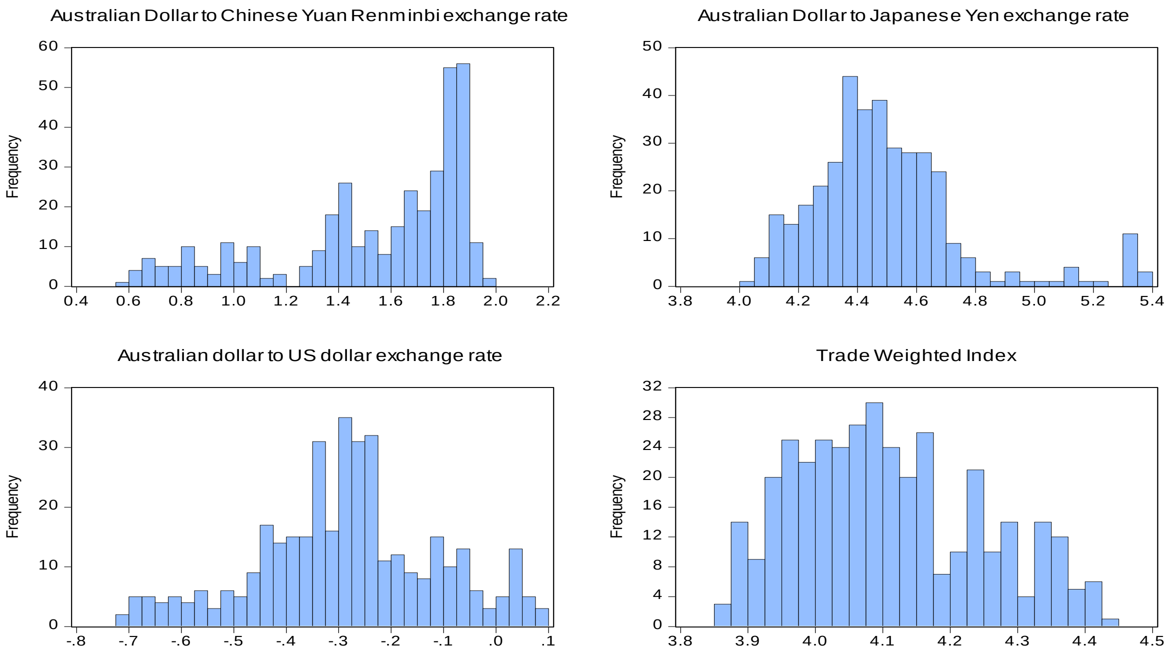


Figure 6.2: Distribution of Exchange Rates & Trade-Weighted Index (Dec/83-Dec/14)

The histograms in Figure 6.2 show that the distribution of the four series is skewed and the descriptive statistics in Table 6.1 confirmed this observation. Specifically, the descriptive statistics indicate that the exchange rates for the Australian dollar to the Chinese Yuan and the Australian dollar to the US dollar is negatively skewed. Conversely, the exchange rate of the Australian dollar to the Japanese Yen and the TWI is positively skewed. The Jarque-Bera test statistics indicate that the null hypothesis for normality can be rejected at a 5% level of significance in three cases. This indicates that with the exception of the exchange rate of the Australian dollar to the US dollar, the distributions of the other series are non-normal. The bilateral exchange rate between Australian dollars to the US dollars is normally distributed.

Continuously compounded monthly returns for each series were estimated using Equation 4.5 (in chapter 4), in which R_t is the logarithmic return of each series at time t, P_t is the value of each series in month t and P_{t-1} is the value of each series in month t-1. By definition, GARCH models require the use of stationary series in the estimation models. The level of each series as plotted in Figure 6.1 appears to be non-stationary. Conversely, Figure 6.3 shows the plots the estimated returns for the four series that appear to be stationary. Formal unit root tests were used to check for a stationary process in the level of each series and the first difference (or returns) of each series. A detailed discussion of the ADF unit root testing procedure is contained in Section 4.2.4 of chapter 4. Unit root tests for the level and the first difference were performed using Equations 4.8 and 4.9 respectively. Table 6.3 shows the unit root test results for all the series. The level of all series was found to be non-stationary while the returns of all series were found to be stationary at a 5% level of significance. As a result, the returns of each series were used to estimate the GARCH model of each series.

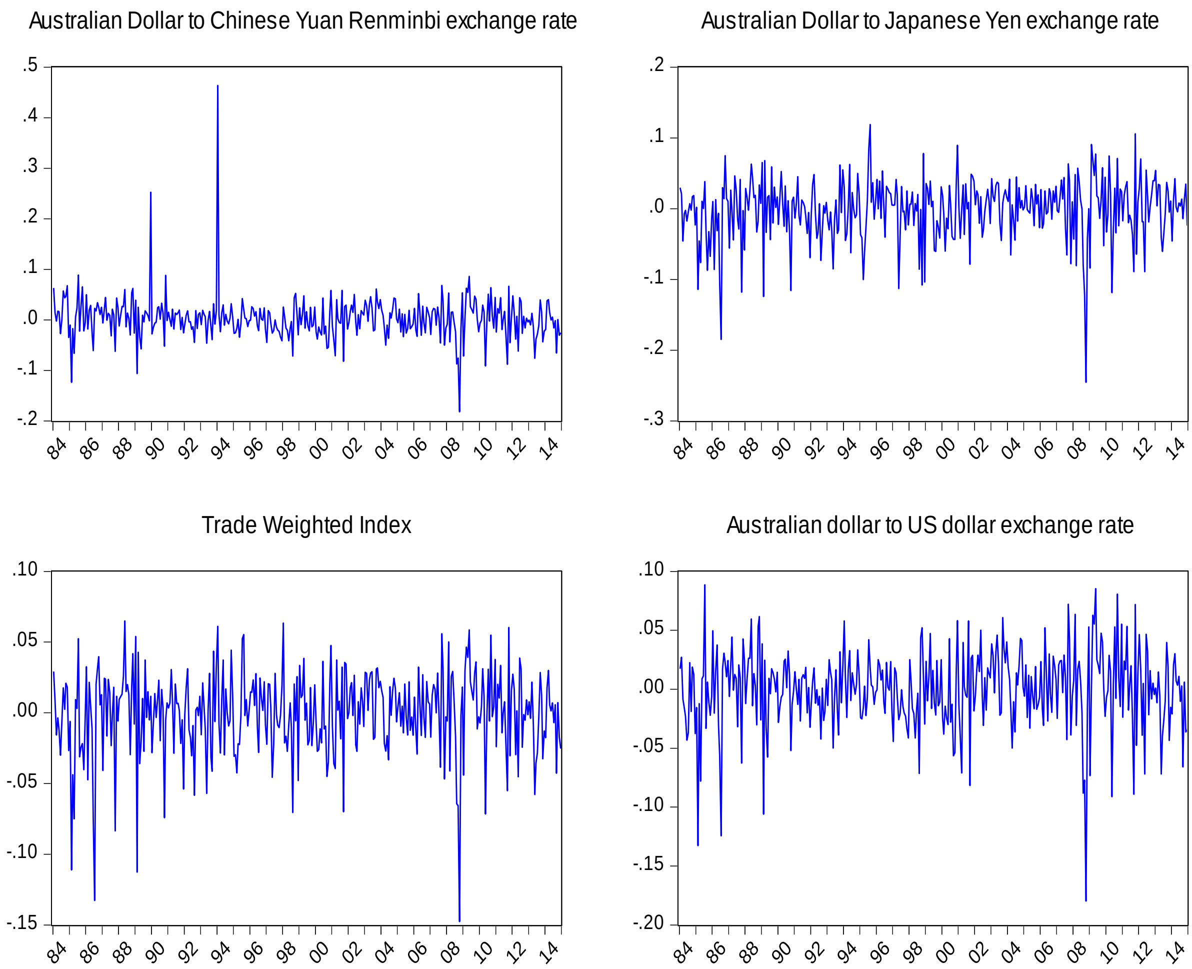


Figure 6.3: Monthly Returns Exchange Rates & Trade-Weighted Index (Jan/84-Dec/14)

Table 6.3: ADF Unit root tests for the TWI and exchange rates

Variables	Level	First difference
TWI	-3.223*	-18.021***
AUD to CNY	-2.006	-9.967***
AUD to JPY	-2.632	-11.967***
AUD to USD	-2.393	-9.820***

Note: * indicates that the Dickey-Fuller tau statistic is significant at a 10% (*), 5% (**), or 1% (***) level. TWI, AUD to CNY, AUD to JPY and AUD to USD stand for the Trade Weighted Index, the exchange rate of the Australian dollar to the Chinese Yuan Renminbi, the exchange rate of the Australian dollar to the Japanese Yen and the Australian dollar to the US dollar respectively

Table 6.4: AR (1)-GARCH (1, 1) models for the TWI and exchange rates

	TWI	AUD to CNY	AUD to JPY	AUD to USD
ϕ_0	0.0002	-0.0006	-0.0006	-0.0006
	(0.0016)	(0.0036)	(0.0023)	(0.0017)
ϕ_1	0.0301	0.0259	0.0204	0.0745
	(0.0695)	(0.0907)	(0.0656)	(0.0583)
α_0	0.0006***	0.0010	0.0008***	0.0001**
	(0.0001)	(0.0015)	(0.0002)	(0.00003)
α_1	0.2500***	-0.0120	0.2883***	0.1083***
	(0.0538)	(0.0151)	(0.0586)	(0.0254)
β_1	0.0251	0.6119	0.2795*	0.8382***
	(0.1609)	(0.5958)	(0.1480)	(0.0392)
$\alpha_1 + \beta_1$	0.2751	0.6112	0.5678	0.9465

Note: Robust standard errors in parentheses: * indicates that a coefficient is significant at a 10% (*), 5% (**), or 1% (***) level. TWI, AUD to CNY, AUD to JPY and AUD to USD stand for the Trade Weighted Index, the exchange rate of the Australian dollar to the Chinese Yuan Renminbi, the exchange rate of the Australian dollar to the Japanese Yen and the Australian dollar to the US dollar respectively.

Table 6.4 shows the four AR (1)-GARCH (1, 1) models that were estimated using monthly returns. The equations for estimated GARCH process are as specified in Equations 4.10a and 4.10b (in chapter 4). The highly significant GARCH parameters indicate that the AR (1)-GARCH (1, 1) model adequately models the volatility of monthly returns in the exchange rate of the Australian dollar (AUD) to the US dollar (USD). Moreover, the coefficient for the lagged squared residual (α_1) and the lagged conditional variance (β_1) are both positive and the sum of the coefficients is less than unity. The constant term (α_0) of the GARCH model is relatively small (0.0001) compared to the other GARCH coefficients; this indicates that an IGARCH model would be a better model volatility in the exchange rate of the AUD to the USD. Accordingly, an IGARCH model was fitted to the data and the estimated model is reported in Table 6.5. As expected, the results of the IGARCH model are similar to the results of the GARCH model. The IGARCH model reports highly significant coefficients for the ARCH (α_1) and GARCH (β_1) coefficients.

Table 6.5: AR (1)-IGARCH (1, 1) model for the AUD to USD exchange rate

	Coefficient	**Standard error**
ϕ_0	-0.0005	(0.0014)
ϕ_1	0.0619	(0.0506)
α_1	0.0862***	(0.0143)
β_1	0.9138***	(0.0143)

Note: Robust standard errors are reported in parentheses. * indicates a coefficient is significant at a 10% (*), 5% (**), or 1% (***) level. All estimated values are reported to 4 decimal places.

With respect to the GARCH model for monthly returns of the Australian dollar (AUD) to the Chinese Yuan (CYN), the model appears to be a poor fit for two reasons. First, the GARCH model coefficients are insignificant. Second, the ARCH coefficient (α_1) of the model is negative which violates the non-negative requirements as specified by Bollerslev (1986). According to Brooks (2008) a negative ARCH coefficient could result in a negative conditional variance which cannot be meaningfully interpreted. This is because by definition a variance measure is calculated by squaring a standard deviation. Regardless of whether the estimated standard deviation is positive or negative, the squared value of the standard deviation (the variance) would results in a positive value. For these reasons, the estimated GARCH (1, 1) model is deficient and should not be used to measure volatility in the AUD to CNY exchange rate. The other two models proved inadequate because even though the ARCH coefficients are highly significant in the case of the TWI and the exchange rate of the Australian dollar (AUD) to Japanese Yen (JPY), the GARCH coefficients are insignificant in the former case and weakly significant in the latter. The GARCH coefficients for these two models (TWI and AUD to JPY) were found to be insignificant at a 5% level of significance. In conclusion, the GARCH (1, 1) process fails to adequately model the conditional volatility. Therefore, three GARCH models were estimated for the TWI and exchange rates of Australian dollar to Chinese Yuan and Australian dollar to Japanese Yen. These included an AR (1)-GARCH (1, 2), an AR (1)-GARCH (2, 1) and an AR (1)-EGARCH (1, 1) model. The estimated AR (1)-GARCH (1, 2) model can be expressed in mathematical form as shown in Equation 6.1 a and 6.1 b. The estimated model coefficients are reported in Table 6.6.

$$y_t = \hat{\phi}_0 + \hat{\phi}_1 y_{t-1} + \hat{e}_t \qquad (6.1a)$$

$$\hat{\sigma}_t^2 = \hat{\alpha}_0 + \hat{\alpha}_1 \hat{e}_{t-1}^2 + \hat{\beta}_1 \hat{\sigma}_{t-1}^2 + \hat{\beta}_2 \hat{\sigma}_{t-2}^2 \qquad (6.1b)$$

Table 6.6: AR (1)-GARCH (1, 2) models for TWI, AUD/CNY, and AUD/JPY exchange rates

	TWI	AUD to CNY	AUD to JPY
$\boldsymbol{\phi_0}$	0.0002	0.0022	-0.0008
	(0.0016)	(0.0029)	(0.0023)
$\boldsymbol{\phi_1}$	0.0290	0.0209	0.0179
	(0.0696)	(0.0707)	(0.0661)
$\boldsymbol{\alpha_0}$	0.0006***	0.0002	0.0009***
	(0.0002)	(0.0002)	(0.0003)
$\boldsymbol{\alpha_1}$	0.2501***	-0.0104**	0.2964***
	(0.0537)	(0.0049)	(0.0606)
$\boldsymbol{\beta}_1$	0.0224	0.6521	0.1729
	(0.1585)	(1.0930)	(0.1674)
$\boldsymbol{\beta_2}$	0.0230	0.2416	0.0723
	(0.1639)	(1.0237)	(0.1391)

Note: Robust standard errors in parentheses: * indicates a coefficient is significant at a 10% (*), 5% (**), or 1% (***) level.

Unfortunately the GARCH (1, 2) models failed to provide better results with all models reporting weakly insignificant GARCH coefficients for β_1 and β_2. Once again ARCH coefficient for the AUD to CNY model violates the non-negative requirement. This study now considers the GARCH (2, 1) model. The estimated AR (1)-GARCH (2, 1) model can be expressed in mathematical form as shown in Equation 6.2 a and 6.2 b. The estimated model coefficients are reported in Table 6.7. The results provide some highly significant coefficients but also yield model coefficients that violate the non-negativity requirement.

$$y_t = \hat{\phi}_0 + \hat{\phi}_1 y_{t-1} + \hat{e}_t \qquad (6.2a)$$

$$\hat{\sigma}_t^2 = \hat{\alpha}_0 + \hat{\alpha}_1 \hat{e}_{t-1}^2 + \hat{\alpha}_2 \hat{e}_{t-2}^2 + \beta_1 \hat{\sigma}_{t-1}^2 \qquad (6.2b)$$

Table 6.7: AR (1)-GARCH (2, 1) Models for TWI, AUD/CNY & AUD/JPY exchange rates

	TWI	AUD to CNY	AUD to JPY
$\boldsymbol{\phi_0}$	0.00003	0.0025	-0.0013
	(0.0016)	(0.0031)	(0.0023)
$\boldsymbol{\phi_1}$	0.0312	0.0216	0.0154
	(0.0691)	(0.0809)	(0.0652)
$\boldsymbol{\alpha_0}$	0.0002	0.0004	0.0001
	(0.0002)	(0.0002)	(0.0001)
$\boldsymbol{\alpha_1}$	0.2440***	-0.0108	0.2884***
	(0.0538)	(0.0123)	(0.0601)
$\boldsymbol{\alpha}_2$	-0.1792**	-0.0005	-0.2262***
	(0.0895)	(0.0108)	(0.0668)
$\boldsymbol{\beta_1}$	0.7656***	0.8487***	0.8628***
	(0.2778)	(0.1077)	(0.0902)

Note: Robust standard errors in parentheses. * indicates that a coefficient is significant at a 10% (*), 5% (**), or 1% (***) level.

The GARCH models, that have been estimated thus far, have yielded unsatisfactory results. Of utmost concern is the violation of the non-negativity constraint that is required for the GARCH models to provide meaningfully estimates of the conditional variance or volatility in the variables. In order to address this drawback of the estimated GARCH models this study employed the exponential GARCH (EGARCH) model which was originally proposed by Nelson (1991). The expression of the EGARCH model used in this study is derived from the estimation procedure used in Eviews7. The mathematical expression of an AR-EGARCH model is as shown in Equations 6.3a and 6.3b.

$$y_t = \hat{\phi}_0 + \hat{\phi}_1 y_{t-1} + \hat{e}_t \tag{6.3a}$$

$$ln(\sigma_t^2) = \omega + \beta\, ln(\sigma_{t-1}^2) + \gamma \frac{e_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \alpha \frac{|e_{t-1}|}{\sqrt{\sigma_{t-1}^2}} \tag{6.3b}$$

Where y_t and y_{t-1} is the value of the series at time t and t-1 respectively. $\hat{\phi}_0$ is the estimated constant term, $\hat{\phi}_1$ is the estimated coefficient for the lagged series and $\hat{e}_t$ is the error term of the estimated autoregressive (AR) model. For the EGARCH part of the model, σ_t^2 and σ_{t-1}^2 is the conditional variance and the lagged conditional variance respectively; alternatively, this can be interpreted as the GARCH term and the lagged GARCH term. e_{t-1} is the lagged error term and ω is a constant term. β is the coefficient of the natural logarithm of the lagged conditional variance; high values of this coefficient are indicative of persistent conditional volatility. The γ coefficient captures the asymmetric or leverage effect in a series. The leverage effect occurs because bad news seems to have a greater effect on financial markets than good news. Thus, there is increased volatility in the financial markets following a bad announcement and lower volatility in the markets following good announcement (Black, 1976). The α coefficient represents the symmetric effect of the estimated model.

There are two advantages to using the EGARCH model specification. Firstly, the model is designed to estimate coefficients for the logged variance instead of the variance itself. This allows for the meaningful interpretation of positive and negative values of the estimated coefficients. Specifically, the estimated variance would always be positive but the logged value of the variance could be positive or negative. For example, consider two variance values of 100 and 0.25; the natural logarithm of these two values is approximately 4.605 and -1.386 respectively. Here, both variance measures are positive but the logged variance provides a negative value in one case and positive value in the other; both can be meaningfully interpreted. Secondly, the EGARCH model includes a leverage term that is missing in the GARCH model. Table 6.8 shows the three estimated models. With the exception of the AR (1) model coefficients, the other coefficients are significant to a 5% level of significance. As before, the estimated models for the three series include some negative coefficients but this is permissible in the case of EGARCH models.

Using a 5% level of significance, the intercept terms are significant for all three models. The exchange rate of the AUD to CNY (0.8483) exhibits more persistent volatility than the exchange rate of the AUD to JPY (0.5921) or the TWI (0.5183). The leverage coefficient (γ) is significant and negative in all cases. This is indicative of the leverage effect in the Australian exchange market with bad news having a greater impact than good news. The symmetric effect coefficient is significant at a 5% level of significance in all models. The exchange rate of the AUD to the JPY has a greater symmetric effect while the lowest symmetric effect is noticed in the AUD to the CNY. Overall, the EGARCH models appear to be a better fit. Consequently, the estimated EGARCH models are incorporated in the final financial stress index of this study.

Table 6.8: AR (1)-EGARCH (1, 1) models for the TWI, AUD/CNY and AUD/JPY

	TWI	AUD to CNY	AUD to JPY
ϕ_0	-0.0003	0.0023	-0.0019
	(0.0016)	(0.0023)	0.0023
ϕ_1	0.0310	0.0054	0.0219
	(0.0684)	(0.0402)	0.0677
ω	-3.6339**	-0.8949***	-2.9212***
	(1.4993)	(0.2039)	0.7954
β	0.5183**	0.8483***	0.5921***
	(0.2082)	(0.0364)	0.1217
γ	-0.1105**	-0.1434***	-0.1255**
	(0.0484)	(0.0340)	0.0567
α	0.2876***	-0.1009**	0.4247***
	(0.0698)	(0.0473)	0.0823

Note: Robust standard errors in parentheses: * indicates a coefficient is significant at a 10% (*), 5% (**), or 1% (***) level.

Figure 6.4 provides a visual representation of the conditional variance as estimated by EGARCH models.

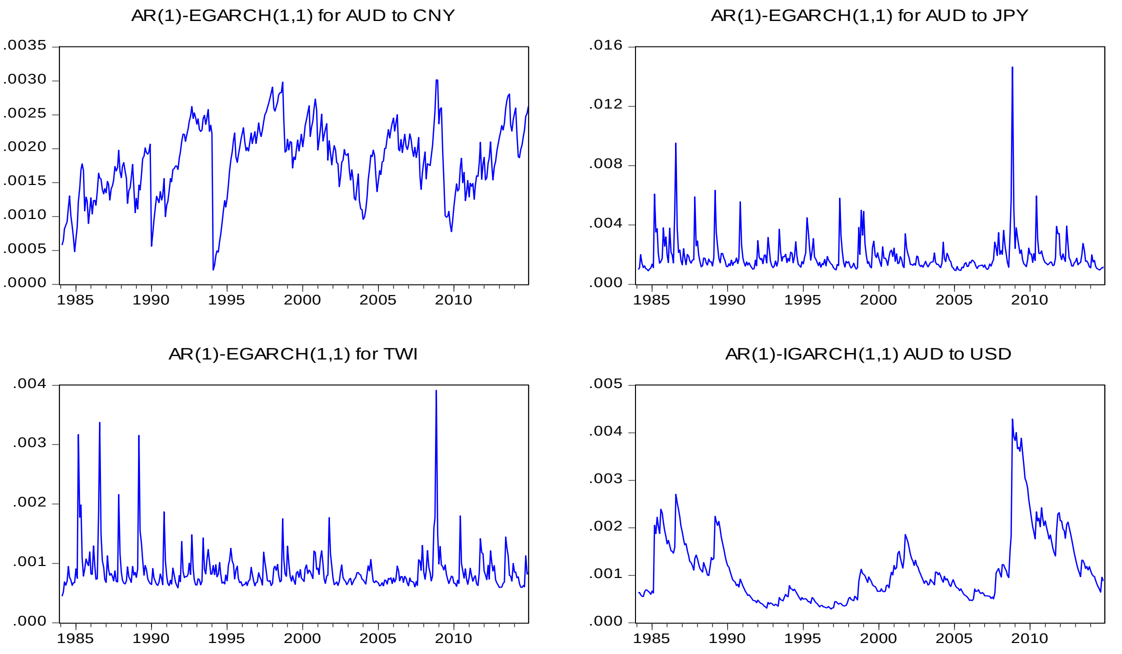


Figure 6.4: EGARCH Models for Exchange Rates & Trade-Weighted Index (Feb/84 to Dec/14)

6.4.2 *Exchange Market Pressure Index (EMPI)*

This study follows Balakrishnan et al. (2011) approach to estimate the EMPI. This method of estimating exchange market pressure considers changes in the level of foreign reserves and the prevailing exchange rate the most important indicators of distress in the exchange market. The monthly data for the exchange rate of the AUD to the USD was sourced from the RBA website and ranges from December 1983 to December 2014. Monthly foreign reserves data is sourced from the A4 spreadsheet from the RBA website and ranges from July 1969 to December 2014. Therefore, the EMPI was estimated for the time spanning from January 1984 to December 2014. The EMPI mathematical expression is as shown in Equation 6.4.

$$EMPI_t = \frac{(\Delta e_t - \mu_{\Delta e})}{\sigma_{\Delta e}} - \frac{(\Delta R_t - \mu_{\Delta R})}{\sigma_{\Delta R}} \qquad (6.4)$$

Where Δe_t is the month-over-month percentage change in the exchange rate of the Australian dollar to the USD. ΔR_t is the month-over-month percentage change in the total foreign reserves at time t minus the gold component of reserves at time t. The mean and standard deviation of the sampled data are denoted as μ and σ respectively. This study employs the definition of crisis as outlined by Kaminsky and Reinhart (1999). A successful speculative attack is signalled when the value of the EMPI is more than three standard deviations above its mean value. The standard deviation of the estimated EMPI was found to be 1.562794. Hence, three standard deviations above the mean is equal to about 4.6884. Using this criterion, one episode of distress in the Australian currency markets was indicated in September 2007 (5.8). A graphical representation of the distress is shown in Figure 6.5 where there is only one spike in the EMPI (in the unshaded region); this is indicative of a currency crisis. This is as expected since the reference country for the exchange rate is the US that suffered the 2007-2009 Global Financial Crises. It is worth noting at this point that the EMPI provides an earlier warning signal of crisis as opposed to the GARCH models, which signalled the 2007-2009 GFC in November 2008. Therefore, the EMPI would facilitate earlier detection and policy intervention than the GARCH models.

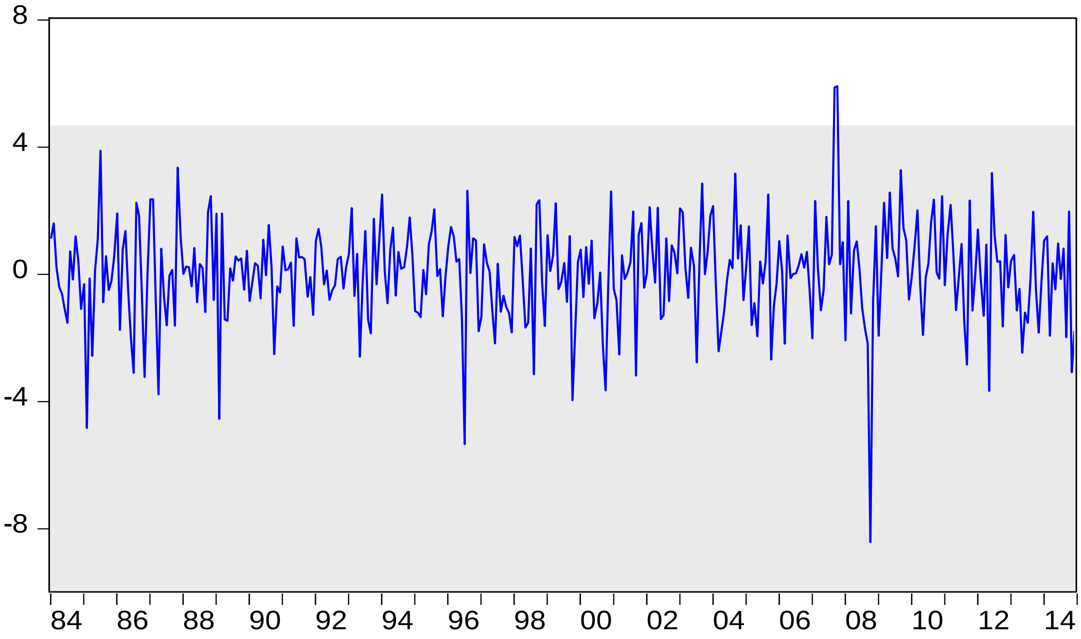


Figure 6.5: The Australian EMP Index (January 1984 to December 2014)

The EMPI variable is explanatory to the extent that the American currency markets are in distress or have suffered contagion of a crisis from other markets or the Australian currency market is itself in crisis. However, it is possible that this variable could fail to highlight currency crises that originate from countries, other than the US or Australia. If the crisis spreads from these countries to Australia and not the US, it may not be reflected in the exchange rate of the AUD to the USD. In order to address this weakness of this variable, it would be prudent to consider a variable that gauges the overall depreciation of the AUD relative to other countries' currencies such as the TWI. Accordingly, the inverted CMAX variable of the TWI was also estimated in order to assess the likelihood that a country had suffered a currency crisis. Section 6.4.3 discusses this variable in detail.

6.4.3 *Inverted CMAX variable of the TWI*

The TWI gauges the average appreciation or depreciation of the AUD relative to the currencies of Australia's key trading partners. Generally, a depreciating AUD[37] causes imports to decline and exports to rise because imports to Australia would be more expensive while Australian exports would become more competitive but earn less revenue. A loss of confidence in the AUD would increase currency speculation and cause large depreciations of the AUD relative to other currencies. Investors would change the composition of their portfolios by selling off the AUD in order to minimise their losses from the depreciation of the dollar (Krugman, 1979). With decreased demand for the Australian dollar, few investors would want to purchase dollars and the overall value of the Australian dollar relative to other currencies would drop; this would also cause the TWI to drop. Illing and Liu (2006) argue that the CMAX measure of a basket of currencies is a suitable for measuring stress in countries with a floating exchange rate regime. This study uses an inverted CMAX measure of the TWI to measure stress in the currency market. The estimation procedure is similar to the one discussed inn Section 4.2.1 of chapter 4. Instead of using a moving window of 24 months, this study uses a 12 month window as recommended by Illing and Liu (2006). The estimated variable shown in Figure 6.6, the highest peaks are observed in July 1986 (1.084) and January 2009 (1.081). While the second peak coincides with the 2007-2009 GFC, the inverted CMAX variable lags the EMPI variable in signalling the onset of the GFC.

[37] This study uses the Australian dollar to explain the concept of Australian TWI. However, it should be noted, that Australian commodities are usually priced in US dollars (Cole & Nightingale, 2016)

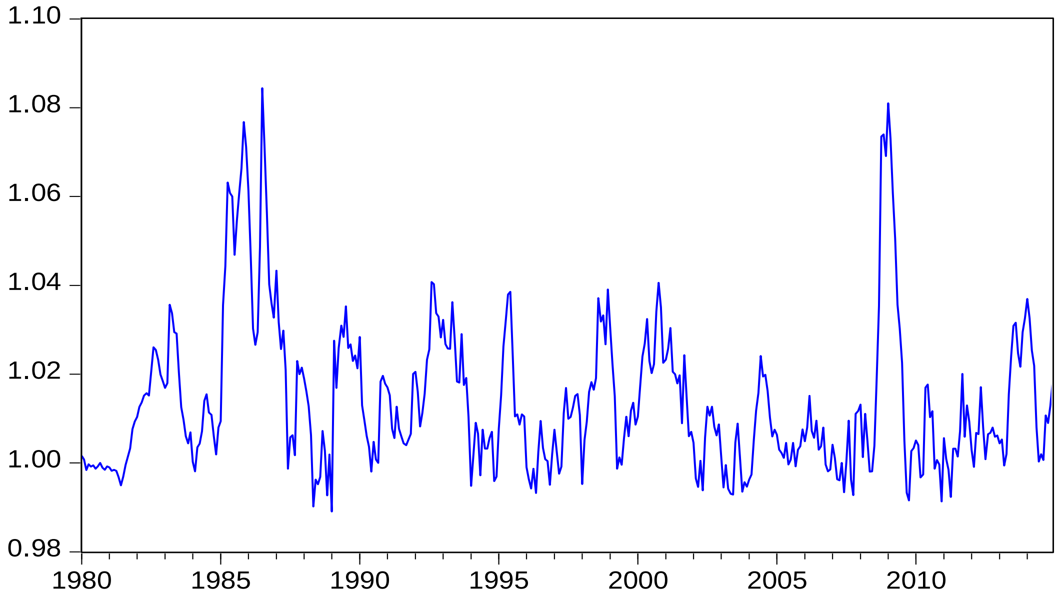


Figure 6.6: Inverted CMAX for TWI variable

6.5 Banking sector

For purposes of this study, the banking sector is comprised of Australian owned financial institutions that act as 'custodians' of deposits received from the public and provide long-term and short-term lending facilities in the form of mortgages, loans or credit card facilities. Thus, the banking sector consists of Australian commercial banks and excludes the central or Reserve bank of Australia. In relation to bank deposits, bank customers can access deposited funds through various means including the use of a chequebook, debit card, internet banking facilities or making a withdrawal at an automated teller machine (ATM).

Generally, a bank's customers believe that money is safer in the bank than it would be in the customers' homes or businesses where money could be lost, stolen or destroyed by fire. It is unlikely that customers will withdraw all the money deposited at the bank at any given time. This is because customers hold money for three main motives; John Maynard Keynes identified these as transaction, speculative and precautionary motives (Keynes, 1936b). According to Lipsey and Chrystal (1999), transaction motivations for holding money arise because the time that money is received differs from the time that payments need to be made.

For instance, a business could predict the time when payments for utilities such as electricity and water may fall due. However, the timing of receipts fluctuate, depending on the sales are made within a given period. Speculative motives for holding money relate to investment opportunities. Firms and individuals hold money in order to take advantage of investment opportunities that may arise in the near future. An investment in interest earning securities, under-priced assets or mispriced currencies could earn the investor a return on money invested. Precautionary motives relate to holding money for emergencies or unforeseen expenditure. Prachowny (1985) argues most businesses and individuals hold money for transaction or speculative motives. This is because access to credit facilities such as credit cards can be used to finance the precautionary demand for money. Given that a bank's customers are unlikely to withdraw all deposits at any given time, banks can invest the deposited funds in financial markets or use deposits to finance loans or credit facilities offered to customers. In this way, a mutually beneficial relationship exists between the banks and customers. On one hand, customers who make deposits at the bank are assured that the money deposited is safe. Moreover, if the customer wishes to access additional funds they can apply for a loan or another credit facility. On the other hand, banks make a profit by charging interest or bank fees on funds loaned to customers. This relationship is heavily reliant on the belief that the bank is able to play its role as a custodian of deposited funds. If people begin to doubt, a bank's ability to safeguard the deposits, due to for instance liquidity problems, a bank's customers would speculate that the bank could soon be under receivership or liquidated. Customers would soon begin to act in line with their suspicions by withdrawing funds from the bank and depositing them in another bank or investing them in assets or securities. A bank run occurs when several customers withdraw money from their bank accounts. If a crisis originates from the banking sector, bank runs tend to occur in the several banks especially if customers become convinced that their money is no longer safe in bank accounts. In this case, a banking crisis is associated with panic and the rapid decline in the deposits held by commercial banks. This is perhaps why studies on banking crises use the level of deposits as an early indicator of a developing crisis in the banking sector.

It is important to note that certain factors can determine how vulnerable a banking sector is to bank runs. This study discusses two main factors. The first factor is depositor behaviour. Iyer and Puri (2012) suggest that depositors would be less inclined to participate in a bank run if they have been banking with a bank for a long time or the depositor is heavily dependent on the bank for a number of banking services such as investment services. These depositors are more likely to decide to stay loyal to the bank even during a crisis period. The second factor is the deposit insurance. Several studies suggest that deposit insurance in the form of government guarantees of financial institutions, can help to reduce the likelihood of bank runs especially if the guarantee was obtained during a pre-crisis or tranquil period (Anginer, Demirguc-Kunt, & Zhu, 2014; Boyle, Stover, Tiwana, & Zhylyevskyy, 2015; Iyer & Puri, 2012). However, obtaining deposit insurance during a crisis was found to be less effective in preventing the panic that often leads to bank runs (Boyle et al., 2015). This is because it is possible that the bank runs would already have begun before the government guarantees are introduced or are implemented. While government guarantees of bank deposits can help to encourage bank stability during a financial crisis, Anginer et al. (2014) suggests that it can encourage moral hazard among banks and depositors, in the form of increased risk taking behaviour. For this reason, countries that implement government guarantees also improve bank supervisory practices, thereby discouraging excessive risk taking within the banking sector. Because this study focuses on possible indicators of banking crisis in the Australian market, a brief discussion of the Australian banking sector was deemed necessary. Thus, Section 6.5.1 discusses the Australian banking sector.

6.5.1 *The Australian Banking sector*

The main objective of this section is to provide a brief overview of the current nature of the Australian banking sector in order to determine the potential for risk of a banking crisis in the near future. For this reason, discussions in this section are centred on the Australian banks that are locally owned and have a major influence on the operations of the financial system. In this respect, this study considers the Australian banking sector to comprise of all local banks operating in Australia. Information regarding the banks operating in Australia is maintained by the regulatory body known as Australian Prudential Regulation Authority (APRA). APRA regulates and monitors the operations of local and foreign banks operating in Australia. In particular, it maintains a monthly record of the assets, deposits and loans of banks operating in Australia. As at August 2015, APRA recorded that there were 73 local and foreign-owned banks operating in Australia (APRA, 2015). The presence of foreign and local banks points toward two possible sources of a crisis in the Australian banking sector; these are mainly internal and external origins of a crisis. An internal origin of a crisis refers to an Australian banking crisis that is caused by lax regulatory of banks, moral hazard practices among banks or other weaknesses in the banking sector, which would render local banks more susceptible to the onset of a crisis. An external origin of a banking crisis results from shocks to a foreign banking system that culminates in a banking crisis. If many Australian banks extended loans to foreign banks that are based in the 'crisis country', such that Australia can be deemed a major lender, then it is more likely that problems would spill over from the foreign banking sector into the Australian banking sector. It is more likely that liquidity problems experienced by the foreign banks due to the banking crisis will affect the foreign banks' ability to service loan repayments. Consequently, Australian banks would probably suffer losses in the form of bad debts. This study argues that the contagion of foreign banking crises to Australia is only relevant if it adversely affects operations in

Australian banks. After all, foreign governments may intervene to prevent the banking crisis from spilling over into other sectors of the economy or across borders. This intervention may curb the spread of the crisis and minimise the threat of cross-border contagion. Besides, in the event that there was contagion of a banking crisis to Australia, a resilient Australian banking sector would be able to withstand shocks to the Australian banks and it would be unlikely that a foreign banking crisis would translate to a local banking crisis.

At this point, it is worth mentioning that a combination of external and internal factors could further exacerbate a crisis of local origin. For instance, Kaminsky and Reinhart (2000) explains how foreign banks could further exacerbate a developing crisis; by limiting credit to a country experiencing a crisis or requesting for earlier payment of loans to the afflicted country. However, this would only occur if there were already weaknesses in the banking sector. In this case, regulation and policy implementation may prove inadequate in combating pre-existing systemic problems. For example, Dabrowski (2010) states that, during the global financial crisis (GFC), even though policy response was delayed and poorly co-ordinated, systemic weaknesses were prevalent in European banks that were overleveraged. These weaknesses made the European banks more vulnerable to the spread of the GFC to European markets. In the absence of systemic weaknesses, adaptive policies could help to minimise the effects of a crisis on an economy. For example, strict regulation and supervisory practices by the Australian Prudential Regulation Authority's (APRA) is a major reason why Australian banks fared well compared to banks in other developed countries during the GFC (Pais & Stork, 2011). Edwards (2010) argues that unlike the USA and the UK, Australian financial institutions had not exposed themselves to the similar levels of risk. Specifically, there only existed non-conforming loans in the Australian market that were less risky than subprime mortgages, and even if lenders had riskier loans, they bore the risk of default instead of passing it on to investors. In addition, the Australian government took pre-emptive measures to ensure Australian banks had sufficient foreign currency at their disposal to prevent bank runs. Further, even after the GFC was well established, Australia enjoyed an extended economic boom, due (in large part) to the exports of its mining industries (Perlich, 2009).

So far, this discussion has centred on the two origins of a banking crisis. External origins that are linked to problems in foreign countries banks while internal origins are linked to problems in Australian banks. Regardless of the origin of the crisis, this part of the study is mainly concerned with the adverse impact of a crisis on the Australian banking sector. The notion is that local banks tend to hold a larger proportion of deposits than foreign banks; therefore, Australian banks would give a more representative measure of the health of the Australian banking sector than foreign banks would. In this study, the health of domestic banks is used as an indirect measure of cross-border contagion to Australian banks, whereby negative effects of contagion are of primary interest. Consequently, the discussion shall proceed with an emphasis on Australian owned banks.

The August 2015, APRA (2015) report is used to identify the top 10 Australian banks, based on the total residential assets held by each bank. Table 6.9 shows the rank of the top 10 banks based on total assets and the corresponding market capitalisation. A graphical representation of the market capitalisation for the top 10 banks is provided in Figure 6.7. The information in Table 6.9 and Figure 6.7 shows that four banks dominate the Australian banking sector; in order of market capitalisation, the ‘big four’ comprise of the Commonwealth Bank of Australia, Westpac Banking Corporation, National Australia Bank and Australia and New Zealand Banking Group Limited. It can be argued that the impact of a shock to the banking sector would be more pronounced if the big four were negatively affected than if smaller banks were affected. This is because the four banks hold most of the assets of customers including individuals, businesses and other banks (in case of interbank lending). Thus, a banking crisis and liquidity problems among the big four could negatively affect the Australian economy.

Table 6.9: The top 10 banks in the Australian banking sector

Bank	Total Assets ($ millions)	Rank (based on total assets)	Market capitalisation ($ millions)
Westpac Banking Corporation	752,868	1	96,154.00
Commonwealth Bank of Australia	715,525	2	121,421.00
National Australia Bank Limited	627,826	3	79,819.30
Australia and NZ Banking Group Limited	550,230	4	77,838.20
Macquarie Bank Limited	74,394	5	24,831.50[d]
Suncorp-Metway Limited	58,607	6	16,108.20[d]
Bendigo & Adelaide Bank Limited	58,740	**7**	4,771.83
Bank of Queensland Limited	45,270	8	4,553.04
Members Equity Bank Limited	16,905	9	n/a[c]
AMP Bank Limited	14,169	10	16,740.80[d]

Note:
a. Banks are ranked based on the total resident assets for the end of August 2015, as reported by APRA.
b. Market capitalisations are for the trading day ended 1 September 2015. Data for market capitalisations is sourced from the Market index website (http://www.marketindex.com.au/all-ordinaries).
c. There is no market capitalisation reported for Members Equity Bank Limited because it is a privately owned company.
d. Macquarie Bank Limited, Suncorp-Metway Limited and AMP Bank Limited are listed on the Australian Securities Exchange as Macquarie Group Limited, Suncorp Group Limited and AMP Limited, respectively.

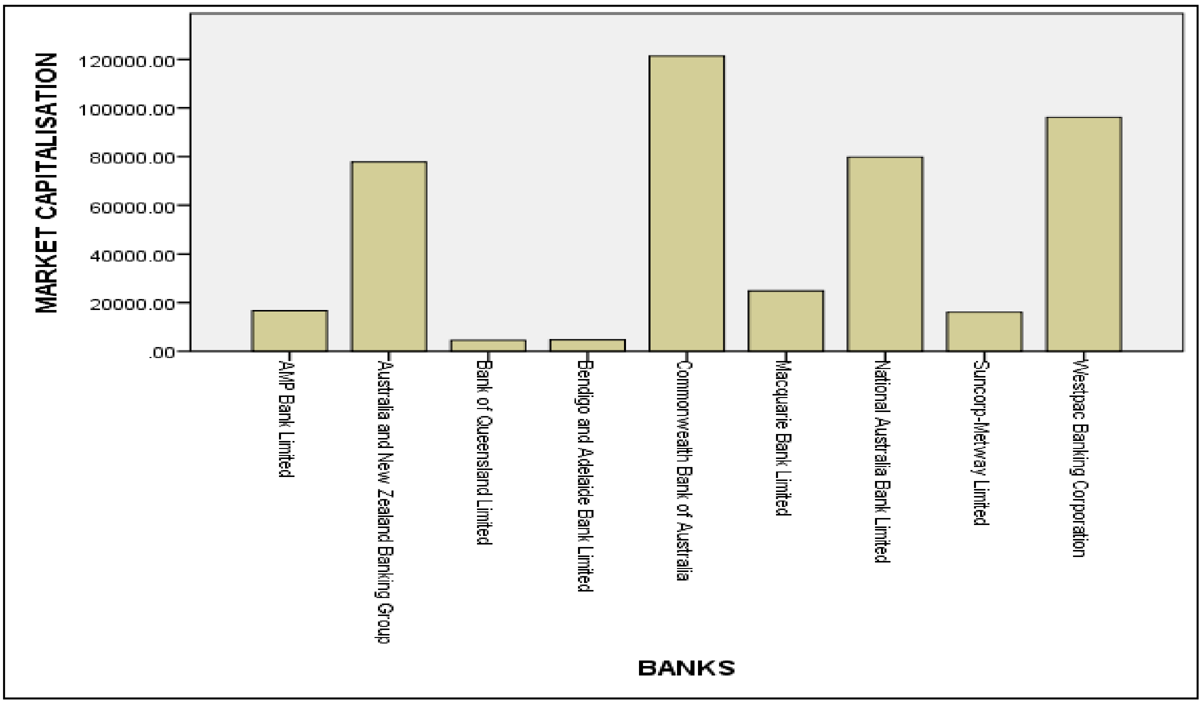


Figure 6.7: Market capitalisation of the top 10 Australian banks

6.6 Banking crises

Generally, banking crises are an indication that something went wrong in the banking industry, possibly due to: poor regulation, systemic weaknesses, or cross-border interbank contagion. Laeven and Valencia (2008) argue that a systemic banking crisis may be caused by contagion of stress or crises in other sectors of the economy. In particular, these authors focus on the case of a crisis that is caused by large defaults by major financial institutions and companies. This is indicative of problems in the business or financial sector of an economy that have spilled over into the banking sector. The banks would have to write-off outstanding loans as bad debts and work on surviving on dwindling levels of capital and rising reserves requirements. It is only when a country's banks liquidity is severely hampered that the early signs of a crisis begin to emerge in the banking sector. While Claessens and Kose (2013) cite bank runs as one cause of banking crises, Laeven and Valencia (2008) argue that bank runs are experienced in the latter stages of a banking crisis when the public are already aware of the weaknesses in the banking sector. It is possible that both studies are correct. On one hand, a banking crisis may have resulted from a bank run; On the other hand, other factors may have caused the onset of the banking crisis that culminated in a bank run in the latter stages of a banking crisis. It is important to note that it is possible for a banking crisis to occur in the absence of a bank run (especially if the government guarantees all deposits under a relatively large limit). Claessens and Kose (2013) provide two examples of this; the first are the banking crises experienced by Sweden, Finland and Norway in late 1980s to early 1990s, the second is the Japanese banking crisis of the late 1990s; both crises were not accompanied by bank runs. These examples indicate that other factors played a key role in the development and onset of these crises. Claessens and Kose (2013) cite work by Lindgren, Garcia, and Saal (1996) and Barth, Caprio, and Levine (2006) who identify large defaults loans, under-capitalization of banks, ownership of several complex and opaque securities such as mortgage-backed securities of the GFC, moral hazard among financial market players and failures by regulators as other possible causes of banking crises.

Hutchison and Noy (2005) state, from an empirical perspective, that the measurement of certain aspects of banking crises such as bank runs has proved challenging due to data limitations. Several authors suggest that large drops in equity or asset prices such as real estate prices and large increases in the non-performing loans are an indication that a banking crisis is imminent (Claessens & Kose, 2013; Demirguc-Kunt & Detragiache, 1998; Kaminsky & Reinhart, 1999; Laeven & Valencia, 2008). Reinhart and Rogoff (2008a, 2008b, 2009a, 2009b) find that banking crises are often preceded by credit booms and asset-price bubbles. By examining financial crises and the movements and duration of economic variables, they also find that, on average: a 35 percent real drop in housing prices spread over a period of 6 years, an equity prices fall of 55 percent over 3½ years, an output fall of 9 percent over two years, an unemployment rise of 7 percent over 4 years, and a rise in central government debt of 86 percent as compared to its pre-crisis level make it difficult to reverse.

Demirguc-Kunt and Detragiache (1998, 2005) also state that low GDP growth rates, high real interest rates and high inflation indicate increased vulnerability of an economy to a banking crisis. Furthermore, it is asserted that increased interbank linkages can help a developed countries hedge against credit risk associated with operating in a country. Demirguc-Kunt and Detragiache (1998) argue that increased integration of banks may be key to strengthening banks worldwide since entry of foreign banks encourages healthy competition and adoption of better banking regulation practices. However, setting up these linkages will also increase the vulnerability of a country to financial-stress contagion, so countries should be careful when encouraging increased financial integration across borders.

Hardy and Pazarbasioglu (1999) explored the use of banking sector and economic indicators in 50 different countries with the aim of identifying suitable banking-stress indicators. Banking sector variables mainly comprised of banks liabilities to foreign countries, to the private sector and other liabilities against deposited funds. All variables were expressed as a ratio to GDP. Apart from GDP, the performance of domestic consumption, inflation, exchange rates and investments was also examined. Consistent with other studies, Hardy and Pazarbasioglu (1999) found that countries with declining GDP growth rates and higher interest and inflation rates were more likely to suffer a crisis. A notable finding was that exchange rate variables provided leading signals of a banking crisis in comparison to GDP ratio variables. This suggests that policy makers could risk delayed policy intervention if they solely relied on information from GDP ratios. This problem could be remedied by also examining exchange rate variables in addition to GDP ratio variables; this is the approach that is adopted in this study. In a study of 40 developed countries from 1970 to 2010, Babecký et al. (2012), examined the performance of the credit to GDP ratio and found it to be the most reliable and leading indicator of a banking crisis. Moreover, these authors provide a criteria for identifying possible distress in the banking sector, specifically this related to if the ratio "deviates by more than 2% from its trend value" (Babecký et al., 2012, p. 34). For this reason, this study shall focus on the domestic credit to GDP ratio as a possible indicator of banking crises.

6.7 Indicators of stress in the banking sector

This section discusses the indicators of distress in the banking sector in Australia. The motivation for the choice of variables is based on literature. It should be noted that in the case of the domestic credit to GDP ratio, that the data for the domestic credit variables and GDP variable are only available at annual or quarterly frequency. This study follows the use of an interpolation method as recommended by Edison (2003) to transform the quarterly estimates to monthly estimates of the ratio. The following section discuss the banking beta (Section 6.7.1), the inverted yield spread (Section 6.7.2) and the domestic credit to GDP ratio (Section 6.7.3).

6.7.1 *Banking beta*

Many researchers have used the beta coefficient of the Capital Asset Pricing Model (CAPM) to measure the level of stress in the banking sector (Apostolakis & Papadopoulos, 2014; Balakrishnan et al., 2011; Cardarelli et al., 2011; Illing & Liu, 2006; Melvin & Taylor, 2009). Perold (2004) suggests that the theoretical principles of the CAPM were mainly developed by several scholars in the 1960s (Lintner, 1965a, 1965b; Mossin, 1966; Sharpe, 1964; Treynor, 1965). The principles proposed by these authors formed the basis for a model that can be expressed as shown in Equation 6.5.

$$R_j = R_f + \beta_j(R_m - R_f) \qquad (6.5)$$

Where R_j represents the expected return of an asset j based on the CAPM, R_f represents the risk free rate which is usually represented by the rate of return on a government issued security, β_j represents the beta of security j, and R_m represents the return on a market index. The beta coefficient in Equation 6.5 measures the risk of asset j relative to the risk of the overall market. It is estimated using returns on an asset and returns on a composite market index. The procedure for estimating the beta of asset j involves a three-step process. Step one involves calculating the covariance of asset j's returns to the returns on the market index. Step two finds the variance of the returns of the composite market index is calculated. The third and last step involves dividing the covariance measure from step one by the variance measure from step two. The mathematical formula for estimating the beta of an asset can, therefore, be expressed as shown in Equation 6.6.

$$\beta_j = \frac{Covariance(R_j, R_m)}{Variance\ (R_m)} \tag{6.6}$$

The ordinary least squares (OLS) method can also be used to estimate the value of beta. The returns of a specific company are usually regressed on the returns of a composite market index in order to find the value of beta. For stocks, the estimated value of beta compares the performance of a publicly listed company to the overall performance of stocks traded in a market. The estimated beta can be interpreted in three ways. First, if the estimated beta value is less than one, a firm is said to be less risky compared to the market. Second, a beta measure of one indicates that a firm is as risk as the market. Third, when beta is greater than one, this indicates that a firm is more risky than the overall market (Brealey et al., 2011).

One way to measure, the level of stress in the banking sector would be to estimate betas of the publicly listed banks in Australia. The estimated betas can then be included in a portfolio in order to calculate the beta of the banking industry. In the case of Australia, the S&P/ASX 200 banks accumulation index can be viewed as a portfolio of Australian banks. This index is a subindex of the S&P/ASX 200, which is a weighted index of 200 companies that are traded on the ASX. The weights of the index are based on the prevailing market capitalisation of the traded company. This study estimates beta using the returns[38] of the S&P/ASX 200 and S&P/ASX 200 banks index.[39] Consequently, the S&P/ASX 200 banks will be considered as the asset j and the estimated beta will be measuring risk of the banking sector relative to the risk in the market. Therefore, when the level of beta exceeds one, this is indicative of a banking sector that is distress. Since the beta values that are greater than one are of greater interest than the values which are less or equal to one, most scholars modify the beta measure

[38] Returns are calculated based on the value of the index in a particular month compared to the value of the index in the same month a year ago. The end-of-day data was sourced from SIRCA and used to estimate monthly average values for the S&P/ASX200 and S&P/ASX 200 banks indexes (SIRCA, 2015).

[39] There are two main accumulation market indexes for the Australian market, namely the S&P/ASX200 and the All Ordinaries index. While a subindex for the banking sector is reported for S&P/ASX200, there is no subindex for the All Ordinaries index. This study focuses on the S&P/ASX200.

to reflect the values that indicate distress. The refined measure of beta reflects the values of beta that are greater than one only and sets the values that are less than or equal to one to zero. A dummy variable can be used to transform the estimated beta to the refined beta. As shown in Equation 6.7a the dummy variable takes the value of 1 if the estimated beta is greater than one and zero otherwise. The formula for estimating the refined beta is the calculated as shown in Equation 6.7b.

$$D_i = \begin{cases} 0 \; if \; \beta_j \leq 1 \\ 1 \; if \; \beta_j > 1 \end{cases} \tag{6.7a}$$

$$Refined\ beta = D_i \beta_j \tag{6.7b}$$

Generally, financial analysts and scholars use a longer period to estimate the value of beta. In the case of monthly data, a banking beta is usually estimated using four to five years of data, which is the equivalent of a 48 or 60-month window.

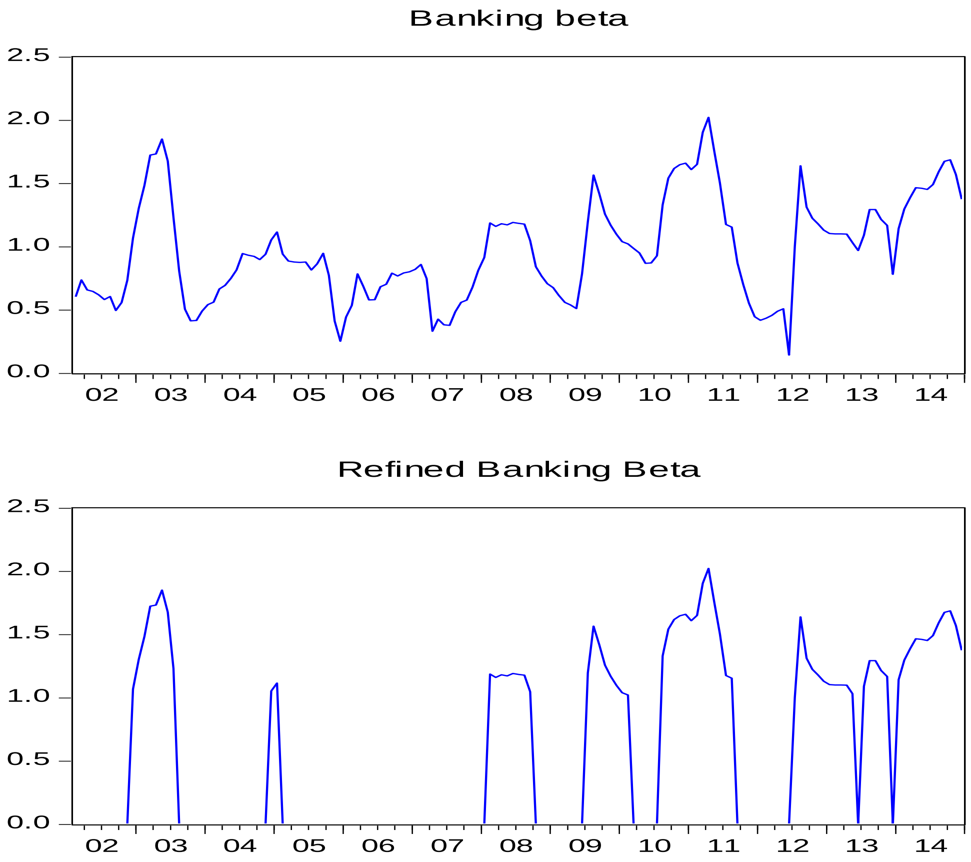


Figure 6.8: 12-month beta and refined beta for Australian banking sector

While, it is common practice to use longer time horizons to estimate beta, Peterson and Fabozzi (1999) argue that a valid estimate of beta can be obtained using at least 12 months. Several studies have successfully used a 12-month window to gauge the level of stress in the banking sector (Apostolakis & Papadopoulos, 2014; Balakrishnan et al., 2011; Illing & Liu, 2006). Consequently, this study chose to estimate a banking beta using a 12-month window. Figure 6.8 shows the estimated banking beta and refined banking beta for Australia. The final index shall incorporate the refined beta.

6.7.2 *Inverted Yield Spread*

The inverted yield spread is also referred to as the inverted term spread or the slope of the yield curve and is estimated by taking the difference between a long-term security and a short-term security. Illing and Liu (2006) argue that the inverted yield spread can be used to measure interest rate shocks. Several studies suggest that it can provide early indications of problems in a country's banking sector (Apostolakis & Papadopoulos, 2014; Cardarelli et al., 2011; Melvin & Taylor, 2009; Vermeulen et al., 2015). Estrella and Hardouvelis (1991) argue that the inverted term spread can help predict the recessions that often precede financial crises. However, Tsuji (2005) found that the spread had no predictive power in the case of Japan. Alles (1995) explored the usefulness of this variable in the case of Australia and found it had predictive power for economic recessions. For this reason, this study deems the inverted yield spread as a relevant predictor of crises for Australia.

Theoretically, the yield curve slopes upwards because short-term securities earn less interest than long-term securities. Lenders expect to receive higher yields when they forego the use of funds for a longer period. This can be shown by examining the yields of Australian issued government securities of different maturities. Table 6.10 shows the yields on commonwealth government and treasury corporation bonds for the month of November 2014 as reported by the RBA in sheet F 2.1 (Reserve Bank of Australia, 2017).The yields on the bonds increases as the time to maturity increases, for example a 2 year government bond has a lower yield than a 3 year government bond. The yield curve of government bonds in November would be upward sloping as shown in Figure 6.9.

Table 6.10: Yields for Australian Bonds of different maturities (November 2014)

	Yields on bonds (in percentage)	
Maturity	**Government bond**	**Treasury Corporation bond**
2	2.51	
3	2.55	2.77
5	2.77	3.08
10	3.26	3.67

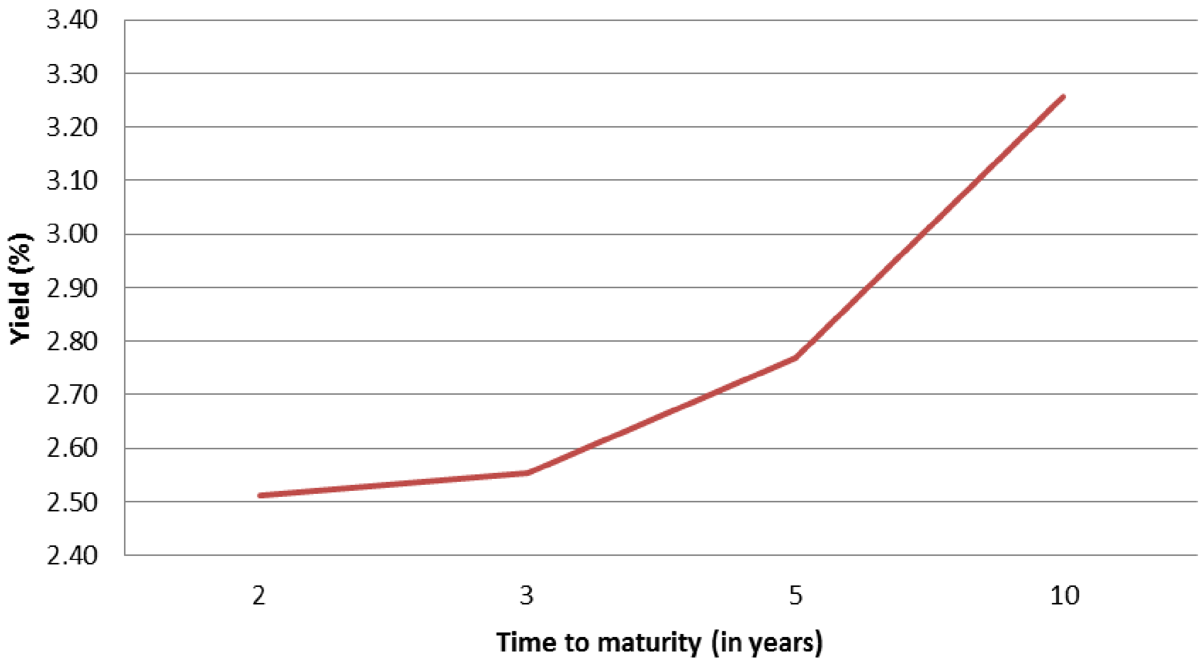


Figure 6.9: Yield Curve for Australian Government bonds (November 2014)
Source: Reserve Bank of Australia (2017)

Banks take advantage of the difference in rates of securities of different maturities in order to make profit. Banks use deposits to finance loans to other customers and profit from the interest charged on loans. However, if the yield curve becomes inverted (a downward sloping yield curve) it could result in the bank receiving lower rates on long-term loans and diminished profitability on loans (Cardarelli et al.). In this case, an inverted yield curve may signal distress in the banking sector.

This study estimates the inverted yield spread for Australia using the interest rates on a 10-year government bond and a 3-month treasury bill to represent a long-term security and a short-term security respectively. The inverted spread was estimated by deducting the interest rate of the long-term security from the interest rate of the shorter-term security. The logic being long-term rates are the equilibrium rate and stress is experienced when the short-term rate surpasses the long-term ones. Figure 6.10 shows the inverted yield spread from January 1970 to December 2014. This variable indicates episodes of distress in the banking sector in the May 1974, April 1982, December 1985 and August 1989. The last episode of distress corresponds to the 1989-1992 Australian Banking Crisis.

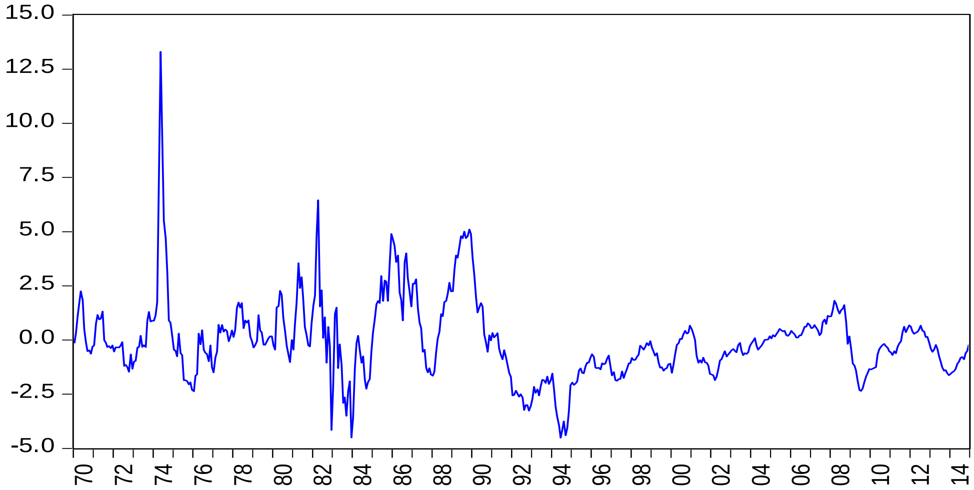


Figure 6.10: Inverted Yield Spread for Australia (January 1970 to December 2014)
Source: Authors calculations based on Reserve Bank of Australia (2017) data

6.7.3 *Domestic Credit to GDP*

The domestic credit to GDP ratio is estimated by dividing the domestic credit by the real GDP. Different researchers tailor the definition of domestic credit to suit the aims and objectives of their research. Here are three examples of different interpretations of the term domestic credit: i) Domestic credit is the total credit including credit to households, businesses, banks and non-financial institutions; ii) Domestic credit consists of the private credit provided to households and businesses; and iii) domestic credit is the total credit to banks and non-financial institutions. Since this study seeks to estimate the domestic credit to

GDP ratio as an early warning indicator of problems in the Australian banking sector, the third interpretation of domestic credit is deemed suitable. Consequently, the domestic credit to GDP ratio is estimated using the total credit extended to banks and non-bank financial institutions and real GDP. Data was obtained from the RBA website.[40] While the domestic credit is provided at a monthly interval, the real GDP is only available at the quarterly frequency. The quarterly GDP is converted to monthly frequency via interpolation such that the monthly GDP trend coincides with the quarterly GDP trend. Figure 6.11 shows a graphical representation the estimated monthly GDP as compared to the quarterly GDP.

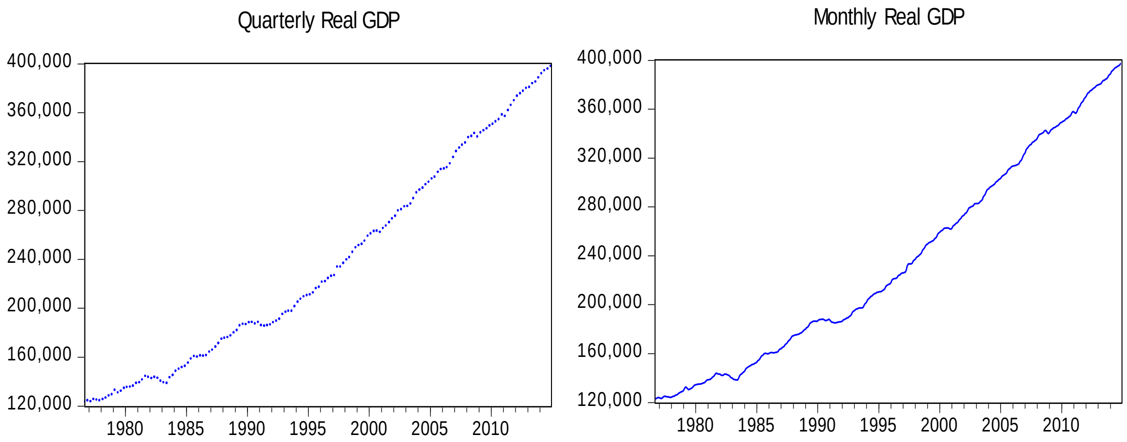


Figure 6.11: Monthly and Quarterly GDP (September 1976 to December 2014)
Source: Reserve Bank of Australia (2017) and authors calculations

The monthly GDP is used to estimate the credit to GDP ratio, which is computed by dividing the monthly credit by the monthly estimate for real GDP. A graphical representation of the estimated credit to GDP ratio is provided in Figure 6.12. The estimated ratio is trending upwards and does not seem to provide any useful information for predicting crises. Perhaps a refined measure of the credit to GDP ratio would have more predictive power. Section 6.7.3.1 this study explores the use of the credit to GDP gap which is a modified measure of the credit to GDP ratio as proposed by Borio and Lowe (2002).

[40] Historical data for real GDP was obtained from the H1 spreadsheet while credit to banks and non-banking financial institutions was obtained from the D2 spreadsheet on the RBA website.

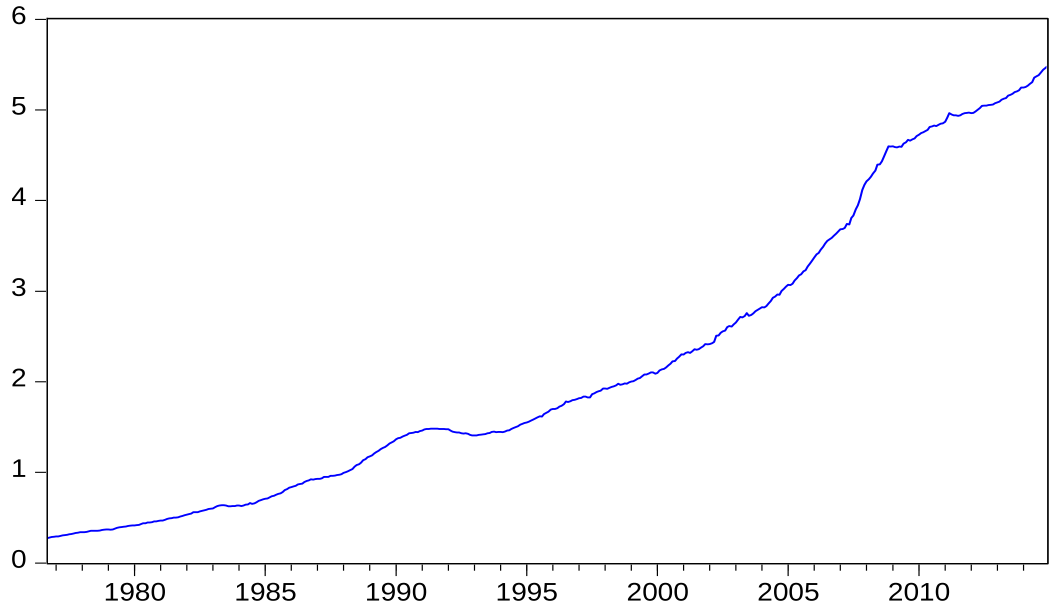


Figure 6.12: Credit to GDP ratio (September 1976 to December 2014)
Source: Authors calculations based on Reserve Bank of Australia (2017) data

6.7.3.1 Credit to GDP gap

Borio and Lowe (2002) argue that the credit to GDP gap is useful in identifying the credit booms that precede financial crises. Moreover, a large gap is indicative of rapid rises in credit levels and increased likelihood of financial crisis in the near future. Drehmann and Tsatsaronis (2014) arrived at a similar conclusion and argues that this variable is a robust measure for increased vulnerabilities in developed and developing countries. The credit to GDP gap is estimated using the credit to GDP ratio and the trend of the credit to GDP ratio. The trend component of the ratio is deducted from the credit to GDP ratio in order to obtain the gap. The trend of the credit to GDP ratio is estimated using the one-sided Hodrick Prescott filter add-in of Eviews. Drehmann and Tsatsaronis (2014) recommend that this variable be estimated using a minimum of at least 10 years of data. Therefore, this study uses data for approximately 38 years (for months from September 1976 to December 2014); this satisfies the ten-year requirement. Figure 6.13 shows the estimated credit to GDP gap for Australia. The highest peak in the variable is recorded in December of 2007 which corresponds to the timing of the 2007-2009 GFC.

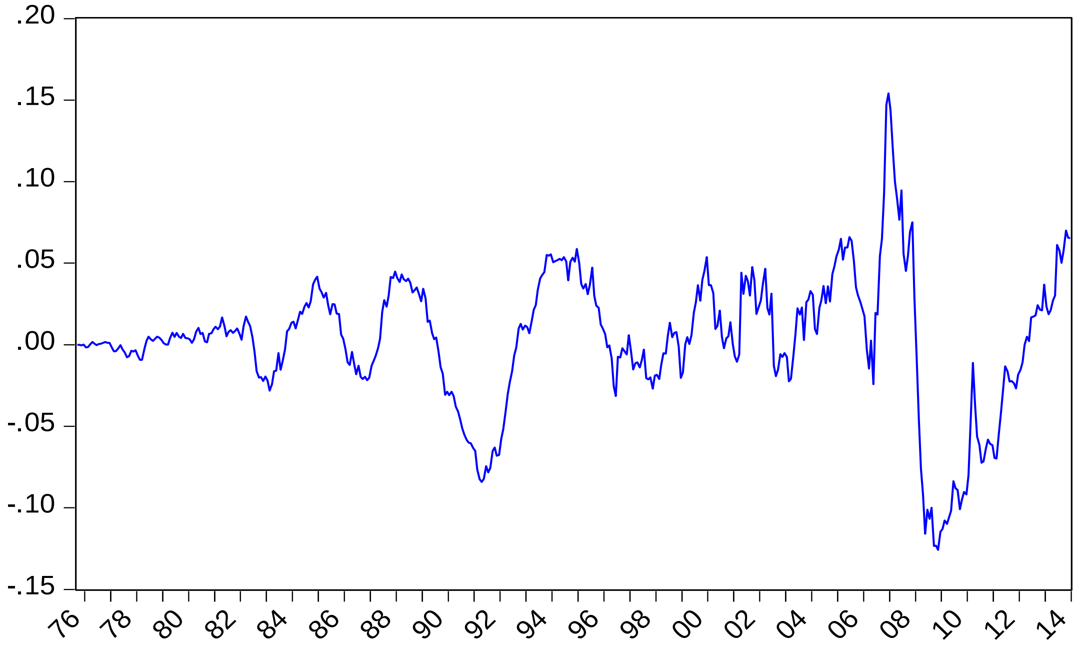


Figure 6.13: Credit to GDP for Australia (September 1976 to December 2014)
Source: Authors calculations based on Reserve Bank of Australia (2017) data

6.8 Twin Crises

A currency crisis may be more severe if it is accompanied by a banking crisis, a phenomenon that is commonly referred to as "twin crises". In a detailed study of the twin crisis phenomenon, Kaminsky and Reinhart (1999) examined 26, 76 and 19 incidents of banking, currency and twin crises respectively. There are four noteworthy findings of this study. First, a bidirectional relationship exists between the two types of crises especially after the liberalization of financial markets. On one hand, the authors argued that currency devaluation could trigger a banking crisis or worsen a developing banking crisis. On the other hand, weaknesses in the banking industry could trigger a bank run that makes a country more susceptible to a currency crisis. Hence, the incidence of a banking crisis could help predict a future currency crisis and vice versa. Second, either crisis was less severe in isolation in comparison to a twin crisis. This is because in a twin crisis there is a feedback pathway whereby one crisis exacerbates the other crisis. Ideally, it would be preferable if a country experienced no crisis. However, if a country suffered a financial crisis either a currency or banking crisis would be much ‘kinder’ than twin crisis. Third, weakened or deteriorating economic fundamentals predisposed a country to either or both crises such that it is only a matter of when a crisis will occur and not if a crisis will occur. Fourth, both types of crises were often preceded by a recession. However, Kaminsky and Reinhart (1999) noted that the severity of the recession could vary. Bordo et al. (2001) found that recessions accompanied by financial crises were much worse and lasted longer than recessions in out-of-crisis periods.

With regard to empirical measurement of twin crises, this study explored the notion of variables that signal twin crises. However, a review of literature found that no studies seem to have developed a measure for the twin crises. Instead, most studies focus on examining the incidence of either the banking or currency crisis. Moreover, the occurrence of either crisis is often regarded as an early indicator of a potential twin crisis in the near future. This is one limitation of this study and a possible avenue for future research.

6.9 Conclusion

This chapter proposed measures of currency market stress based on increased volatility in exchange markets, the prevailing exchange rate and the level of foreign reserves. Volatility in Australian currency markets was assessed using GARCH volatility models and data for approximately three decades (from 1983 to 2014). Distress in the currency markets was also gauged using an exchange market pressure index and data over the same time frame. Three variables were used to measure distress in the banking sector; the refined banking beta, inverted yield spread and domestic credit to GDP. The inverted yield spread and the ratio of credit to GDP were estimated from 1970 to 2014 and 1976 to 2014, respectively, to provide ample data in order to evaluate the performance of the variable during past episodes of distress. However, in the case of the credit to GDP variable it should be noted that the real GDP is reported at the quarterly level and an interpolation method was used to derive the monthly values from the quarterly data. This study imposes a linear trend on the interpolated values. However, it is possible that the estimated level of the trend is incorrect and that the interpolated or estimated value of GDP may differ from the actual value of GDP; the prevailing value may be above or below the estimated value of GDP. It is not possible to know the degree of the estimation error without access to monthly estimates for GDP, which are not publicly available. This is one limitation of the interpolation method that was used. It is worth noting that this limitation is only applicable to the estimated levels of stress for interpolated months. Future studies could make use of variables that have monthly data available in order to reduce the estimation error. Moreover, due to restrictions on data available from SIRCA, this study could only estimate the refined banking beta from 2002 to 2014. Due to this data limitation, it is only possible for the performance of this variable over the 2007-09 GFC. Future research could possibly address this shortcoming by identifying alternative proxies for the banking beta measure which have a larger range of data.

CHAPTER 7

SUPPLEMENTARY AUSTRALIAN-BASED INDICATORS OF FINANCIAL STRESS

7.1 Introduction

The purpose of this chapter is to highlight and discuss other Australian-based indicators of stress that were not identified in Chapters 4, 5, or 6, but are still relevant measures of distress in the Australian financial markets. Section 7.2 of this chapter is dedicated to exploring the feasibility of using LIBOR spreads as measures of financial stress in Australia. The sub-sections of Section 7.2 are organised as follows. Subsection 7.2.1 provides a definition of the LIBOR which is a commonly used interest rate in the global banking sector. Factors that determine the interest rate charged by banks are also discussed in this subsection. The use the LIBOR and LIBOR spread as indicators of financial stress is explored in Subsections 7.2.2 and 7.2.3 respectively. Subsection 7.2.4 deliberates on whether the LIBOR is relevant in the Australian financial markets. Subsection 7.2.4 and 7.2.5 discusses whether the LIBOR and LIBOR spreads are suitable measures of financial stress in Australian markets. In Subsection 7.2.5, this study explains why the LIBOR was found to be an unsuitable measure of banking risk in Australia. Accordingly, the subsection that follows (Subsection 7.2.6) contains a discussion of alternatives to the LIBOR and LIBOR spreads. In Sections 7.3 and 7.4 this study presents the case for the use of an inverted CMAX property index the inverted CMAX metals and mining index as barometer of stress in the Australian property market and mining sector respectively. The variables developed in Subsection 7.26 and Sections 7.3 and 7.4 are subsequently used in the construction of composite stress indexes in Chapter 9.

7.2 LIBOR Spreads

7.2.1 What is the LIBOR?

LIBOR is an acronym that stands for the London Interbank Offered Rate (LIBOR). The LIBOR was originally formulated by the British Bankers Association (BBA) in 1986. Following its introduction, the LIBOR was widely used to determine the rates on swaps, forward contracts, futures contracts, bonds, syndicated loans, and interbank loans (Abrantes-Metz, Kraten, Metz, & Seow, 2012; Bryan & Rafferty, 2016 ; Fouquau & Spieser, 2015). When the LIBOR is used in cross-border transactions it reflects a country's willingness to lend money to another country. Moreover, it reflects the rate at which local banks are willing to lend money to foreign banks. Abrantes-Metz et al. (2012) state that the BBA used information from eight out of a panel of 16 banks to estimate daily quotes of the LIBOR for 10 currencies[41] in the following manner. Sixteen banks were polled regarding the cost of funding in order to determine the interest rate each bank would be willing to charge for interbank transactions. The rates of the sampled banks are ranked in order before selecting the rates of the middle eight banks. The mean of the rates quoted by the middle eight banks is calculated and reported as the LIBOR (Abrantes-Metz et al., 2012). This procedure for estimating the LIBOR is based on the notion that the local banks are trustworthy and will provide honest quotes. In practice two scenarios can occur when estimating the LIBOR in this manner. In the first scenario, all the banks surveyed for the estimating the LIBOR are actually trustworthy and the integrity of the LIBOR as a reference rate for global transactions is upheld. In the second scenario, some of the banks surveyed could provide false quotes which are used to estimate the LIBOR. In this case the estimated LIBOR would be mis-specified and the legitimacy of the LIBOR can be called into question. Fouquau and Spieser

[41] These currencies were the Danish krone, Swiss Franc, European euro, Swedish krona, Japanese yen, US dollar, British pound, Australian dollar, Canadian dollar, and New Zealand dollar.

(2015) suggest that one reason that banks may provide false quotes is to give other banks the false impression that they were safe to lend money to even if they were not.

Recent investigations of banks suggest that the second scenario may have prevailed in financial markets since 1991 and it was only in 2012 that it became apparent that major banks like Citigroup, HSBC, JPMorgan, Barclays, and Chase were fixing rates in order to earn profits on transactions in financial markets (Fouquau & Spieser, 2015). Following these revelations, regulators, and market players began to call for a review of the LIBOR. This was the main motivation for the Wheatley report which offered several recommendations to the manner in which the LIBOR was estimated and reported (Wheatley, 2012). There are three notable recommendations from the Wheatley report. Firstly, the report recommended that surveyed banks should be able to provide data of regular interbank transactions in order to demonstrate that the estimated LIBOR is a reliable benchmark for interbank transactions. This report found that 50 percent of the reported LIBORs satisfied this requirement. On one hand it was found that there was sufficient transactional data to justify the estimation of the LIBORs for the US dollar, British pound, Japanese yen, European euro and the Swiss franc. On the other hand there was insufficient data to support the estimation of the LIBORs for the Canadian dollar, New Zealand dollar, Australian dollar, Danish kroner, and Swedish krona. It can, therefore, be concluded that it was not ideal to continue to estimate the ten LIBORs as LIBORs for five currencies failed to provide a suitable reference rate for interbank transactions. Accordingly, the second recommendation was that the LIBORs of the five currencies with insufficient transaction data be discontinued. A third notable recommendation was that a new administrator for the LIBOR be appointed. In response to these recommendations, a new administrator, The Intercontinental Exchange (ICE) Benchmark Administration, now determines the LIBOR based on information collected from a panel of banks eleven to seventeen in a particular country. The new administrator reports LIBORS for the five currencies that have sufficient interbank transactional data; these are the US dollar, the Japanese yen, the British pound, the European euro, and the Swiss Franc. According to the Intercontinental Exchange (ICE) website the quoted LIBOR rate is estimated by ordering the submitted rates in descending order before using the rates for the middle 50 percent of the data values to obtain the average interest rate of the rates charged by different banks in a given country (Intercontinental Exchange, 2017a, 2017b). It is necessary to estimate an average rate since it is unlikely that several local banks would have the same risk preferences and charge the same rate of interest on funds loaned to foreign banks. For instance, consider the leading local banks in Australia.[42] The local banks would demand different levels of return on money loaned to foreign banks depending on the perceived level of risk. It is common for banks to perform a risk assessment in order to identify the different kinds of risk associated with a loan and estimate the probability of loss of the money loaned. The level of risk and desired return on the loaned funds determine the rate of interest charged on the loaned funds. The sections that follow highlight some of the factors that may influence the LIBOR (the short-term interest rate charged by a bank when extending credit to another bank; Sections 7.2.1.1 to 7.2.1.4).

7.2.1.1 The risk preference of the bank

Some banks are more willing to accept comparatively higher levels of risk in exchange for higher return while other banks may be more conservative (i.e. risk averse). Blenman (2010) states that the specific details of a bank's risk preference are confidential; only the bank's employees have access to this information. This author argues that the following factors influence the risk preference of bank managers: i) Capital available for investment; ii) Extent of control available to bank management; iii) Prevailing concerns about the bank's reputation; and iv) Executive compensation schemes.

[42] The top four banks in Australia are Westpac, Commonwealth Bank, Australia and New Zealand Banking Group, and National Australia Bank.

(i) Capital Availability

Sengupta and Hogue (2014) assert that regulators impose minimum capital requirements on banks in order to ensure that the banks can bear unexpected losses and continue as a going concern. The recent incidence of financial crises has renewed regulators concern about the banking sectors ability to withstand economic shocks and not succumb to a crisis. In Australia, the minimum capital requirements are determined by APRA. For example, Letts (2015) states that APRA (in July 2015) reviewed the minimum capital requirements for the four main Australian banks upwards by 30 billion dollars in order to bolster the banks for future financial stress or crises. More recently, APRA has further increased minimum capital requirements for Australian banks to 1.5 percent points in the case of the four major banks and 0.5 percent points in the case of smaller banks. All banks were given until 31 December 2019 to satisfy the new capital requirements (APRA, 2017; Janda, 2017). Once a bank satisfies the minimum capital requirements specified by APRA, it is expected that banks with access to more capital are more likely to be risk takers as opposed to banks with less capital.

(ii) Management Control

Blenman (2010) argues that in public listed companies shareholders are more likely to dictate the risk preference of managers; in this case the shareholders control the decisions relating to risk. Conversely, in private companies management are more likely to influence the risk decisions. It is possible for managers in public companies to have more control if the shareholders vote for the manager to determine the preferable level or risk. Shareholder controlled[43] banks tend to be more inclined to taking risk while management controlled banks tend to be more risk averse (Faccio et al., 2011; García-Kuhnert et al., 2015). Managers of banks with higher reputation would require higher compensation and would be more risk averse. Banks that design executive compensation schemes, which reward risk-taking

[43] This is true of shareholders with a diversified portfolio, as opposed to shareholders with a non-diversified portfolio as shown by Faccio, Marchica, and Mura (2011) and García-Kuhnert, Marchica, and Mura (2015).

behaviour via bonuses, are more likely to nurture managers that are more inclined to taking risk. Up to this point, most arguments presented favour the tendency to either risk taking or risk averseness among bankers. However, Benston (2010) presents a convincing argument that it is possible for banks to be risk neutral especially if a bank manager has diversified into a portfolio of assets or securities. The same idea could be extended to a portfolio of loans, such that a bank manager could incorporate different loans with different levels of risk in order to diversify the overall risk borne by the bank. In summary, it should be noted that the list of factors is that determine risk preference is not exhaustive; indeed prevailing economic conditions may cause bank managers to change previous risk preference in order to ensure that the bank survives an episode of economic distress.

(iii) Bank's Reputation

A bank's reputation can determine the rate of interest that a lending bank is willing to charge the borrowing bank for interbank transactions. Specifically, banks that have a track record for honouring their financial obligation as and/or when they fall due have a good reputation while banks that frequently fail to meet their financial obligations when they fall due are regarded as having a bad reputation and in some cases could even be blacklisted. The lending bank would prefer to lend money to a borrowing bank with the borrowing bank with good reputation and would be reluctant to offer funds to a borrowing bank with a bad reputation. This is because the bank with a good reputation is more likely to honour loan repayments when they fall due than the bank with bad reputation. Sadly financial crises can cause a quick shift in the perceived reputation of a bank. In particular, lending banks may be reluctant to lend to a borrowing bank with good reputation if it is located in a country that is affected by the crisis. This is true about local and foreign lending banks. For instance, Kidwell, Blackwell, Whidbee, and Sias (2016) found that soon following the collapse of the Lehman Brothers investment bank, American banks were more reluctant to offer loans to other

American banks. During the 2007-2009 GFC many American banks became exposed to losses from subprime mortgage loans. Because of this it is likely that American banks were more reluctant to extend credit during the crisis period for fear of exposing themselves to increased risk of default and future bad debts if they opted to provide loans to other American banks (Gertler & Kiyotaki, 2015). The general perception in financial markets was that American banks which otherwise had a good reputation in the pre-crisis period could potentially be in possessing of "toxic assets" in the form of subprime mortgage loans. Consequently, it can be concluded that during and following the GFC there was a shift in the perceived reputation of American banks which otherwise had a good reputation, with the general assumption being that American banks were more likely to default and could, therefore, be regarded as being banks with a bad reputation. Because of this, the cost of funding to American banks was higher during the GFC that it would be in tranquil periods (Gertler & Kiyotaki, 2015). It should also be noted that relationships between banks may factor into the assessment of a banks reputation. If a bank has a proven track record of honouring their financial obligations, a bank manager may be willing to overlook the general perception of increased risk of default during a crisis period. In this case the relationship between the bank managers has factored into the overall assessment of the borrowing banks reputation.

(iv) Executive Compensation Schemes

The means by which executives are remunerated can indirectly influence the risk taking behaviour of executives in the banking sector. According to Guo, Jalal, and Khaksari (2015) bank managers that were paid more were more motivated and were less likely to mismanage the banks resources for; this was found to be true regardless of the presence of absence of a financial crisis. If a bank manager's compensation is linked to his/her performance, it is possible that lending decisions that reflect improved performance are preferred to lending decisions that could give the impression of poor managerial performance. In this case, the interbank lending will only be offered to other banks if it is likely that the banks will honour the repayments of the loan thereby resulting in a reflection of good performance on the bank manager of the lending bank. In most cases, this would involve only lending to banks with good reputation and credit rating. Usually banks encourage managers to acquire more stock in a bank so as to motivate the bank managers to maximise shareholder wealth. However, in a study of sixty eight banks and seventy CEOs, Chen, Steiner, and Whyte (2006) found that there was growing popularity of the use of stock options in the American banking sector and that as managers acquired stock through stock options were more likely to be risk takers when making managerial decisions. Moreover, there is no proof that share options contribute to increased shareholder wealth. This risk preference is likely to affect the bank manager's decision to lend funds to certain banks. It could also influence the lending rate that the manager is willing to set for the interbank loan.

7.2.1.2 Duration of the loan

Ceteris paribus, banks tend to require higher rates of return on longer-term loans as compared to shorter-term loans. Higher interest rates compensate the bank for foregoing the use of funds over a longer period and the potential risk that the borrower may not be able to repay the loan in future. This is consistent with the financial theory of the term structure of interest rates, which explains the relationship between interest on short and long-term loans. McEachern (2012, p. 204) argues that based on this theory, "the interest rate usually increases with the duration of the loan other things constant".

7.2.1.3 Exchange rate risk

Australian banks may loan funds to a foreign banks in the local currency as well as in currencies other than the Australian dollar, depending on the foreign banks financing needs.

Loans denominated in foreign currency expose Australian banks to exchange rate risk, since it is not known whether the foreign currency will appreciate or depreciate (Ross, Westerfield, & Jaffe, 1996). If the Australian dollar appreciates relative to the value of a foreign currency, Australian banks will make a loss on the loan repayments received in the foreign currency. This is because once the foreign currency is converted to Australian dollars the banks will receive less money than they would have had the Australian dollar not depreciated. For example, consider a nominal loan of 1000 US dollars from an Australian bank to an American bank in the United States (US). At the time of the loan agreement, each Australian dollar (AUD) was worth 70 US cents and the Australian dollar appreciates to a value of 78 US cents for every AUD at the time of repayment. At the time of the loan agreement, the repayment of the principal would be worth approximately AUD 1,428.57 (1000/0.7) and after the AUD appreciated the Australian bank would expect a repayment of the principal amount of approximately AUD 1,282.05 (1000/0.78). In the end, the bank would have made a loss due to the exchange of currency back to Australian dollars. Brealey et al. (2011) argue that it is possible for Australian banks to hedge against this kind of risk by entering into currency forward or currency futures contracts with the American bank.

7.2.1.4 Default risk

Default risk is the risk that a bank that has borrowed funds will be unable to pay back the full amount of the principal plus the interest as and when they fall due (Rose, 2000). Some countries may pose higher risk of default than others, due to a waning economic environment or a poor economic outlook of that country. Banks with significant operations in countries experiencing financial stress or a crisis may be viewed as having a higher risk of default. Depending on the extent of financial distress suffered by the country, banks may refuse to offer any credit to the banks based in the ‘afflicted’ country especially if financial institutions in that country have been negatively affected by the crisis. Australian banks would be more reluctant to lend to countries affected by a crisis for fear that interbank lending would expose the banks to cross-border contagion. Alternatively, a local bank may decide to lend money to a foreign bank if the bank demonstrates that it will be able to make the repayments at the agreed upon times. It should be noted however, that the banks may choose to charge a higher than usual rate of interest on the funds loaned.

Banks may also use a foreign bank's credit rating to assess the probability of it defaulting.[44] Banks with higher ratings[45] (As) are regarded as having the lowest risk of default, while banks with lower ratings (Cs or Ds) are believed to have higher default risks. Consequently, local banks would be more reluctant to lend money to foreign banks with lower credit ratings and vice versa. Also, local banks will charge higher interest rates on loans to foreign banks with lower rating while lower interest will be charged on loans to those with higher ratings.

It is important to note that the four risks discussed above are not the only risks that a bank may consider when determining the rate of interest to charge on interbank loans. Other risks may arise due to political or economic factors that are unique to the foreign country in which the borrowing bank is situated. This means that an interbank lending rate could also reflect a bank manager's judgement of several risks and the perceived creditworthiness of a foreign bank. During times of financial crises, the LIBOR can be viewed as barometer for the perceived risk of default by banks located in the country that is, or countries that are, in the epicentre of a financial crisis. Moreover it can be seen as an indicator of the prevailing sentiment among lending banks at different stages of a crisis; these stages are the pre-crisis, crisis and post-crisis stages. During financial crisis, lending banks may be more reluctant to extend credit to banks that are based in the affected country and would demand a higher interest rate to compensate for the increased risk in terms of default, liquidity and exchange

[44] A detailed discussion of the credit ratings is provided in section 6.2 for chapter 6.
[45] The major rating agencies for Australian banks are Moody's and Standard and Poor's.

rate risk; this list is not exhaustive. The affected country will report rising levels of the LIBOR during crisis periods as compared to ‘tranquil’ or out-of-crisis periods. The market sentiment shall gradually change as a country transitions out of a crisis. As the affected country begins to recover from the financial losses caused by the crisis, lending banks will begin to charge lower levels of the LIBOR from banks in the affected countries. In this manner, the LIBOR will reflect current and changing perceptions of the risk associated with loans to a foreign country.

7.2.2 The LIBOR as an indicator of financial stress

The LIBOR’s ability to reflect changing perceptions of risk is particularly useful when monitoring the health of an economy. A rising LIBOR may indicate concerns of the financial sector in an economy or the country’s overall economic well-being probably due to speculation and/or the observed weakening of macroeconomic fundamentals. Therefore, an examination of the trending patterns of the LIBOR can help to identify whether the country is perceived to be suffering stress or a crisis. In order to illustrate this, historical data for the monthly quotes of the 3-month LIBOR were obtained for five major currencies. These include the Yen, dollar, Pound sterling, Franc, and the Euro for Japan, the US, the UK, Switzerland, and the European Union. Data was obtained from the Federal Reserve Bank of St. Louis database. The starting point of each series is based on data availability; the earliest starting date is January 1986. A graphical representation of the trending behaviour of interest rates from January 1986 to December 2014 is shown in Figure 7.1.

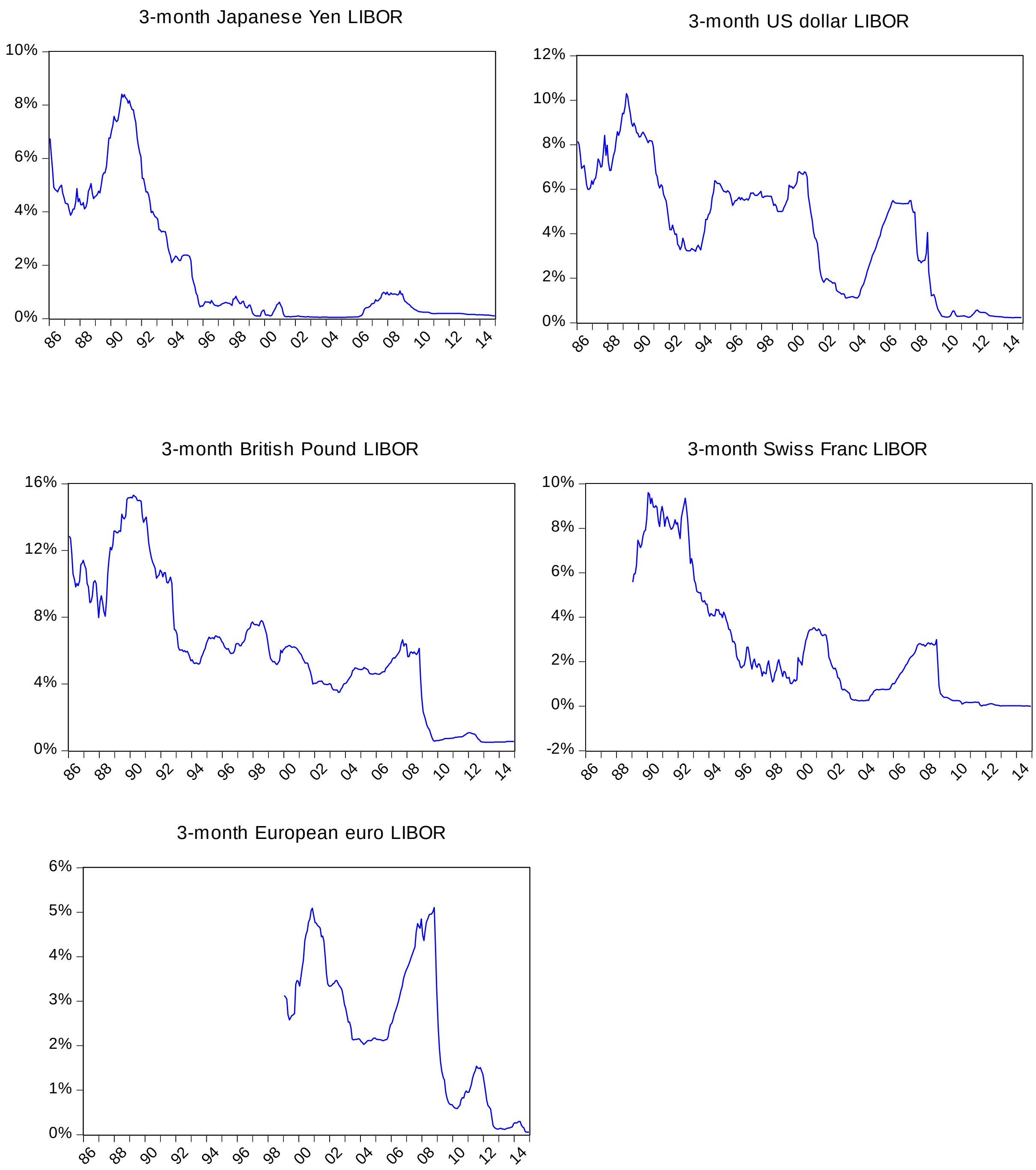


Figure 7.1: 3-Month LIBOR of major currencies (Jan 1986 to Dec 2014)

Data Source: Federal Reserve Bank of St. Louis (2015)

There are two noticeable peaks in the European Union LIBOR, in November 2000 and October 2008. The last spike in the LIBOR coincides with the timing of the 2007 GFC. Although there is a spike in the UK LIBOR in February 1990 there does not seem to be a record of any crisis in the UK at the same time. Similarly, the high values of the Swiss

LIBOR from January 1990 to May 1992 are not indicative of a corresponding crisis at around that time. High values of the US LIBOR were recorded on October 1987, March 1989, May 2000, and September 2007 which correspond to the timing of the 1987 Black Monday, 1980-1989 Savings and Loan Crisis, 2000-2002 Dot-com Crisis, and the 2007-2009 Subprime Mortgage Crises respectively. In the case of Japan, rising levels of the Japanese LIBOR until it peaks in November 1990 correspond to 1990s Japanese banking crisis. Kindleberger and Aliber (2005) state that following the collapse of the Japanese stock and property market, Japanese banks caused large financial losses that rendered banks insolvent and at the mercy of the Japanese government as a lender of the last resort. Furthermore, delayed intervention by the government to mitigate the crisis may have nurtured increased angst among foreign banks evaluating creditworthiness of Japanese banks.

An examination of the LIBORs of the five countries in Figure 7.1 suggests that the LIBOR provide useful information for predicting the incidence and timing of financial crises. In practice however, a LIBOR spread (instead of the LIBOR) is used to assess the credit-worthiness of banks borrowing funds. Two LIBOR spreads are commonly used to gauge the risk of default; these are the use of the LIBOR- OIS (Overnight Indexed Swap) spread and the TED (a LIBOR to treasury bill) spread especially after the 2007 to 2009 Global Financial Crisis (GFC). Section 7.2.3 explores the performance of the two LIBOR spreads in the five countries.

7.2.3 LIBOR-OIS and TED spreads

The LIBOR-OIS spread is a calculated by taking the difference between the LIBOR and the OIS rate[46] of the same maturity. The former United States (US) Federal Reserve chairman Alan Greenspan states that the “LIBOR-OIS remains a barometer of fears of bank

[46] The FED reports the Overnight Index Swap (OIS) rate as the Effective Federal Funds Rate.

insolvency" such that rising levels of uncertainty in the financial market are mirrored by rising levels of the LIBOR-OIS spread (Thornton, 2009). Based on this definition it would seem that the LIBOR-OIS spread is a measure of the prevailing interbank lending sentiments. However, it should be noted that large increases in the LIBOR-OIS spreads were reported after the GFC had begun to unfold. Seemingly, not all LIBOR-spreads are sufficient measures for risk of default. Upon examining LIBOR-OIS spreads of different maturities (1, 3, and 6 month), Thornton (2009) suggests that the 3 and 6 month spreads provide better estimates of prevailing 'market perceptions' about the health of the banking sector than the 1-month spread. Gefang, Koop, and Potter (2011) hold a somewhat opposing view that unique information can be obtained from LIBOR spreads of different maturities. The one and three month LIBOR-OIS spreads were found to be good indicators of rising liquidity risk while the 12-month LIBOR-OIS could help to gauge credit and liquidity risk. An interesting finding of a study by Hammoudeh, Chen, and Yuan (2011) was that the TED spread played the same role as the 12-month LIBOR-OIS spread; sufficiently gauging liquidity and credit risk even in times when information asymmetry seems to have increased in financial markets. Because the TED and 12-month LIBOR-OIS are considered similar indicators of distress, this study focuses on the estimation of the 3-month LIBOR-OIS spreads and the 3-month TED spread. Further, instead of using the daily frequency that is used in some studies (Hammoudeh et al., 2011; Olson, Miller, & Wohar, 2012), this study uses monthly spreads; this is because the ultimate aim of this study is to develop a financial stress index of monthly frequency.

The TED spread was originally defined as the difference between the Eurodollar interest rate (ED) and the Treasury bills interest rate (T) of a country. However, recent studies define the TED spread as the difference between the London Interbank Offered Rate (LIBOR) and the rate on treasury bills (Hammoudeh, Chen & Yuan, 2011; Lee, Shrestha & Welch, 2007). The latter definition is more common in recent studies and is employed in this study. Hammoudeh et al. (2011) states that rising TED spreads are an indication that banks are unwilling to lend to each other for fear of default loss. Moreover, the same authors hold that the TED spread performs better as a warning indicator as compared to the LIBOR-OIS spread. The reason for this argument is that the LIBOR-OIS spreads remained narrow even in periods when it was evident in late 2007 that the GFC had begun to wreak havoc on the American financial system. TED spreads tend to widen in the lead up to a financial crisis. The widening in the TED spread is partially due to decreasing confidence in the financial markets and decreasing yields on the treasury bills during the crisis period (Lashgari, 2000).

This study shall now explore the performance of the two LIBOR spreads during periods of financial crisis. Data for the 3-month LIBOR was obtained for five countries from the Saint Louis Federal Reserve website; these countries are Japan, the US, the UK, Switzerland, and the European Union (EU). Data for the OIS rates were sourced from various websites as follows. The Japanese OIS is the Tokyo Overnight Average Rate (TONAR) as reported on the Bank of Japan website. The US OIS is the effective federal funds rate as reported on the Saint Louis Federal Reserve website. The UK OIS is the Sterling Overnight Index Average (SONIA) as reported on the Bank of England website. The Switzerland OIS is available from the Swiss National Bank and is the Swiss Average Rate Overnight (SARON) (formerly referred to as the repo overnight index). The EU OIS is the Euro Overnight Index Average (EONIA) which was sourced from the European central bank website. Figure 7.2 shows the LIBOR OIS spread for the five main currencies. Overall, there appears to be a noticeable spike in the spreads that corresponds to the timing of the 2007-2009 GFC. Notably, the Japanese LIBOR-OIS spread is higher in the 1990s which corresponds to the 1990s banking crisis that affected shares and property markets.

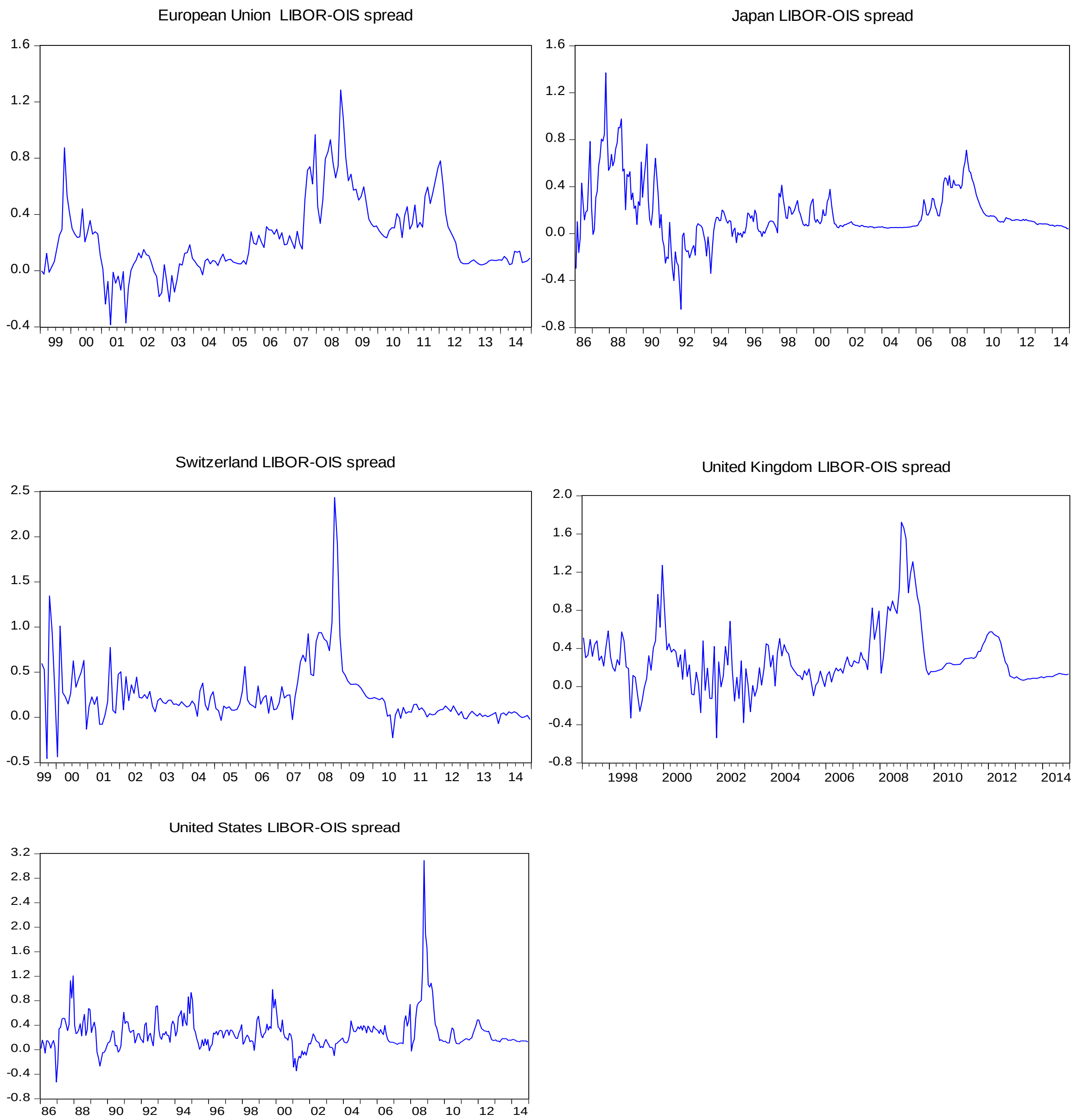


Figure 7.2: LIBOR-OIS Spread for Major Currencies (Jan/86 to Dec/14)
Data Sources: Authors calculation based on data from Bank of England (2015); Bank of Japan (2015); European Central Bank (2015); Federal Reserve Bank of St. Louis (2015); Swiss National Bank (2015)

This discussion now turns to the estimation of the TED spreads. In the case of the US the reported TED spread was sourced from the St Louis Federal Reserve. Data for the treasury bills rates was sourced from different sources, in order to estimate the other TED spreads, as follows. The 3-month Japanese Treasury bill rates were obtained for the St Louis Federal Reserve; data was available from April 1955 onwards. The UK Treasury bill rate is the average monthly rate of discount on 3-month Treasury bills in Pound Sterling as reported by the Bank of England; data was available from January 1975 onwards. In the case of Europe, the 3-month Treasury bill rate for the EU is the Short Term European Paper yields (STEP) of 32 to 91 maturity days; yields are available from the European Central bank from April 2007 onwards. The Swiss 3-month Treasury bill rate is the yield on federal money market debt register claims for 3 months; the Swiss National Banks published data online from January 1992 onwards and there are some series breaks especially in 1992 to 1993. The graphical representation of the Treasury bill yields for Japan, the UK, Switzerland, and the EU are shown in Figure 7.3.

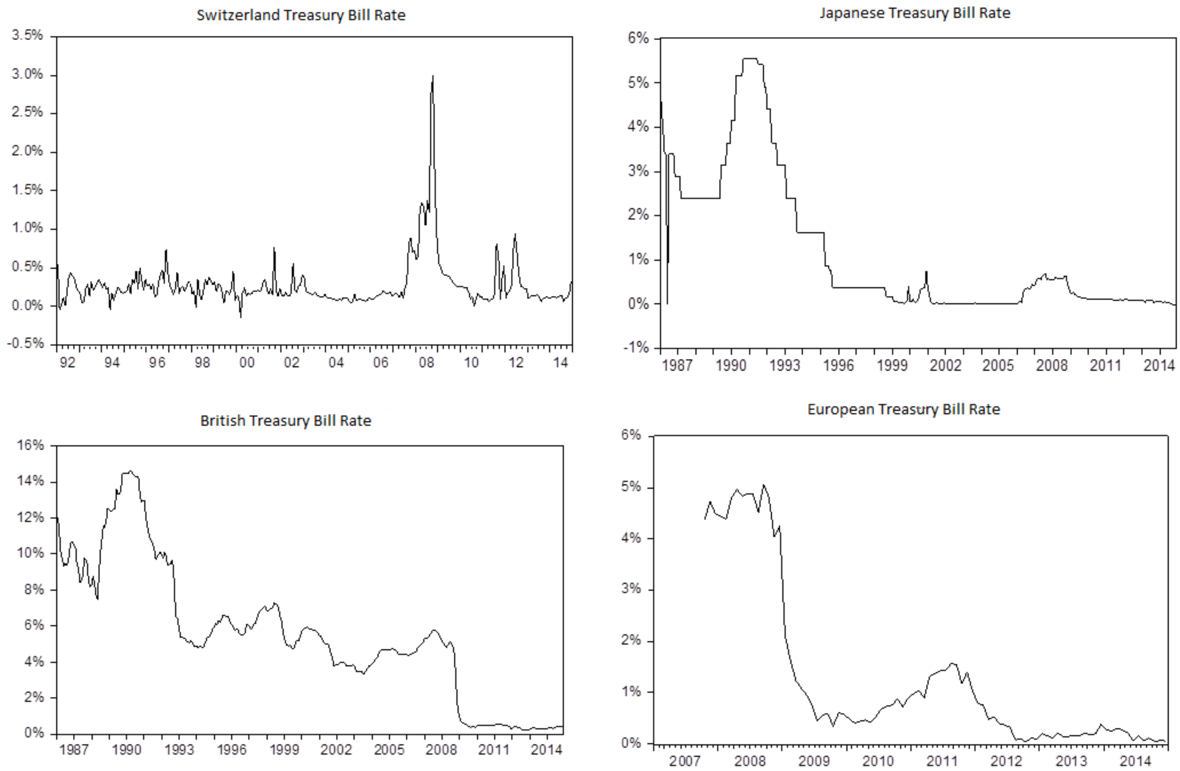


Figure 7.3: Treasury bill rates for all countries (Jan/86 to Dec/14)
Data Sources: Bank of England (2015); Bank of Japan (2015); European Central Bank (2015); Swiss National Bank (2015)

TED spreads were estimated based on the availability of data. For example in the case of the EU, the TED spread is estimated from 2007 onwards since there is no data available for the STEP before October 2007. The estimated TED spreads for all countries is shown in Figure

7.4.[47] The TED spreads follow a similar trend with the noticeable spikes in the spreads at the timing of the GFC. Since most spreads seem to signal the GFC, the subsequent discussion focuses on the GFC.

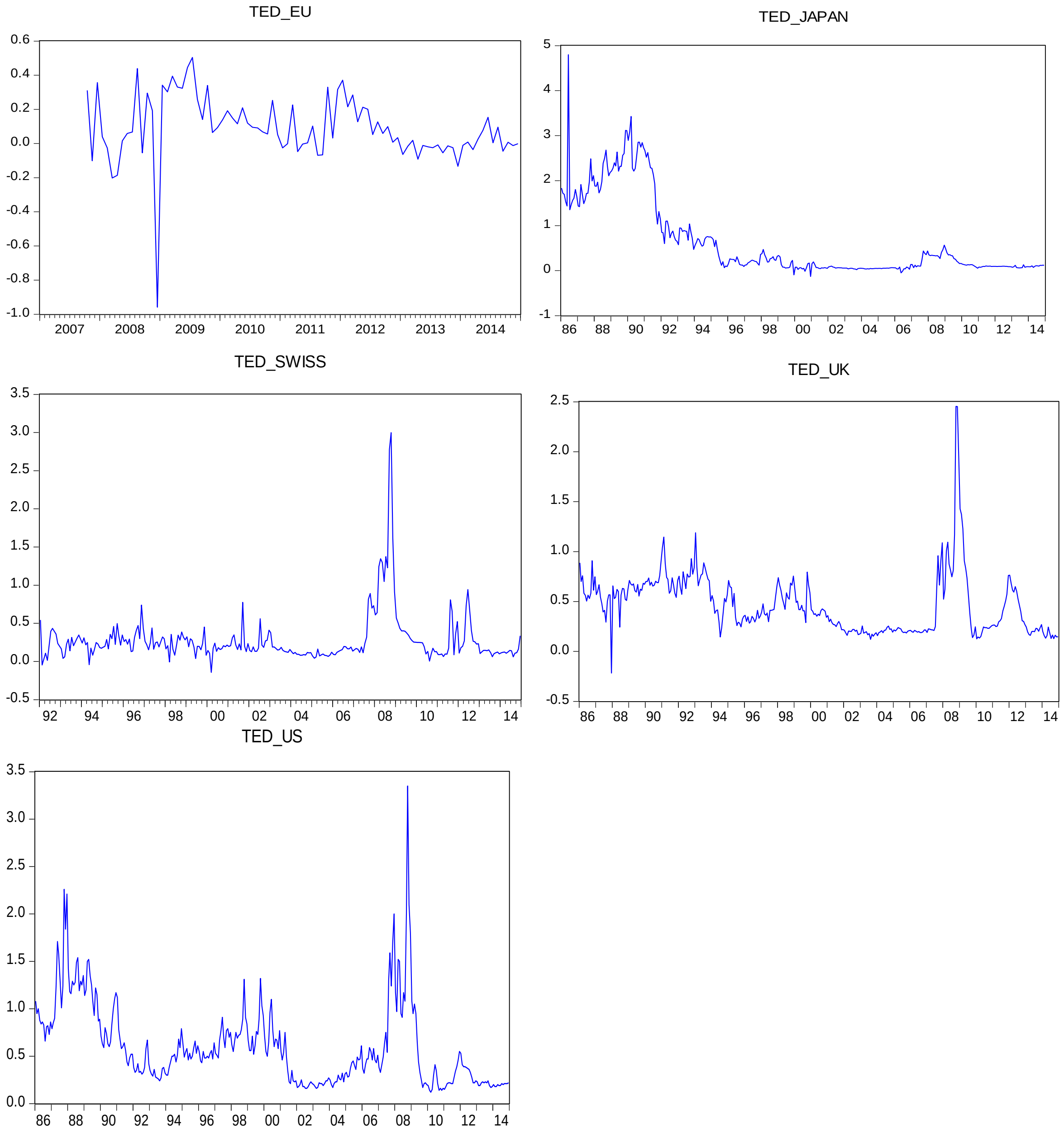


Figure 7.4: TED spreads for all countries (January 1986 to December 2014)
Data Sources: Bank of England (2015); Bank of Japan (2015); European Central Bank (2015); Federal Reserve Bank of St. Louis (2015); Swiss National Bank (2015)

Figure 7.5 shows an example of the trending of the LIBOR-OIS and TED spreads of the US during the GFC. The LIBOR-OIS spread is calculated by taking the difference between the 3-

[47] This study estimated three out of the five spreads since data for the other countries treasury bills was not readily available.

month LIBOR and the OIS[48] in US dollars. The TED spread is a monthly estimate as reported by Federal Reserve Bank (FRB) and is the difference between the 3-month LIBOR and the 3-month Treasury bill rate expressed in US dollars. As expected, both spreads report the highest values when the crisis was at its worst in October 2008; after a large investment bank, (Lehman brothers) filed for Chapter 11 bankruptcy on September 15, 2008. In the US, Chapter 11 bankruptcy occurs when a company files for bankruptcy[49] based on the criteria outlined in the eleventh chapter of the bankruptcy code. It is interesting to note that leading credit rating agencies may have played a role in the market panic that ensued. Usually, credit rating agencies are supposed to provide ratings of securities to investors so that the investors can adequately assess the risk before making an investment. The general idea is that securities with lower risk of default receive lower ratings and vice versa, thereby allowing investors that are risk averse to select investments with high ratings as they believe that these investments would have lower risk of default. In theory this sounds good however in practice the credit rating agencies failed to provide ratings that reflected the true riskiness of an investment. For example, Ivry, Pittman, and Harper (2009) claim that Standard & Poor's, Moody's Investors Service, and Fitch Ratings, gave commercial papers issued by Lehman the highest ratings in the lead up to the bankruptcy announcement. These ratings caused investors to operate under the illusion that securities issued by Lehman were very safe and the bankruptcy announcement must have come as a shock. The announcement also came as a shock to global investors and the lenders adjusted the LIBOR upwards to reflect the increased riskiness of investment in US financial institutions during the GFC.

[48] The OIS rate is reported as the effective federal funds rate. Federal Reserve Bank of St. Louis (2015) defines the federal funds rate as "…the interest rate at which depository institutions trade federal funds (balances held at Federal Reserve Banks) with each other overnight."

[49] Once the company has filed for a petition with the bankruptcy court, it is classified as *a Chapter 11 debtor* which is allowed to reorganize the structure of their assets and liabilities in order to continue as a going concern and facilitate payment of its creditors over time (Administrative Office of the US Courts, 2015).

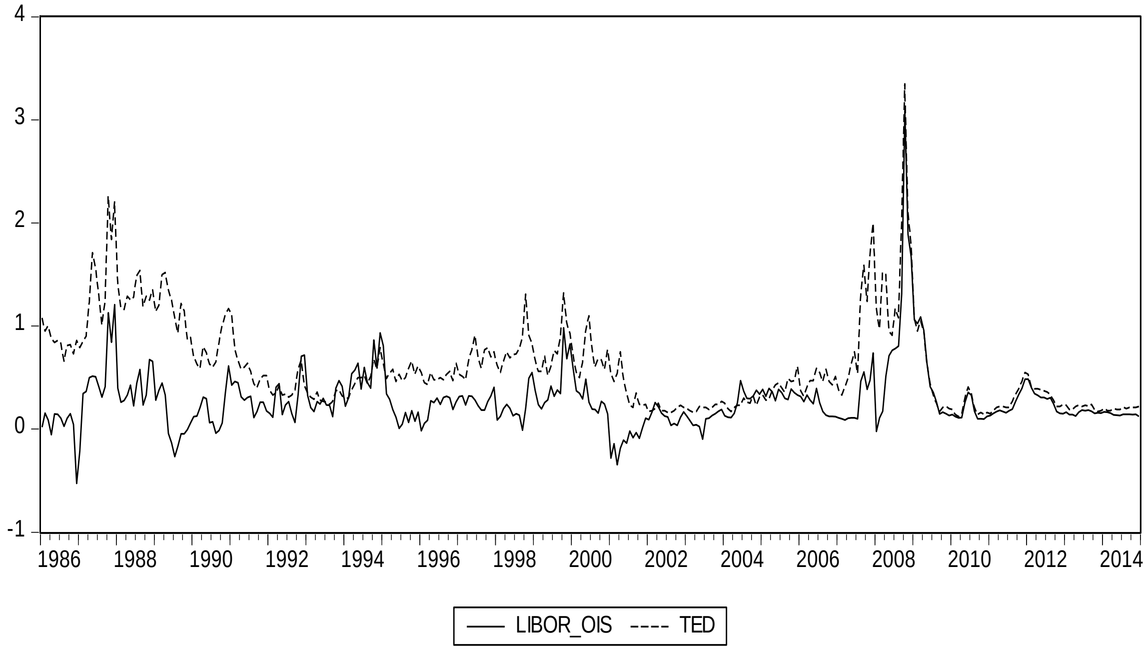


Figure 7.5: 3-Month LIBOR-OIS and TED for US (January 1986-December 2014)
Data Source: FRED (2015) [50]

7.2.4 Is the LIBOR relevant for the Australian financial market?

The LIBOR and LIBOR spreads appear to be suitable measures for predicting banking stress or crisis. However, the issue of concern is, should the LIBOR be used as a barometer of the health of the Australian banking sector? A graphical representation of the Australian LIBOR in Figure 7.6 shows the trend of the 3-month LIBOR from January 1989 to May 2013. The highest levels of the LIBOR are observed in June to September 1989. These peaks in the LIBOR may be attributed to the deregulating the banking industry in the 1980s.

[50] Data Source: FRED, Federal Reserve Economic Data, Federal Reserve Bank of St. Louis: TED Spread; https://research.stlouisfed.org/fred2/series/TEDRATE; accessed May 11, 2015.

Data Source: FRED, Federal Reserve Economic Data, Federal Reserve Bank of St. Louis: 3-Month London Interbank Offered Rate (LIBOR) based on US Dollar; ICE Benchmark Administration Limited; https://research.stlouisfed.org/fred2/series/USD3MTD156N;accessed May 9, 2015.

Data Source: FRED, Federal Reserve Economic Data, Federal Reserve Bank of St. Louis: Effective Federal Funds Rate; https://research.stlouisfed.org/fred2/series/FEDFUNDS; accessed May 11, 2015.

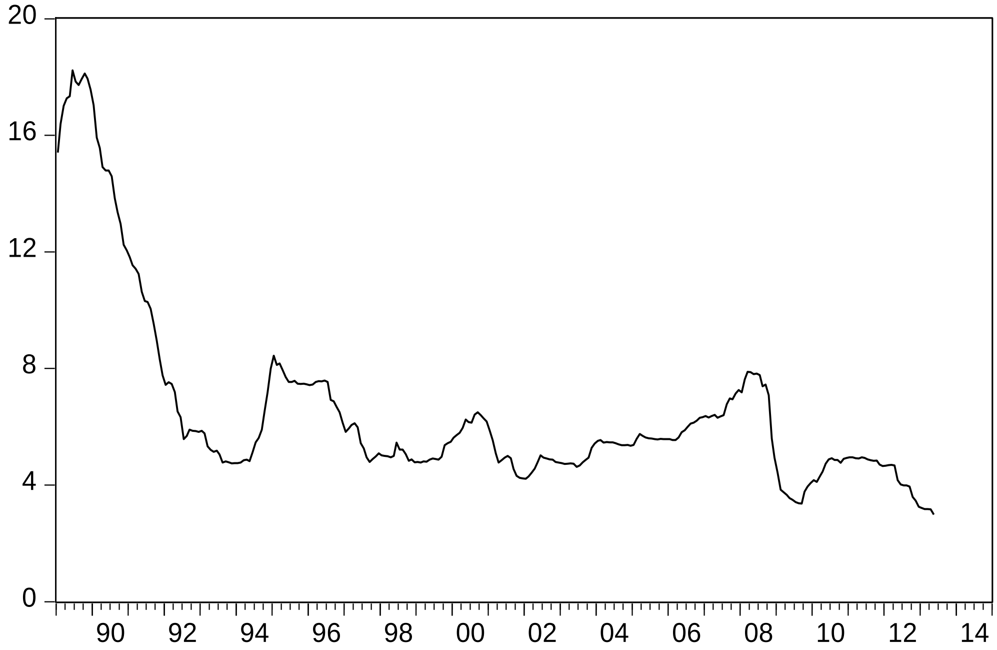


Figure 7.6: 3-Month Australian LIBOR (January 1989 to May 2013)
Data Source: Federal Reserve Bank of St. Louis (2015)[51]

7.2.4.1 The Wheatley Review of the Australian LIBOR

Based on the presented facts, one may be convinced that the LIBOR is a suitable barometer for Australian banking health. This was the prevailing school of thought until the release of the 2012 Wheatley report that suggested among other things that the Australian LIBOR was based on inadequate trade data making it over reliant on estimation techniques and vulnerable to manipulation (and probably was manipulated). So sceptical was Wheatley (2012) of the reliability of the reported LIBOR that he suggested that the LIBOR for the Australian be scrapped altogether; which is was since May 2013. Following the release of report it was discovered that Barclays bank was guilty of manipulating the LIBOR in the UK and USA markets (Chartered Financial Analyst Institute, 2012). In counterpoint, some steps have been taken to restore confidence in the LIBOR including the change of management in 2012 from British Banks Authority (BBA) to a more objective administrator Intercontinental Exchange

[51] Data Source: FRED, Federal Reserve Economic Data, Federal Reserve Bank of St. Louis: 3-Month London Interbank Offered Rate (LIBOR), based on Australian Dollar; ICE Benchmark Administration Limited; https://research.stlouisfed.org/fred2/series/AUD3MTD156N; accessed May 9, 2014.

Group (ICE) (Intercontinental Exchange, 2017b). However, until the new administrator (ICE LIBOR) establishes a credible record of accomplishment, this research will err on the side of caution and refrain from using the LIBOR spreads in the Australian financial stress index. Nonetheless, the importance of the LIBOR may still prove useful in other countries where no problems where highlighted in the Wheatley Review.

7.2.5 What is the way forward for evaluating banking risk in Australia?

Despite the popularity of the LIBOR in other countries, it does not seem to be a suitable measure for measuring gauging risk in the Australian sector. Nevertheless, this study uses LIBOR spreads as a starting point for developing alternative risk spreads. More precisely, past movements in the LIBOR spreads are viewed as a guideline on how proxy spreads should trend during periods of financial stress or crises. The main issue of concern is to correct for the misstatement of LIBOR by choosing a more representative rate that realistically represents sentiments among Australian banks that is more importantly less vulnerable the manipulation highlighted in the Wheatley report. Therefore, this study shall proceed to use the LIBOR as a reference for developing alternative spreads and compare the movements in other spreads with movements in the LIBOR spreads. This was done in four steps. First, the LIBOR and TED spreads for Australia were estimated using the data from January 1986 to May 2013. Second, the LIBOR component of the LIBOR-OIS and TED spread was substituted with other proxy variables. Third, pairwise correlation coefficients of the proxy series and the LIBOR spreads were estimated. Last, the proxy series with the highest correlation coefficients are selected for inclusion in the final stress index. The following section provides a detailed discussion of how the four steps were implemented.

7.2.6 Alternatives to the LIBOR

After the LIBOR scandal was highlighted in the Wheatley report, various stakeholders sought suitable substitutes for the LIBOR. Chartered Financial Analyst Institute (2012) published a survey report that explored possible alternatives to the use of the LIBOR. Majority of the survey responses are from CFA Institute charter holders at the management or analyst level. 39 and 32 percent of the respondents from the Asia Pacific region recommend the use of other market-based interest rates and overnight indexed swap rates respectively. These were the most preferred options. Examples of other market-based interest rates include yields on treasury bills, certificates of deposit, and commercial papers. In the case of Australia, Bank Bill Swap (BBSW) rate that is estimated and reported by the Australia Financial Markets Association (AFMA) is widely accepted as the best proxy for the LIBOR. Unfortunately, the historical data for the BBSW rates are only provided to AFMA subscribers. Consequently, this study explores the use of other proxy rates in lieu of the BBSW rate. Accordingly, the next phase of this study explores the use of alternative interest rates as proxies of the LIBOR in the estimation of TED and LIBOR-OIS spread. The sections that follow discuss proxies for the LIBOR spreads using the four-step procedure outlined in Section 7.2.5.

7.2.6.1 Proxy for the LIBOR in the TED spread

This section is devoted to finding a suitable alternative measure of the LIBOR for estimating the TED spread. First, the Australian TED spread is estimated using the 3-month LIBOR in Australian dollars and 90-day bank accepted bill (BAB) to represent the Treasury bill rate in Australia. The 90-day BAB yield is subtracted from the 3-month LIBOR in order to arrive at the TED spread. In order to estimate the proxy TED spread, this study considered the use of the Treasury note yields and the interbank overnight cash rate. The Treasury note yields were considered due to the recommendations of the CFA institute report. However, due to insufficient data, the use of the treasury notes was deemed insufficient. Specifically, the RBA only reports the 3-month treasury notes yields from January 1995 to April 2002 and March 2009 to May 2013. This series gap coincides with the timing of the GFC and makes it impossible to examine the performance of the Treasury note yields as a proxy. The interbank overnight cash (IOC) rate was selected due the notion that it would capture the interbank lending preferences that would be reflected in the trade of BBSW. This study did not find another variable that is closely linked to interbank trades. In the case of the IOC rate, there is sufficient data ranging from May 1976 onwards. Therefore, the proxy variable was estimated by taking the difference between the IOC cash rate and the 3-month BAB. Figure 7.7 shows the graph of the estimated TED spread and the proxy TED or IOC-BAB spread. The graph shows that the proxy TED does not seem to track movements in the TED spread well. The data for the two series was used to calculate the correlation coefficient. The calculated spearman correlation coefficient is only 0.296 which indicates a weak positive linear relationship. Due to the poor performance of the proxy TED variable, this study did not utilise this variable in the final stress index.

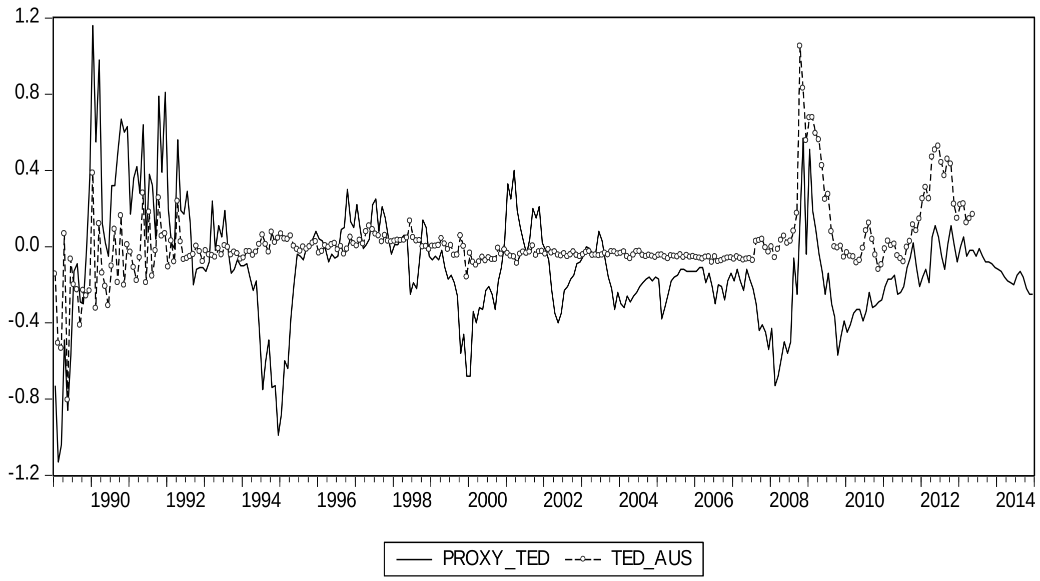


Figure 7.7: The Australian TED & Proxy TED spread (Jan/86 to Dec/14)

7.2.6.2 Proxy for the LIBOR in the LIBOR-OIS spread

This subsection is devoted to finding a suitable alternative measure of the LIBOR for estimating the LIBOR-OIS spread. The 3-month LIBOR-OIS spread is the difference between the 3-month LIBOR and 3-month OIS rate. It is only possible to estimate the spreads from 2001 since the data for the OIS is only available from July 2001 onwards. The proxy LIBOR-OIS variable is the IOC-OIS spread, which was estimated by taking the difference between the IOC and the 3 month OIS. Figure 7.8 shows the resultant LIBOR-OIS and its proxy. The correlation coefficient for the LIBOR-OIS and the IOC-OIS spreads was calculated and found to be equal to 0.780, which is indicative of a strong positive linear correlation. Owing to the strong relationship between the two variables, this study opted in favour of including this proxy variable in the final financial stress index.

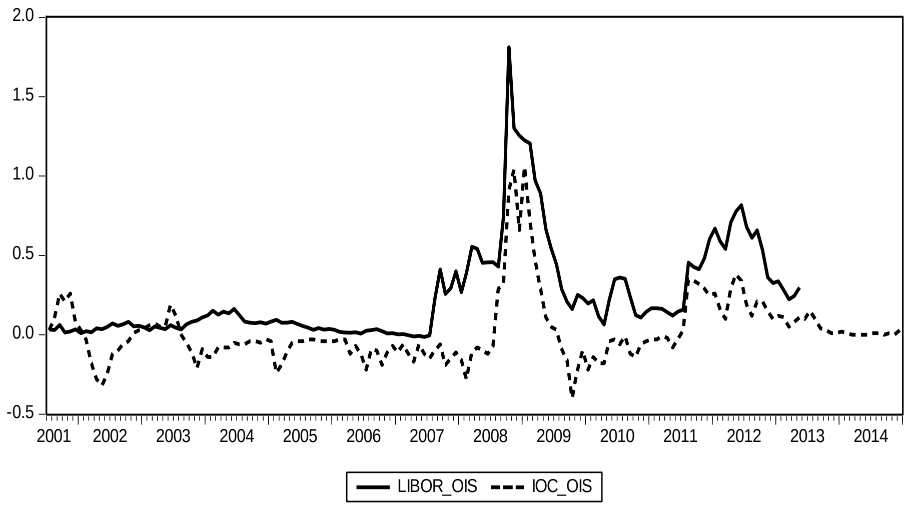
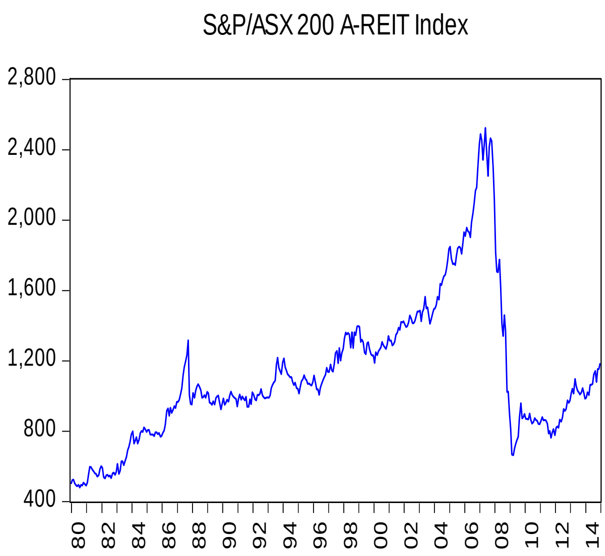


Figure 7.8: The Australian LIBOR-OIS & Proxy LIBOR-OIS (Jan/86 to Dec/14)

7.3 Inverted CMAX Australian Property Index

Several studies suggest that the property bubbles precede financial crises such that rising property prices could signal a weakening in the financial system (Alessi & Detken, 2011; Claessens & Kose, 2013; Kindleberger & Aliber, 2005; Luc & Valencia, 2008). This study uses the S&P/ ASX 200 Australian Real Estate Investment Trusts (A-REITs) composite index to monitor the overall changes in the Australian property prices. This index is a subindex of the S&P/ASX 200 and it comprises of companies that earn rental income or own properties. A rise in the property prices and income from the rented properties would be accompanied by a corresponding rise in the A-REITs. Consequently, a rapid rise in the A-REITs could signal that a property bubble is developing and the progressive rise of property prices to unsustainable levels could potentially lead to a financial crisis once the bubble bursts (Kindleberger & Aliber, 2005). The contemporaneous presence of moral hazard, rising prices and rising mortgage debt would make a country more vulnerable or likely to suffer a financial crisis that is similar to the 2007-09 GFC.

The S&P/ASX 200 A-REIT index was used to estimate the 12-month inverted S&P/ASX 200 A-REIT property index. Figure 7.9 shows the A-REIT index and the estimated inverted property A-REIT index. As expected there is a noticeable spike in the CMAX index in March 2009 that corresponds to the timing of the GFC. Moreover, the inverted CMAX index adequately captures a month of the highest levels of stress (March 2009) as identified by (Sykes, 2010). Consequently, this variable is included in the final stress index.



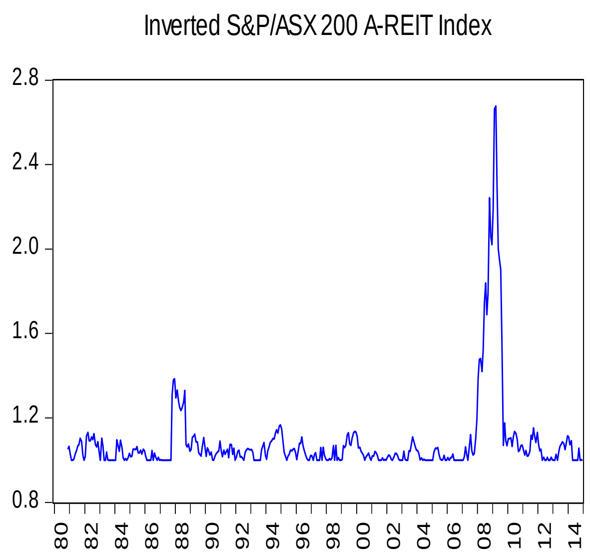


Figure 7.9: Australian Normal and Inverted A-REIT Property Index (Dec/79 to Dec/14)

7.4 Inverted CMAX Australian Mining Index

7.4.1 The Importance of Mining to Australia

This study would not be complete without the mention of a mining variable. Mining is the back bone of the Australian economy with mineral resources dominating the exported goods from Australia. Because Australia is primarily a resource-based economy, the extraction of mineral resources for export is a key source of export revenue and employment. For example, the 2016 Trade at a Glance report analysed the data for the top exports from the Australian economy. Mined resources and fuels made up to 42.2 percent[52] of the total exports from Australia with iron, coal, natural gas, gold, aluminium, copper, coke, uranium, and various metallic ores being ranked among the top 20 export earners for Australia. Most recently available data shows that mined resources and fuels ranked highly in the list of Australian exports. For example in 2015, iron ore and concentrates, coal and natural gas ranked first, second, and fourth, respectively, out of the top 20 exported goods and services for that year. Moreover these top three mineral exports earned Australia export revenue of 102,580 Australian dollars out of the total export revenue of 315,748 Australian dollars (DFAT, 2016b). Given the major role that mining plays in the Australian economy, it is expected that during a resource boom, Australia would enjoy an increase in the production and sale of mineral products and a corresponding increase in revenue from exports to other countries. Conversely, a significant decline in the demand of mineral exports could translate to a decrease in export revenue which could prove harmful to the Australian economy.

The Australian mining sector has benefitted from a Chinese property boom and bubble in recent years. However, reports of a bursting property bubble in the last quarter of 2014 due to declining demand for Australia’s key exports and an economic slowdown in the Chinese economy has economists and analysts worried for all the right reasons. Firstly, China is

[52] Mined resources and fuels generated of A$ 133,285 out of A$ 315,748 of the total export revenue from goods and services.

Australia's leading bilateral trader. For example, China accounted for approximately $29.4 billion, $28.5 billion, and $47.4[53] billion dollars in net exports in, respectively, 2011, 2012 and 2013 (DFAT, 2012, 2013, 2014). Secondly, Australia's top three mineral and fuel exports to all economies are iron ore and coal. Incidentally, two of the three exports are the leading exports to China. For example in 2013, Australia's top three exports consisted of iron ores and concentrates, coal and natural gas worth $69,494 million, $39,805 million, and $14,602 million, respectively. The top three exports to China consisted of iron ores and concentrates ($52,654 million), coal ($9082 million), and gold ($8074 million). In terms of Australia's leading exports, China accounted for about 75.76 percent of all iron ore exports and 22.81 percent of all coal exports (DFAT, 2015b). These figures indicate that the Australian economy is heavily reliant on the Chinese economy and that a significant decline in demand for mineral exports such as iron ore could affect Australia negatively. Large declines in the export of minerals and fuels would be indicative of stress in the Australian mining sector which is an issue of concern to policy makers. Unfortunately, there are already signs that the slowing economic growth in China is being mirrored by a declining demand for iron ore.
An examination of historical trends in iron ore prices is used to illustrate the recent decline in prices. Historical data of iron ore prices was obtained from the Market Index website. Reported price quotes are based on data provided by the International Monetary Fund (IMF). The monthly quotes for iron ore prices are estimated by taking the average of the spot price of iron ore that are traded at the Tianjin port in China and the average price is quoted in US dollars per tonne of iron ore (Market Index, 2017). The historical trend in the iron ore prices from January 1980 to December 2016 is shown in Figure 7.10. Percentage changes in iron ore prices were also estimated. A graphical representation of the percentage changes in iron ore prices from a month ago for the same period is provided in Figure 7.11.

[53] The net exports value is estimated as the difference between exported and imported goods (e.g., in 2013, exports and imports were valued at $94,709 million and $47,250 million, respectively; DFAT, 2015b).

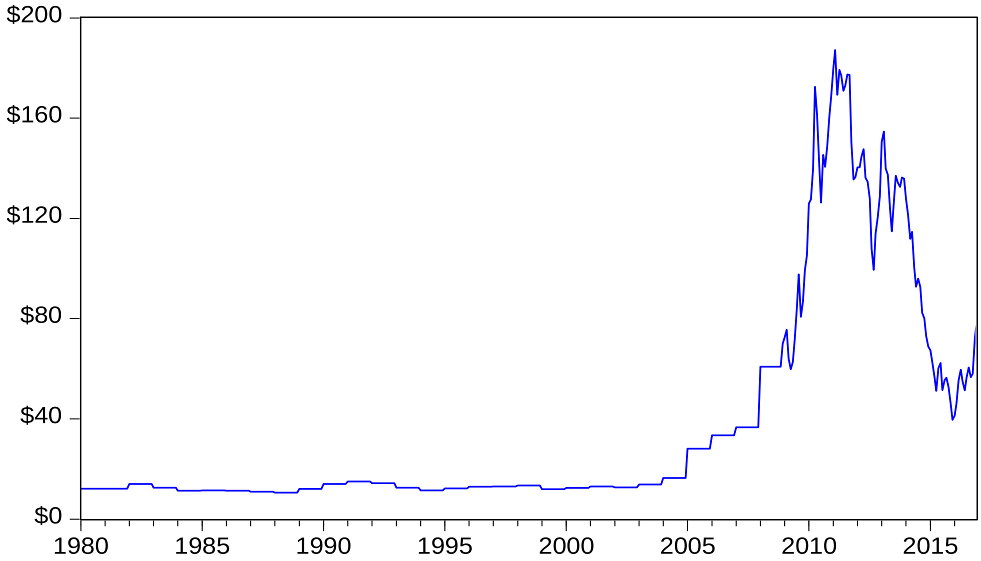


Figure 7.10: Spot Iron Ore Price in USD/tonne (Jan/80 to Dec/16)
Source: Market Index (2017)

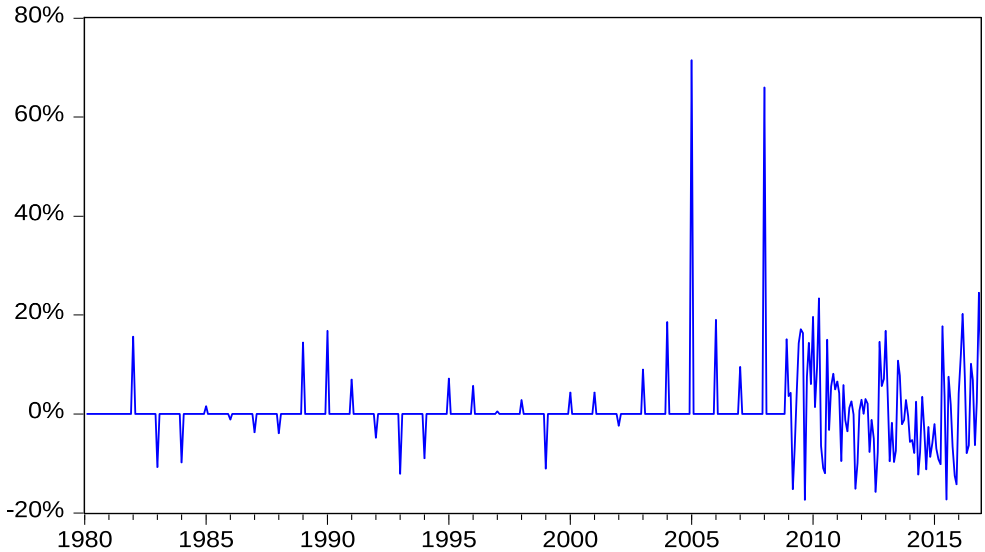


Figure 7.11: Percentage Change in Iron Ore Price from prior month (Jan/80 to Dec/16)

An examination of Figure 7.10 reveals that there have been major declines in the price of iron ore especially over the last four years until December 2016. Most notably, the iron ore price dropped from USD 136/tonne in November 2013 to USD 40/tonne in December 2015. The frequent decline in the price of iron ore is more noticeable when the percentage changes in spot prices for the iron ore are examined. An examination of Figure 7.11 reveals larger than usual percentage changes in the iron ore prices were recorded in the wake of the 2007-2009 GFC with the first major decline being recorded as a 15 percent drop in the spot price for iron ore in the month of March 2009 compared to the spot price in February of the same year. Recent declines in the prices of the iron ore are indicative of stress in the iron ore mining industry. Signs of the iron ore bubble fading were seen as early as January 2014, when iron ore prices begun to decline as shown in figure 7.10. Hutchens (2014) estimated a fall in revenue from iron ore to the tune of between 20 and 25 billion Australian dollars if prices continued to decline from 2014 onwards which they did. In particular, the Reserve Bank of Australia (2015b) found that in the span of 12 months to February 2015 spot iron ore prices had almost halved and led to a significant decline in the export revenue for Australia. The large declines in iron ore prices is in part due to the decreasing demand for iron ore and concentrates in the Chinese markets (Hutchens, 2014). Some negative effects of the falling demand for iron ore are higher than normal job cuts in the mining sector and losses in the value of Rio Tinto and BHP Billiton shares; these are major mining companies that trade on the Australian Securities Exchange (Keane, 2015). Garnaut (2015) suggests that the decline in iron ore prices is bound to continue in the near future especially because the best years of the Chinese resource boom that lasted for seven years, ended in 2014. It would, therefore, be prudent for Australia to seek out alternative buyers of iron ore in the Southeast Asia region.

The decline in iron ore prices is of particular concern; however, what would be more concerning would be an overall decline in the demand for all mined products that Australia produces. Consequently, this discussion will now consider the use of an aggregate measure to gauge the overall trend of prices and the level of financial stress in the Australian mining sector. The S&P/ASX 300 metals and mining index was found to be a suitable aggregate measure for tracking the aggregate changes in prices of mined resources and fuels. In the subsection that follows this study explored how the metals and mining index could be used to construct a variable that gauges the level of stress in the Australian mining sector.

7.4.2 A Stress Indicator for the Australian Mining Sector

This subsection uses information from the S&P/ASX 300 metals and mining index (XMM) to construct a stress indicator for the Australian mining sector. The XMM is a subindex of the S&P/ASX 300 that consists of 300 Australian publicly listed companies. It tracks movements in the trading prices of companies that mine and sell gold, aluminium, steel and other precious or diversified metals or minerals. Moreover, the XMM provides a valuable tool for monitoring the health and performance of mining sector companies in a timely manner, thereby making it a suitable tool for investor portfolio management (Australian Securities Exchange, 2010). This study obtained the data for the XMM in the following manner. Daily end-of-day values of the index were obtained from SIRCA's Thomson Reuters Tick History database. Data is available from April 2000 onwards; this study uses data until July 2017. This study obtained data until July 2017 in order to check the performance of the estimated stress variable in recent periods of stress in the Australian mining sector. However, only data from April 2000 to December 2014 will be used in the construction of the aggregate stress index. Daily data was transformed to monthly data by considering the closing price of the last trading day of each month; the resulting series is shown in Figure 7.12.

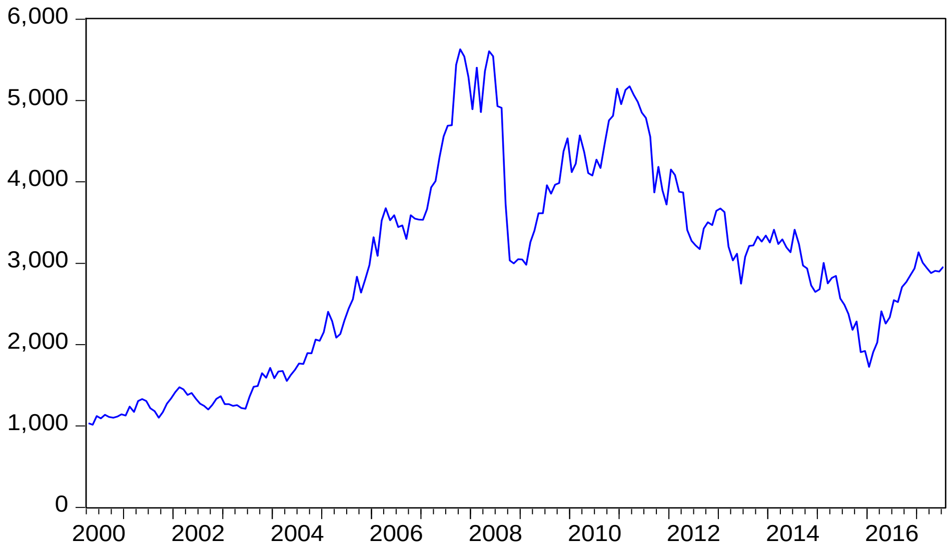


Figure 7.12: S&P/ ASX 300 Metals & Mining Index (Mar/00 to Jul/17)
Source: SIRCA (2015)

An inspection of Figure 7.12 reveals a general downward trend in the prices of mined resources as indicated by the XMM from March 2011 to January 2016 when the reported value of the XMM was 5174 and 1727 respectively. Thereafter, the prices of mined resources and fuels appear to be on the rebound. The XMM was used to construct an inverted CMAX measure was estimated for the Australian mining industry. A two year moving window was used to estimate this CMAX measure. Details of the CMAX estimation procedure are provided in Chapter 4 of this thesis. Figures 7.13 shows the inverted CMAX index for the Australian mining sector. Figure 7.14 provides a standardised version of the CMAX index presented in Figure 7.13. Values of the inverted CMAX measure in Figure 7.14 that are more than two standard deviations above the mean of the variable are indicative of stressful periods in the Australian mining sector. Stressful periods in the mining sector are contained in the unshaded region of Figure 7.14. There are three stressful periods that were identified. The first period was from October 2008 to March 2009 when the values of the inverted CMAX variable were 2.69 and 2.14 respectively. The second stressful period is probably the shortest and occurred in June 2013 as indicated by variable measure of 2.21. The third and most recent period of stress lasted from November 2015 to February 2016 when the index recorded values of 2.41 and 2.40 respectively. It is important to note that the recent declines in the iron ore prices are also reflected in the constructed stress variable via the spike in February 2016. This confirms the hypothesis set out by this study, in Section 3.2 of Chapter 3, that significant decline in exports from the mining sector over a prolonged period could actually contribute to increased vulnerability to financial stress within the Australian economy. Moreover, while the first period of stress coincides with the timing of the 2007-2009 GFC, the other two periods do not coincide with the timing any financial crisis. Therefore, it can be argued that the inverted CMAX metals and mining variable provides some insights into the level of financial stress in the Australian mining sector that are not readily apparent when examining trends in the Australian equity markets. For this reason the inclusion of this variable in the composite index for stress in Australia is justified.

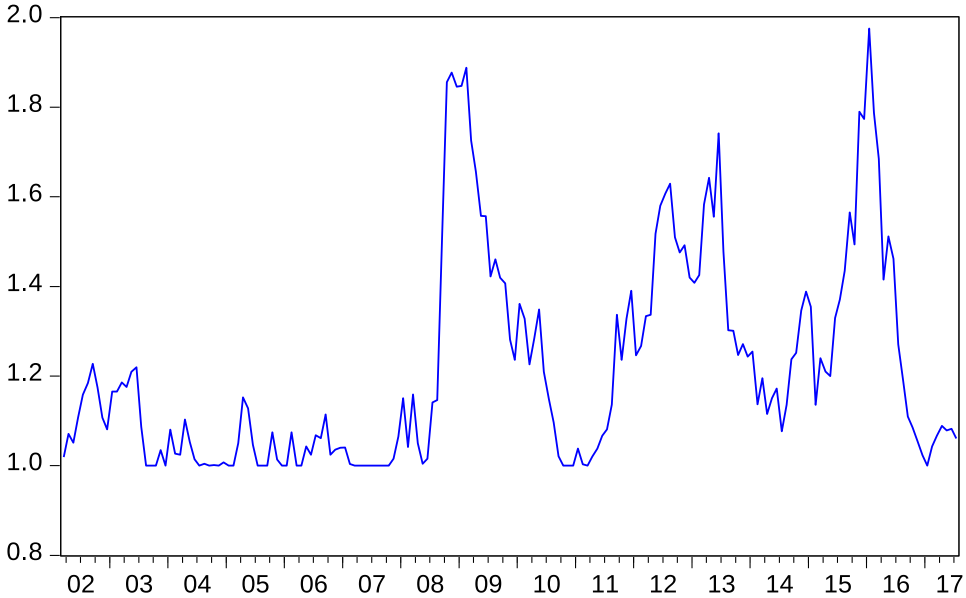


Figure 7.13: Inverse 24-month CMAX for S&P/ASX 300 Metals & Mining Index (Mar/00 to Jul/17)

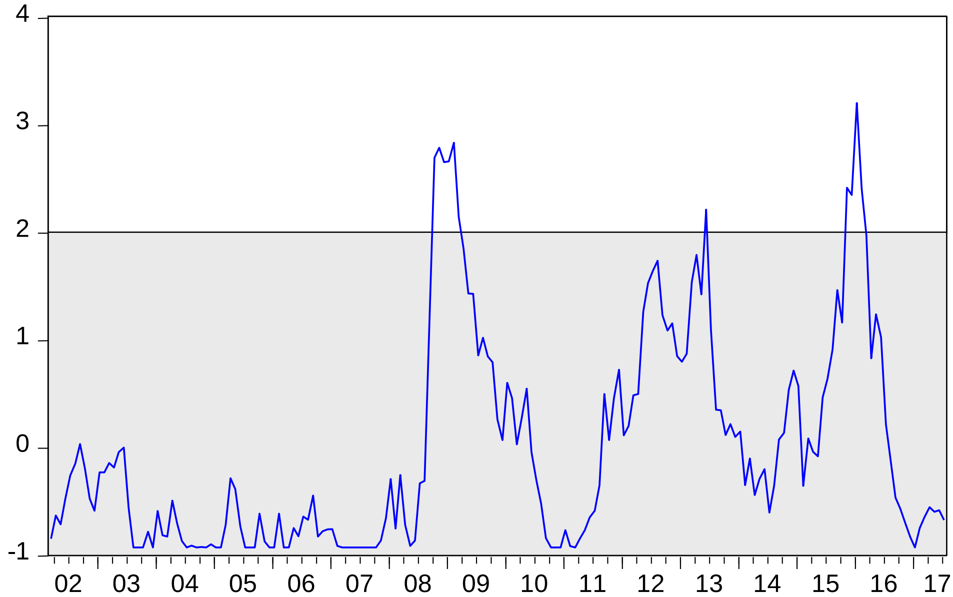


Figure 7.14: Standardised 24-month Inverse CMAX for S&P/ASX 300 Metals and Mining Index (March 2000 to July 2017)

7.5 Conclusion

This chapter discusses the feasibility of using the LIBOR and LIBOR spreads as barometers of financial stress. The LIBOR was found to be an unsuitable measure for stress. Among many issues, in Australia, it could easily be manipulated as highlighted by Wheatley (2012). As a result of the Wheatley report (2012), the Australian LIBOR was discontinued and there is insufficient data to continue to use it as a future stress indicator for Australia. Alternative measures for LIBOR spreads were proposed in this study, with the most feasible being the IOC-OIS spread. Unfortunately, the use of this proxy variable has its limitations. In particular, while the proxy variable for the LIBOR-OIS spread performs relatively well, some movements in the LIBOR-OIS spread cannot be explained by the IOC-OIS spread. Consequently, the proxy variable may introduce a margin of error in estimation that would not have been present had better proxies such as the BBSW been used, but the data for the BBSW is not readily available. This chapter also estimated an inverted CMAX property index and an inverted CMAX mining index which shall be used in the final stress index to gauge the level of stress in the Australian property and mining market respectively. Overall, this chapter has proposed useful indicators for stress that can gauge the level of stress in different sectors of the Australian economy that have not been considered in other studies.

This study has to this point focussed on using Australian variables as early indicators of financial stress. Those variables measure economic or financial attributes of the Australian financial sector in order to gauge Australia’s potential for financial crisis in the near future. It would be interesting to consider if foreign-based variables can provide some insight into the potential for financial stress in the Australian markets or offer predictions in future market movements in Australia. This is one of the motivations for the inclusion of following chapter in this thesis. Chapter 8 of this study is dedicated to exploring whether it is viable to use foreign country-based variables as early indicators of stress in the Australian financial markets.

CHAPTER 8

FOREIGN-BASED INDICATORS OF FINANCIAL STRESS

8.1 Introduction

This chapter presents foreign-based variables that can be used as indicators of financial stress in Australia. For purposes of this study, a foreign-based variable is defined as an economic or financial variable, of countries other than Australia, which is deemed relevant for explaining potential for distress in the Australian economy. This chapter performs exploratory empirical analysis in order to identify foreign variables that are suitable for measuring stress in Australian equity markets. Based on the outcome of the exploratory analysis, a decision was made to either omit or include a variable in the final composite stress index. The subsequent sections and subsections of this chapter are organised as follows. Section 8.2 highlights the important role that linkages can play in the transmission of financial stress. Here a brief overview of the Australian economy and the importance of trade with Australia's top four bilateral traders are also provided. Section 8.3 performs an empirical analysis in order to identify the foreign-based variables that were suited for gauging the potential for financial stress in Australian equity market in Section 8.3. The analysis in this section mainly focuses on examining the relationship between returns and trading volume for major composite stock indexes of Australia and four countries with key bilateral trade links with Australia. Therefore, the subsections of Section 8.3 are organised as follows. The data selection procedure and research methods used in this study are outlined in Subsections 8.3.1 and 8.3.2 respectively. The empirical analysis and presentation of results are contained in Subsection 8.3.3 of this chapter. The implications of the findings to this study are highlighted and discussed in Subsection 8.3.4. Based on the findings of the empirical analysis, this study proposed the use of two foreign-based variables, which are the inverted CMAX measures for the lagged Hang Seng and the S&P 500 indexes in Section 8.4. Both variables were subsequently included in the composite index for Australian financial stress. Section 8.5 contains the chapter summary while Section 8.6 concludes this chapter.

8.2 Linkages as Conduits for Financial Stress

The recent GFC has enhanced interest among financial researchers on the factors that lead to the spread of financial crisis from one country to another and on finding appropriate policy stances that mitigate such occurrences. There are diverging views as to why and how financial crises spread and why some countries are more vulnerable to financial contagion, whereas, others appear to be more immune to financial difficulties experienced by neighbouring countries. Academics often disagree as to whether cross-border transmissions of a crisis arise from financial links, trade links or a combination of both. Here are some explanations offered by scholars on financial contagion and possible channels of transmission of stress or crises. Kaminsky and Reinhart (2000) define contagion as the process by which "financial difficulties spread from one economy to another in the same region and beyond" via trade and financial linkages (p. 51). The aforementioned authors posit that in addition to trade links, financial links that exist between banks or financial markets can also help explain channels of contagion. Forbes and Rigobon (2002) suggest that contagion occurs when a financial shock results in a significant increase in the cross-market linkages and co-movement in the countries' financial markets. Glick and Rose (1999) assert that currency crises are often experienced by countries within the same geographical area and spread via bilateral trade links. However, being in close proximity to another country does not guarantee that a country with suffer from contagion. For instance, Park and Song (2001) confirm the importance of trade links but stresses that herding behaviour, speculative attacks among investors and common macroeconomic practices contributed to the contagion of the 1997 Asian Crisis. It is difficult to determine if contagion experienced at the regional level is due mostly to financial or to trade links, because countries tend to concurrently establish regional trade agreements and the interbank linkages needed to facilitate the associated trade (Caramazza, Ricci, & Salgado, 2004). In fact, Forbes and Rigobon (2002) argue that it is difficult to directly measure how the various linkages contribute to the development as well as the propagation of crises across borders.

Overall it appears that most researchers agree that linkages, whether trade or financial, play a role in the transmission of financial crisis. The linkages act as a conduit for the cross-border or global transmission of financial stress or crisis. Consequently, it is important for policy makers to consider the role that either or both financial and trade links play in the development and spread of financial crises. Further, empirical studies on linkages may help develop early warning indicators to facilitate timely intervention to forestall or ameliorate future crises. The empirical exercises conducted in this thesis focus on the role that inter-country linkages with key bilateral traders may play in the spread of financial crises is of particular interest.

This study focuses on the notion that trade and financial linkages can be used to explain why and how financial crises spread from one country to another. This research hypothesises that a country is more likely to experience contagion of a crisis arising in a country with which it has extensive trade links and that an examination of financial links will reveal the channels of crisis transmission (Mukulu, Hettihewa, & Wright, 2014). The notion is that a financial crisis will cause a decline in regional and global trade especially in the case of the country or countries that are the epicentre of the crisis. Moreover, during a financial crisis it is expected that the panic responses to a shock/s in the financial system will reverberate through the financial markets. As investors become aware of the unfolding crisis, panic selling of financial assets may ensue. This study examines movements in the equity markets of Australia and four of its key bilateral trading partners in order to determine whether Australia's key trading relationships influence or can help anticipate movements in its equity market and/or the equity markets of its trading partners. The section that follows provides a brief overview of the Australian economy and the existing trade links.

8.2.1 The Australian Economy and Trade links

Australia is an open economy that engages in trade agreements based on shared political and economic interests. Australia has not had a dominant trading partner over the past 150 years; that role has rotated from the UK, to the USA, to (at present) China. The Department of Foreign Affairs and Trade (DFAT, 2015c) asserts that Australia's top four bi-lateral trading partners in 2015 were (in order of importance) China, Japan, the US, and the republic of Korea. Mining plays an important role in Australia's economy with minerals being Australia's key export. The most recently available data shows that in 2014 Australia exported goods worth 326.9 billion dollars with 157.3 billion dollars, almost half all exports consisting of mineral and fuel products. In 2014 Australia's leading bilateral trader China imported $89,998 million of goods of which about 80 percent ($71,817 million) consisted mainly of mineral and fuel resources[54]. The top three exports to China are iron ore and concentrates, coal, and gold, in that order. Imports from China mainly consisted of tele-communication products, computers, and furniture, which accounted for 12,866 million dollars. Japan, Australia's second bilateral trader, imported goods worth 48,193 million dollars in 2014 of which mineral and fuel products such as coal, iron ore, copper, and aluminium comprised of almost half (23,991 out of 48193 million dollars) of all imports.

[54] DFAT (2015b) states that China imported iron, coal, gold, other ores, copper ores and copper worth $50,582 million, $8,326 million, $7,023 million, $2,074 million, $2,056 million, and $1,756 million, respectively.

Exports from Japan mainly consisted of cars and refined petroleum worth 9,802 million dollars (DFAT, 2015b). Collaborations on security matters include the 2007 Joint Declaration on Security Co-operation (ABS, 2012). The US, ranks third as a bilateral trading partner, has had a free trade agreement with Australia since 2005-the Australia-United States Free Trade Agreement (AUSFTA). Unlike other countries that mainly import minerals, US primarily imports agricultural products such as beef and alcoholic beverages. In 2014, the only mineral resource exported was zinc worth 200 million dollars; this is barely two percent[55] of the total exports to the US. A decline in the demand for mineral products by the US would have the least impact on the Australian mining industry. The republic of Korea was ranked as Australia's fourth trading partner in 2014, with bilateral trade in goods and services amounting to approximately 34.6 and 30.2 billion dollars respectively. Exports to Korea are primarily iron ore and coal (worth $10,325 million) (DFAT, 2015b).

Given the considerable degree of trade between Australia and its top four bilateral traders, this study examines whether the existing trade links can help to explain the interdependence in stock market movements among these five countries (Australia, China, Japan, Korea, and the USA). Increased economic integration of markets is often accompanied by increased financial market integration and correlation in the stock market prices. Paramati, Roca, and Gupta (2016) used returns on composite stock indexes to explore the impact of bilateral trade between Australia and ten Asian countries. This study found no significant link between bilateral trade and the correlations of returns of the Australian and Chinese equity markets. However, bilateral trade links seems to explain the correlation between the Australian equity markets and its three key bilateral traders (Japan, South Korea, and Singapore).[56] The mixed

[55] According to DFAT (2015b), zinc ore worth 200 million dollars was exported to the US and the total revenue from goods exported to the US in 2014 was $11,890 million. Therefore, zinc made up approximately (200/ 11,890) 1.682 percent of all the exports to the American economy.

[56] Based on recently available data, Singapore is ranked as Australia's fifth bilateral trader (DFAT, 2016a). The author of this thesis considered examining the movements of the Singaporean versus the Australian equity markets. Unfortunately, the data for the Singaporean markets was not readily available via the Yahoo finance

findings of this study indicate that the relationship between bilateral trade links and the correlations between equity markets is far more complex. It seems that the sole examination of the returns did not give a comprehensive view of the market dynamics in this case. Perhaps, a better understanding of the co-movements in equity markets could have been gained if other (or a combination of) factors was considered when examining the relationship between economic and financial links. Consequently, the section that follows is dedicated to gaining a broader understanding how key bilateral trading relationships can be used to explain market movements in the Australian equity market. Specifically, instead of focusing on the analysis of the composite index returns alone, this study follow the approach adopted by more recent studies by considering volume in addition to returns in order to explain equity market movements (Chen, 2012; Tapa & Hussin, 2016; Yadav, Aggarwal, & Khurana, 2015).

8.3 An Examination of Returns-Volume Relationship

This section focuses on the examining the relationship between closing prices (or returns) of assets and the volume of assets traded in an equity market. This study shall now embark on the contemporaneous examination of market returns together with volume in different countries as this could provide useful insights to policy makers about the market dynamics of global markets. The focus of this analysis is to understand how the market dynamics could help to explain co-movement in prices in different markets and the potential for propagation of shocks to the Australian financial market. The rest of this section discusses the work by scholars that have carried out this contemporaneous examination of market returns together with volume before embarking on a similar analysis for the Australian case.

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website. Daily closing prices were only available from November 1, 2016. Therefore, this study omitted Singapore from the empirical analysis.

According to Gallant, Rossi, and Tauchen (1992), the contemporaneous study of price and volume is important as it provides a better understanding of the market and volatility that would not have been possible when considering prices or returns alone. These authors analysed daily closing values for the American S&P 500 to better understand the price-volume relationship in the US. Some key findings of this study were that changes in volume lagged price changes (returns) and a positive relationship existed between changes in price and changes in volume such that large price increases were associated with large increases in volume. In regards to investors, Kamath (2008) argues that the consideration of the price and volume could help to identify the prevailing market sentiment as either bullish or bearish. This information could help investors of different risk preferences and investment goals to identify an opportune time to invest. According to Mahajan and Singh (2008), both price and volume are important considerations, since each variable gauges different characteristics in the stock market. These authors assert that the price-volume relationship may be dependent on market efficiency, information asymmetry, market size, and trading restrictions, all of which could affect the rate or timing of the flow of information (e.g. given that investors trading in the equity markets receive information sequentially, price changes would reflect the average knowledge of new information while changes in trading volume would reflect the aggregate response of investors to the price change). Mahajan and Singh (2008) found that the change in returns led the change in trading volume, which meant that past values of returns could help explain the current trading volume of the Indian stock market. At this point, it is important to note that it is possible for a ‘feedback mechanism’ to exist between returns and volume such that volume leads returns, making volume useful for predicting returns. In this case, current changes in volume could help to gauge prevailing investors’ expectations and signal possible changes in price (or returns) in the near future.

Researchers that have considered the idea that there is a predictive relationship between stock returns and trading volume have arrived at two main conclusions. Scholars assert that the relationship exists in two main forms; either a unidirectional (one-way) or bidirectional (two-way) relationship exists between returns and volume. In the former case, only current values of stock returns can be used to predict future values of trading volume; current values of trading volume have no predictive value for future stock returns. Alternatively, by the same token, there are instances where current values of trading volume can be used to forecast future stock returns; in this case current values of the stock returns have no predictive value for future trading volume. In the latter case, past values of the trading volume can be used to explain the current stock returns and vice versa. Here are a few examples of some studies on the price-volume relationship. Kamath (2008) explored the relationship between daily returns and traded volume in the Chilean stock market over three years from 2003-2006. Linear granger causality tests developed by Granger (1969) were used to examine this relationship. This author found a positive relationship between returns and the traded volume, whereby rising returns were associated with a rise in trading volume and vice versa. Moreover, there was a one-way causation from returns to traded volume, no causal relationship was found from the trading volume to the returns. This meant that the general rise in the returns was associated with increased optimism among investors and consequently more trading (buying and selling) of shares on the stock market. Assogbavi, Schell, and Fagnissè (2007) examined this relationship using weekly data for the Russian market and similar granger causality tests. This study found bidirectional causation existed between returns and traded volume. Mahajan and Singh (2008) took a slightly different approach to examining the daily returns on the Indian stock market. Instead of just examining the relationship between price and volume, these authors also considered the stock volatility in their analysis. Stock market volatility was modelled using GARCH models and causality tests were performed on the three variables (stock returns, trading volume, and return volatility). This study revealed unilateral linear causality from volume to return and volatility to volume. The flow of causality from volatility to volume to returns suggests that market volatility has predictive power and offers relevant information when examining the price-volume relationship. Mahajan and Singh (2008) suggest that the nature of the relationship among the three variables may be indicative of existing market inefficiencies in the Indian market.

So far, this section has focussed on studies that use linear causality tests to explore the relationship between price and volume. Linear causality tests assume that if there is a relationship between the two variables that it is a linear one and this assumption forms the basis for how the linear causality test is designed. However, if the relationship between the two variables is nonlinear then the assumption that there is a linear relationship between the two variables is incorrect. As a result, the linear causality test would be an inefficient tool for detecting the causal relationship between the two variables, primarily because it assumes a linear relationship. Indeed, Hiemstra and Jones (1994) assert that linear causality tests have low power in revealing nonlinear causal relationships between two variables. Thus, a better approach to testing for causality would be to use a nonlinear causality test if one suspects that a nonlinear relationship exists between two variables. In this manner, the test for causality would take into account the nonlinear aspect of the relationship when exploring the nature of the relationship, whether unidirectional, bidirectional or no causal relationship at all. This is why this discussion will soon turn to understanding the notion of nonlinear causality. Nevertheless, before doing so it is important at this point to note that because it is not always known beforehand whether the relationship between two variables is a linear, reasonably approximated by a linear relationship, or must be given as a nonlinear one, a more prudent approach to testing for causal relationships would be to examine whether either a linear or a nonlinear causal relationship exists between two variables. Accordingly, this study will check for the presence (or absence) of linear or nonlinear causal relationships between two variables; this is similar to the approach adopted by several scholars (Baek & Brock, 1992; Diks & Panchenko, 2006; Gallant et al., 1992; Lin, Yeh, & Chien, 2013; Pavlidis, Paya, & Peel, 2015; Silvapulle & Choi, 1999).

Much of the work on the nonlinear causality tests is based on a working paper by Pavlidis et al. (2015) that explored the uses of a correlation integral and conditional probabilities to develop a nonlinear causality test that examines the relationship between two variables; in this study the economic variables were money and income. This foundational work suggested that the residuals of a bivariate vector autoregressive (VAR) model could be examined to reveal the presence (or absence) of a nonlinear relationship. In order to implement this test Pavlidis et al. (2015) assume that the two series being examined for causality were mutually independent and identically distributed (*i.i.d*). This assumption is one of the main shortcomings of Baek and Brock's testing procedure since it leads to power and finite-sample size estimation problems as highlighted by Gallant et al. (1992). Gallant et al. (1992) consequently developed a modified version of Baek and Brock's test for nonlinear causality and found that the modified test revealed a bidirectional nonlinear relationship between daily returns and volume in the US stock market unlike the linear causality tests which only revealed the presence of a unidirectional causal relationship. Unfortunately, the modified version of the Pavlidis et al. (2015) also has its shortcomings. Specifically, Hiemstra and Jones (1994) test is biased as it tends 'over-reject' the null hypothesis of non-Granger causality; this tendency to over-reject the null increases with the sample size (Diks & Panchenko, 2005; Lin et al., 2013). Lin et al. (2013) offer an improved testing framework that solves the over-rejection problem even when the sample size increases. Therefore, this study will proceed to use framework provided by Lin et al. (2013) to check for the presence of nonlinear causal relationships between variables.

The subsections that follow provide a detailed explanation of how the causal tests were performed. Because the sequential steps followed in this analysis can seem laborious, a brief overview of the steps followed is necessary. In order to perform the linear and nonlinear causality tests the following steps were followed. First, the data for the composite stock indexes and trading volume was downloaded at daily frequency for the five countries. Second, all series were used to obtain the monthly averages of each series. Third, the data at monthly frequency was expressed in Australian dollars and natural logarithmic form. Fourth, the percentage changes in all series were obtained; this is the percentage change in monthly returns and the percentage change in trading volume of the stock indexes. Fifth, unit root tests were performed on the returns and volume series. Sixth, all series were adjusted for month-of-year effects.[57] Seventh, linear and nonlinear causality tests were performed. Eighth, the findings of the causality tests were discussed. Finally, the implications of the results for this study were outlined.

8.3.1 Data selection and transformation

This research uses composite equity indexes for Australia and its top four bilateral trading partners to explore the potential of cross-border transmission of financial stress or crises to Australia. Two characteristics of the composite indexes shall be examined; these are the changes in share prices and trading volume.[58] Pairwise linear and nonlinear tests are used to investigate the causality relationships between price and volume. All tests are performed using data at a monthly frequency because the final composite stress index is also constructed using monthly data. The purpose of this investigative analysis is to provide some insight as to

[57] This process uses the two step procedure outlined by Silvapulle and Choi (1999). In addition to month-of-the-year effects, Gallant et al. (1992) also remove the day-of-the-week and holiday effects. However, day-of-the-week and holiday effects are not relevant since this study uses the monthly average values of the composite stock indexes and trading volume.

[58] This study did not examine the relationship between returns and volatility, because the returns and volume are adjusted for market volatility.

the possible usefulness of either volume or stock returns in the prediction of future price changes in the Australian equity market.

8.3.1.1 Stock Returns Data

This study commenced the investigation of the price and volume relationships by using daily values of the composite indexes to estimate monthly average values. Data was obtained at the daily frequency in order to obtain the monthly average returns for each stock index. Daily data comprised of the closing prices at the end of a day of trading. On days when there were no stocks traded there is no data reported. The daily closing prices for the All Ordinaries (Australia), Hang Seng (China), S&P 500 (US), KOSPI (South Korea), and NIKKEI 225 (Japan) stock indexes were obtained from the Yahoo finance database (Yahoo, 2017). Each composite stock index series is reported in the home currency indicated in table 8.1. The range of data available varies and the starting dates of each series vary as shown in table 8.1.

Table 8.1: Time range and home currencies composite stock indexes

Index	Currency	Time range	
		Daily closing price	Daily traded volume
All Ordinaries	Australian Dollar	August 3, 1984 onwards	February 24, 2003 onwards
Hang Seng	Chinese Yuan Renminbi	December 31, 1986 onwards	July 9, 2001 onwards
S&P 500	US Dollar	January 3, 1950 onwards	January 3, 1950 onwards
KOSPI	South Korean Won	July 1, 1997 onwards	April 28, 1998 onwards
NIKKEI 225	Japanese Yen	January 4, 1984 onwards	June 10, 2002 onwards

In relation to the closing prices of the composite indexes, the latest starting date of data sourced from the Yahoo finance website is on July 1, 1997; this relates to the starting date for the KOSPI index. However, it was possible to obtain data for the KOSPI index from May 1, 1990 to June 30, 1997 from the SIRCA Thomson Reuters Tick History database. Hence, this study chose to use data from two sources for the KOSPI index; the closing price values from May 1, 1990 to June 30, 1997 were sourced from SIRCA. The other closing price value of the stock indexes was sourced from the Yahoo finance website. Henceforth, a standardized sampling period ranging from 1 May 1990 to 30 September 2016 was obtained for each equity index.[59] The monthly averages for each series were obtained using a simple averaging method. An example can be used to illustrate how this method is implemented. In the case of Australia, the average closing prices for the All Ordinaries index in month of January 2014 were obtained as follows. First, the daily closing prices for all trading days in January 2014 were added up and divided by the number of days when the stocks were traded on the Australian Securities Exchange (ASX). There were 21 trading days based on the closing quotes provided. Therefore, the sum of closing prices was divided by twenty one. The monthly averages for the subsequent months and other stock indexes were calculated in a similar manner. Once all data was expressed at a monthly frequency, the range of the resulting monthly series for each stock index consists of 317 data points.[60]

For ease of comparison with the Australian All Ordinaries index, all composite indexes are expressed in Australian dollars. Each series was converted to Australian dollars using the monthly exchange rates reported on the Reserve Bank of Australia website; the resultant series are then expressed in natural logarithmic form. Figure 8.1 shows the graphical representation of the resultant series while Table 8.2 presents the summary statistics for each series after the logarithmic transformation.

[59] The end date was chosen as September 2016, so as to maximise the number of data points available for the analysis. However, the final index will still be estimated with data up to December 2014.

[60] The resulting returns series will consequently contain 316 data points.

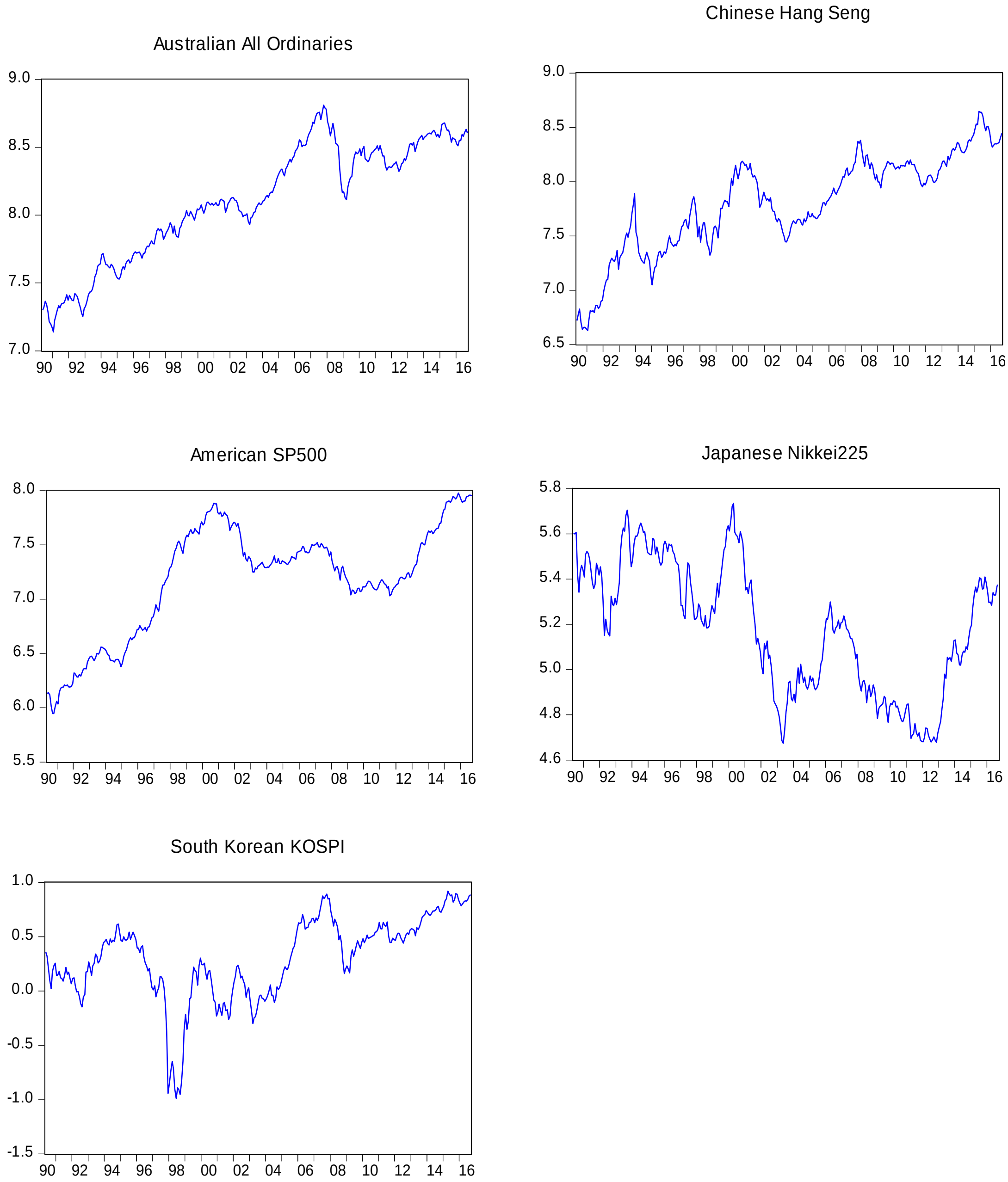


Figure 8.1: Logged stock indexes for all countries (May/90 to Sep/16)

Table 8.2: Summary Statistics for Logged Stock Indexes (May 1990 to September 2016)

	Australia (All Ordinaries)	China (Hang Seng)	Japan (NIKKEI 225)	Korea (KOPSI)	US (S&P 500)
Mean	8.1007	7.7920	5.1815	0.2968	7.1815
Median	8.1068	7.8301	5.1949	0.3397	7.2957
Maximum	8.8096	8.6476	5.7351	0.9196	7.9752
Minimum	7.1386	6.6301	4.6741	-0.9889	5.9464
Standard Deviation	0.4288	0.4469	0.2869	0.3820	0.5094
Skewness	-0.4061	-0.5553	-0.0717	-0.8554	-0.6128
Kurtosis	2.0732	2.7938	1.8395	4.0469	2.4530
Jarque-Bera Statistic	20.058***	16.851***	18.059***	3.131***	3.791***

Note: * indicates that the Jarque-Bera test statistic is significant at the 10% (*), 5% (**) or 1% (***) level.

For the period of study, Australia has the highest mean monthly return while Korea has the lowest mean monthly return. Based on the reported standard deviations for the five series, the highest variation in stock prices occurred in the USA market has 0.2595 (0.5094^2) while the least variation in stock prices was observed in the Japanese market 0.0823(0.2869^2). This suggests that for the period being examined, the USA markets were the most risky or volatile while the Japanese were the lease risky. All series have negative skewness. With the exception of Korea series that has kurtosis that is greater than three (4.05) and is fat-tailed, all other series have smaller tails than a normal distribution. The test statistics for Jarque-Bera test are significant at all levels of significance for all series. Thus, the null hypothesis for a normal distribution of all series is rejected at a 5% level of significance. Thus, it can be concluded that all series are not normally distributed.

The logarithmic values of each index were used to calculate the continuously compounded return as shown in equation 8.1[61] where R_t is the average logarithmic return of a stock index in month t, P_t is the average value of the stock index in month t and P_{t-1} is the average value of the index in month t-1.

[61] Equation 8.1 is similar to the return equation 4.5 that was first discussed in chapter 4. The main difference between the two equations is that equation 4.5 represents the change in stock prices (returns) and is calculated as follows: $R_t = ln(P_t) - ln(P_{t-1})$, while equation 8.1 uses percentage change in returns which is estimated by $R_t = [ln(P_t) - ln(P_{t-1})] * 100$

$$R_t = [ln(P_t) - ln(P_{t-1})] * 100 \tag{8.1}$$

It should be noted that the monthly values are the average closing price for each month. Hence, the monthly return is estimated by comparing the average value of an index in a particular month with the average value of the index in the previous month. Figure 8.2 shows the graphical representation of the returns series for the five countries while table 8.3 presents the summary statistics for the returns of the composite stock indexes.

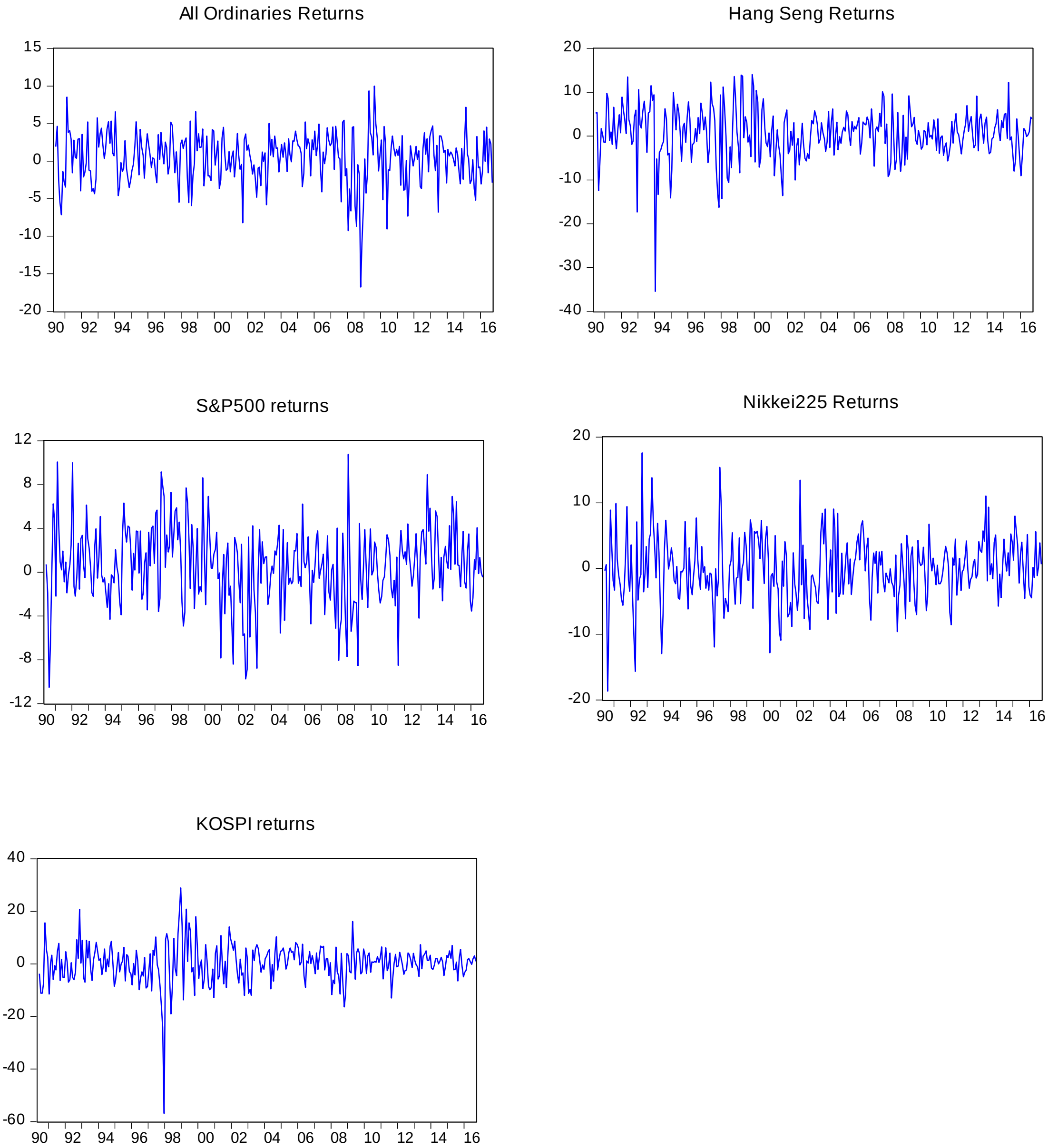


Figure 8.2: Stock indexes returns for all countries (May/90 to Sep/16)

Table 8.3: Summary Statistics for Stock returns (June 1990 to September 2016)

	Australia (All Ordinaries)	China (Hang Seng)	Japan (NIKKEI 225)	Korea (KOPSI)	US (S&P 500)
Mean	0.4126	0.5453	-0.0721	0.1674	0.5763
Median	0.8100	0.9535	-0.3627	0.7860	0.6052
Maximum	9.9906	14.0588	17.5930	28.9277	10.7525
Minimum	-16.7522	-35.4283	-18.6700	-56.8685	-10.5061
Standard Deviation	3.3637	5.7803	4.8633	7.3781	3.5020
Skewness	-0.7612	-0.9259	0.0122	-1.3003	-0.2114
Kurtosis	5.1482	7.5126	4.2205	14.4266	3.6858
Jarque-Bera Statistic	91.2820***	313.276***	19.622***	1,808.188***	8.546**

Note: * indicates that the Jarque-Bera test statistic is significant at the 10% (*), 5% (**) or 1% (***) level.

With the exception of Japan, all countries have positive mean returns. Similarly, skewness was negative for all countries except Japan. All series reported a kurtosis that is more than three; this is indicative of a fat-tailed distribution instead of a normal distribution of the returns. The Jarque-Bera tests confirm the non-normal properties of the returns series. The test statistics for all Jarque-Bera tests are significant and the null hypothesis for a normal distribution of all series is rejected at a 5% level of significance.

8.3.1.2 Trading Volume Data

In relation to the closing values of the trading volume for the composite indexes, the latest starting date of data sourced from the Yahoo finance website is on February 24, 2003; this relates to the starting date for the All Ordinaries index. It was not possible to obtain more historical data for all series from the SIRCA Thomson Reuters Tick History database. Hence, this study uses a standardized sampling period for the volume series 1 March 2003 to 30 September 2016[62] was obtained for each equity index. The daily trading volume series are used to obtain the monthly averages for each series using a simple averaging method similar to the one used to obtain monthly stock prices. With the exception of the Australian case, the

[62] There is no data available for the trading volume of the All Ordinaries index for five months from January to May 2015. Thus, for purposes of empirical analysis, the Australian volume series ranges from March 2003 up to December 2014.

dataset for each volume series consists of 163 data points.[63] The monthly series were then expressed in natural logarithmic form. Figure 8.3 shows the graphical representation of the resultant series while table 8.4 presents the summary statistics for each series after the logarithmic transformation.

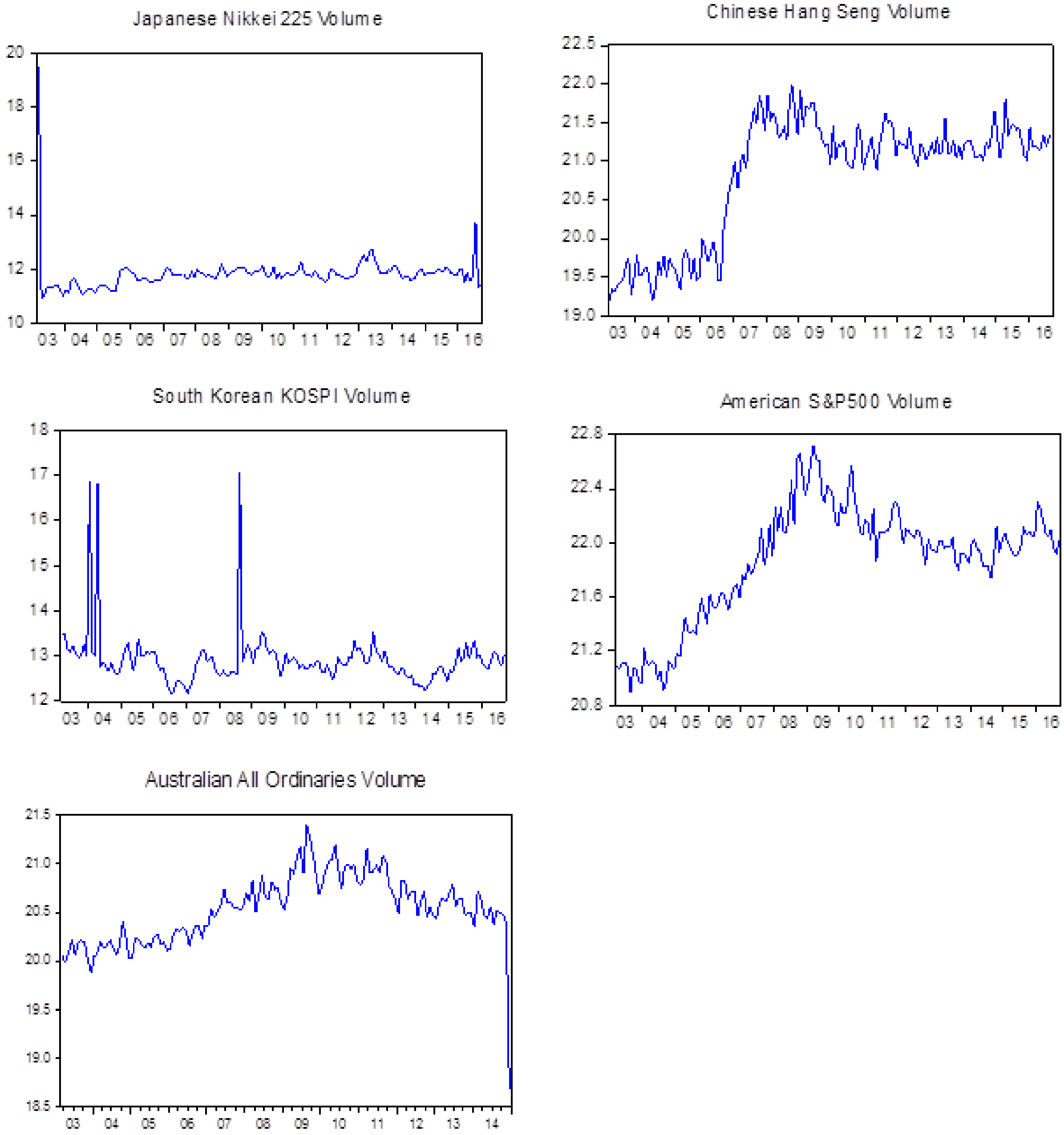


Figure 8.3: Logged Trading Volume for Stock Indexes (March 2003 to September 2016)

[63] Australia has missing data points and the volume series is truncated to 142 data points.

Table 8.4: Summary Statistics for Logged Trading Volume (Mar/03 to Sep/16)

	Australia (All Ordinaries)	China (Hang Seng)	Japan (NIKKEI 225)	Korea (KOPSI)	US (S&P 500)
Mean	20.5262	20.8280	11.8075	12.9153	21.8663
Median	20.5266	21.1551	11.7819	12.8546	21.9693
Maximum	21.4075	21.9929	19.4908	17.0593	22.7189
Minimum	18.6704	19.1853	10.8962	12.1453	20.8929
Std. Dev.	0.3414	0.7883	0.6968	0.6184	0.4318
Skewness	-0.7682	-0.8431	8.3714	4.9597	-0.5885
Kurtosis	7.2739	2.2131	92.3751	32.9618	2.6364
Jarque-Bera Statistic	136.650***	23.517***	56,155.020***	6,765.187***	10.307***

Note: The Jarque-Bera test statistic is significant at the 10% (*), 5% (**) or 1% (***) level.

For the period of study, the US (21.87) and Japan (11.81) has the highest and lowest mean monthly traded volume respectively. Based on the reported standard deviations for the five series, the highest variation in trading volume was recorded in the Chinese market has 0.6214 (0.7883^2) while the least variation in stock prices was observed in the Australian market 0.1166 (0.3414^2). With the exception of Chinese volume (2.21) and US volume (2.64), the other series have kurtosis that exceeds three and are fat-tailed; the Chinese and the US volume series have smaller tails than a normal distribution. The test statistics for Jarque-Bera test are significant at all levels of significance for all series. Thus, the null hypothesis for a normal distribution of all series is rejected at a 5% level of significance. It can be concluded that all series are not normally distributed.

The logarithmic values of the volume traded of each index were used to calculate the percentage changes in trading volume as shown in equation 8.2. Where TV_t is the percentage changes in the trading volume of a stock index in month t, V_t is the average trading volume of the stock index in month t and v_{t-1} is the average trading volume of the index in month t-1.

$$TV_t = [ln(V_t) - ln(V_{t-1})] * 100 \qquad (8.2)$$

It should be noted that the monthly values are the average trading volume for each month. Figure 8.4 shows the graphical representation of the percentage changes in volume series for the five countries while table 8.5 presents the summary statistics for the percentage changes in volume traded of the composite stock indexes.

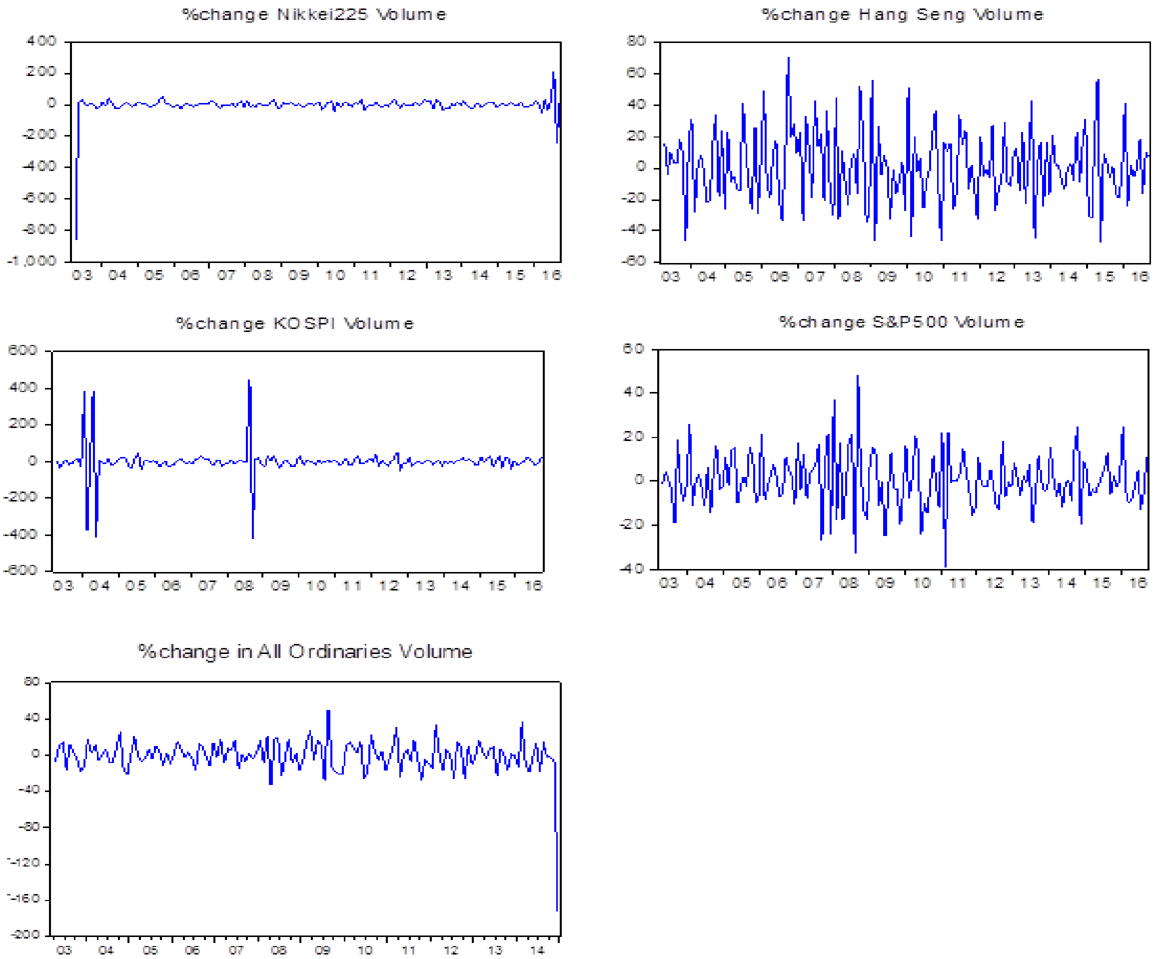


Figure 8.4: % Change in Trading Volume of all Stock indexes returns (Apr/03 to Sep/16)

Table 8.5: Summary Statistics for % Change in Trading Volume (Apr/03 to Sep/16)

	Australia (All Ordinaries)	**China (Hang Seng)**	**Japan (NIKKEI 225)**	**Korea (KOPSI)**	**US (S&P 500)**
Mean	-0.9818	1.3429	-4.9696	-0.2614	0.5824
Median	0.1902	1.5699	-1.0822	-1.0976	-0.8379
Maximum	50.5313	70.8584	205.9231	446.1432	48.4259
Minimum	-172.6039	-46.8289	-859.4631	-417.6090	-39.0965
Std. Dev.	20.4540	23.6445	74.0960	80.0084	12.7229
Skewness	-4.0511	0.2382	-9.6118	0.1368	0.2370
Kurtosis	36.5094	2.7959	111.6543	24.6523	4.1288
Jarque-Bera Statistic	6,982.5900***	1.8128	82,183.2700***	3,165.0480***	10.1161***

Note: * indicates that the Jarque-Bera test statistic is significant at the 10% (*), 5% (**) or 1% (***) level.

On average, there is a negative average percentage change in the volume traded on the Australian (-0.98), Japanese (-4.97) and Korean (-0.26) equity markets, indicating an average decline in the volume of assets traded in the three aforementioned equity markets during the period of study. Conversely, on average there is a positive percentage change in volume traded on the Chinese (1.34) and American (0.58) markets; indicating an average increase in volume traded in these two equity markets. The test statistics for all Jarque-Bera tests are significant and the null hypothesis for a normal distribution of all series is rejected at a 5% level of significance, suggesting that all of the series are not normally distributed.

8.3.2 Research Methods

Granger causality tests were used to explore causality relationships between stock indexes of Australia and its four key trading partners. Two kinds of causality tests are employed in this study; these are the linear and nonlinear causality tests. The causality testing procedure used in this study is similar to the one used by Baek and Brock (1992). As a starting point, it was necessary to examine the univariate properties of the estimated series to confirm that they were stationary,[64] as this is a necessary condition for Granger causality tests. For this reason, this study performed unit root tests on the estimated returns and percentage change in the volume series before implementing the causality tests. After the unit root testing, all series were adjusted for calendar effects. The adjusted series were used to estimate a linear bivariate VAR model. The linear bivariate VAR model was used to test for linear granger causality. The residuals of the same VAR model were adjusted for volatility effects before testing for non-linear granger causality. The discussions that follow briefly highlight the empirical tests applied prior to conducting Granger causality tests.

[64] A stationary series has mean reverting tendencies and contains no unit root while a non-stationary series follows a random walk and contains a unit root.

(i) Unit Root Testing Procedure

Two kinds of unit root tests were used to check for the presence of a unit root in this study. One type of unit root test was performed with no structural breaks while the other type was designed to test for the presence of a unit root when data has a structural break. The section that follows provides a detailed overview of unit root testing procedures before performing unit root tests to check whether the series are stationary.

- **Review of Unit Root Testing Procedures**

A review of literature indicates that two kinds of unit root tests are popular among scholars namely the Augmented Dickey Fuller (ADF) and the Phillips-Perron (PP) unit root tests (Phillips & Perron, 1988; Said & Dickey, 1984). This study shall refer to these two tests as the classical tests for unit root henceforth. The classical tests are an extension of the Dickey Fuller (DF) unit roots tests and provide a testing procedure that corrects for serial correlation and heteroscedasticity of errors (Dickey & Fuller, 1979, 1981). Popularity of the classical tests can be attributed to the fact that they have been in use since the 1980s, can easily be estimated using most statistical software and are easy to interpret.

Said and Dickey (1984) designed the traditional ADF tests with a null hypothesis that a series contains a unit root. The mathematical expressions for testing the null hypothesis as show in equations 8.3 and 8.4. Equation 8.3 has a constant and no trend while equation 8.4 has a constant and a trend term.

$$\Delta y_t = \alpha + \rho y_{t-1} + \gamma_1 \Delta y_{t-1} + \cdots + \gamma_p \Delta y_{t-p} + e_t \qquad (8.3)$$

$$\Delta y_t = \alpha + \beta t + \rho y_{t-1} + \gamma_1 \Delta y_{t-1} + \cdots + \gamma_p \Delta y_{t-p} + e_t \qquad (8.4)$$

Where Δy_t is the first difference of the stock returns, α is a constant term, β is the coefficient of the trend term, t is the trend term and ρ is the correlation coefficient of the lagged stock returns. γ_1 is the coefficient of the first difference of the first lag of the stock returns, γ_p is the coefficient of the first difference of the p^{th} lag of the stock returns and e_t is the error term.

Similar equations can be used to test for the presence of a unit root in the percentage change in volume. Ng and Perron (2001) recommend the used of the Modified Akaike Information Criterion (MAIC) to select the number of lags (p) to include in equations 8.3 and 8.4. The null hypothesis of a unit root is rejected if $\rho = 0$, and it will be concluded that a series is stationary; conversely, if $\rho < 0$, the null hypothesis of existence of a unit root cannot be rejected and a conclusion should be made that the series is non-stationary.

The alternative PP unit root test offered by Phillips and Perron (1988) is often reported alongside the ADF tests. While the ADF method improves on work by Dickey and Fuller (1979) by including lagged differenced terms in the ADF, Phillips and Perron (1988) opt to modify the DF test statistic in order to deal with the problem of possible autocorrelation of the errors. Due to this correction, there is no longer a need for including extra lagged terms when conducting the PP tests. The null and alternative hypotheses for the PP test are borrowed from the DF test. In particular, mathematical expressions for testing the null hypothesis as show in equations 8.5 and 8.6. Equation 8.5 has a constant and no trend while equation 8.6 has a constant and a trend term.

$$\Delta y_t = \alpha + \rho y_{t-1} + e_t \qquad (8.5)$$

$$\Delta y_t = \alpha + \beta t + \rho y_{t-1} + e_t \qquad (8.6)$$

Where Δy_t is the first difference of the stock return (or percentage change in volume), α is a constant term, β is the coefficient of the trend term, t is the trend term and ρ is the correlation coefficient of the lagged stock return (percentage change in volume). The term e_t represents the error that follows an independent and identically distribution (i.i.d) with a mean of zero and a constant variance ($e_t \sim IID(0, \sigma^2)$). The rejection rules for this test are as outlined for the ADF test.

Though widely accepted, the classical tests are imperfect. Notably, researchers highlight a major drawback in the framework for hypotheses testing in that they fail to account for structural breaks. A structural break occurs when a series undergoes a change in the growth rate or general trending of the series over time. Perron (1989) argues that in the presence of a structural break, classical tests are biased as they are more likely to fail to reject the null even if a series is stationary. In other words, a type II error would have occurred. To avoid making this error, researchers have attempted to address this shortcoming by adjusting the unit root testing procedure to account for the presence of one or more structural breaks.

Perron (1989) proposed a unit root testing procedure based on prior knowledge of an exogenous structural break; in Perron's paper the structural breaks were deemed to coincide with the timing of the 1929 Great crash and the 1973 oil price shock. In the same vein, one could deduce that historical periods of financial crises were accompanied by corresponding breaks in the series of the equity indices considered in this study. Table 8.6 shows the possible exogenous shocks that may translate to structural breaks for five countries considered in the causality analysis.

Table 8.6: Financial Crises from 1970 to 2007

Country	Year of Systemic Banking Crisis	Year of Currency Crisis
Australia	none recorded	none recorded
China	1998	none recorded
Japan	1997	none recorded
The United States	1988, 2007	none recorded
Korea	1997	1998

Source: Luc and Valencia (2008)

Focusing on the timeframe of data used in this study (1990 to 2014), there are two notable crises that are recorded, namely the 1997 to 1999 Asian Crisis and the 2007-2009 Global Financial Crisis (GFC). From Perron's work, one could infer that structural breaks corresponding to the timing of these crises would be seen in the series of the respective countries.

Under the null hypotheses, Perron (1989) allows for three possibilities. Model A (crash model) allows for a structural change in the level of the series, model B (changing growth model) allows for a change in the rate of growth of a series and model C (break model) allows for a structural change in the level followed by a change in the growth rate. Mathematical expressions of these models are shown in equations 8.7, 8.8, and 8.9.

$$Model\ (A) \quad y_t = \mu + dD(TB)_t + y_{t-1} + e_t \tag{8.7}$$

$$Model\ (B) \quad y_t = \mu_1 + y_{t-1} + (\mu_2 - \mu_1)DU_t + e_t \tag{8.8}$$

$$Model\ (C) \quad y_t = \mu_1 + y_{t-1} + dD(TB)_t + (\mu_2 - \mu_1)DU_t + e_t \tag{8.9}$$

Where y_t in all models represents a time series with a unit root that may have a non-zero drift. T_B represents the time of the structural break that occurs at a specific time over a period being considered ($1 < T_B < T$), $D(TB)_t$ is the dummy variable indicating when there is the structural break in the level such that $D(TB)_t = 1$ when $t = T_B + 1$ (when a level-break is present) and zero otherwise. μ is a drift parameter that changes from μ_1 to μ_2 at the time of the break (T_B). DU_t is a dummy variable indicating the change in the growth rate such that is $DU_t = 1$ when $t > T_B$ and zero otherwise. The error term e_t of all the models is specified as a white noise process with i.i.d residuals (Perron, 1989, p. 1364).

The alternative hypotheses for model A is a trend stationary series with a single structural break in the intercept of the series, B is a model allows for a change in the slope without a major change in the level of a series and C is a series with a single change in both the growth rate and level. Equations 8.10, 8.11 and 8.12 show the alternative hypotheses for the respective models.

$$Model\ (A) \quad y_t = \mu_1 + \beta t + (\mu_2 - \mu_1)DU_t + e_t \tag{8.10}$$

$$Model\ (B) \quad y_t = \mu + \beta_1 t + (\beta_2 - \beta_1)DT_t^{\ *} + e_t \tag{8.11}$$

$$Model\ (C) \quad y_t = \mu_1 + \beta_1 t + (\mu_2 - \mu_1)DU_t + (\beta_2 - \beta_1)DT_t + e_t \tag{8.12}$$

Where: y_t, DU_t, μ_1, and μ_2 are as specified in the null. $DT_t^* = t - T_B$, $DT = 1$ if $t > T_B$ and zero otherwise. This means that if $t \leq T_B$, $DU_t = DT_t = 0$. Slow growth in a series is characterised by $\beta_2 < \beta_1$.

While Perron's hypothesis framework is setup based on the notion of a known exogenous break, subsequent studies have deemed this idea rather restrictive. For this reason, Zivot and Andrews (1992) (ZA) extends Perron's work based on three models. However, ZA preferred a unit root testing procedure that determined the timing of a structural break endogenously from the data as determining one beforehand could lead to data mining. Moreover, unlike the Perron (1989) approach which allows for a structural break in the null the ZA approach fails to allow for a structural break in the null. Rather the break is only included in the alternative hypothesis of the ZA test. In this case, rejection of the null may imply two things that the series has no unit root or that the series has a unit root with structural breaks. Thus, rejection of the unit root does not mean that a series is stationary. Lee and Strazicich (2001) stress the importance of including a break in the null as it affects the outcome of unit root test and offer an alternative unit root testing procedure that includes a break in the null and the alternative hypothesis.

Lee and Strazicich (2001) unit root tests with one structural break (LS_1) are set up using a data generating process (DGP) that estimates equation 8.13. Where Z_t is a vector containing exogenous variables, $e_t = \beta e_{t-1} + \varepsilon_t$ such that: $\varepsilon_t \sim iid\ N(0, \sigma^2)$, under the null and alternative hypothesis $\beta = 1$ and $\beta < 1$ respectively. In model A, $Z_t = [1, t, D_t]'$ with $D_t = 1$ if $t \geq T_B + 1$ and zero otherwise. T_B is the time of the break. In model C, $Z_t = [1, t, D_t, DT_t]'$ where $DT_t = t - T_B$ for $t \geq T_B + 1$ and zero otherwise. The alternative hypotheses allow for a change in the intercept in model A and a combined change in the intercept and trend in model Lee and Strazicich (2004, pp. 3-4) recommend the estimation of unit root test statistics based on equation 8.14 so that the LM t-test statistic tests whether

$\phi = 0$ under the null. $\tilde{S}_t = y_t - \tilde{\psi}_x - Z_t\delta$, t=2,…,T, *t=2,...,T*; $\tilde{\delta}$ are the coefficients in the regression of Δy_t on ΔZ_t. $\tilde{\psi}_x$ is specified as a restricted maximum likelihood estimation of $\psi_x(\equiv \psi + X_0)$ which is based on $y_1 - Z_1\tilde{\delta}$. [65]

$$y_t = \delta' Z_t + e_t \tag{8.13}$$

$$\Delta y_t = \delta' \Delta Z_t + \phi \tilde{S}_{t-1} + u_t \tag{8.14}$$

Later work by Lee and Strazicich (2003) posits that the consideration of one structural break when a series has two breaks may yield biased results and result in loss of power of unit root tests. Accordingly, these authors propose a Lagrange Multiplier (LM) methodology for testing for a unit root in a series with two endogenously identified structural breaks. Lee and Strazicich (2003) use the models proposed by Perron (1989) with specific emphasis on model A and C, as the consensus among academics is that these two models adequately model most economic variables. Unit root tests with two structural breaks (LS_2) are setup using the DGP in equation 8.13. However, model A and C are specified with two breaks instead of the one. Consequently, model A has two breaks in the intercept with $Z_t = [1, t, D_{1t}, D_{2t}]'$ where $D_{1t} = 1$ and $D_{2t} = 1$, when: $t \geq T_B + 1$, otherwise $D_{1t} = D_{2t} = 0$. Model C allows for two combined breaks in the trend and intercept. Model C is specified as follows: $Z_t = [1, t, D_{1t}, D_{2t}, DT_{1t}, DT_{2t}]'$ where $DT_{jt} = t - T_{Bj}$ when $t \geq T_B + 1$, $j = 1, 2$, and zero otherwise. The unit root test statistics are calculated based on the same methodology as LS_1.

An important feature of the LS_2 hypothesis testing setup is that the null tests a series for a unit root with two structural breaks and the alternative indicates a series has no unit root with two structural breaks. In this respect, rejection of the null clearly indicates that the series is trend stationary. Although Lumsdaine and Papell (1997) (LP) offer a testing procedure with two structural breaks, the framework suffers from the same shortcoming as the ZA approach;

[65] This estimation technique is based on earlier work by Schmidt and Phillips (1992) (Lee & Strazicich, 2001; Lee & Strazicich, 2004).

there are no breaks included in the null and, thus, it is not reasonable to either affirm or reject the null hypothesis. Subsequently, it is possible to conclude there is no unit root present in a series that actually contains a unit root with structural breaks. Thus, it would appear that the method offered by Lee and Strazicich (2003) is more suitable when dealing with the scenario of two endogenous breaks.

After considering various unit root tests, this study suggests that unit root tests with structural breaks are better than the classical unit root tests. Although several scholars prefer to use classical tests, Figures 8.2 and 8.4 reveal that there may be least one structural break in the series and perhaps two. Lee and Strazicich (2003) assert that there is no harm in assuming the presence of two breaks when there are none in a series as it does not lead to major size distortion. Hence, performing unit root tests with breaks precludes possible bias[66] in the results and caters for the scenario that breaks are absent in a series. This is an interesting assertion as it implies there is little use for the classical test results, once the LS_2 results are on hand. However, it is always better to err on the side of caution as is generally encouraged in academia and adopt a certain amount of scepticism about this assertion. Therefore, this study shall perform classical tests in order to assess whether there is a major difference in the results of the unit root tests when structural breaks are included or excluded in the testing procedure. Overall, two kinds of unit root tests were conducted on all series used in this study; classical tests (ADF and PP) and a test with two structural breaks (LS_2). For structural unit root tests, this study allows for a change in the intercept and trend of each series (model C).

- **ADF and PP test results**

As there was no evidence of a deterministic trend component in the returns and percentage change in volume series, the ADF and PP tests were estimated using equations 8.3 and 8.5

[66] Results could be biased because of ignoring the presence of breaks

respectively. Both equations omit the trend component when performing the unit root tests. Table 8.7 shows the results of the unit root tests of all series. The tests results indicate that all series are stationary, since the null hypothesis for no unit root is rejected at the 5% level of significance. The next section shows the unit root test results after allowing for structural breaks in all series.

Table 8.7: Unit root tests without structural breaks

	Returns		Percentage change in volume	
	ADF test	**PP test**	**ADF test**	**PP test**
All Ordinaries (Australia)	-7.4943***	-13.8545***	-9.9760 ***	-9.1290***
Hang Seng (China)	-4.6084***	-14.7570***	-17.1241***	-19.4355***
NIKKEI 225 (Japan)	-4.9395***	-14.2040***	-33.2430***	-123.0591***
KOSPI (Korea)	-4.7523***	-13.4054***	-21.8110***	-44.7530***
S&P 500 (US)	-3.3172**	-13.9711***	-17.3514***	-19.8572***

Note: The Augmented Dickey-Fuller tau statistic is significant at the 10% (*), 5% (**), or 1% (***) level

- **Lee-Strazicich Test Results**

Table 8.8 shows unit root test results for all series after allowing for two structural breaks in the series. The null hypothesis for presence of a unit root is rejected at a 5% level of significance. The outcome of the LS_2 tests is similar to the ADF and PP test results; the unit root tests indicate that the returns of the stock indexes and the percentage change in volume are stationary at any level of significance. Overall, it would appear that in most cases the location of the significant breaks in the level and/or trend of the series correspond to the timing of the GFC and Asian crisis. For instance, the second break of the All Ordinaries and the first break of the S&P 500 returns, KOSPI volume, and S&P 500 volume series correspond to the timing of the GFC. It is worth noting there is no difference in the conclusions arrived at whether a structural break is included or excluded from the analysis. Now that it has been determined that the returns and percentage change in volume series are stationary, all series can be adjusted for calendar effects. The discussion that follows provides a detailed explanation of how the calendar adjustments were performed.

Table 8.8: Unit root tests with structural breaks

Variable	t-statistic	First break	Second break	k
All Ordinaries returns	-14.5151***	Feb-2006	Oct-2008	0
Hang Seng returns	-14.7903***	May-1997	Jun-2000	0
NIKKEI 225 returns	-14.2663***	Apr-1994	Aug-1999	0
KOSPI returns	-13.5529***	May-1998	May-2001	0
S&P 500 returns	-7.3047***	Mar-2008	Jan-2013	7
All Ordinaries volume	-5.7199**	Oct-2006	Jul-2013	2
Hang Seng volume	-16.2821***	Jun-2006	Aug-2010	0
NIKKEI 225 volume	-10.4117***	Dec-2010	Oct-2012	3
KOSPI volume	-22.5128***	Aug-2008	Jan-2015	1
S&P volume	-16.4176***	Aug-2007	Jan-2011	0

Note: **, *** indicate the significance at a 5% and 1% level of significance respectively. Table 2 of Lee and Strazicich (2003, p. 1084) outlines the critical values for the break model. Critical values for the 1, 5, and 10 % level of significance of the break models are -5.823, -5.286, and -4.989 respectively. The variable "k" is the lag selected using on the general-to-specific technique with the maximum starting value of k being set to 8 lags as recommended by Lee and Strazicich (2003, p. 1086).

(ii) Calendar Effects Testing Procedure

From the unit root tests results it has been determined that all series are stationary. All the returns and percentage change in volume can now be adjusted for calendar effects. This study starts by considering a popular and well-documented market anomaly or calendar effect that occurs in the month of January. This anomaly is commonly referred to as the January effect and it is characterised by higher security prices (and/or earnings) in January than in other months of the year. Several authors have endeavoured to explain the reasons why this anomaly occurs. Some explanations for the January effect are that it is: i) A result of asset mispricing in the last few months of the year; ii) Possibly a reflection of investor expectations of company announcements that occur in the beginning of the year in some financial markets; and iii) A reflection of investor selling at a time that ensures tax benefits (Dbouk, Jamali, & Kryzanowski, 2013; Easterday & Sen, 2016; Haug & Hirschey, 2006; Klein & Rosenfeld, 1991). While the January effect is often associated with the US financial market, a study by Gu (2003) suggests that it may be on the decline. He and He (2011) further assert that market dynamics may be changing such that the November effect may be replacing the January effect regardless of the nature of market capitalisation (whether large and small market capitalisation). Moreover, Lumsdaine, and Papell (1997) state that the January effect is not prevalent in all US equity markets at all times. While the tax timing in the US may explain the reason why the January effect occurs, it fails to explain why this anomaly occurs in other countries with different tax reporting times. Nevertheless, since it is possible that the January effect will be present in some of the five markets being studied, the empirical analysis that follows checks whether this anomaly is observed over the period studied. Moreover, this study recognises that even when the January effect is absent, there may be another calendar effect that is experience in the equity markets being studied. For this reason, this study checks for the presence of different month-of-the-year effects using the testing approach proposed by Marrett and Worthington (2011).

The month-of-the-year testing procedure was performed in the following manner. Twelve dummy variables were constructed for every month of the year. Each dummy variable is a binary variable that takes the value of one in the month of interest and zero otherwise. For example, in the case of January, the January dummy would be equal to one in the months of January and zero in the other months of the different years; the dummy is equal to zero in the months of February through to December. Each series was then regressed on the twelve dummy variables; a constant coefficient was excluded from the regression equation to avoid the problem of the dummy trap. Equation 8.15 shows the mathematical expression of the regression for the case of the stock returns. A similar regression was used to test for calendar effects in the percentage change in volume series; the mathematical expression of the regression is given in equation 8.16. Where R_t represents the average returns, β represents the parameters to be estimated, $i = 1,2, \dots ,12$ depending on the month of interest (e.g., i is equal to one in the month of January, two in the month of February, and so on). TV_t is the percentage change in the trading volume of a stock index in month t and M_{it} represents the dummy variables constructed for the twelve months. ε_t and v_t are the error terms.

$$R_t = \sum_{i=1}^{12} \beta_i M_{it} + \varepsilon_t \quad (8.15)$$

$$TV_t = \sum_{i=1}^{12} \beta_i M_{it} + v_t \quad (8.16)$$

Table 8.9 reports the estimated coefficients for the month-of-the-year effect (MOY) in stock returns for the five countries. With the exception of the Australian market, all other markets fail to exhibit the January effect for the period of study. Even in the case of Australia, the January coefficient is weakly significant and only significant at the 10 percent level of significance. For purposes of this study a five percent level of significance will be used to determine whether the effect is significant, thus, the seeming presence of the January effect in Australia will be disregarded. Accordingly, it is concluded that there is no January effect in the monthly stock returns of the five markets. In the case of Australia, significantly higher average returns are reported in the month of April. This is similar to what Dbouk et al. (2013). However, unlike the aforementioned authors, this study failed to find significantly higher returns in the months of July and December.[67] In regards to the other equity markets, significantly higher average returns are reported in the months of November and December in the US. This is an indication of a December effect instead of a January effect in the American equity market. Surprisingly, no significant calendar effects were found in the Chinese, Japanese or Korean markets.

Table 8.9: Estimated coefficients for calendar effects in stock returns

	All Ordinaries (Australia)	Hang Seng (China)	NIKKEI 225 (Japan)	KOSPI (Korea)	S&P 500 (US)
January	1.2486*	-1.8441	-1.0925	0.5227	0.3634
	(0.6591)	(1.1392)	(0.9623)	(1.4604)	(0.6861)
February	0.9192	1.0889	0.2638	-0.0574	0.6980
	(0.6591)	(1.1392)	(0.9623)	(1.4604)	(0.6861)
March	0.3612	-0.3612	0.8485	-0.5212	0.4213
	(0.6591)	(1.1392)	(0.9623)	(1.4604)	(0.6861)
April	**1.6401****	1.0811	0.3311	2.3910	0.4491
	(0.6591)	(1.1392)	(0.9623)	(1.4604)	(0.6861)

[67] This may be due to use of data of different frequency and the examination of data from different time periods. Dbouk et al. (2013) uses daily data for the All Ordinaries from September 1996 and the series contains 2,635 observations, whereas, this study uses monthly averages from June 1990 to September 2016.

	All Ordinaries (Australia)	Hang Seng (China)	NIKKEI 225 (Japan)	KOSPI (Korea)	S&P 500 (US)
May	0.2536	1.2165	0.3741	-0.4140	1.1770*
	(0.6591)	(1.1392)	(0.9623)	(1.4604)	(0.6861)
June	-0.7093	0.4349	-0.1775	-0.2281	0.5096
	(0.6468)	(1.1179)	(0.9443)	(1.4331)	(0.6733)
July	0.9221	1.1657	0.2773	0.7961	0.0127
	(0.6468)	(1.1179)	(0.9443)	(1.4331)	(0.6733)
August	0.3135	0.5250	-1.0904	-0.9255	0.0703
	(0.6468)	(1.1179)	(0.9443)	(1.4331)	(0.6733)
September	-0.3369	-0.1608	0.3039	-0.2519	0.0842
	(0.6468)	(1.1179)	(0.9443)	(1.4331)	(0.6733)
October	-0.1363	1.1138	-0.7798	-0.4627	-0.4294
	(0.6591)	(1.1392)	(0.9623)	(1.4604)	(0.6861)
November	0.2701	1.7498	-0.7044	1.7057	**2.0218*** **
	(0.6591)	(1.1392)	(0.9623)	(1.4604)	(0.6861)
December	0.2619	0.5422	0.5962	-0.4962	**1.6004** **
	(0.6591)	(1.1392)	(0.9623)	(1.4604)	(0.6861)

Note: Coefficients for each month are given in each cell followed by the standard errors in parentheses; *, **, and *** are statistically significant at, respectively, the 10, 5, and 1% level.

The percentage change in trading volume variables were also checked for calendar effects. Table 8.10 reports the results of the test for the month-of-the year-effects. For Australia, there is a significantly higher percentage change in the volume of stocks traded in February and August. Conversely, there is a significantly lower percentage change in the volume of stocks traded in July and December during the period under study. For China, the percentage change in volume of stocks traded is significantly higher in January and September. However, the percentage change in volume of stocks traded in the Chinese market is significantly lower in February. Japanese markets only show evidence of significantly lower percentage change in trading volumes in the month of April. At a five percent level of significance, there is no significant evidence of any calendar effects in the Korean equity markets. America has significantly lower percentage change in volume of stocks traded in February and December. Conversely, there are significantly higher percentage changes in the volume of stocks traded in January and September. Overall, there is only significant evidence of the January effect in the Chinese and American markets. This is an interesting finding given that an examination of the returns found no evidence of the January effect in the equity markets under study. These findings illustrate the importance of the contemporaneous examination of volume and stock returns as it could provide more insight into investor behaviour and equity market dynamics.

Table 8.10: Estimated coefficients of calendar effects in trading volume

	Australia[68]	China	Japan	Korea	US
January	0.4132	**27.6806*** **	15.5948	32.1876	**17.3064*** **
	(5.3601)	(5.8250)	(20.5273)	(22.0842)	(3.1015)
February	**15.6279*** **	**-20.3642*** **	3.4489	-28.0858	**-6.4538** **
	(5.3601)	(5.8250)	(20.5273)	(22.0842)	(3.1015)
March	8.2588	9.9095*	-4.0847	-0.5972	3.5121
	(5.3601)	(5.8250)	(20.5273)	(22.0842)	(3.1015)
April	-9.2576*	0.3677	**-63.3001*** **	35.1842	-0.6778
	(5.1319)	(5.6131)	(19.7806)	(21.2808)	(2.9887)
May	6.2905	-5.4240	0.1242	-37.6293*	0.3137
	(5.1319)	(5.6131)	(19.7806)	(21.2808)	(2.9887)
June	6.2842	8.0068	-4.7804	-4.5706	-1.7857
	(5.1319)	(5.6131)	(19.7806)	(21.2808)	(2.9887)
July	**-16.6755*** **	-7.9064	9.1374	7.0612	-1.6170
	(5.1319)	(5.6131)	(19.7806)	(21.2808)	(2.9887)
August	**12.6203** **	2.2682	-16.4956	26.7239	-4.4783
	(5.1319)	(5.6131)	(19.7806)	(21.2808)	(2.9887)
September	2.4284	**14.0442** **	7.2235	-22.0806	**8.5229*** **
	(5.1319)	(5.6131)	(19.7806)	(21.2808)	(2.9887)
October	-7.5081	5.0563	3.4248	-1.4058	5.1555*
	(5.1319)	(5.8250)	(20.5273)	(22.0842)	(3.1015)
November	-5.2753	-6.9046	-1.3053	-7.7343	-5.8467*
	(5.1319)	(5.8250)	(20.5273)	(22.0842)	(3.1015)
December	**-22.7177*** **	-10.8728*	-5.6790	-2.6715	**-6.7152** **
	(5.1319)	(5.8250)	(20.5273)	(22.0842)	(3.1015)

Note: Coefficients for each month are given in each cell followed by the standard errors in parentheses; *, **, *** are statistically significant at, respectively, the 10 %, 5 % and 1 % level.

Based on the findings of the calendar effect tests, the returns adjusted in the following manner. The Australian returns series was adjusted for an April effect and the US returns series was adjusted for the November and December effects. These adjustments were facilitated by consideration of the significant dummy variables for the aforementioned months. No calendar effects were found in the Chinese, Japan, and Korean returns series. In

68 No trading-volume data is available for the All Ordinaries index for five months (January to May 2015). Therefore, the Australian month-of-year equation is estimated using April 2003 to December 2014 data.

addition to the data specific adjustments for calendar effects, this study follows Baek and Brock (1992),[69] and Francis, Mougoué, and Panchenko (2010); (Phillips & Perron, 1988) and also adjusts all returns for the January effect.

Based on the findings of the calendar effect tests, the percentage change in volume series adjusted in the following manner. The Australian volume series was adjusted for the February, July, August, and December effects. The Chinese volume series was adjusted for January, February, and September effects. The Japanese volume series was adjusted for the April effects. No calendar effects were identified in the Korean volume series. The US volume series was adjusted for January, February, September, and December effects. Apart from the data specific adjustments, an adjustment for January effect was made even if it was found to be insignificant in all markets except the US.

(iii) Adjustments for Calendar effects

Given that the significant month-of-the-year effects have been identified, this study will now proceed to adjust for calendar effects in the mean and variance using a two-step procedure proposed by Silvapulle and Choi (1999). In the first step, the mean and variance for the relevant returns, and volume series are estimated. To understand how this is done it is worthwhile to consider how this adjustment was performed on the returns series. The mean and variance equations for adjusting the returns series can be expressed mathematically as shown in equations 8.17 and 8.18.

Mean equation: $$M_{1,t} = D_t \beta_M + e_t \tag{8.17}$$

Variance equation: $$\ln(\hat{e}_t^2) = D_t \varphi_M + u_t \tag{8.18}$$

[69] A study by Baek and Brock (1992) found similar results of insignificant January effects for the Korean stock market. In particular, January dummies were found to be insignificant in all mean equations of estimated volatility models. There were mixed results of the significance of the January dummies in the variance equations; the January effect seemed significant in two sampled periods and insignificant in one sample period. Nevertheless, Baek and Brock (1992) stressed on the importance of considering the January dummy in the analysis of changes in equity markets due to past studies that identify the January effect as essential to understanding movements in financial markets.

Where $M_{1,t}$ stands for the mean returns and D_t is a vector of dummy variables representing the month-of-year-effect. β_M and φ_M represent the parameter vectors for the estimated equations. e_t and u_t are the residuals for the estimated equations. The dependent variable in the variance equation 8.18 is the natural logarithm of the squared value of residuals obtained from the mean equation 8.17. The choice of which dummy variables to include is in part data dependent, based on the results of the month-of-the-year tests. The January effect is considered in addition to the significant effects for this adjustment exercise. If no significant effects are identified, the mean and the variance are adjusted for the January effect only. Table 8.11 shows a summary of all the adjustments are made to the returns and volume series.

Table 8.11: Summary of Calendar Adjustments

Variable	Calendar adjustment months
All Ordinaries returns	January, April
Hang Seng returns	January
NIKKEI 225 returns	January
KOSPI returns	January
S&P 500 returns	January, November, December
All Ordinaries volume	January, February, July, August, December
Hang Seng volume	January, February, September
NIKKEI 225 volume	January, April
KOSPI volume	January
S&P 500 volume	January, February, September, December

In the second step, the residuals of the mean equation are standardised as shown in equation 8.19[70]. Where $M^*_{1,t}$ represents the standardised residuals of the returns of a given country, e_t is the error term obtained from equation 8.17 and $D_t\varphi_M$ stands for the estimated values of variance as obtained from equation 8.18. Similar equations were estimated for the percentage change in volume series.

[70] This method of standardization is similar to the one employed by Lin et al. (2013).

$$M_{1,t}^{*} = \frac{e_t}{exp\left(\frac{D_t \varphi_M}{2}\right)} \tag{8.19}$$

Figures 8.5 and 8.6 provide the graphical representations of the adjusted returns and volume series respectively. The calendar-adjusted series can now be used to perform the linear and nonlinear granger causality tests.

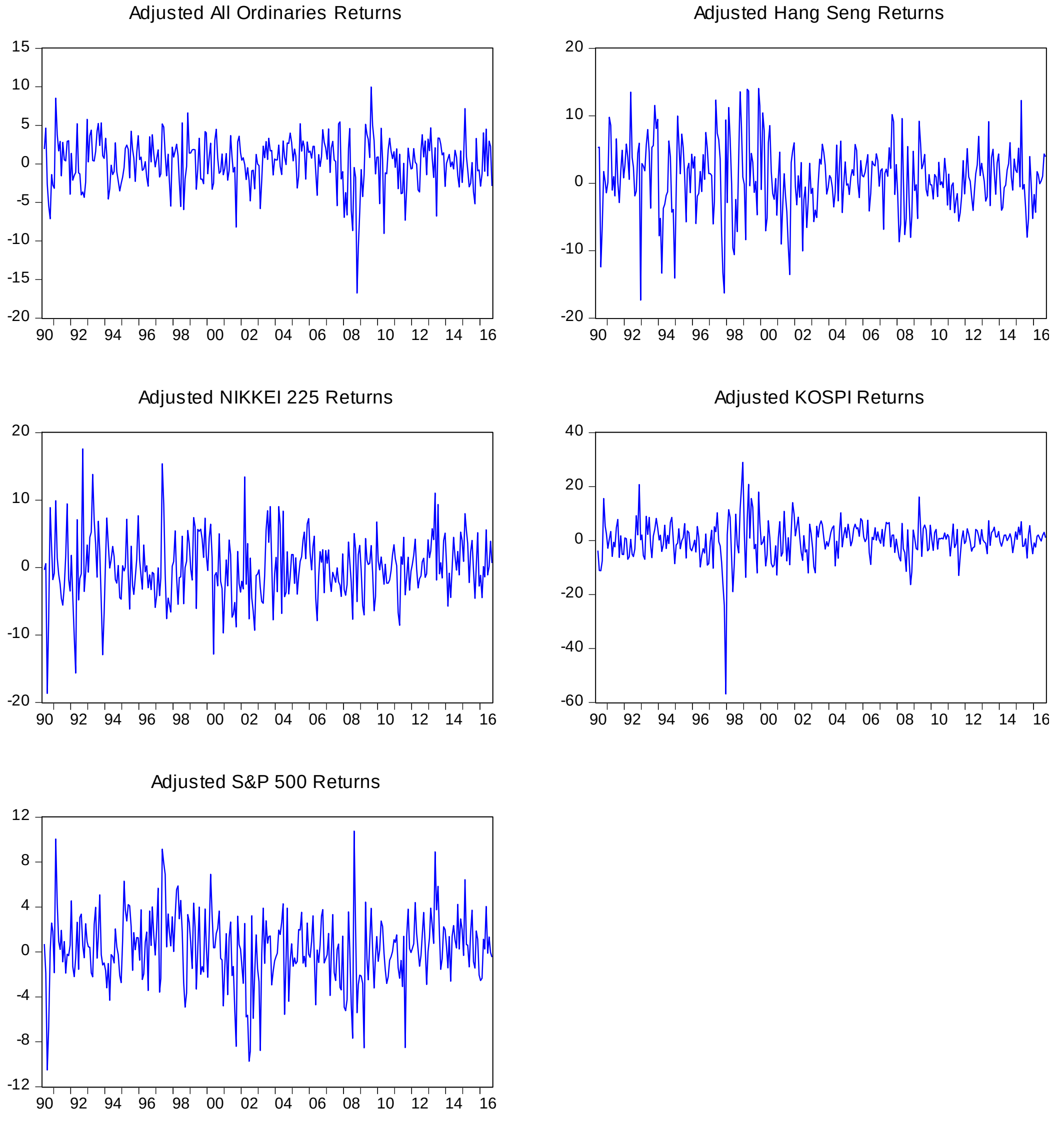


Figure 8.5: Adjusted Returns Series (May/90 to Sep/16)

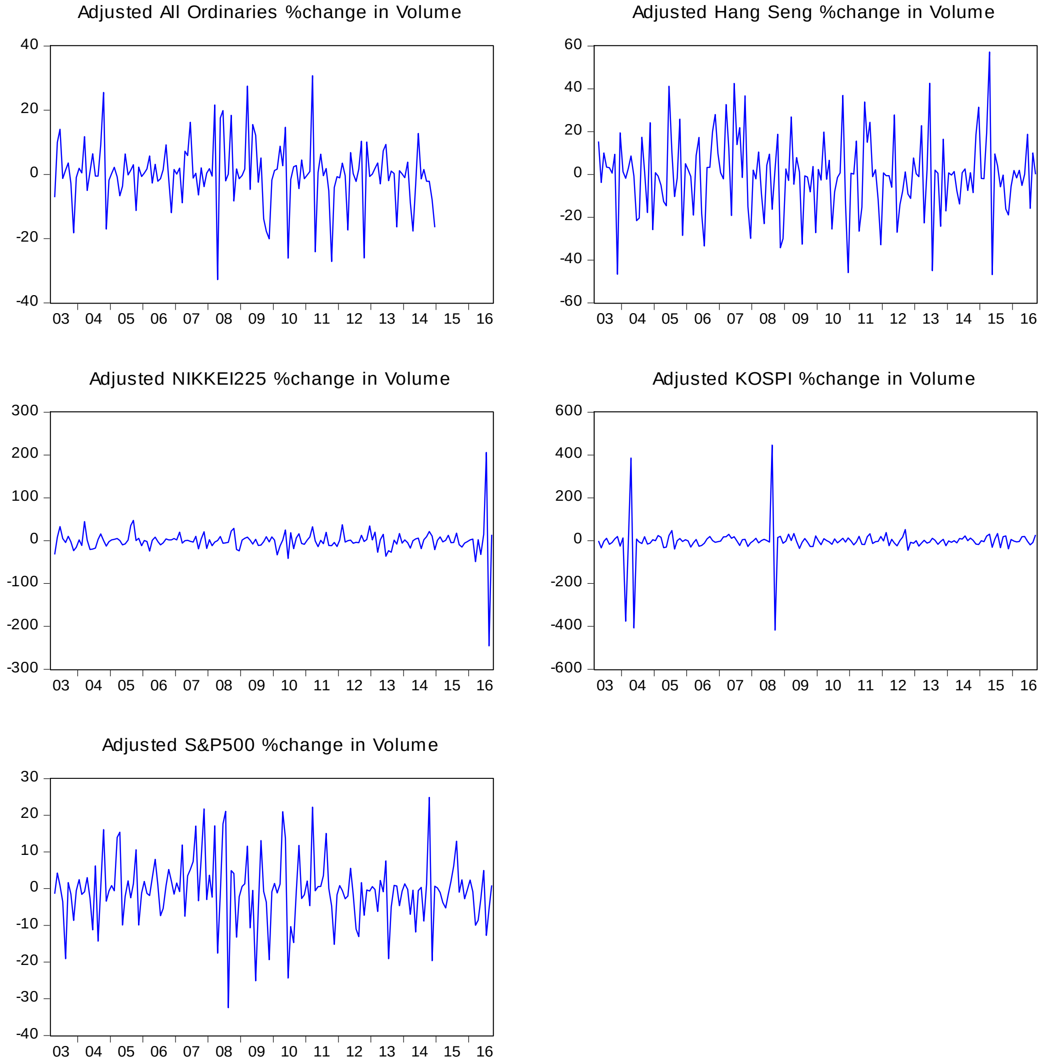


Figure 8.6: Adjusted % Change in Volume series (Mar/03 to Sep/16)

8.3.3 Empirical Analysis and the Results

i. Linear Granger Causality

The concept of linear Granger causality was first introduced by Granger (1969) who argued that Granger Causality occurs when past values of one series (A_t) can be used to predict the current value of another series (B_t). A_t is said to *Granger cause* B_t if it contains information that can be used to predict series B_t and vice versa. The nature of causality may be unidirectional or bidirectional. Unidirectional causality occurs when A_t *Granger cause* B_t but B_t does not *Granger cause* A_t. Bi-directional causality is when A_t *Granger causes* B_t and B_t *Granger cause* A_t; in other words, the two variables are interdependent.

Investigation of Granger causality relationships between economic or financial variables can form the basis for risk management. For instance, a study on causal relationships between world oil and agricultural commodity prices could reveal that causal relationships exist (Nazlioglu & Soytas, 2012). If this is the case, importers and exporters of either commodity could hedge against anticipated fluctuation in prices of either commodity by using forward or future contracts. This subsection focuses on the analysis of two financial variables; the stock returns and the percentage change in trading volume. The procedure followed for linear causality tests is discussed in this subsection while the nonlinear causality testing procedure is the subsequent subsection. It is worthwhile to note at this point that both tests for Granger causality shall be used to examine the presence or absence of these four causal relationships:

a) Stock returns for country A *Granger causes* stock returns in country B
b) Stock returns in country B *Granger cause*s stock returns in country A
c) Percentage change in volume in country A *Granger causes* stock returns in country A
d) Returns in country A *Granger causing* percentage change in volume in country A

In order to initiate the linear Granger causality tests linear bivariate vector autoregressive (VAR) models were constructed using the calendar adjusted series for stock returns and percentage change in trading volume series. The bivariate VAR models checked for existence of short-run causal relationships between two series. Granger (1969) recommends that when two series are level stationary[71] (meaning they are integrated of order zero I (0)), the Granger causality relationship can be tested using the bivariate vector autoregressive (VAR) model in equations 8.20 and 8.21.

$$A_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i} A_{t-i} + \sum_{i=1}^{k} \alpha_{2i} B_{t-i} + \varepsilon_{1t} \qquad (8.20)$$

$$B_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i} A_{t-i} + \sum_{i=1}^{k} \beta_{2i} B_{t-i} + \varepsilon_{2t} \qquad (8.21)$$

Where $\mathrm{A_t}$ and $\mathrm{B_t}$ represent returns (or percentage change in volume) series, $\mathrm{A_{t-i}}$ and $\mathrm{B_{t-i}}$ are the i[th] lagged coefficients of $\mathrm{A_t}$ and $\mathrm{B_t}$ respectively, α_0 and β_0 are constant terms, and ε_{1t} and

[71] The results of the unit root tests in tables 8.7 and 8.8 indicate that the stock returns and the percentage change of trading volume series are level stationary.

ε_{2t} are the error terms of the estimated VAR models. Series B_t *Granger causes* series A_t if any α_{2i} is not equal to zero and A_t *Granger causes* B_t if any β_{1i} is not equal to zero. Thus, if all α_{2i} and β_{1i} are zero, there is no causal relationship between A_t and B_t. Since Granger causality tests are sensitive to the variation in the lag-length, the number of lags used in the tests was determined by estimating unrestricted VAR models between different pairs of series. Four lag selection criteria were used to determine the optimal number of lags to include in the linear bivariate VAR models; these were the finite prediction error, Akaike information criterion, Schwarz information criterion and the Hannan-Quinn information criterion. Tables 8.12 and 8.13 shows the optimal lag length identified for the pairwise Granger causality tests.

Table 8.12 presents the linear Granger causality test results for the returns of the five countries. The null hypothesis checks for Granger non-causation, whereby a rejection of the null hypothesis means that a causal relationship exists. At a five percent level of significance, the GC test results highlight three causal relationships from China-to-Australia, US-to-Australia, and Australia-to-Japan.

Table 8.12: Linear Granger Causality Tests Results –Returns

Null hypothesis	F-Statistic	Lag
China Returns $-/\rightarrow$Australia Returns	7.4129***	1
Japan Returns $-/\rightarrow$Australia Returns	1.1864	1
Korea Returns $-/\rightarrow$Australia Returns	1.7215	1
US Returns $-/\rightarrow$Australia Returns	3.2665***	8
Australia Returns $-/\rightarrow$China Returns	0.5828	1
Australia Returns $-/\rightarrow$Japan Returns	4.5554**	1
Australia Returns $-/\rightarrow$Korea Returns	0.0206	1
Australia Returns $-/\rightarrow$US Returns	1.1977	8

Notes:

1. Granger causality tests check for non-causation between two series. The null hypothesis of each test is stated in the following manner.H_0: $\text{Country A Returns } -/\rightarrow \text{ Country B Returns}$, where "$-/\rightarrow$" stands for "does not *Granger cause*".
2. * indicates that the coefficient is significant at the 10% (*), 5% (**) or 1% (***) level

Linear Granger causality tests for stock returns and percentage change in volume traded are contained in table 8.13. At a five percent level of significance, only one causal relationship was found from the US returns to the US percentage change in volume traded. Two causal relationships were found from the percentage change in volume to returns in the Japanese and Korean stock markets.

Table 8.13: Linear Granger Causality Tests Results –Returns-Volume

Null hypothesis	F-Statistic	Lag
Australia returns −/→Australia %Δ in volume	0.9509	1
China returns −/→China %Δin volume	1.7793	2
Japan returns −/→Japan %Δin volume	2.2371*	4
Korea returns −/→Korea %Δin volume	1.7064	7
US returns −/→US %Δ in volume	5.6046***	4
Australia %Δ in volume −/→ Australia returns	0.0140	1
China %Δ in volume −/→China returns	2.2907	2
Japan %Δ in volume −/→Japan returns	3.3522**	4
Korea %Δ in volume −/→Korea returns	3.1293***	7
US %Δ in volume −/→US returns	1.2292	4

Notes:
1. Granger causality tests check for non-causation between two series. The null hypotheses of the first five tests and the last five tests are stated in the following manner respectively: $\mathrm{H_0}$: Country A Returns −/→ Country A %Δ in volume and $\mathrm{H_0}$: Country A %Δ in volume −/→ Country A Returns.
2. Where "−/→" stands for "does not *Granger cause*" and "%Δ" stands for "percentage change" .
3. * indicates that the coefficient is significant at the 10% (*), 5% (**) or 1% (***) level

ii. Nonlinear Granger Causality

The nonlinear Granger causality technique that is used in this study is the modified Hiemstra and Jones (1994) testing framework as developed by Diks and Panchenko (Lin et al., 2013; Perron, 1989). This testing framework can best be understood by considering an example. Accordingly, suppose there are two stationary series $\mathrm{A_t}$ and $\mathrm{B_t}$. In order to test for nonlinear causality between the two series conditional probabilities will be employed in the following manner. Let A_t^n represent an n-length vector for $\mathrm{A_t}$ such that the length of the vector can be defined as shown in equation 8.22; where $n \geq 1, t \geq 1$.

$$A_t^n = \{\mathrm{A_t}, \mathrm{A_{t+1}}, \mathrm{A_{t+2}}, \dots, \mathrm{A_{t+n-2}}, \mathrm{A_{t+n-1}}\} \qquad (8.22)$$

If the letter L is used to denote a lag operator then L_A and L_B represent the lengths of the lag vectors for series $\mathrm{A_t}$ and $\mathrm{B_t}$ respectively. The lagged vector series can be denoted by $A_t^{L_A}$ and $B_t^{L_B}$ and are specified as shown in equations 8.23 and 8.23 b.

$$A_{t-L_A}^{L_A} = \{\mathrm{A}_{\mathrm{t}-L_A}, \mathrm{A}_{\mathrm{t}-L_A+1}, \mathrm{A}_{\mathrm{t}-L_A+2}, \dots, \mathrm{A}_{\mathrm{t}-1}\}, t = L_A + 1, L_A + 2, \dots \quad (8.23\text{ a})$$

$$B_{t-L_B}^{L_B} = \{\mathrm{B}_{\mathrm{t}-L_B}, \mathrm{B}_{\mathrm{t}-L_B+1}, \mathrm{B}_{\mathrm{t}-L_B+2}, \dots, \mathrm{B}_{\mathrm{t}-1}\}, t = L_B + 1, L_B + 2, \dots \quad (8.23\text{ b})$$

The following conditions must hold in order to initiate the conditional probability framework. Let $L_A \geq 1$, $L_B \geq 1$, and k denote a constant such that $k > 0$. Then $\mathrm{B_t}$ does not strictly *Granger cause* $\mathrm{A_t}$ if:

$$\begin{aligned} P(\|A_t^n - A_s^n\| < k \,|\, \|A_{t-L_A}^{L_A} - A_{s-L_A}^{L_A}\| < k, \|B_{t-L_B}^{L_B} - B_{s-L_B}^{L_B}\| < k) \\ = \qquad P(\|A_t^n - A_s^n\| < k \,|\, \|A_{t-L_A}^{L_A} - A_{s-L_A}^{L_A}\| < k) \end{aligned} \quad (8.24)$$

Where $P(.)$ denotes the probability, $\|.\|$ denotes the maxim norm.

The left hand side of equation 8.24 represents the conditional probability that the two arbitrary n-length of $\mathrm{A_t}$ are within a k distance of each other given that the lagged vectors of $\mathrm{A_t}$ and $\mathrm{B_t}$ are also within k distance of each other. The right hand side of equation 8.24 represents the conditional probability that two arbitrary vectors of $\mathrm{A_t}$ are within k distance of each other given that their corresponding lagged vectors being within k distance of each other. Using the framework developed by Gallant et al. (1992) and improved by Lin et al. (2013) correlation integrals of joint probabilities can now be specified in order to implement the test for nonlinear causality. Equation 8.25 shows the expression of the ratio of conditional probabilities used to perform the tests. The joint probabilities that are used in equation 8.25 are as estimated as shown in equations 8.26a to 8.26d.

$$\frac{CI(n+L_A\,, L_B, k)}{CI(L_A\,, L_B, k)} = \frac{CI(m+L_A\,, \mathrm{k})}{CI(L_A\,, \mathrm{k})} \quad (8.25)$$

$$CI(n + L_A\,,\ L_B, k) \equiv \mathrm{P}\left(\|A_{t-L_A}^{n+L_A} - A_{s-L_A}^{n+L_A}\| < k, \|B_{t-L_B}^{L_B} - B_{s-L_B}^{L_B}\| < k\right), \quad (8.26\text{a})$$

$$CI(L_A\,,\ L_B, k) \equiv\ P\left(\|A_{t-L_A}^{L_A} - A_{s-L_A}^{L_A}\| < k, \|B_{t-L_B}^{L_B} - B_{s-L_B}^{L_B}\| < k\ \right) \quad (8.26\text{b})$$

$$CI(m + L_A, \mathrm{k}) \equiv \left(\left\|A_{t-L_A}^{n+L_A} - A_{s-L_A}^{n+L_A}\right\| < k\right) \quad (8.26c)$$

$$CI(L_A, \mathrm{k}) \equiv P\left(\left\|A_{t-L_A}^{L_A} - A_{s-L_A}^{L_A}\right\| < k\right) \quad (8.26d)$$

Lin et al. (2013) followed three steps when testing for nonlinear causality. Step one involved estimating a linear bivariate VAR model and storing the residuals of the estimated model[72]. In step two, the nonlinear causality tests were performed on the residuals and residuals that had been adjusted for volatility effects. An EGARCH (1, 1) was used to purge volatility effects from the residuals. Specifically, an EGARCH (1, 1) model was estimated and the standardized residuals were obtained by dividing the residuals of the bivariate VAR model by the estimated volatility of the EGARCH (1, 1) model. The results of the tests were discussed in the third step. This study used a similar procedure.[73] The results of the nonlinear Granger causality tests are contained in table 8.14.

Table 8.14: Nonlinear Granger Causality Tests Results –Returns

Null hypothesis	Before filtering T-statistic	After EGARCH filtering T-statistic
China Returns −/→Australia Returns	2.185**	1.166
Japan Returns −/→Australia Returns	-0.683	-0.545
Korea Returns −/→Australia Returns	0.755	1.160
US Returns −/→Australia Returns	0.610	0.505
Australia Returns −/→China Returns	-0.401	-0.243
Australia Returns −/→Japan Returns	0.300	0.159
Australia Returns −/→Korea Returns	0.824	0.684
Australia Returns −/→US Returns	0.966	1.063

Notes:

1. Granger causality tests check for non-causation between two series. The null hypothesis of each test is stated in the following manner. H_0: Country A Returns $-/\rightarrow$ Country B Returns , where "−/→" stands for "does not *Granger cause*".
2. * indicates that the coefficient is significant at the 10% (*), 5% (**) or 1% (***) level.
3. All tests were performed with one lag (n=1) and a bandwidth of 1.5 (k=1.5).

[72] This step is only necessary if a researcher has not estimated a bivariate VAR model. Given that this study has already estimated linear bivariate VAR models when performing the linear causality tests, it was not necessary to estimate bivariate VAR models again.

[73] Diks and Panchenko (2005, 2006) developed the nonparametric Granger causality testing technique that is used in this study. One of the co-authors, Valentyn Panchenko, provides programs and interfaces that can be used to perform the nonlinear Granger causality tests in Microsoft Windows, C programming language and Microsoft Command Prompt. This study uses the GCtest-win.exe program to execute the nonlinear Granger causality tests. This program is available for download on Valentyn Panchenko's website at the University of New South Wales School of Economics (Panchenko, 2017).

At a five percent level of significance there is only one causal relationship identified from the Chinese Hang Seng returns to the Australian All Ordinaries returns; this causal relationship is only evident in the data before filtering from volatility effects, no causal relationship is identified in the data that has been filtered for volatility effects. No other nonlinear causal relationship was found.

Table 8.15 shows the nonlinear Granger causality test results for returns and percentage change in volume. All tests were performed before, and repeated after, filtering for volatility effects. No causal relationships were identified at a five percent level of significance. It is only at a ten percent level of significance that weak nonlinear causal relationships were identified. Korean returns were found to nonlinearly *Granger cause* the percentage change in volume; this causal relationship exists regardless of whether the data was filtered or unfiltered. The results also indicate that Korean percentage change in trading volume was found to nonlinearly *Granger cause* Korean returns in the unfiltered data; no causal relationship between Korean returns and volume was found in the filtered data.

Table 8.15: Nonlinear Granger Causality Tests Results –Returns-Volume

Null hypothesis	T-statistic (before filtering)	T-statistic (after filtering)
Australia returns −/→Australia %Δ in volume	-0.012	-1.037
China returns −/→China %Δin volume	0.245	0.337
Japan returns −/→Japan %Δin volume	-1.107	0.022
Korea returns −/→Korea %Δin volume	1.590*	1.609*
US returns −/→US %Δ in volume	0.586	0.619
Australia %Δ in volume −/→ Australia returns	0.695	-0.485
China %Δ in volume −/→China returns	0.940	0.260
Japan %Δ in volume −/→Japan returns	-1.002	0.115
Korea %Δ in volume −/→Korea returns	1.357*	1.006
US %Δ in volume −/→US returns	-0.065	0.734

Notes:

1. Granger causality tests check for non-causation between two series. The null hypotheses of the first five tests and the last five tests are stated in the following manner respectively: $\mathrm{H_0}$: Country A Returns −/→ Country A %Δ in volume and $\mathrm{H_0}$: Country A %Δ in volume −/→ Country A Returns. Where "−/→" stands for "does not *Granger cause*" and "%Δ" stands for "percentage change" .
2. * indicates that the coefficient is significant at the 10% (*), 5% (**) or 1% (***) level.
3. All tests were performed with one lag (n=1) and a bandwidth of 1.5 (k=1.5).

8.3.4 Implications of the Results for this study

This subsection summarises the results of the Granger causality tests for the returns and percentage change in volume series. The implications of these findings for this study are discussed thereafter. Table 8.16 provides a summary of all the linear and nonlinear causality tests that were conducted in the Section 8.3.3. A five percent level of significance was used to identify significant cases of Granger causality.

Table 8.16: Summary of linear and nonlinear causality results

Null hypothesis	Linear Causality	Nonlinear Causality	
		Unfiltered	Filtered
China Returns −/→Australia Returns	Y	Y	N
Japan Returns −/→Australia Returns	N	N	N
Korea Returns −/→Australia Returns	N	N	N
US Returns −/→Australia Returns	Y	N	N
Australia Returns −/→China Returns	N	N	N
Australia Returns −/→Japan Returns	Y	N	N
Australia Returns −/→Korea Returns	N	N	N
Australia Returns −/→US Returns	N	N	N
Australia returns −/→Australia %Δ in volume	N	N	N
China returns −/→China %Δin volume	N	N	N
Japan returns −/→Japan %Δin volume	N	N	N
Korea returns −/→Korea %Δin volume	N	N	N
US returns −/→US %Δ in volume	Y	N	N
Australia %Δ in volume −/→ Australia returns	N	N	N
China %Δ in volume −/→China returns	N	N	N
Japan %Δ in volume −/→Japan returns	Y	N	N
Korea %Δ in volume −/→Korea returns	Y	N	N
US %Δ in volume −/→US returns	N	N	N

Notes:

1. Granger causality tests check for non-causation between two series.
2. "−/→" stands for "does not *Granger cause*" and "%Δ" stands for "percentage change".
3. Y stands for "Yes" and indicates that a causal relationship between two series is present.
4. N stands for "No" and indicates that a causal relationship between two series is absent.

The linear Granger causality test results indicate the presence of more causal relationships than the nonlinear Granger causality tests; six linear Granger causal relationships compared to one nonlinear Granger causal relationship. In regards to the Australian equity market, the linear causality test results suggest that American and Chinese equity markets play a key role in influencing movements in the Australian equity markets. These linear causality results indicate that in the short-run, movements in American and Chinese markets lead the movements in the Australian market. Therefore, past values of returns of the two aforementioned equity indexes can provide useful information for predicting the current value of the Australian All Ordinaries index. Furthermore, past movements in the Australian returns can help predict current movements in the Japanese returns. It is worth noting that there is only one case where the results indicate a linear and a nonlinear causality relationship between two variables; this is the unidirectional causal relationship from the Chinese returns to the Australian returns. From these two tests, it can be concluded that movements in the Chinese market are a more important predictor of movements in the Australian equity markets than the movements in the American market.

Now that it has been established that equity market movements in Chinese and American markets may provide clues on future movements in the Australian equity market, it follows that an examination of other possible Chinese-based and American-based variables that may provide some useful information about the potential for financial stress in the Australian financial markets. Hence, this study turns to an explorative analysis of other foreign variables especially with relation to their usefulness in predicting Australian financial stress. The section that follows discusses the variables that were identified as relevant for this analysis and the procedures used to assess the variables usefulness in gauging financial stress in Australia.

8.4 Foreign-based Indicators of Stress in Australian Equity Markets

It has widely been documented that financial crises are often accompanied by larger than usual drops in share prices and increased volatility in share prices (Edison, 2003; Kindleberger & Aliber, 2005; Patel & Sarkar, 1998). The increased volatility and rapid decline of share prices are two symptoms of panic among investors in equity markets as investors attempt to sell off shares during the early stages of a crisis in order to minimise crisis related losses at the peak of the financial crisis. This study proposes the use of two foreign-based variables that are able to detect either or both of these symptoms in order to predict the potential for a crisis in the Australian equity market. Following on the results of the Granger causality tests, this section focuses on the use of information from the Chinese and American composite stock indexes in order to predict the potential for stress and/or subsequently crisis in the Australian equity market. The basic premise is that, in the short-run, movements in Chinese and American equity markets can be used to explain movements in the Australia, such that the movements in the Chinese market have more impact on the Australian market than the American market. Specifically, if this premise was to hold true then it can also be concluded that the current values on the Chinese Hang Seng and US S&P 500 can be used to predict future movements in the Australian All Ordinaries Index. By the same logic, it can be stated that the past values of the Hang Seng and US S&P 500 can help predict current values of the All Ordinaries Index; here the two aforementioned indexes lead the movements of the Australian index. Therefore, rising levels of stress in either the Chinese or American equity markets are useful for predicting the level of stress in the Australian equity markets. Owing to the lead-lag relationship that exists between Australia and China and Australia and the US, this study focuses on the analysis of the lagged values of the American and Chinese composite indexes from this point henceforth. Consequently, this study uses the lagged values of the Chinese and American stock indexes to develop stress indicators which could predict the potential for stress in the Australian equity market. In the discussion that follows, this study explains how the stress indicators were estimated.

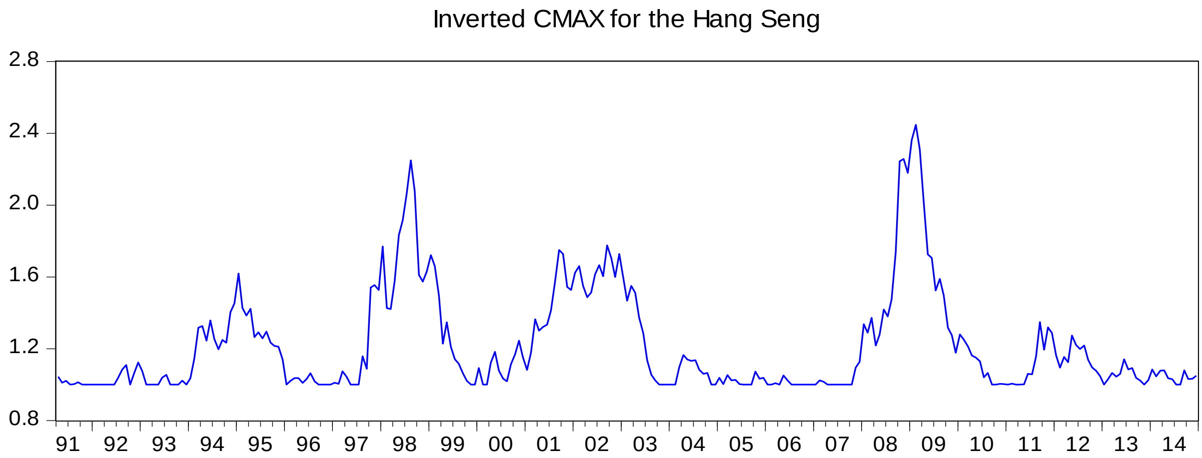
The month-end closing values of the Hang Seng (China) and (US) indexes were downloaded from the Yahoo finance website. The two series were then lagged by one month so as to develop the indicators for future stress in the Australian market. This study used an inverted

CMAX index to gauge developing stress in the Chinese and American markets. The inverted CMAX index is a modified measure the prevailing level of share volatility that is based on the CMAX measure developed by Patel and Sarkar (1998). In order to distinguish financial stress from financial crisis, this study makes some inference based on the criteria designed by Vila (2000).[74] Consequently periods of crisis are identified when the value of the inverted CMAX index are 1.5 or 2 standard deviations above the mean value of the series are indicative of stress that has developed into a crisis. A detailed discussion of the procedure for estimating the inverted CMAX variables is provided in section 4.2.1 of chapter 4.

Figure 8.7 presents the two estimated inverted CMAX series that were estimated using a 2-year window. There are two noticeable peaks in the Hang Seng CMAX in August 1998 and February 2009, which correspond to the timing of the 1997-1999 Asian financial crises and the 2007-2009 Global financial crises. The two episodes of the crisis were identified by considering values of the CMAX series that are more than two standard deviations above the mean value of the estimated CMAX series; the mean was 1.2181 and the standard deviation was 0.2910 so that the threshold to be exceeded was 1.8001 (1.2181+(2*0.2910)). A similar approach was used to identify the crises in the US market. In the American case, the mean of the US CMAX series was 1.1041 with a standard deviation of 0.1895 such that a crisis was identified when the series exceeded the threshold of 1.4831 (1.1041+(2*0.1895)). There are two peaks in the US CMAX series on September 2002 and February 2009, which correspond to the 2000-2002 Dot-com and the Global financial crises, respectively. The two CMAX series adequately capture the timing of crises that affected the Chinese and American markets. It is expected that at times of the crisis, periods of distress in China and the US would indirectly cause stress in the Australian equity market (if not a crisis). Therefore, these

[74] Vila (2000) propose the criteria of 1.5 or 2 standard deviations below the mean value of the CMAX series. However, since this study makes use of the inverted CMAX index this study uses the criteria of 1.5 to 2 standard deviations above the mean value of the inverted CMAX series.

two foreign-based variables were incorporated into the final composite index to measure stress in the Australian market.



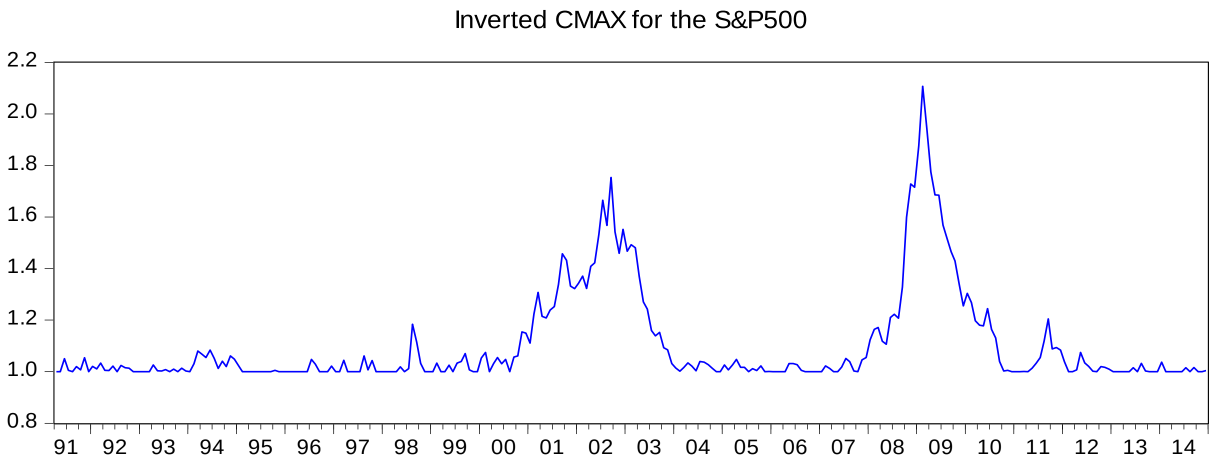


Figure 8.7: 24-Month Inverted CMAX for China and the US

8.5 Conclusion

This chapter focused on the identification of foreign-based variables to measure stress in the Australian equity market. After conducting empirical analysis of composite stock indexes of Australia and its top four trading partners, it was concluded that policy makers would benefit from a closer examination of the movements in the Chinese and American equity markets when trying to predict future movements in the Australian equity markets. Two foreign-based variables were estimated to incorporate the lead-lag relationship that exists between China-and-Australia and the US-and-Australia. The two inverted CMAX series for the two countries were incorporated into the final stress index for Australia. It should be noted that this chapter only focused on the identification of foreign variables for measuring stress in the equity market since the investor panic and large drops in asset prices are often more noticeable in equity markets. Nonetheless, it is possible that other foreign-based variables can be constructed to gauge the impact that financial crisis has on neighbouring currency markets or the banking sectors and via contagion the Australian market. This could be an avenue for future research into foreign-based indicators of financial stress in Australia. The chapter that follows discusses the aggregation techniques that were used to design the Australian composite financial stress index.

CHAPTER 9

INDEX AGGREGATION AND EVALUATION

9.1 Introduction

This chapter assembles a composite stress index to measure financial stress in the Australian financial market. This study uses 22 variables presented in chapter four to chapter eight of this thesis to construct a composite financial stress index. Two weighting techniques are considered when combining stress variables into an aggregate measure of financial stress. These techniques are the variance-equal-weights approach and the principal components analysis approach. These techniques are used to construct two composite indexes that are then compared in order to assess the performance of the two indexes. For the sake of comparison, this study standardises the variables of the stress indexes before including them in stress subindexes and subsequently in the composite stress index. The rest of this chapter is organized as follows. First, the procedure used to standardise the stress variables is outlined and implemented. Second, the standardised variables are used to construct stress subindexes. Third, a brief review of different index aggregation techniques is provided. Fourth, composite stress indexes are constructed using two index aggregation techniques. Fifth, the performance of the estimated indexes assessed. Last, concluding remarks are provided at the end of this chapter.

9.2 Standardisation of the Variables

This section discusses the importance of standardising variables prior to their inclusion in a composite index. It consists of an examination of the properties of the variables before standardisation, a discussion of the standardisation procedure utilised in this study and a brief discussion of the properties of the standardised variables. This study considers the use of 22 variables for inclusion in the composite stress index; a detailed discussion of how each variable was constructed is contained in Chapters 4 to 8 of this thesis. Table 9.1 provides reference to the specific chapters and subsections that contain these discussions.

Table 9.1: Cross References to the Variables

Category of Variables	Chapter	Section(s)	Variables
Equity market	4	4.2.1 4.2.2-4.2.3 4.2.4 4.2.5	• Inverted CMAX for the All Ordinaries index • Modified percentage change in the All Ordinaries index from a year ago • Negative Equity returns on the All Ordinaries Index • Volatility (AR(1)-IGARCH(1,1) model for the All Ordinaries index
Bond market	5	5.3.1	• 3-year BBB to A corporate bond yield spreads • 5-year BBB to A corporate bond yield spreads • 7-year BBB to A corporate bond yield spreads • 10-year BBB to A corporate bond yield spreads
Currency markets	6	6.4.1 6.4.2 6.4.3	• Currency market volatility models for the: a. Australian Dollar to the Chinese Yuan Renminbi b. Australian Dollar to the Japanese Yen c. Australian Dollar to the US dollar d. Australian trade weighted index • Exchange Market Pressure Index (EMPI) • Inverted CMAX Australian Trade Weighted index
Banking sector	6	6.7.1 6.7.2 6.7.3	• Refined banking beta • Inverted yield spread (10 year Government bond to 90 day treasury bill) • Credit to GDP gap
Supplementary Australian-based indicators	7	7.2.6 7.3 7.4	• Proxy LIBOR-OIS spread: interbank overnight cash-overnight indexed swap (IOC-OIS)spread • Inverted CMAX Australian property index • Inverted S&P/ASX 300 Metals and Mining
Foreign-based indicators	8	8.3	• Inverted CMAX for lagged Chinese Hang Seng Index • Inverted CMAX for lagged American S&P 500 Index

9.2.1 The Importance of Standardising Variables

The ultimate purpose of this study is to develop an aggregate stress index that subsumes information derived from the 22 variables. Given that these variables are often measured and/or presented at different (rather than a) common scale/s, it is imperative to start with a consideration of variable scaling (Oet et al., 2015). When variables are measured using different scales, it can result in variables with extreme values inappropriately emerging as a dominant indicator of financial stress. If one were to examine each variable separately with due consideration for the scaling used, it would be possible to correctly identify the extreme value or threshold that signals the presence of financial stress. However, if one were to combine variables of different scales without bearing in mind the effect that the different scales could have on the aggregate measure; it would result in a composite measure that only identifies presence of stress based on the highest value of set the variables being aggregated. Thus, there is a risk that a variable with the highest values will be inappropriately highlighted as the most important factor for explaining financial stress while a variable with lowest values will be deemed the least important. Consequently, the resulting composite stress index would be susceptible to the ad hoc identification of the most important indicator of stress being the variable with the highest values. It is important to note that this could change depending on the range of data collected by a researcher, the choice of variables to be included in the composite index and so on. This problem can be addressed by standardising the variables before using them in the composite index. This study uses standardisation to rescale the variables to a common scale and rebases the variables via indexing from 0 to 100 before aggregating the variables into a composite index. This is an approach that was utilised by Cardarelli et al. (2011) and Illing and Liu (2006). Standardised variables are measured on one scale and it is possible to identify and set a global threshold or identify extreme value that signal financial stress (or crisis). Moreover, standardised variables will be easier to compare and interpret both prior to, and after, the aggregation of the variables into a composite measure. In the subsection that follows this study will proceed to examine the variables of interest while bearing in mind the variable scaling. Hereafter, variables will be standardised before being incorporated into composite measures of stress.

9.2.2 Procedure for Standardising Variables

This study now inspects the scaling of variables used to determine whether standardisation of the variables is appropriate. One way to examine the variable scaling is by finding the maximum and minimum values of the variables of interest. Table 9.2 reports the maximum and minimum values for the 22 variables used in this study along with other summary statistics. At first glance, the scaling of the percentage change in equity index variable is far removed from the scaling of the other 21 variables. In particular, the observed values of this variable approximately range between 55 and 146 whereas most of the other variables approximately range between negative eight and six. The difference in scaling of the variables is due to the fact that each variable is constructed in a different manner, which results in each variable being measured on a different scale as is evident in Table 9.2. The use of variables with varying scales poses distinct problem to a researcher especially when all variables have to be subsumed into a composite index. While it is easy to use the individual variables to assess the presence (or absence) of stress in different sectors of the Australian economy, it is difficult to incorporate variables with diverse scales into one index that can be easily and meaningfully interpreted. In particular, this means that each variable will have a different threshold or extreme value that signals a crisis. The importance of scaling of variables can be illustrated considering two variables. Specifically, let the variables being considered be the percentage change in the Australian equity index and the inverted CMAX for the All Ordinaries stock exchange. Now suppose further, that these two variables are to be included in a composite index that was comprised of these variables only. If this is the case, then an examination each variable prior to their inclusion in the composite index is warranted. Refer to the summary statistics of the percentage change in the Australian equity index and the inverted CMAX for the All Ordinaries provided in Table 9.2. Extreme values that would signal a crisis would be the maximum values. In the case of the inverted CMAX for the All Ordinaries and the percentage change in the Australian equity index, the maximum values would be 2.006 and 145.729 respectively. If the composite index were to be obtained by a simple average of the two variables then the new value that indicates a crisis would be 73.8675 ((2.006+145.729)/2). The average maximum value (73.8675) is much higher than the maximum value of the inverted CMAX for the All Ordinaries (2.006) and much lower than the maximum value of the percentage change in the Australian equity index (145.729). Moreover, it is not truly representative of the maximum value of either of the variables; this is because the average maximum value is far removed from the maximum values of the two variables that were subsumed into the composite index. If the standardised variables were used instead then the maximum values of the two variables as shown in Table 9.3 would be 4.858 and 3.008 for the inverted CMAX of the All Ordinaries and the percentage change in the equity index respectively. The maximum average of the two variables now would be 3.993 ((4.458+3.008)/2); this would be the value of the composite index of the two variables. Note that in this case the average of the standardised variables provides a maximum average that is not far removed from the maximum values of the variables that form the index. Moreover, it can also be concluded that average measure obtained from standardised variables is a better representation of the maximum values of the variables that are contained in the summary measure. For this reason, this study expresses all variables in a standard form and incorporates the standardised variables into a composite stress index; the resultant composite index can easily be interpreted. It is important to note that standardised variables are still able of gauge the potential for stress or crisis in the Australian financial market.

Table 9.2: Descriptive Statistics for All Variables

	Min	Max	Mean	Standard deviation
Inverted CMAX for the All Ordinaries	1.000	2.006	1.145	0.232
Percentage change in equity index	55.143	145.729	93.814	18.636
Negative Equity returns, All Ordinaries Index	0.000	0.168	0.013	0.027
Volatility in the All Ordinaries index	0.000	0.006	0.001	0.001
3-year BBB to A yield spread	-0.160	3.930	0.745	0.693
5-year BBB to A yield spread	-0.040	5.050	0.791	0.774
7-year BBB to A yield spread	-0.020	2.130	0.692	0.481
10-year BBB to A yield spread	-0.100	4.790	0.807	0.752
Volatility, Australian Dollar to Chinese Yuan Renminbi	0.001	0.003	0.002	0.000
Volatility, Australian Dollar to the Japanese Yen	0.001	0.015	0.002	0.001
Volatility, Australian Dollar to the US dollar	0.000	0.004	0.002	0.001
Volatility of Trade Weighted index (TWI)	0.001	0.004	0.001	0.000
Exchange Market Pressure Index	-8.459	5.884	0.048	1.778
Inverted CMAX TWI	0.991	1.081	1.011	0.018
Refined banking beta	0.000	1.802	0.330	0.560
Inverted yield spread	-2.350	1.810	-0.134	0.927
Credit to GDP gap	-0.126	0.154	-0.002	0.066
IOC-IOS spread	-0.400	1.060	0.035	0.235
Inverted CMAX Australian property index	1.000	2.677	1.187	0.356
Inverted S&P/ASX 300 metals and mining	1.000	1.888	1.234	0.240
Inverted CMAX, lagged Chinese Hang Seng Index	1.000	2.447	1.187	0.314
Inverted CMAX, lagged American S&P 500 Index	1.000	2.108	1.122	0.225

Several authors suggest that a variable can be adequately standardised by considering its mean and standard deviation in order to estimate z-score values (Corbet, 2014; Dahalan et al., 2016; Ekinci, 2013; Hakkio & Keeton, 2009; Oet et al., 2015; Siņenko et al., 2013; Vermeulen et al., 2015).Therefore, each series was standardised by calculating the sample mean and standard deviation, and these measures are used to estimate the z-values for each series as shown in formula 10.1. Where z_t is the estimated z-score value of a given variable at time *t*, x_t is the value of the variable at time *t* and the arithmetic mean and the sample standard deviation are, respectively, $\bar{x}$ and s.

$$z_t = \frac{x_t - \bar{x}}{s} \qquad (9.1)$$

Table 9.3: Descriptive Statistics for Standardised Variables

	Min	Max	Mean	Standard deviation
Inverted CMAX for All Ordinaries√	-0.608	4.858	0.000	1.000
Percentage change in equity index√	-4.062	3.008	0.000	1.000
Negative Equity returns on the All Ordinaries Index√	-0.425	12.720	0.000	1.000
Volatility in the All Ordinaries index√	-0.562	8.608	0.000	1.000
3-year BBB to A yield spread$^{\Delta}$	-1.306	4.595	0.000	1.000
5-year BBB to A yield spread$^{\Delta}$	-1.074	5.504	0.000	1.000
7-year BBB to A yield spread$^{\Delta}$	-1.479	2.989	0.000	1.000
10-year BBB to A yield spread$^{\Delta}$	-1.206	5.297	0.000	1.000
Volatility, Australian Dollar to the Chinese Yuan Renminbi√	-2.949	2.213	0.000	1.000
Volatility, Australian Dollar to the Japanese Yen√	-0.826	10.544	0.000	1.000
Volatility, Australian Dollar to the US dollar √	-1.131	4.300	0.000	1.000
Volatility of Trade Weighted index (TWI) √	-1.179	8.370	0.000	1.000
Exchange Market Pressure Index√	-5.407	3.764	0.000	1.000
Inverted CMAX TWI√	-1.469	4.009	0.000	1.000
Refined banking beta§	-0.519	2.946	0.000	1.000
Inverted yield spread§	-2.463	2.356	0.000	1.000
Credit to GDP gap§	-2.132	2.552	0.000	1.000
IOC-IOS spread$^{\Delta}$	-1.849	4.352	0.000	1.000
Inverted CMAX Australian property index$^{\Delta}$	-0.526	4.190	0.000	1.000
Inverted S&P/ASX 300 metals and mining$^{\Delta}$	-0.976	2.725	0.000	1.000
Inverted CMAX for lagged Chinese Hang Seng Index$^{\Delta}$	-0.595	4.009	0.000	1.000
Inverted CMAX for lagged American S&P 500 Index$^{\Delta}$	-0.541	4.374	0.000	1.000

Note: The range of data sampled varies as follows.

1. √ indicates that data is sampled from February 1984 to December 2014
2. Δ indicates that data is sampled from January 2005 to December 2014
3. § indicates that data is sampled from February 2002 to December 2014

Table 9.3 presents the summary statistics for the standardised variables. From this point onward, this study used the standardised variables in the following manner. First, some of the standardised variables were used to construct stress subindexes. Second, standardised variables that were excluded from the stress subindexes were combined with the stress subindexes in order to construct composite stress indexes. The section that follows explains why this study uses stress subindexes and outlines how each stress subindex was constructed.

9.3 Construction of the Stress Subindexes

While the primary goal of this thesis is to construct a composite financial stress index, this study acknowledges that different stakeholders may be interested in measuring the level of stress in certain sectors of the Australian economy. In order to cater to needs that are more specialised, this chapter estimated four subindexes in addition to the composite stress indexes. The four subindexes are an equity market, bond market, currency market, and banking sector subindexes. These subindexes are designed to gauge financial stress that could be emanating from different sectors of the Australian economy. Further, these subindexes should cater for the specialised needs of most stakeholders in the financial markets. Also, this study uses the subindexes to reduce the risk of a certain sector of the economy being given higher priority than other sectors of the economy simply because there are more indicators for gauging the potential for stress in that sector than in any other sector (Oet et al., 2015). In order to understand the potential for this risk, refer to the summary of variables shown in Table 9.1. This study considers the use of 22 stress variables. Now, suppose the 22 variables were to be incorporated in a composite index without the use of subindexes. The following would ensue, the currency market category would be deemed the most important in determining the potential for stress in the Australian market because it has the greatest number of variables (six variables) compared to the other categories. Following the same logic, the equity and bond or money markets would be ranked second in importance (with four variables each). The ranking of the other categories seems ad hoc, especially since the importance of a category is merely dependent on the number of variables available in a particular category, there is no economic rationale to justify why that category is most important in determining the likelihood of stress in the Australian economy. In order to avoid the risk of overstating the importance of certain sectors as indicators of financial stress, this study proposes the use of the four subindexes. The constructed subindexes were subsequently incorporated into the composite stress indexes along with other variables, which were omitted from subindex measures. The sections that follow outlines the procedures used to estimate the four stress subindexes used in this study.

9.3.1 Equity Market Subindex

The equity market subindex is a composite measure of financial stress in the Australian equity market. It consists of four standardised variables, namely: the inverted CMAX of the All Ordinaries index, the percentage change in the All Ordinaries index from a year ago, the negative equity returns on the All Ordinaries index and the volatility in the All Ordinaries index variable. The range of data points available for the four series varies as shown in Table 9.4. This study uses the latest starting date to determine the range of the equity market subindex. As a result, the equity market subindex is constructed using the data from February 1984 to December 2014 by taking the arithmetic mean of the four standardised variables. Figure 9.1 shows the graphical representation of the estimated equity market subindex.

Illing and Liu (2003) suggest that stressful events can be identified by examining the value of this subindex relative to its long-run mean whereby values of the equity market subindex that are more than two standard deviations from the mean are considered as stressful events. This criterion was used to identify episodes of financial stress or crisis in this study. Accordingly, Figure 9.1 was shaded in order to highlight values that lie within two standard deviations of the mean. None of the values of the subindex is more than two standard deviations below the mean. However, some values of the subindex are more than two standard deviations above the mean. A demarcation line has been included in Figure 9.1 in order to identify the values that require further examination. A closer examination of the equity market subindex reveals that there are two noticeably peaks in the equity market subindex in November 1987 and November 2008. These two points correspond to two stressful episodes in the Australian equity market due to the 1987 stock market crash and 2007-2009 subprime mortgage crises. It would appear that the impact of the former crisis was greater than the latter.

Table 9.4: Range of Data for Equity Subindex Variables

Variable	Range of data		Number of observations
	Starting date	Ending date	
Inverted CMAX for All Ordinaries	December 1981	December 2014	397
% change in the All Ordinaries over a year	January 1980	December 2014	420
Negative Equity returns on the All Ordinaries	January 1980	December 2014	420
Volatility for the All Ordinaries index	February 1984	December 2014	371

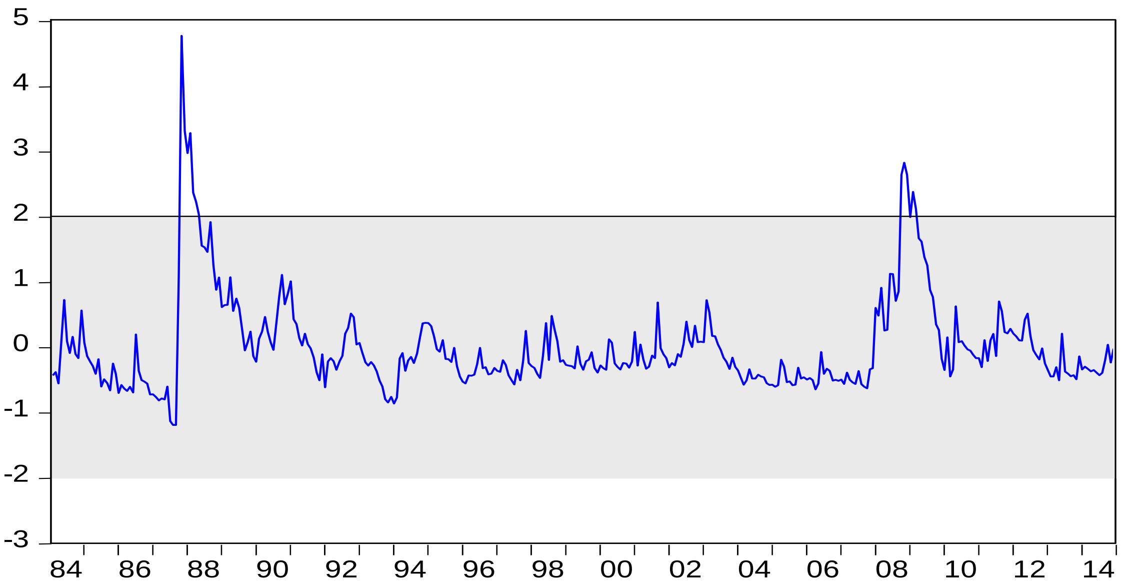


Figure 9.1: Equity Market Subindex (Feb 1984 to Dec 2014)

9.3.2 Bond Market Subindex

The bond market subindex is comprised of four variables which are the standardised BBA to A corporate bond yield spreads for fixed maturities; these are for 3, 5, 7, and 10 years. Data for all variables ranges from January 2005 to December 2014 such that each series has 120 observations. The bond market subindex was estimated by taking the arithmetic mean of the four yield spreads. The resultant index is graphed in Figure 9.2. The highest value of the bond subindex was recorded in December 2008 with an index value of 4.3; this value is more than two standard deviations above the mean value of the index and indicative of high levels of distress. This episode of distress in the bond markets corresponds to the timing of the 2007-2009 subprime mortgage crises.

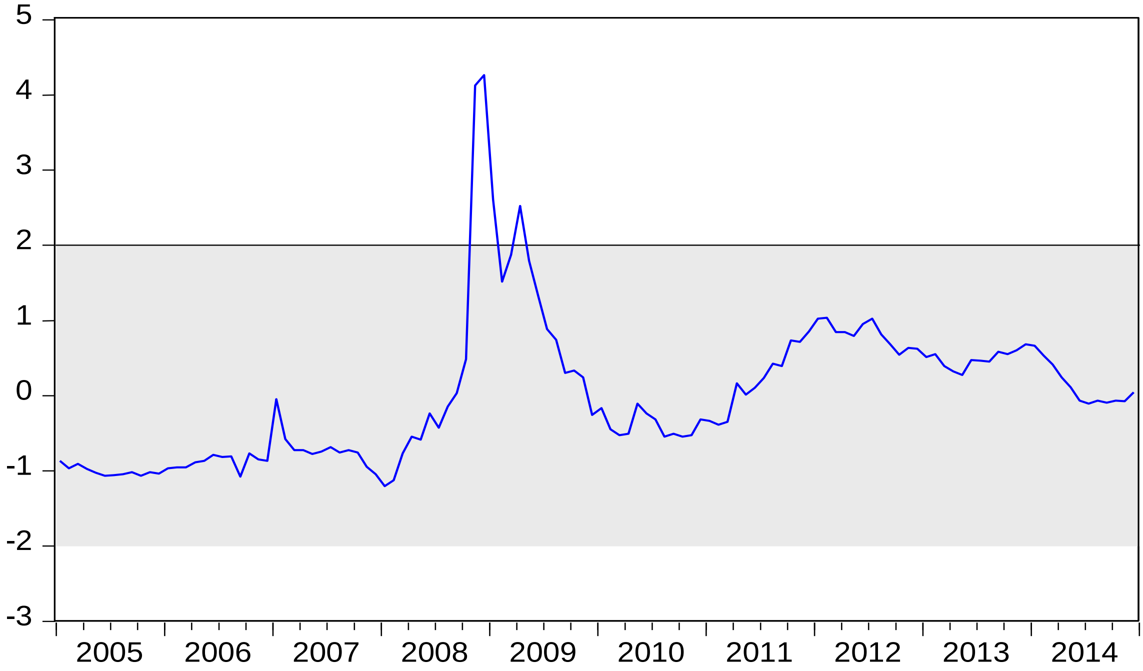


Figure 9.2: Bond Market Subindex (Jan 2005 to Dec 2014)

9.3.3 Currency Market Subindex

Six variables were used to construct the currency market subindex. These variables are an Exchange Market Pressure Index (EMPI), an inverted CMAX Australian Trade Weighted index (TWI) and four volatility models for: i) The Trade Weighted Index; ii) Australian dollar to the Chinese Yuan Renminbi (AUD/CNY); iii) Australian dollar to the Japanese Yen (AUD/JPY); and iv) Australian dollar to the American dollar (AUD/USD). The number of data points available for each variable varies as shown Table 9.5. The latest starting date was used to determine the range of the subindex. Consequently, the currency market subindex ranges from February 1984 to December 2014 and was estimated by taking the arithmetic mean of the six variables. The resultant subindex is represented graphically in Figure 9.3. The currency market subindex peaks at two points in August 1986 and November 2008. Both points exceed two standard deviations from the mean value of the currency subindex. These two points are indicative of distress in Australian currency markets that corresponds to the timing of two major crises. The data suggests the Australian currency markets suffered more distress during the 2007-2009 subprime mortgage crises compared to the than in the 1987 stock market crash.

Table 9.5: Range of Data for Currency Subindex Variables

Variable	Range of data		Number of observations
	Starting date	Ending date	
Volatility of the AUD/CNY	February 1984	December 2014	371
Volatility of the AUD/JPY	February 1984	December 2014	371
Volatility of the AUD/USD	February 1984	December 2014	371
Volatility of TWI	February 1984	December 2014	371
Exchange Market Pressure Index	January 1984	December 2014	372
Inverted CMAX TWI	January 1980	December 2014	420

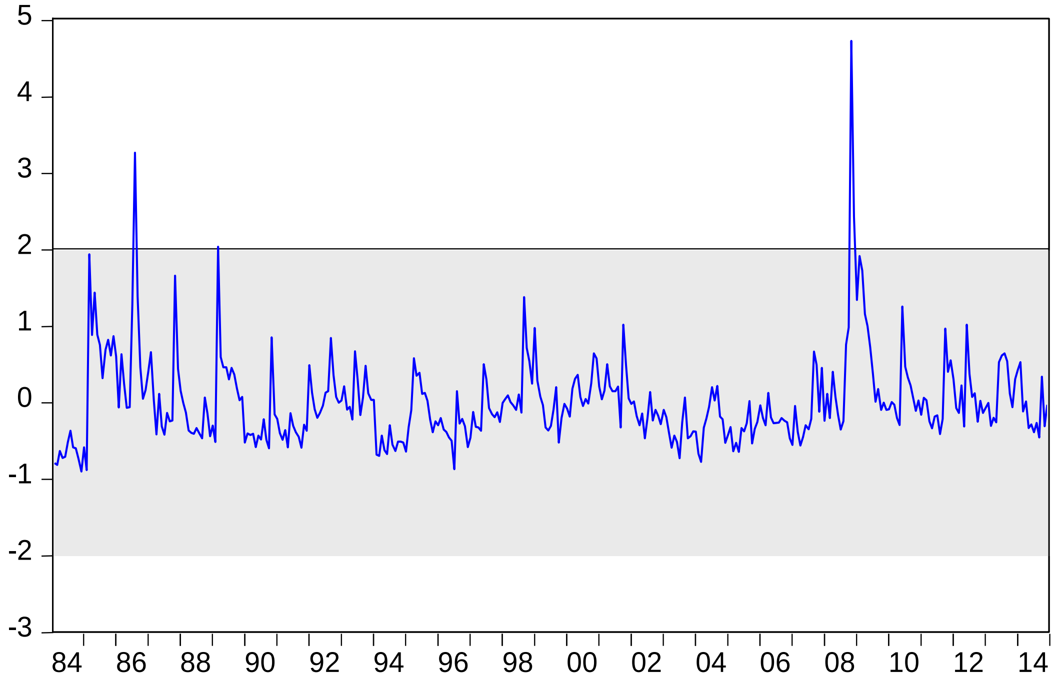


Figure 9.3: Currency Market Subindex (Feb 1984 to Dec 2014)

9.3.4 Banking Sector Subindex

This study constructed the banking sector subindex by finding the arithmetic mean of three standardised variables. These variables are the refined banking beta, inverted yield spread, and credit-to-GDP gap. The range of data points available for each variable varies as shown in Table 9.6. The latest starting date was used to determine the starting point of the subindex. Consequently, the banking sector subindex ranges from February 2002 to December 2014 and a graphical representation of the estimated subindex is provided in Figure 9.4. There are no values of the banking sector subindex lies beyond two standard deviations from the mean. Hence, it can be concluded that there were no episodes of distress in the Australian banking sector from February 2002 to December 2014. It is interesting to note that Australian banks fared better than other countries during the 2007-2009 subprime mortgage crisis in part due to the presence of lower risk loans in the Australian banks' portfolio and strict regulatory requirements enforced by the Australian Prudential Regulation Authority (Edwards, 2010; Pais & Stork, 2011).

Table 9.6: Range of Data for Banking Sector Variables

Variable	Range of data		Number of observations
	Starting date	Ending date	
Refined banking beta	February 2002	December 2014	155
Inverted yield spread	January 1970	December 2014	540
Credit to GDP gap	September 1976	December 2014	460

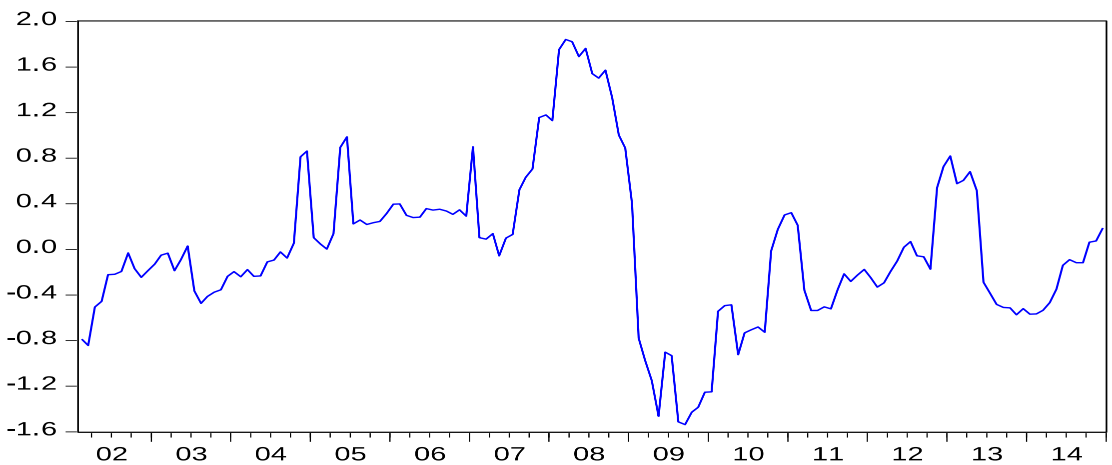


Figure 9.4: Banking Sector Subindex (Feb 2002 to Dec 2014)

At this point, it is important to note that the estimated stress subindexes no longer possess the standardised features of the original variables (a mean of zero and a standard deviation of one). This study standardised the stress subindexes to maintain uniformity of all variables being used in the composite stress index. The descriptive statistics of the standardised stress subindexes are shown in Table 9.7. This study now proceeds to use the constructed stress subindexes and other stress variables[75] to construct composite stress indexes. The section that follows outlines the procedure used to construct composite stress indexes.

Table 9.7: Descriptive Statistics for Standardised Stress Subindexes

Variable	Minimum	Maximum	Mean	Standard Deviation
Equity Market Subindex	-0.939	3.722	0.000	1.000
Bond Market Subindex	-1.268	4.408	0.000	1.000
Currency Market Subindex	-1.107	6.856	0.000	1.000
Banking Sector subindex	-2.131	2.404	0.000	1.000

9.4 Construction of Composite Stress Indexes

The procedures used to estimate composite stress indexes are outlined in this section. The subsequent subsections are organised as follows. First, a brief overview of commonly used approaches to index aggregation is discussed. Here the issue of different weighting techniques that could be used for index aggregation is discussed before determining the weighting techniques that are suitable for construction of the Australian stress index.

9.4.1 Overview of Index Aggregation Approaches

Few studies explore the performance of different index aggregation techniques. A notable study is one by Illing and Liu (2006) which compares four aggregating approaches, namely the credit weights, the variance-equal weights (VEW), the principal component analysis (PCA), and the transformation based on sample cumulative distribution functions (CDF) approach. The aforementioned authors transformed all stress variables so that each variable lay between 0.0 and 100.0, inclusive. This transformation ensured that the variables could be represented on the same scale. The transformed variables were then used to construct four indexes. Stressful events were identified when values lay more than two standard deviations above the mean.[76] The four indexes were compared and the performance of the indexes was assessed based on the ability of these indexes to provide accurate predictions of an episode of

[75] These stress variables were excluded from the stress subindexes.

[76] The threshold for identifying a crisis was set based on the two standard deviations above the mean based on the 68-95-99.7 empirical rule. Therefore, stress index values that are more 97.5 highlight the presence of a crisis (Illing & Liu, 2003, 2006).

financial stress. The best performing index was identified as the index based on the credit weights approach since it reported the least type I and II errors.[77] In a more recent study, Oet et al. (2015) examined the performance of the four weighting approaches and arrived at the same conclusion when considering monthly data. An interesting finding of the aforementioned authors study was that, when dealing with quarterly data, the credit weights and the PCA stress indexes performed better than the VEW and the CDF stress indexes. Nevertheless, the credit weights index seems to be the preferred option overall because the choice of weights can be economically justified.

While the use of the credit weights approach seems ideal, it is often not the approach of choice for many researchers because data needed to estimate the weights is not always readily available. By definition, the credit weights approach divides an economy into sectors and then assigns stress variables to those sectors. Quantitative data for the identified sectors of the economy is obtained and used to calculate the weights of the stress variables. This approach is most successful when the variables can be grouped into categories that are representative of the economy. Moreover, the researcher must be able to identify suitable quantitative measures that can be used to represent the identified sectors of the economy. Illing and Liu (2006) use total credit in the Canadian economy to determine the credit weights and successful categorise stress variables based on whether the credit was owed to the government, banks, corporate bodies or the equity market.

Oet et al. (2015) employed the credit weights technique by dividing the financial system up into six segments in order to estimate credit weights for the stress variables. These segments were comprised of the property, equity, credit, currency, securitization, and funding markets. Attempts to obtain data for the six segments proved unsuccessful in some cases and it was

[77] A *Type I Error* occurs when the estimate stress index indicates that there is no crisis while there actually was a crisis. A *Type II Error* occurs when there is actually no crisis but the index indicates that there is a financial crisis. Illing and Liu (2006) use a survey to identify periods of financial crisis.

necessary to allocate equal weights for segments with no data. This ad hoc assignment of the weights could compromise the economic significance of the weights, especially since the choice of weights can no longer be economically justified.

This study suggests that, when in doubt, it is better to avoid ad hoc assignment of the weights to variables that might result in weights of questionable economic relevance. Balakrishnan et al. (2011) adopt this approach when dealing with the credit weights identification problem. The aforementioned authors examined 35 countries (17 advanced and 18 emerging countries) in order to determine the potential for transmission of financial stress from advanced to emerging countries. The credit-weighted approach was considered, but obtaining comparable weights for all countries being considered in the study was difficult. Therefore, Balakrishnan et al. (2011) chose to use the VEW approach instead—it was useful in developing a stress index that performed just as well as the credit weights approach stress index and offered weights that were as robust as those obtained from the PCA approach.

With respect to this study, the use of the credit weights approach was considered and deemed inadequate for a number of reasons. Apart from the foreign and currency market variables, the other variables can be grouped into the following categories: equity market, bond market, and banking sector. An attempt was made to segment the Australian economy into three sectors based on the total credit outstanding to the bond market, equity market, and banks. With the exception of the foreign-based variables[78] and currency market variables,[79] other sectors could adequately be used to classify most of the stress variables used in this study. Data for credit outstanding is available for the three sectors from the Australian Bureau of

[78] These variables are the lagged Chinese Hang Seng index and the lagged US S&P 500 index.

[79] These variables are the exchange market pressure index (EMPI), the inverted Australian trade weighted index and volatility measures for the Australian dollar to the Japanese Yen, US dollar and Chinese Yuan.

Statistics[80] website, albeit at a quarterly interval.[81] The Australian Bureau of Statistics reports total credit information for credit owed to the rest of the world. However, the focus of this study, especially with respect to the foreign-based variables, is the historical credit owed in the American and Chinese financial markets, as this is what would be relevant in determining the credit weights for the foreign-based variables. Data relating to currency market was not readily available. Therefore, in summary, this study opted against the use of the credit weights approach due to lack of data at monthly frequency that could be used to accurately estimate credit weights for the currency market and the foreign-based variables. Therefore, the discussion that follows will now focus on the use of the VEW, the transformation by CDFs and the PCA aggregation approaches.

Siņenko et al. (2013) explores the use of the VEW, the transformation by CDFs and the PCA approaches when constructing a stress index for the Latvian financial market on a quarterly interval. The aforementioned authors argue that the VEW and PCA approaches were noted to provide similar estimates of financial stress and performed better than the transformation by sample CDFs approach. The methodology used in the transformation by sample CDFs approach was criticised for yielding stress estimates that were more amplified (higher or lower) than the other two approaches. Furthermore, the transformation by sample CDFs seemed to distort the structure of the stress variables and the composite stress index in a manner that could suggest that periods with varying levels of financial stress had the same level of financial stress (Siņenko et al., 2013). Oet et al. (2015) also raised similar concerns about the transformation by sample CDFs approach in stress index construction. In particular, the aforementioned authors argued that the process of transformation by sample CDFs could be used to develop a stress index, which adequately identified when financial stress had

[80] Data for the total credit is available from ABS spreadsheets of catalogue number 5232.0 - Australian National Accounts: Finance and Wealth.

[81] The Reserve Bank of Australia also provides information of credit aggregates at an annual interval (Reserve Bank of Australia, 2017).

occurred. Unfortunately, the same index made it difficult to determine the degree of financial stress that had occurred. It is imperative to develop a financial stress index that not only measures the prevailing level of stress but also provides a reasonable estimate of the magnitude of stress at a given time. Moreover, it is likely that an index aggregation approach that limits the stress index's ability to adequately signal the magnitude of stress also makes that stress index an unsuitable measure of financial stress. This study opted against using a transformation by sample CDFs approach in the index construction because of the drawbacks of this approach, that are highlighted in literature (Oet et al., 2015; Siņenko et al., 2013).

This discussion now turns to the usefulness of the last two index aggregation approaches, the VEW and the PCA approach. The VEW approach seems to be the most popular method of index aggregation (Balakrishnan et al., 2011; Cardarelli et al., 2011; Ekinci, 2013; Illing & Liu, 2006; Park & Mercado, 2014; Siņenko et al., 2013). This is probably because it is easy to estimate and interpret a stress index that is constructed by the VEW approach. All that is required in this approach is estimation of the arithmetic mean of standardised variables in order to obtain a composite stress index. Values of the stress index that lie more than two standard deviations above the mean are indicative of a stressful or crisis period. One shortcoming of this approach is it assumes that the stress variables are normally distributed when in fact they may be non-normally distributed (Illing & Liu, 2006). Moreover, Oet et al. (2015) argue that assigning equal weights to all variables could cause the resulting stress index to be dominated by the sector that contains the most stress indicators.[82] However, Siņenko et al. (2013) compared the performance of a stress index constructed with equal weights (VEW approach) and a stress index with varying weights (PCA approach) and found no significant difference in the estimated level of financial stress. Overall, proponents of the VEW approach argue that it sufficiently captures the periods of financial stress and crisis that

[82] This issue was discussed in more detail earlier and is one of the main motivations for the use stress subindexes in this study.

have been documented in literature (Balakrishnan et al., 2011). This is most likely why the VEW approach is still widely accepted method for index aggregation.

Several studies have explored the use of the principal component analysis (PCA) weighting approach for constructing a composite financial stress index (Dahalan et al., 2016; Hakkio & Keeton, 2009; Illing & Liu, 2006; Park & Mercado, 2014; Siņenko et al., 2013). PCA is often used to summarise essential information from a set of interrelated variables into a single variable. Furthermore, the PCA approach is used to determine the weights to be assigned to the stress variables when combining the variables to a composite index. Hakkio and Keeton (2009) use monthly data for 11 stress indicators and the PCA approach to develop the Kansas City Financial stress index (KCFSI). The stress indicators were standardised before estimating the principal component, which explained about 61 percent of the variation in all the indicators. Values of the KCFSI that were greater than two standard deviations above the mean adequately highlighted the incidence of the 2007-2009 GFC. In particular, the highest value of stress recorded on the KCFSI was 5.6 standard deviations from the mean, which was reported in October 2008. This corresponds to the timing when the crisis was at its worst. Park and Mercado (2014) used the PCA approach to estimated financial stress indexes for forty countries[83] and found that the resulting indexes adequately highlighted the historical incidents of crisis as identified in literature. This study will follow a similar approach when using the PCA approach. The estimated PCA stress index shall be checked to see whether it captures historical periods of crisis or stress.

This study estimated two composite stress indexes using two weighting approaches, namely the VEW and the PCA approaches. The subsequent subsections discuss how the stress subindexes and other stress variables are used to construct the two composite stress indexes.

[83] This study examined fifteen advanced and twenty five emerging countries.

For ease of comparison and interpretation, all composite stress indexes are expressed in standardised form.

9.4.2 Variance-equal Weights Approach

This subsection outlines the procedures followed when estimating the Australian composite financial stress index using the variance-equal weights (VEW) approach. The resulting index is referred to in subsequent sections as the VEW stress index.

The variance-equal weights (VEW) approach is one of the simplest approaches to aggregating an index. This approach calculates the arithmetic mean of the standardised variables in order to determine the value of the composite index. This study uses the stress subindexes that were constructed in Section 9.3 and other variables that were excluded from these subindexes to assemble the VEW stress index. As a result, the VEW stress index is comprised of nine variables; these are five variables and four subindexes. Table 9.8 lists the variables of the VEW stress index and the range of data available for each variable or subindex. In order to estimate the composite stress index this study sampled data ranging from January 2005 to December 2014. This range of data was chosen in order to avoid the problem of missing data. For instance, if data was sampled from February 1984 to December 2014, there are missing data points from February 1984 to December 2004 for five variables and the bond subindex. Additionally, there would be missing data points from February 1984 to January 2002 for the banking sector subindex. Therefore, the VEW composite index was estimated by calculating the arithmetic mean of the nine variables with data ranging from January 2005 to December 2014.

Table 9.8: Range of Data for VEW Index Variables

Variable	Range of data
Equity Market Subindex	February 1984 to December 2014
Bond Market Subindex	January 2005 to December 2014
Currency Market Subindex	February 1984 to December 2014
Banking Sector subindex	February 2002 to December 2014
IOC-IOS spread	January 2005 to December 2014
Inverted CMAX Australian property index	January 2005 to December 2014
Inverted S&P/ASX 300 metals and mining	January 2005 to December 2014
Inverted CMAX for lagged Chinese Hang Seng Index	January 2005 to December 2014
Inverted CMAX for lagged American S&P 500 Index	January 2005 to December 2014

Equation 9.1 shows the formula for calculating the index. Where x_{it} is the value of variable *i* at time *t* and *n* is the total number of variables in the index. Since the VEW index contains nine variables, the value of the stress index at time *t* would be obtained by summing the value of the nine variables at time *t* and dividing this sum by nine.

$$VEW\ Stress\ Index = \sum_{i=1}^{n} \frac{x_{it}}{n} \tag{9.1}$$

A graphical representation of the estimated VEW stress index is provided in Figure 9.5. Values of the VEW stress index that are more than two standard deviations from the long-run mean are identified as stressful events. One period of stress is identified that lasted from October 2008 to March 2009 when the estimated values of the index are 2.4 and 2.3, respectively. The most stressful month for the period being studied is identified as November 2008 when the value of the index was 3.5. The timing of the episode of stress identified by this index corresponds to the timing of the 2007-2008 Global Financial Crisis as cited in literature. For instance, Sykes (2010) states that the worst months of the financial crisis were from September 2008 to March 2009. This study re-estimates composite stress indexes using the principal components analysis weighting approaches in the next section of this chapter.

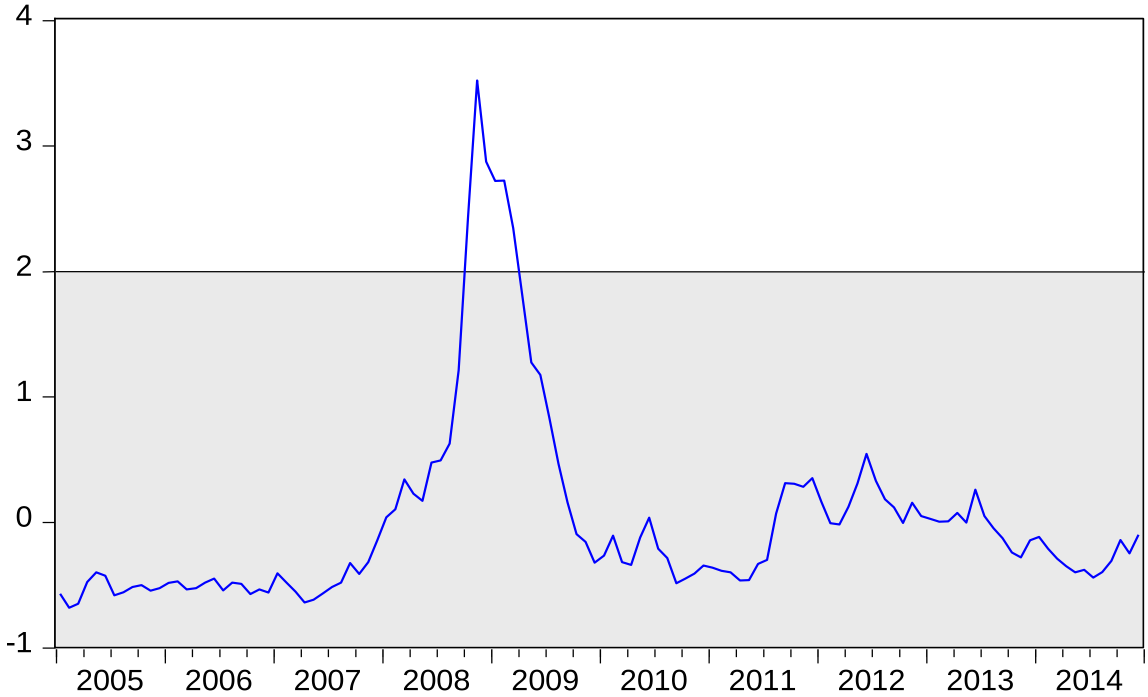


Figure 9.5: Composite VEW Stress Index (Jan 2005 to Dec 2014)

9.4.3 Principal Components Analysis

This subsection outlines the procedure followed when estimating the Australian composite financial stress index using the principal components analysis (PCA) approach. The resultant index will be referred to in subsequent sections as the PCA stress index. PCA estimations were performed using IBM SPSS version 22 statistical software package.

Much like the VEW stress index, the PCA stress index is comprised of the nine variables listed in Table 9.7. This study uses PCA approach to summarise essential information from five stress variables and four subindexes into a composite stress index. It is good practice to examine the relationship between variables in a data set before engaging in a PCA exercise. This will help to determine whether the use of the PCA is warranted. Accordingly, this study shall examine the set of data to see if the nine variables meet three criteria. If these three criteria are met, the use of PCA is warranted, otherwise the use of the PCA may be inappropriate. The first criterion is that at least two pairwise correlation coefficients of the variables under study should be more than 0.3. The second criterion is that the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO-MSA) (Kaiser, 1970, 1974) for the estimated principal components should be greater or equal to 0.6. A KMO-MSA value of 0.6 or more indicates that the sample is adequate and suitable for PCA. Therefore, this study checks if the KMO-MSA for individual variables and the set of variables is over 0.6. The third criterion is that the reported Bartlett's test of sphericity statistic (Bartlett, 1954) for the estimated principal components is significant at a five percent level of significance. A significant Bartlett test statistic suggests that a sufficient correlation exists among the set of variables being studied (Leech, Barrett, & Morgan, 2005; Pallant, 2011; Tabachnick & Fidell, 2007).

This study uses pairwise correlation coefficients for the nine variables to determine if the first criterion was satisfied. Table 9.9 contains a summary of the estimated correlation coefficients that are presented in the form of a correlation matrix. An inspection of the correlation matrix reveals the presence of several coefficients that exceed 0.3. Notably, it is only the correlation coefficients relating to the banking sector subindex that are all less than 0.3. There are very strong positive correlations between the four pairs of variables. These are the inverted lagged Hang Seng index and the inverted Australian property index, the inverted lagged S&P 500 index and the inverted Australian property index with correlation coefficients of 0.933 and 0.906 respectively. In addition, the inverted lagged Hang Seng index and the inverted lagged S&P 500 index have correlation coefficients of 0.942 while the Australian equity market subindex and the inverted lagged Hang Seng Index have correlation coefficient of 0.935. The strong positive correlations indicate that an increase in one variable is associated with an increase in the other variable. For example, a one-month-lagged increase in the prices on the American and Chinese stock markets is associated with increases in the Australian property market. Generally, highly correlated variables could lead to the problem of multicollinearity[84] when performing regression analysis. However, this is not an issue of concern when performing PCA because the technique can be performed on a set of variables that are highly correlated. In fact, Kennedy (2008) states that the PCA is better than regression analysis because it can be used to eliminate redundant information.

Table 9.9: Correlation Matrix for PCA Index Variables

	IOC-OIS Spread	Inverted Property Index	Inverted Metals & Mining Index	Inverted lagged Hang Seng Index	Inverted lagged S&P 500 Index	Bond Market Subindex	Equity Market Subindex	Currency Market Subindex	Banking Sector Subindex
IOC-OIS Spread	1.000	-	-	-	-	-	-	-	-
Inverted Property Index	0.578	1.000	-	-	-	-	-	-	-
Inverted Metals & Mining Index	0.726	0.554	1.000	-	-	-	-	-	-
Inverted lagged Hang Seng Index	0.719	0.933	0.718	1.000	-	-	-	-	-
Inverted lagged S&P 500 Index	0.538	0.906	0.637	0.942	1.000	-	-	-	-
Bond Market Subindex	0.762	0.554	0.815	0.688	0.616	1.000	-	-	-
Equity Market Subindex	0.694	0.891	0.674	0.935	0.875	0.701	1.000	-	-
Currency Market Subindex	0.691	0.635	0.615	0.723	0.660	0.738	0.703	1.000	-
Banking Sector Subindex	0.065	0.062	-0.192	-0.027	-0.229	-0.275	-0.008	-0.055	1.000

The statistics relating to the other two criteria are presented in Tables 9.10 and 9.11. The KMO-MSA for the individual variables is reported in Table 9.10. With the exception of the banking sector subindex, measures of sampling adequacy for all other variables are greater than 0.6. Table 9.11 reports the KMO-MSA and the Bartlett's test of sphericity for the set of nine variables. The overall KMO-MSA is 0.831 which is greater than 0.6. The estimated chi-

[84] Multicollinearity can lead to a number of problems. In particular, if an ordinary least squares regression model is estimated using highly correlated variables, the resulting model can contain coefficients with high standard errors or variances, coefficients with wrong signs and the hypothesis tests checking for significance of the estimated coefficients could yield incorrect results. See Kennedy (2008) for a more detailed discusion.

squared value for Bartlett's test of sphericity is 1411.134 with a probability of zero; this indicates that the test statistic is significant at a five percent level of significance. Overall, the first and third criteria were satisfied, while the second criterion was not satisfied. This study omitted the banking sector subindex from the set of variables in order to ensure the second criterion was satisfied. Once the banking sector subindex was excluded from the set of variable, the resulting set of eight variables were found to have a KMO-MSA that satisfied the second criterion. This meant that the three criteria were satisfied and that the use of PCA was acceptable. Consequently, this study will now proceed to estimate the principal components for the eight variables instead of nine variables.

Table 9.10: KMO Test Results for Variables

Variable	Kaiser-Meyer-Olkin Measure of Sampling Adequacy
IOC-OIS	0.837
Inverted Property Index	0.903
Inverted Metals & Mining Index	0.881
Inverted lagged Hang Seng Index	0.797
Inverted lagged S&P 500 Index	0.753
Bond Market Subindex	0.827
Equity Market Subindex	0.954
Currency Market Subindex	0.917
Banking Sector Subindex	0.161

Table 9.11: KMO-MSA and Bartlett's Test Results

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	Bartlett's Test of Sphericity		
	Chi-squared statistic	Degrees of freedom	Probability
0.831	1411.134	36	0.000

PCA is able to express a set of correlated variables as a new set of independent uncorrelated variables, which are referred to as principal components. The number of principal components estimated depends on the number of variables being used in the analysis. In general, mathematically terms, it can be said that PCA will estimate *k* principal components for a set of *k* variables. In the case of this study, PCA will extract eight principal components from the eight variables. Each principal component is a linear expression of the original set of variables which is obtained by calculating the weighted sum of the original set of variables (Vyas & Kumaranayake, 2006). A mathematical expression of principal components for *k* variables is provided in equation 9.2. Where $c_1, c_2, \ldots, c_k$ represent the principal components for a set of *k* variables, $w_{11}, w_{12}, \ldots, w_{kk}$ represent the factor loadings or weights, and $y_1, y_2, \ldots, y_k$ represent the original set of variables.

$$\begin{gathered} c_1 = w_{11}y_1 + w_{12}y_2 + \cdots + w_{1k}y_k \\ c_2 = w_{21}y_1 + w_{22}y_2 + \cdots + w_{2k}y_k \\ \vdots \\ c_k = w_{k1}y_1 + w_{k2}y_2 + \cdots + w_{kk}y_k \end{gathered} \tag{9.2}$$

The factor loadings are estimated using a procedure that restricts the sum of squares of the coefficients for each component to one. This constraint can be expressed mathematically as shown in equation 9.3. Since the variables used in this study have been standardised, the factor loadings are equal to the eigenvectors of the covariance matrix for the nine variables.

$$\begin{gathered} w_{11} + w_{12} + \cdots + w_{1k} = 1 \\ w_{21} + w_{22} + \cdots + w_{2k} = 1 \\ \vdots \\ w_{k1} + w_{k2} + \cdots + w_{kk}y_k = 1 \end{gathered} \tag{9.3}$$

PCA with varimax rotation[85] was performed in order to assess the underlying structure of the eight variables. The un-rotated factor loadings for the extracted component are provided in Table 9.12. PCA revealed there was only one component with an eigenvalue of 6.075, which was greater than one. This component explained 75.935 percent of the variance in the eight variables. Since there was only one component extracted, no rotation was performed on the factors. All variables load very highly (over 80 percent) on the extracted component but it is

[85] The *Varimax Rotation* technique is used to extract uncorrelated variables from correlated variables.

the inverted lagged Chinese Hang Seng Index that loads the highest (96.1 percent) on the extracted component. The IOC-OIS has the lowest loading on the extracted component. Figure 9.6 contains the scree plot of the eigenvalues of each component. An inspection of the scree plot shows that a one principal component solution was adequate.

Table 9.12: Un-rotated Factor Loadings for PCA

	Factor Loadings	Communalities
Inverted lagged Chinese Hang Seng Index	0.961	0.923
Equity Market Subindex	0.935	0.874
Inverted lagged American S&P 500 Index	0.894	0.799
Inverted Australian Property Index	0.877	0.769
Bond Market Subindex	0.837	0.700
Currency Market Subindex	0.824	0.679
Inverted Metals and Mining Index	0.819	0.670
IOC-OIS spread	0.813	0.662
Eigenvalues percentage of variance	75.935	n.a.

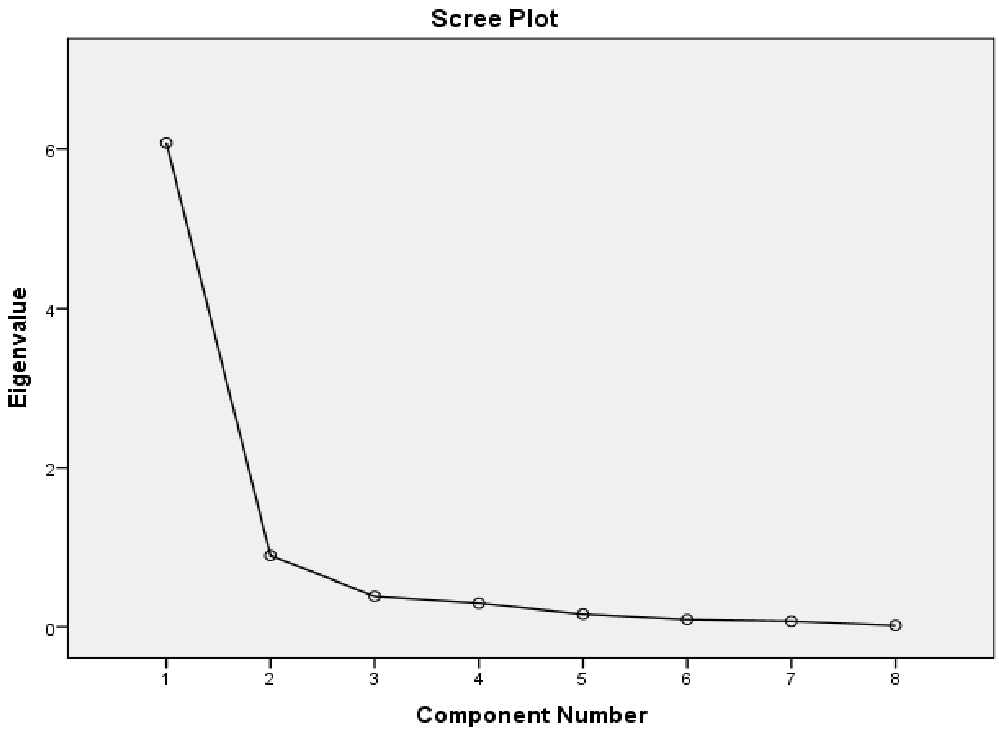


Figure 9.6: Scree Plot for the Eight Components

Parallel analysis was also performed to check whether the use of one principal component was justified. This study uses statistical software developed by Marley Watkins to perform

Monte Carlo simulations of PCA for parallel analysis (Watkins, 2000). A hundred iterations were used to perform parallel analysis on a random data set with eight variables and 120 subjects; this facilitated the generation of a data set that was similar to the one used in this study. Table 9.13 provides the output for the parallel analysis.

Table 9.13: Output for the Parallel Analysis

Eigenvalue Number	Random Eigenvalue	Standard Deviation
1	1.4091	0.0851
2	1.2458	0.0576
3	1.1333	0.0415
4	1.0328	0.0439
5	0.9343	0.0432
6	0.8418	0.0439
7	0.7570	0.0457
8	0.6460	0.0506

Monte Carlo PCA for Parallel Analysis

The random eigenvalues in Table 9.13 were compared with the actual eigenvalues reported in SPSS output for the PCA in order to determine how many components should be used in this study. Hypothesis tests were performed for the null hypothesis that the component should be included in the PCA. The alternative hypothesis is that the component should be excluded from the PCA. The criterion values for the hypothesis tests are the random eigenvalues that were obtained from the parallel analysis. The decision rule is that the null hypothesis is accepted if the actual eigenvalues greater than the criterion values, otherwise the null hypothesis is rejected in favour of the alternative hypothesis. Table 9.14 provides comparison values and the decision for the hypothesis tests performed.

Table 9.14: Comparison of PCA and Parallel Analysis Eigenvalues

Component	Actual Eigenvalue (PCA)	Random Eigenvalue (Parallel Analysis)	Decision
1	6.075	1.409	accept
2	0.898	1.246	reject
3	0.384	1.133	reject
4	0.297	1.033	reject
5	0.161	0.934	reject
6	0.094	0.842	reject
7	0.072	0.757	reject
8	0.019	0.646	reject

The parallel analysis confirms that the use of one principal component is warranted. Consequently, this study used the extracted component to estimate the financial stress index for Australia. The estimated PCA stress index is represented graphically in Figure 9.7.

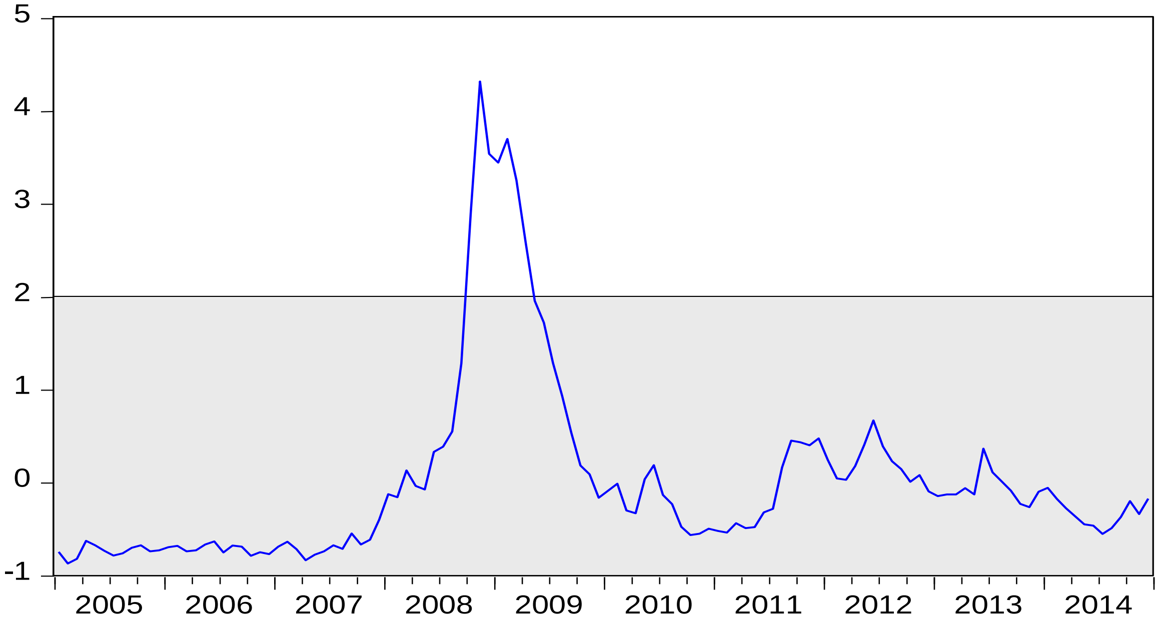


Figure 9.7: Composite PCA Stress Index (Jan 2005 to Dec 2014)

Values of the PCA stress index that exceed two standard deviations from the long-run mean are identified as stressful events. One period of stress is identified that lasted from October 2008 to April 2009 when the estimated values of the index are 2.9 and 2.6 respectively. The most stressful month for the period being studied is identified as November 2008 when the value of the index is 4.3. The timing of the episode of stress identified by this index corresponds to the timing of the 2007-2008 Global Financial Crisis as cited by Sykes (2010). This study compares the performance of the estimated PCA and VEW stress indexes in the next section of this chapter.

9.5 Assessment of the Performance of the Indexes

This section of the chapter is dedicated to examining two aspects of the performance of the VEW and PCA stress indexes; these are the monitoring and the forecasting capabilities of the estimated stress indexes. This study hypothesised in Section 3.2 of

Chapter 3 that the choice of index aggregation methods would affect the performance of the composite stress index. In the subsection that follows, this study evaluates the effectiveness of the stress indexes as tools for monitoring financial stress in the Australian economy. Here the ability of the stress indexes to capture the incidence of past and current episodes of financial stress or crisis was examined. Thereafter, this research explored the forecasting potential of both stress indexes. Here the forecasting performance of both indexes was evaluated in order to determine if one was superior to the other or if both are at par. Overall, this section seeks to determine whether either or both of the composite stress indexes are viable tools for monitoring and forecasting tools Australian financial stress.

9.5.1 Monitoring Australian Financial Stress

This research used two criteria to assess the potential use of the VEW and PCA stress indexes as a monitoring tool. The first criterion is that the stress indexes should adequately capture the incidence of past episodes of financial crisis for the period being studied; this is from January 2005 to December 2014. The second criterion is that the stress indexes should be able to gauge the prevailing level of stress in the Australian economy. For the second criterion, this study considered all monthly data available up to the time when this chapter was written. At the time of writing it was the month of July 2017, so this study attempted to obtain data for all stress variables until June 2017. With the exception of the credit to GDP gap variable, it was possible to extend the series for 21 stress variables until June 2017. With respect to the credit to GDP gap, no data for the real GDP[86] was reported for the quarter ending June 2017 on the RBA website. The most recently available data for the real GDP was for the quarter ending March 2017. Consequently, this study opted to extend the stress

[86] Real GDP is one of the components that is required to estimate the credit to GDP gap.

indexes for the period ranging from January 2005 to March 2017 in order to examine the ability of both indexes to gauge the prevailing level of financial stress in Australia.

A visual representation of the time series of VEW and PCA stress indexes was used to evaluate the first criterion. Figure 9.8 presents a comparative line graph in which both indexes adequately capture the incidence 2007-2009 GFC. There are two main differences between the two indexes. The first difference is that the PCA stress index indicates higher levels of stress compared to the VEW stress index especially during the peak month of the crisis (November 2008).

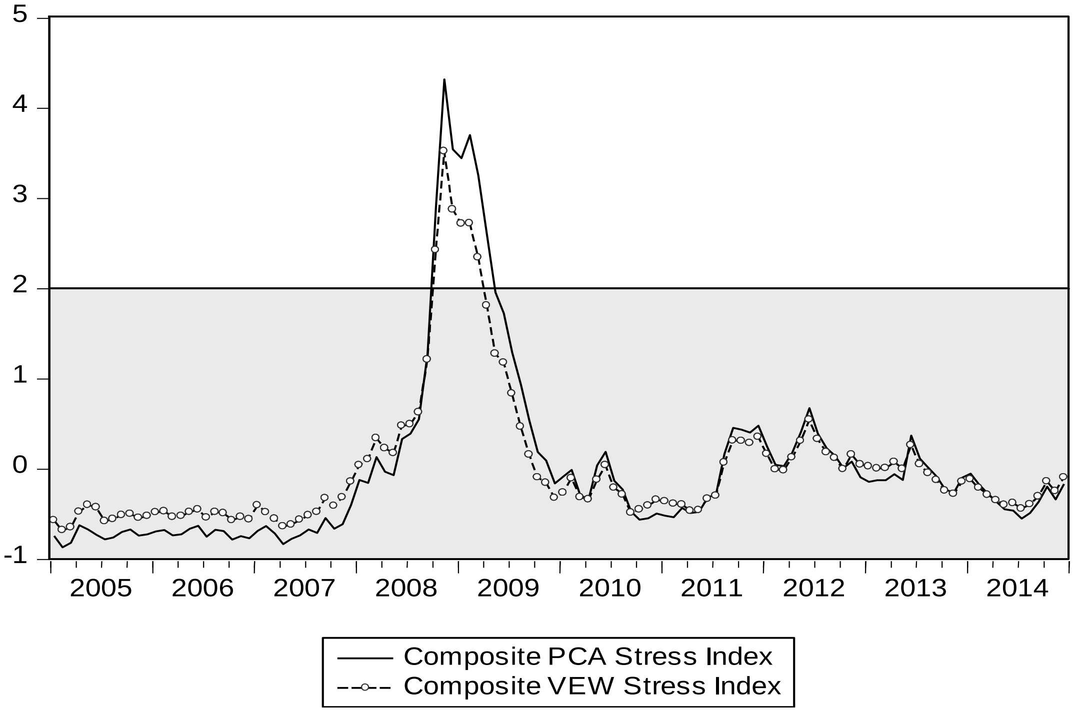


Figure 9.8: Comparison of Composite Stress Indexes

The second difference is that the duration of the episode of stress as identified by the two stress indexes differs slightly by a month. Specifically, both stress indexes highlight the onset of the GFC in October 2008, but the VEW stress index indicates that the episode of stress lasted for six months until March 2009 while the PCA stress index indicates that the episode of stress lasted until April 2009. Nevertheless, both indexes sufficiently provided indications that the Australian economy was in distress at the time of the crisis.

In order to assess whether the stress indexes could gauge the prevailing level of stress, this study extended the data set to include the most recently available data (at the time of writing). Consequently, data was sourced for the 22 variables and the VEW and PCA stress indexes were re-estimated for the extended period ranging from January 2005 to March 2017. All stress variables were standardised and four subindexes were assembled for use in both stress indexes. The descriptive statistics of the extended stress variables and subindexes after standardisation is provided in Table 9.15. The graphical representations of the extended stress variables and subindexes are provided in Figures 9.9 to 9.10 respectively.

Table 9.15: Descriptive Statistics for Stress Subindexes and Variables

Subindex / Variable	Minimum	Maximum	Mean	Standard Deviation
Equity Market Subindex	-1.012	4.144	0.000	1.000
Bond Market Subindex	-1.146	5.234	0.000	1.000
Currency Market Subindex	-1.192	7.445	0.000	1.000
Banking Sector subindex	-1.929	3.089	0.000	1.000
IOC-IOS spread	-2.077	4.813	0.003	1.010
Inverted CMAX Australian property index	-0.498	4.691	0.002	1.010
Inverted S&P/ASX 300 metals & mining	-1.018	2.908	0.014	1.005
Inverted CMAX for lagged Chinese Hang Seng Index	-0.922	4.122	0.006	1.008
Inverted CMAX for lagged American S&P 500 Index	-0.667	3.486	0.013	1.006

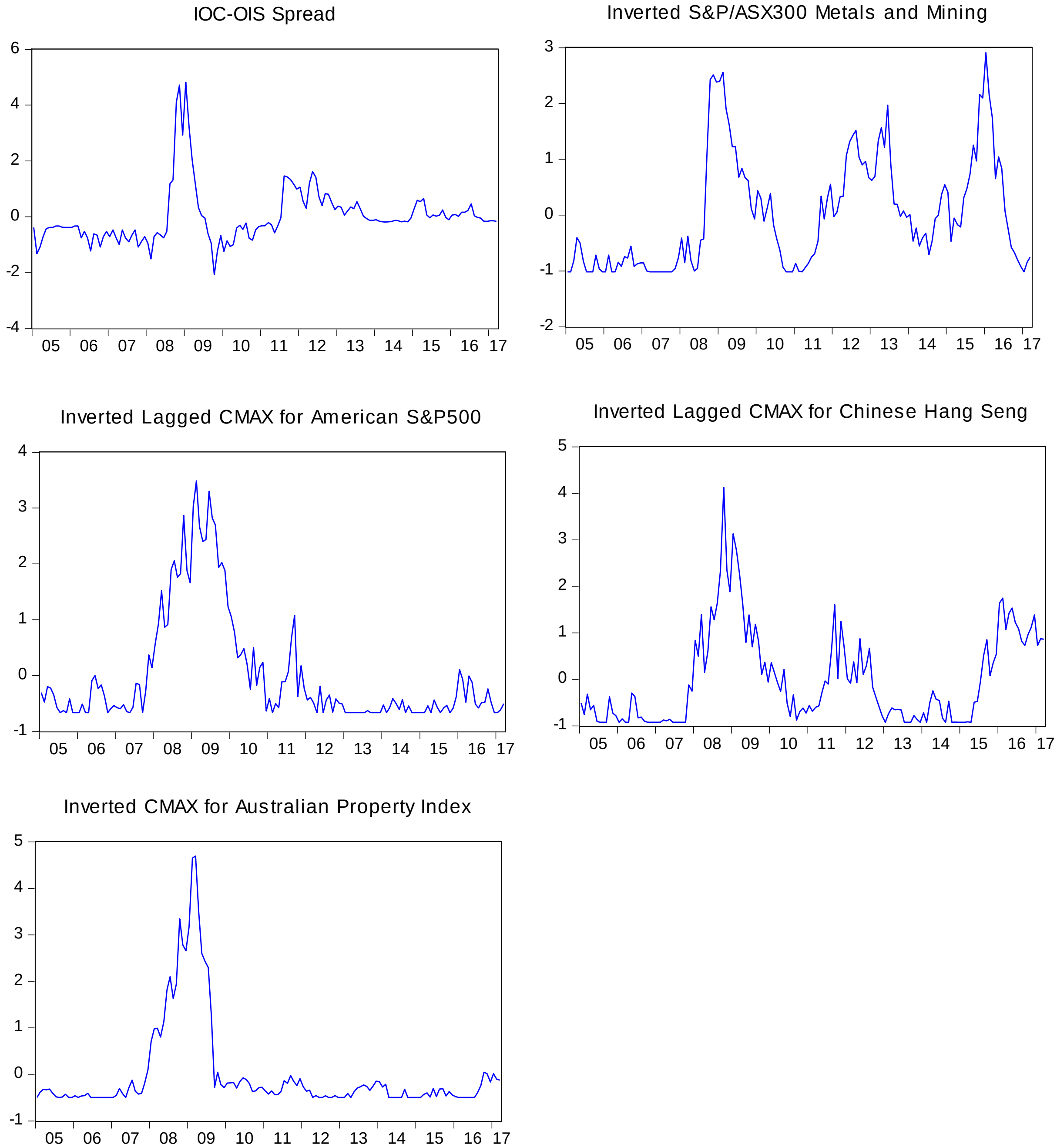


Figure 9.9: Extended Series for Stress Variables (Jan 2005 to Mar 2017)

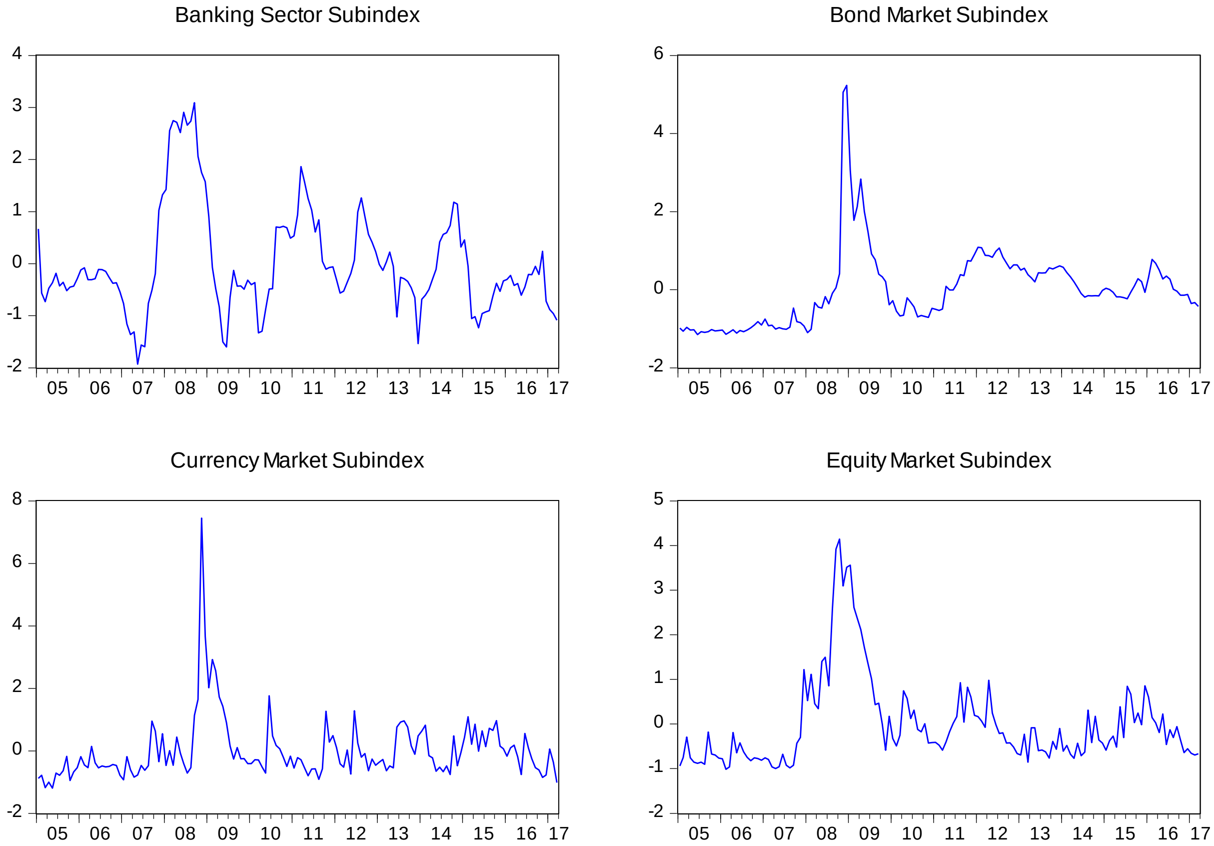


Figure 9.10: Extended Series for Stress Subindexes (Jan 2005 to Mar 2017)

While the same procedure was followed when estimating the extended VEW stress index, a different procedure was used to estimate the PCA stress index. A different procedure had to be adopted because the principal component analysis for the extended series yielded two principal components instead of one. The extended series were examined based on three criteria[87] in order to determine whether PCA was warranted. In order to assess the first criterion, pairwise correlation coefficients for the nine variables were obtained. Table 9.16 presents the correlation matrix for the extended stress variables and subindexes. The first criterion is satisfied because there are several correlation coefficients are greater than 0.3.

[87] These criteria are, also, used to determine whether PCA was warranted in the subsection 9.4.3 of this chapter.

Table 9.16: Correlation Matrix for Extended PCA Index Variables

	IOC-OIS Spread	Inverted Property Index	Inverted Metals & Mining Index	Inverted lagged Hang Seng Index	Inverted lagged S&P 500 Index	Bond Market Subindex	Equity Market Subindex	Currency Market Subindex	Banking Sector Subindex
IOC-OIS Spread	1.000	-	-	-	-	-	-	-	-
Inverted Property Index	0.551	1.000	-	-	-	-	-	-	-
Inverted Metals & Mining Index	0.636	0.420	1.000	-	-	-	-	-	-
Inverted lagged Hang Seng Index	0.589	0.702	0.573	1.000	-	-	-	-	-
Inverted lagged S&P 500 Index	0.335	0.859	0.379	0.703	1.000	-	-	-	-
Bond Market Subindex	0.661	0.816	0.549	0.769	0.748	1.000	-	-	-
Equity Market Subindex	0.763	0.567	0.744	0.557	0.444	0.615	1.000	-	-
Currency Market Subindex	0.675	0.597	0.546	0.412	0.406	0.619	0.731	1.000	-
Banking Sector Subindex	0.201	0.294	0.008	0.307	0.293	0.428	0.102	0.116	1.000

The statistics relating to the second and third criteria are presented in Tables 9.17 and 9.18. For the second criterion, the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO-MSA) (Kaiser, 1970, 1974) values for the individual and the set of variables were examined; values that exceed 0.6 are preferable for PCA. For the third criterion, the reported Bartlett's test of sphericity statistic (Bartlett, 1954) was examined; a Bartlett test statistic that is significant at a five percent level of significance is preferable for PCA. The KMO-MSA for the individual variables is reported in Table 9.17. The measures of sampling adequacy for all variables are greater than 0.6. Table 9.18 reports the KMO-MSA and the Bartlett's test of sphericity for the set of nine variables. The overall KMO-MSA is 0.84 which is greater than 0.6. The estimated chi-squared value for Bartlett's test of sphericity is 1090.825 with a probability of zero; this indicates that the test statistic is significant at a five percent level of significance. Overall, three criteria were satisfied. Therefore, the use of PCA is acceptable. Consequently, this study estimated the principal components for the extended series.

Table 9.17: KMO Test Results for Variables

Variable	Kaiser-Meyer-Olkin Measure of Sampling Adequacy
IOC-OIS	0.831
Inverted Property Index	0.820
Inverted Metals & Mining Index	0.846
Inverted lagged Hang Seng Index	0.895
Inverted lagged S&P 500 Index	0.752
Bond Market Subindex	0.888
Equity Market Subindex	0.855
Currency Market Subindex	0.862
Banking Sector Subindex	0.711

Table 9.18: KMO-MSA and Bartlett's Test Results

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	Bartlett's Test of Sphericity		
	Chi-squared statistic	Degrees of freedom	Probability
0.840	1090.825	36	0.000

PCA revealed the presence of two principal components with eigenvalues exceeding one. The two-component solution explained 74.479 percent of the total variance in the variables. Specifically, the first and second components explain 41.842 and 32.637 percent % of the variance in the nine variables, respectively. Tables 9.19 and 9.20 present the un-rotated and rotated eigenvalues for the PCA. An inspection of the scree plot presented in Figure 9.11 show that two component should be retained for further analysis.

Table 9.19: Un-rotated Factor Loadings for PCA

	Factor Loadings		Communalities
	Component 1	Component 2	
Equity Market Subindex	0.908	0.226	0.875
Inverted Australian Property Index	0.859	0.285	0.818
Inverted lagged Chinese Hang Seng Index	0.826	0.203	0.723
Bond Market Subindex	0.823	-0.408	0.844
IOC-OIS spread	0.800	-0.323	0.745
Inverted lagged American S&P 500 Index	0.761	0.438	0.771
Currency Market Subindex	0.758	-0.326	0.681
Inverted Metals and Mining Index	0.726	-0.445	0.725
Banking Sector Subindex	0.334	0.639	0.521
Eigenvalues percentage of variance	41.842	32.637	

Table 9.20: Rotated Factor Loadings for PCA

	Factor Loadings	
	Component 1	**Component 2**
Equity Market Subindex	0.563	0.747
Inverted Australian Property Index	0.487	0.762
Inverted lagged Chinese Hang Seng Index	0.514	0.678
Bond Market Subindex	0.896	0.201
IOC-OIS spread	0.825	0.253
Inverted lagged American S&P 500 Index	0.315	0.820
Currency Market Subindex	0.794	0.224
Inverted Metals and Mining Index	0.844	0.111
Banking Sector Subindex	-0.143	0.707

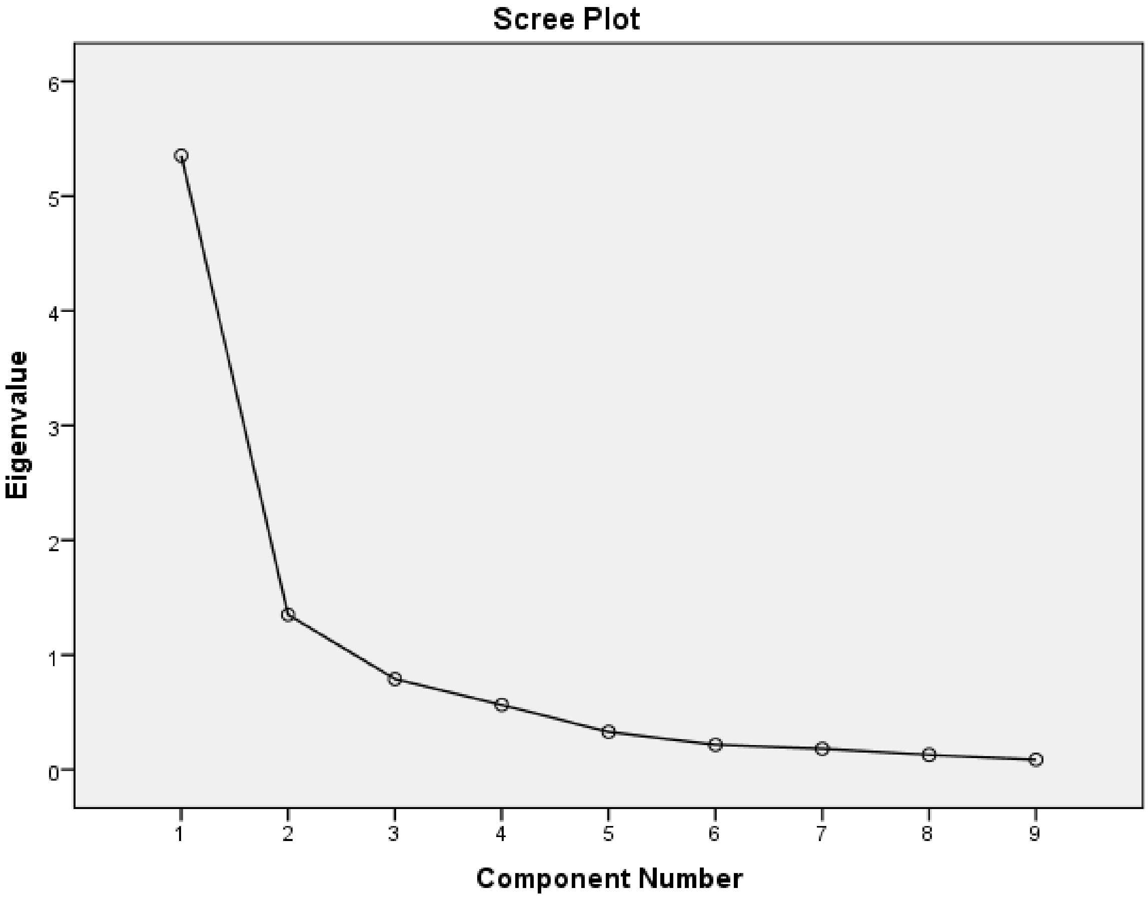


Figure 9.11: Scree Plot for the Nine Components

Parallel analysis was performed in order to determine if the use of two components was warranted. Table 9.21 shows the output for Monte Carlo simulations of PCA for parallel analysis using Marley Watkins software (Watkins, 2000). A hundred iterations were performed on a random data set of nine variables with 147 subjects. The random eigenvalues from the parallel analysis were compared with the eigenvalues from the PCA in order to determine how many components to use in the composite stress index. Hypothesis tests were performed for the null hypothesis that a component should be included in the PCA. The random eigenvalues are used as the critical values for the hypothesis tests. The null hypothesis is accepted if the actual eigenvalue exceeds the critical values, otherwise it is rejected. Table 9.22 lists nine-hypothesis test the decisions. A comparison of the actual and critical eigenvalues indicates that using two principal components is justified. Consequently, the two principal components are used to estimate the extended PCA stress index.

Table 9.21: Output for the Parallel Analysis (Extended series)

Eigenvalue Number	Random Eigenvalue	Standard Deviation
1	1.3872	0.0718
2	1.2662	0.0428
3	1.1586	0.0388
4	1.0671	0.0341
5	0.9904	0.0359
6	0.9058	0.0363
7	0.8242	0.0406
8	0.7428	0.0407
9	0.6577	0.0462

Monte Carlo PCA for Parallel Analysis

Table 9.22: Comparison of PCA and Parallel Analysis Eigenvalues

Component	Actual Eigenvalue (PCA)	Random Eigenvalue (Parallel Analysis)	Decision
1	5.353	1.387	accept
2	1.350	1.266	accept
3	0.790	1.159	reject
4	0.564	1.067	reject
5	0.329	0.990	reject
6	0.216	0.906	reject
7	0.182	0.824	reject
8	0.129	0.743	reject
9	0.087	0.658	reject

This study estimated the extended PCA stress index by obtaining the weighted sum of the principal components obtained from the PCA. The two principal components were weighted based on the variance explained by each component. The mathematical expression of the extended PCA stress index is as shown in equation 9.4. Where c_1 and c_2 denote, respectively, the first and second principal component. A comparative line graph of the extended PCA and VEW stress index is provided in Figure 9.12. The extended PCA stress index reported a stressful period from November 2008 to January 2009 with index values of 2.45 and 2.05 respectively. The extended VEW stress index reported high levels an episode of stress from October 2008 to March 2009 with index values of 2.54 and 2.10 respectively. Both indexes indicated that the stress peaked in November 2008 with the PCA and VEW stress index reporting index values of 2.45 and 3.02 respectively.

$$Extended\ PCA\ Stress\ Index = 0.41842c_1 + 0.32637c_2 \tag{9.4}$$

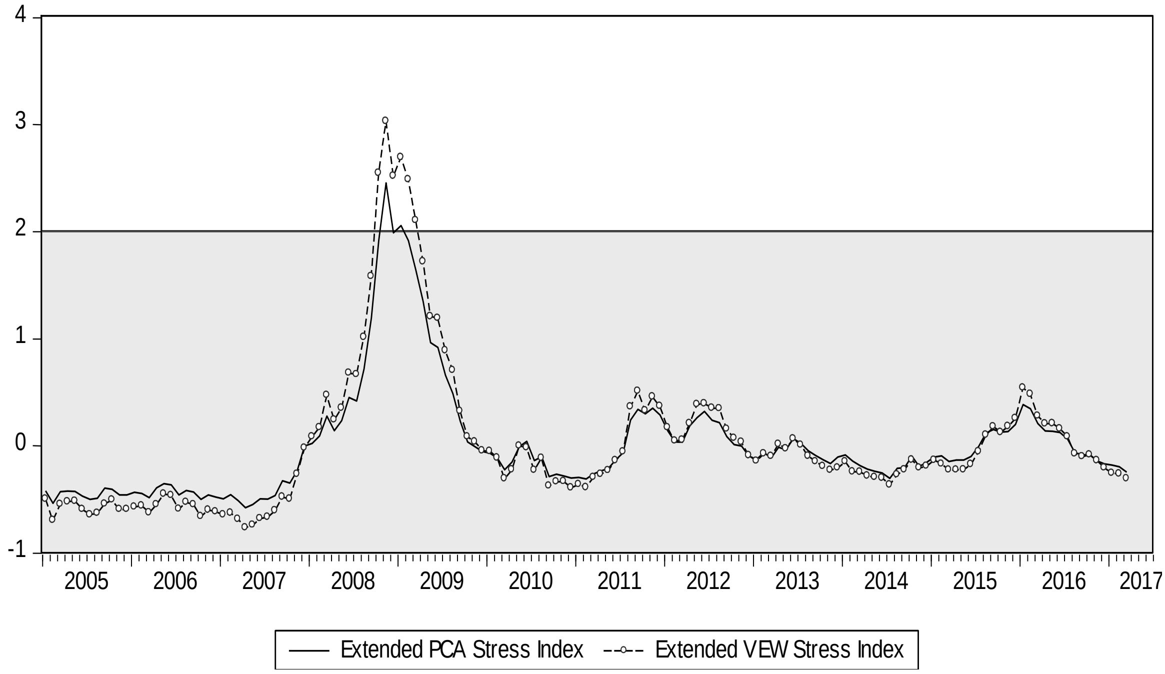


Figure 9.12: Extended PCA and VEW Stress Indexes (Jan 2005 to Mar 2017)

9.5.1.1 Which Index is a better Monitoring Tool?

This subsection compares the performance of the estimated stress indexes as tools for monitoring financial stress. In particular, the VEW and PCA stress indexes were assessed in order to determine if either of the indexes was better at gauging the level of Australian financial stress. Table 9.23 gives a summary of the episodes of financial stress as indicated by the estimated stress indexes.

Table 9.23: Comparison of the Stress Indexes

Stress Index	Duration of Episode		Peak Month
	Start	End	
VEW	October 2008	March 2009	November 2008
PCA	October 2008	April 2009	November 2008
Extended VEW	October 2008	March 2009	November 2008
Extended PCA	November 2009	January 2009	November 2008

All estimated stress indexes highlight November 2008 as the worst month of the 2007-2009 Global Financial Crisis (GFC). The VEW stress indexes seem to provide a more consistent indicator of the duration of the episode of financial stress than the PCA stress indexes. Specifically, both VEW and extended VEW stress indexes indicate that the GFC lasted from October 2008 to March 2009. Conversely, the duration of the GFC as measured by the PCA stress indexes differs. While the PCA stress index suggests that the GFC lasted from October 2008 to April 2009, the extended version of the PCA index indicates that the GFC lasted from November 2009 to January 2009. It is unlikely that the crisis lasted for three months as suggested by the extended PCA stress index. In fact, Sykes (2010) gives a detailed account of the GFC and states that at the very least the worst months of the crisis lasted from September 2008 to March 2009. If this is the case then the extended PCA stress index seems to provide a late warning signal compared to the PCA stress index. This suggests that the monitoring performance of the PCA stress index is superior to the extended PCA stress index. However, the disparity in the estimated duration of stress as reported by the PCA stress index versus the extended PCA stress index indicates that the use of the PCA methodology is unlikely to produce a consistent measure of financial stress. Because the VEW stress indexes produce consistent estimates for the duration of an episode of stress, it can be argued that the VEW stress index is a more reliable tool for monitoring the level of financial stress in Australia. At this point, it is important to mention that there is no guarantee that an index that is a suitable measure of financial stress will also be useful for forecasting financial stress. Consequently, the next section of this chapter examines the performance of the PCA and VEW stress indexes as tools for forecasting Australian financial stress.

9.5.2 Forecasting Australian Financial Stress

This section of the chapter explores whether the PCA and VEW composite stress indexes can be used to forecast financial stress in Australia. Data for both stress indexes was obtained for the months of January 2005 to December 2014 and used to estimate models that forecast financial stress. A notable stressful event occurred during the period under study and several months of financial stress culminated in the 2007-2009 GFC. Therefore, the predictive power of the estimated forecasting models was evaluated with particular emphasis on how well the forecasting models predicted the onset of the GFC. Before engaging in a forecasting exercise, it is important to note that there are some limitations as to what a forecasting model can achieve. This research will briefly discuss two key limitations of forecasting financial stress in order to clarify the potential uses of the forecasting models proposed in this chapter.

The first limitation is that it is impossible to design a forecasting model that can predict the onset of a 'Black Swan' event (Misina & Tkacz, 2009). This is because forecasting models are often based on historical data, which is used to predict the potential for future crises. For this reason it would be easy for policymakers to discern the sequence of events that could lead to a financial crisis especially if history repeats itself. In this case, it would be possible for policymakers to propose and implement policies that would forestall a crisis. However, if a financial crisis occurs that is different from past episodes of crisis then it would be difficult for policymakers to recognise the early stages of a developing crisis. In this case, policy implementation would primarily be geared towards minimising crisis-related losses and restoring the health of the sectors that were affected by the financial crisis.

The second limitation of forecasting models is difficulty in forecasting fluctuations in financial stress, unless symptoms of distress are beginning to strongly perturb the financial system. For example, Vašíček et al. (2017) explored the use of models to forecast financial stress. In order to do this, five indicators of stress were used to estimate a composite stress index. The resultant stress indexes were used to forecast financial stress in 25 countries with particular emphasis on the GFC that had global impact on financial markets. Data for the composite stress indexes was sampled from the 1980s or 1990s until the last quarter of 2006. The sample dataset was used to estimate the level of financial stress for the subsequent quarters until the fourth quarter of 2010. It was established that forecasting models for all countries performed poorly especially when out-of-sample forecasts were examined.[88] Particularly, it was impossible to predict the onset of the 2007-2009 GFC when using the sampled data to predict movements in the financial markets of the 25 countries. The findings of this research are unsurprising especially because the early signs of the GFC only became apparent in the second half of 2007. Another issue of concern is that it is unlikely that a forecasting model will be able to anticipate adequately the level of financial stress over a four years (or 48 quarters) time. A lot can change in financial markets within a 4-year period and one should bear in mind that composite stress indexes exhibit a random walk that is often absent of a seasonal[89] and trend component.[90] A more prudent approach to forecasting financial stress is to assess the prevailing level of financial stress regularly. This is because as the time of the financial crisis draws near, the symptoms of distress in the financial system will begin to emerge. Policy makers will then be able to see early signs of a developing crisis, especially if the onset of the crisis is gradual and decide whether intervention is necessary.

[88] The out-of-sample period ranges from the first quarter of 2007 to the last quarter of 2010. Therefore, out-of-sample forecasts are the predicted values for financial stress from 2007 to 2010.

[89] A series with a seasonal component is characterised by high (or low values) in specific months or quarters. Series with seasonal components tend to oscillate between high and low values in a manner that can easily be predicted by forecasting models.

[90] It is easier to predict the values of a series especially if that series has a long-term trend either upwards or downwards.

According to Christensen and Li (2014), caution should be taken when deciding on the forecasting horizon, especially because it is possible to give a more accurate forecast as the timing of the stressful event draws nearer. For this reason, the aforementioned authors use a dataset from the second quarter of 1982 to the second quarter of 2010. In order to perform a forecast the data was split into two subsets where the first (in-sample) subset ranged from the second quarter of 1982 to the third quarter of 2007 and the second (out-of-sample) subset ranged from the fourth quarter of 2007 to the second quarter of 2010. Better out-of-sample forecasts were obtained in the study by Christensen and Li (2014).

The third limitation of forecasting models is that even if there are early signs of financial crisis, predicting the exact time when a crisis will occur is difficult (Borio & Lowe, 2002). Ideally, it would be desirable to have a forecasting model that is not only able to signal a developing (or ongoing) crisis[91] but can also predict the timing of the onset of the crisis. This is because such a forecasting model would assist policy makers to determine if, and when, it is necessary to intervene in order to forestall a crisis. However, in practice it is difficult to anticipate the exact timing of a crisis and in some cases a forecasting model can provide incorrect forecasts of financial stress. For instance, it is possible that a financial stress index predicts financial stress even if in reality there is no stressful event; this is a Type II error. Alternatively, a financial stress index may fail to issue a warning even if a stressful event has actually occurred; this is a Type I error. In light of the potential for the occurrence of these errors, some studies have suggested that the preference of the policy makers for either of the errors should considered when assessing the forecasting performance of a composite stress index (Alessi & Detken, 2011; Christensen & Li, 2014; Duca & Peltonen, 2013). It should be noted nonetheless that the consideration of policy makers' preference for errors fails to address this limitation of forecasting models.

[91] Tranquil periods are not as detrimental to an economy as crisis periods; this is why this study focuses on the latter instead of the former.

Overall, there is little that can be done to address the three limitations highlighted here. Rather it is important for the forecaster to bear in mind these limitations when making use of the stress index forecasts. The question is then of what use is a forecast of financial stress? Well, there is not much that can be done in regards to the 'Black Swan' events. However, in the short-term a forecast of financial stress could potential help predict a developing crisis especially if early signs of the crisis are already evident. While it is impossible to predict the exact timing of a crisis, the forecast of a crisis in the near future could help policy makers to begin planning and implementation of policies that could make an economy resilient enough to cope with the negative effects of a crisis in the future. For these reasons, this study proposes that financial stress forecasts are still useful. Consequently, this study will now proceed to perform the financial stress forecasting exercise. Before embarking on a forecasting exercise, it is important to identify a model that adequately forecasts Australian financial stress. In order to do this several models were estimated and used to assess the forecasting performance of the stress indexes. The rest of this section provides a detailed discussion of the criteria used to identify the model that is most suited for forecasting Australian financial stress.

This research follows Misina and Tkacz (2009) who use linear models to evaluate the forecasting performance of a composite financial stress index. Two kinds of models are used to assess the forecasting performance of a stress index. The first kind of model is based on the idea that the past information from the composite stress indexes is sufficient to predict the prevailing level of financial stress. In this case past values of financial stress are used to predict current financial stress. The second kind of model is based on the notion that current financial stress can be predicted by using past information of financial stress and explanatory variables. In this case, lagged values of financial stress index and lagged values of explanatory variables are used to predict the prevailing level of financial stress. This study uses linear regression models to estimate the two kinds of models. In order to make it easier to differentiate between the two kinds of model, the first kind of model is referred to as a base while the and second kind of model is referred to as the extended model. The subsections that follow discuss outline the model specification of the two kinds of models.

9.5.2.1 The Base Model

This study used Autoregressive Integrated Moving Average (ARIMA) models to estimate the base models for the PCA and VEW stress indexes. An ARIMA (p,d,q) model is made up to three parts. The first part is the autoregressive component of the model which is comprised of lagged values of a series. The letter ‘p’ denotes the number of lagged terms of the series that are included in the model. The second part of the model is the intergrated part which relates to the number of times a series must be differenced in order to achieve a stationary series. The letter ‘d’ denotes the degree of differencing involved in order to make a series stationary. If a series needs to be differenced once in order to make it stationary, that series is said to intergrated of order one and ‘d’ is equal to one in this case. However, if a series is already stationary then there is no need to difference the series and ‘d’ will be equal to zero. This kind of model can referred to as an ARMA model instead of an ARIMA model because there are no integrated series in the model. The third part of the model is the moving average part of model which is comprised lagged error terms. The letter ‘q’ denotes the number of lagged error terms that are included in a model (Makridakis, Wheelwright, & Hyndman, 1998).

In practice it is common for researchers to embark on a trial and error exercise which involves estimating several ARIMA models and examining correlograms and information criteria in order to identify the model that is suitable for forecasting a series. This is because the values of ‘p’, ‘d’, and ‘q’ are rarely know before hand. The Akaike, Hannan-Quinn and Schwarz information criteria are commonly used information criteria that are used to determine the optimal value of ‘p’ and ‘q’. Some statistical software, like Eviews (version 9.5)[92] provide tools that can automatically perform the trial and error exercise and identify the most suitable ARIMA model for a series. This study uses Eviews’ automated ARIMA forecasting feature and the Akaike information criterion (AIC) to estimate ARIMA models for the two composite indexes. In order to do this the dataset is split into two parts. The first part is the in-sample dataset, which is used to initialise the forecasting process. The in-sample dataset contains monthly data from January 2005 until August 2008, which is just before the worst months of the crisis (Kolb, 2011; Sykes, 2010). The second part of the dataset is the out-of-sample set, which ranges from September 2008 to December 2014. The out-of-sample dataset is used to assess the performance of the forecasting model. Thereafter, the best forecasting models were used to perform forecasts.

Base models for the PCA and VEW stress indexes were estimated as follows. The first difference of the PCA and VEW stress index was obtained in order to achieve a stationary series. ARIMA models were fitted to the differenced stress indexes and the Akaike information criterion (AIC) was used to determine the appropriate model specification. Table 9.24 provides a detailed summary of the AIC values for the models estimated for the PCA and VEW stress indexes. The model with the smallest AIC value was identified as the best model. In the case of the PCA stress index, it was found to be an ARIMA (4, 1, 2) model with an AIC value of -1.385. The estimated coefficients for the model are shown in equation 9.5. Where L is the lagged operator, FSI_t^{PCA} stands for the value of the financial stress index as computed by the PCA method and ϵ is the error term. In the case of the VEW stress index, an ARIMA (0, 1, 1) model was identified as the best model with an AIC value of -1.653. The estimated coefficients for the estimated model are as shown in equation 9.6. Where FSI_t^{VEW}

[92] Older versions of Eviews do not have this feature.

stands for the value of the financial stress index as computed by the VEW method and u is the error term. This study now estimates the extended models in the subsection that follows.

$$(1-L)FSI_t^{PCA} = 0.002 + 0.039FSI_{t-1}^{PCA} - 0.555FSI_{t-2}^{PCA} - 0.334FSI_{t-3}^{PCA} \\ -0.559FSI_{t-4}^{PCA} - 1.382\epsilon_{t-1} + \epsilon_{t-2} \quad (9.5)$$

$$(1-L)FSI_t^{VEW} = 0.003 - u_{t-1} \quad (9.6)$$

Table 9.24: Base ARIMA Models for Composite Stress Indexes

Model #	PCA Stress Index		VEW Stress Index	
	ARIMA specification (p,d,q)	AIC Value	ARIMA specification (p,d,q)	AIC Value
1	(4,1,2)	-1.385	(0,1,1)	-1.653
2	(4,1,3)	-1.375	(2,1,3)	-1.635
3	(0,1,3)	-1.375	(0,1,2)	-1.611
4	(1,1,2)	-1.354	(1,1,1)	-1.609
5	(4,1,4)	-1.352	(0,1,3)	-1.592
6	(1,1,3)	-1.327	(3,1,3)	-1.588
7	(0,1,4)	-1.327	(2,1,4)	-1.588
8	(2,1,2)	-1.326	(2,1,1)	-1.584
9	(0,1,1)	-1.311	(1,1,2)	-1.573
10	(0,1,2)	-1.309	(4,1,2)	-1.570
11	(1,1,1)	-1.294	(0,1,4)	-1.546
12	(2,1,1)	-1.289	(1,1,3)	-1.546
13	(2,1,3)	-1.289	(2,1,2)	-1.538
14	(4,1,1)	-1.282	(3,1,1)	-1.538
15	(1,1,4)	-1.280	(4,1,1)	-1.519
16	(3,1,2)	-1.279	(1,1,4)	-1.499
17	(2,1,4)	-1.247	(4,1,3)	-1.450
18	(3,1,3)	-1.244	(4,1,0)	-1.441
19	(3,1,1)	-1.235	(3,1,4)	-1.414
20	(3,1,4)	-1.204	(4,1,4)	-1.403
21	(4,1,0)	-1.114	(3,1,0)	-1.380
22	(2,1,0)	-1.081	(2,1,0)	-1.352
23	(3,1,0)	-1.076	(1,1,0)	-1.209
24	(1,1,0)	-0.832	(0,1,0)	-1.024
25	(0,1,0)	-0.588	(3,1,2)	0.470

9.5.2.2 The Extended Model

In addition to estimating base models, this study also estimated forecasting ARIMA models, which include explanatory variables. Four explanatory variables were considered for inclusion in the forecasting models. These variables are the inverted CMAX measures for the

S&P/ASX 200 index, coal prices, iron ore prices and the 90-day bank accepted bill yield. The S&P/ASX 200 variable is used to gauge if there is any additional information about the Australian equity market that is not readily available from the All Ordinaries index. End-of-the-month monthly data for the S&P/ASX 200 variable was sourced from the Yahoo finance website. This study chose to include measures of two of Australia's lead exported goods to China; these are coal and iron ore (DFAT, 2012, 2013, 2014, 2015c). It is hypothesised that the prices of coal and iron ore could be useful tracking developing stress levels in the resource sector that is driven for the most part by China. Monthly data of prices for both variables was sourced from the Index Mundi website (Index Mundi, 2017). The yield on the 90-day bank accepted bill is used to gauge changing attitudes among lenders in the short-term. Since bank accepted bills are a short-term debt instrument, it is expected that when a crisis is developing that lenders would be more reluctant to offer short-term debt. Instead, financial institutions would prefer to hold on to more cash with the expectation that the crisis could lead to a credit crunch. Consequently, the yield on bank accepted bills could be reduced in order to discourage purchase of bank bills.

A 24-month window was used to estimate the inverse CMAX measure of the four variables. The explanatory variables under consideration were standardised and a graphical representation of the four series is provided in Figure 9.13. Thereafter, the variables were used to estimate the extended ARIMA models for the PCA and VEW stress indexes as follows. The first difference of the PCA and VEW stress index was obtained in order to achieve a stationary series. ARIMA models were fitted to the differenced stress indexes and a separate model was estimated by adding one explanatory variable to a base model at a time. This means that eight models were estimated: four models for the PCA stress index and four models with the VEW stress index. The Akaike information criterion (AIC) was used to determine the appropriate model specification. Table 9.25 provides a summary of the components of each model and the chosen model based on the minimum AIC value.

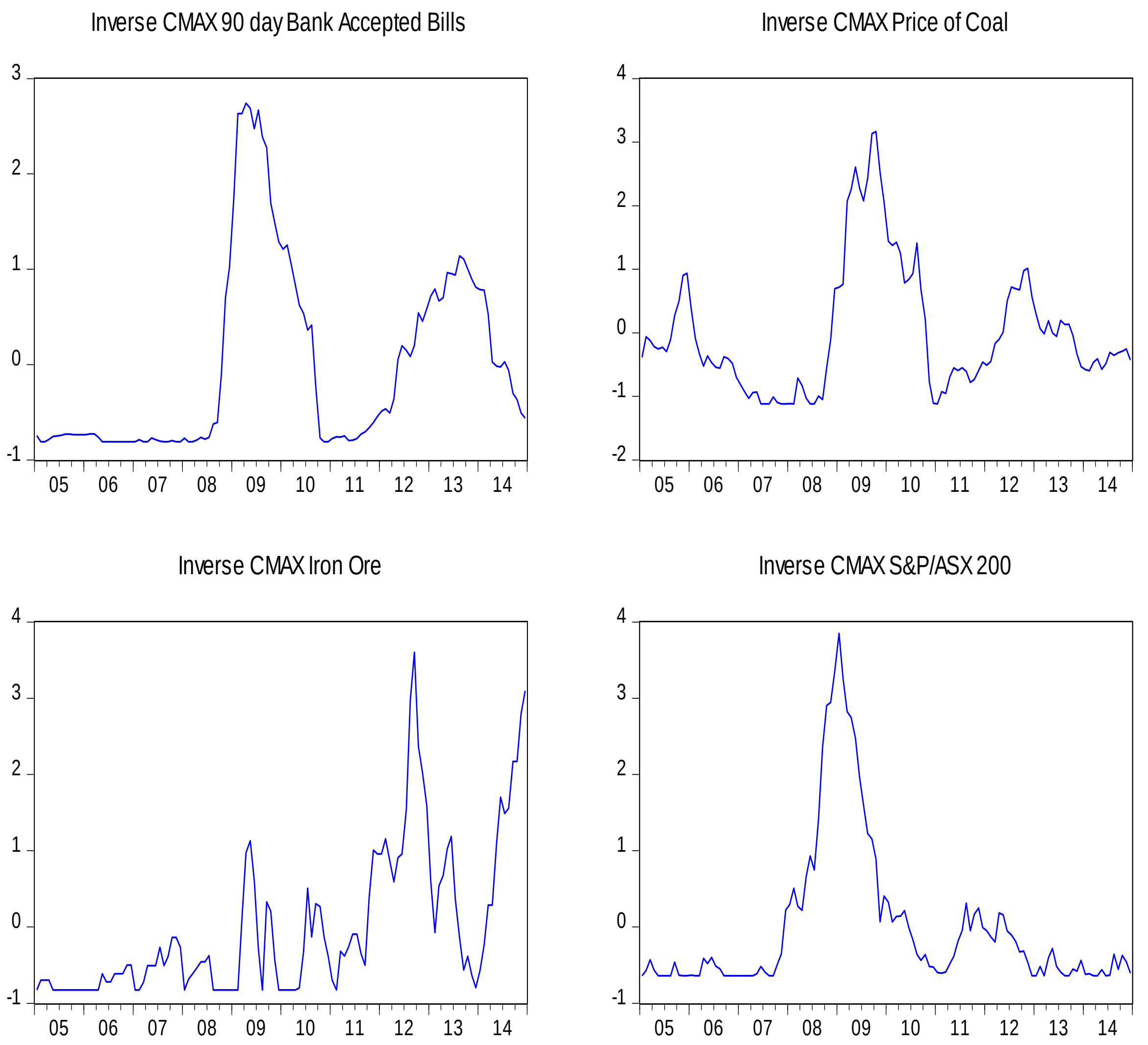


Figure 9.13: Explanatory Variables for Forecasting Australian Financial Stress

Table 9.25: Summary of Extended Models for Stress Indexes

Weighting Method		Explanatory Variable included	ARIMA (p, d, q) model selected
	PCA	Inverted CMAX for S&P/ASX 200 index	(4,1,2)
		Inverted CMAX for coal prices	(0,1,2)
		Inverted CMAX for iron ore prices	(4,1,2)
		Inverted CMAX for 90-day bank bill	(4,1,2)
	VEW	Inverted CMAX for S&P/ASX 200 index	(2,1,3)
		Inverted CMAX for coal prices	(2,1,3)
		Inverted CMAX for iron ore prices	(0,1,1)
		Inverted CMAX for 90-day bank bill	(0,1,1)

So far, it is unclear whether any of the explanatory variables should be included in the forecasting model. It is possible to establish the forecasting potential of the explanatory variables by analysing information from the actual value of the stress index, the base model, and the extended models. The root-mean-squared error (RMSE) was used to perform this analysis. The RMSE can be considered as a measure of the average error of the forecasted values relative to the actual values of financial stress. The RMSE calculates the sum of the squared deviations of the forecasted value compared to the actual value of a series. When comparing two models the one with a lower RMSE value is considered as a model which fits the data better (Makridakis et al., 1998). This study follows Misina and Tkacz (2009) approach which the uses the RMSE of the estimated models to calculate the ratio of RMSE. This was done in the following manner. First, the forecasts of the extended model were compared with the actual value of financial stress as measured by the composite stress index and the RMSE value was calculated. Second, the forecasts of the base model were compared with the actual value of financial stress as measured by the composite stress index the RMSE value was calculated. Equation 9.7 provides the formula for estimating the ratio of the RMSE over the out-of-sample period from May 2005 to August 2008.

$$Ratio\ of\ RMSE = \frac{\sqrt{\sum_{t=2005\ M05}^{2008\ M08}(\widehat{FSI}_{\ EXT,t} - FSI_t)^2/76}}{\sqrt{\sum_{t=2005\ M05}^{2008\ M08}(\widehat{FSI}_{\ BASE,t} - FSI_t)^2/76}} \tag{9.7}$$

M08 and *M05* stand for the months of August and May respectively. $\widehat{FSI}_{\ EXT,t}$ represents the forecasted value of financial stress at time *t* as calculated by the extended model. $\widehat{FSI}_{\ BASE,t}$ represents the forecasted value of financial stress at time *t* as calculated by the base model. FSI_t represents the actual value of financial stress as estimated by either the PCA or VEW weighting method. The numerator of equation 9.7 estimates the RMSE for the forecast of financial stress based on an extended model compared to the actual value of financial stress.

A summary of the calculated ratio of RMSE values for the eight extended models is provided in table 9.26. If the estimated value of the ratio of RMSE is less than one, then it is concluded that adding an explanatory variable to the base model has improved the forecasts of financial stress. If the value of the ratio of RMSE is greater than one, then it is concluded that the addition of the explanatory variable to the base model has impaired the performance of the model (Misina & Tkacz, 2009). An inspection of Table 9.26 reveals that the inclusion of the four explanatory variables to the base models improves the forecasts produced by the model. Therefore, this study will now consider the use of several combinations of explanatory variables when estimating extended models for forecasting financial stress.

Table 9.26: Ratio of RMSE for Forecasting Models

Model	RMSE	Ratio of RMSE
PCA stress index with inverted CMAX for S&P/ASX 200	1.132	0.173
PCA stress index with inverted CMAX for coal prices	0.948	0.145
PCA stress index with inverted CMAX for iron ore prices	4.061	0.620
PCA stress index with inverted CMAX for 90-day bank bill	1.619	0.247
PCA stress index base model	6.549	n.a.
VEW stress index with inverted CMAX for S&P/ASX 200	0.692	0.100
VEW stress index with inverted CMAX for coal prices	0.912	0.131
VEW stress index with inverted CMAX for iron ore prices	3.391	0.488
VEW stress index with inverted CMAX for 90-day bank bill	0.934	0.134
VEW stress index base model	6.948	n.a.

Note: The ratio of RMSE is calculated by comparing each model to the actual value of financial stress as estimated by either the PCA or VEW stress model

This study estimated thirty extended models and used the RMSE measure of each model to determine which extended model provided better forecasts of financial stress. Forecasting models were estimated by adding one to three variables at a time. The ARIMA specification of each model and the estimated RMSE measures for the extended forecasting models are contained in Tables 9.27 and 9.28. Extended forecasting models for the VEW and PCA stress index are presented in Tables 9.27 and 9.28 respectively. An inspection of the RMSE values reveals that the best forecasting model for the VEW stress index is one that includes the inverted CMAX of the S&P/ASX200 variable as an explanatory variable. This model was estimated with an ARIMA (2, 1, 3) process and has an RMSE of 0.692; this is the lowest

RMSE of the fifteen estimated models. In the case of the PCA stress index, the best forecasting model was identified as the ARIMA (0, 1, 2) model that included the coal variable. This model had an RMSE value of 0.948; the lowest of all the estimated models for the PCA stress index. The analysis of the RMSE values suggests that these two models would provide the adequate predictions of financial stress. The remainder of this chapter will focus on comparing and assessing the forecasting performance of these two models.

Table 9.27: Extended Forecasting Models for VEW Stress Index

Explanatory Variables	ARIMA(p,d,q) specification	R-squared	RMSE
S&P/ASX 200	(2,1,3)	0.537	0.692
S&P/ASX 200, coal	(0,1,3)	0.685	3.032
S&P/ASX 200, iron	(0,1,1)	0.524	7.453
S&P/ASX 200, 90-day bank bill	(0,1,1)	0.546	5.901
S&P/ASX 200, coal, iron	(0,1,3)	0.693	2.833
S&P/ASX 200, coal, 90-day bank bill	(0,1,3)	0.689	1.242
S&P/ASX 200, iron, 90-day bank bill	(0,1,3)	0.713	18.958
S&P/ASX 200, coal, iron, 90-day bank bill	(3,1,3)	0.807	58.707
Coal	(2,1,3)	0.681	0.912
Coal, iron	(0,1,3)	0.687	1.661
Coal, 90-day bank bill	(1,1,2)	0.672	1.046
Coal, iron, 90-day bank bill	(1,1,2)	0.737	60.668
Iron	(0,1,1)	0.523	3.391
Iron, 90-day bank bill	(0,1,3)	0.712	16.879
90-day bank bill	(0,1,1)	0.536	0.934

Note: The explanatory variables are all expressed in terms of an inverted CMAX measure with a 24-month window.

Table 9.28: Extended Forecasting Models for PCA Stress Index

Explanatory Variables	ARIMA(p,d,q) specification	R-squared	RMSE
S&P/ASX 200	(4,1,2)	0.731	1.132
S&P/ASX 200, coal	(0,1,3)	0.745	3.592
S&P/ASX 200, iron	(4,1,2)	0.734	5.273
S&P/ASX 200, 90-day bank bill	(0,1,2)	0.645	9.698
S&P/ASX 200, coal, iron	(0,1,3)	0.745	6.118
S&P/ASX 200, coal, 90-day bank bill	(0,1,3)	0.747	5.735
S&P/ASX 200, iron, 90-day bank bill	(0,1,3)	0.765	11.259
S&P/ASX 200, coal, iron, 90-day bank bill	(0,1,2)	0.791	57.843
Coal	(0,1,2)	0.662	0.948
Coal, iron	(0,1,3)	0.742	1.962
Coal, 90-day bank bill	(0,1,3)	0.715	1.040
Coal, iron, 90-day bank bill	(0,1,2)	0.788	64.502
Iron	(4,1,2)	0.726	4.061
Iron, 90-day bank bill	(4,1,3)	0.765	17.013
90-day bank bill	(4,1,2)	0.729	1.619

This study now compares the performance of the two models with regard to forecasting long-term financial stress. Figure 9.14 and 9.15 provide graphical representations of the actual and forecasted values of the PCA and VEW stress index respectively. Unfortunately, both forecasting models fail to predict high levels of stress during the GFC. In fact, all predicted values of the stress index over the forecasting horizon fail to identify any episode of stress.

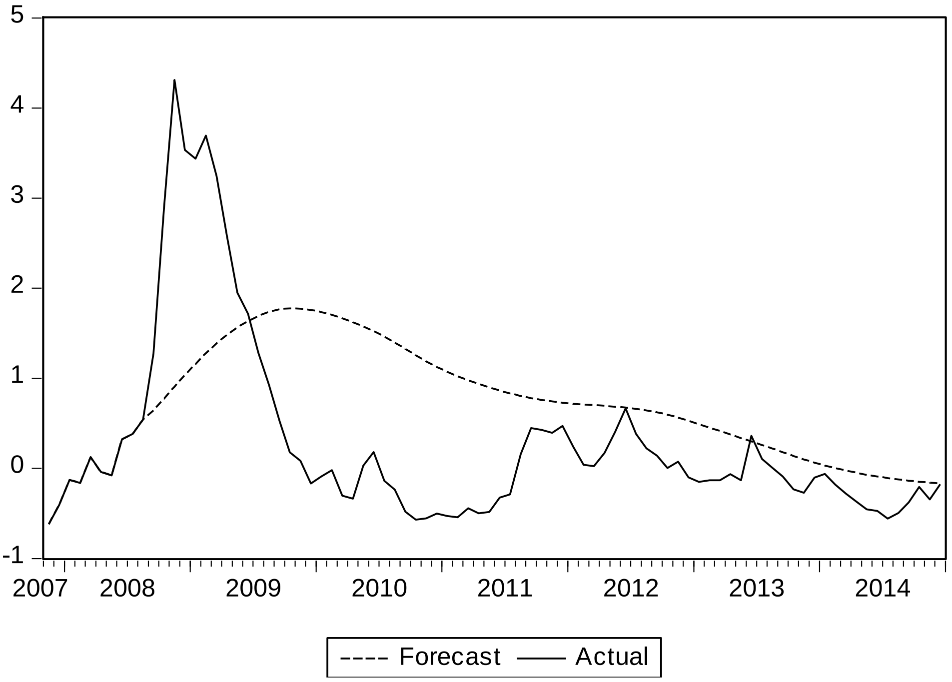


Figure 9.14: Forecasting Australian Financial Stress-PCA Stress Index

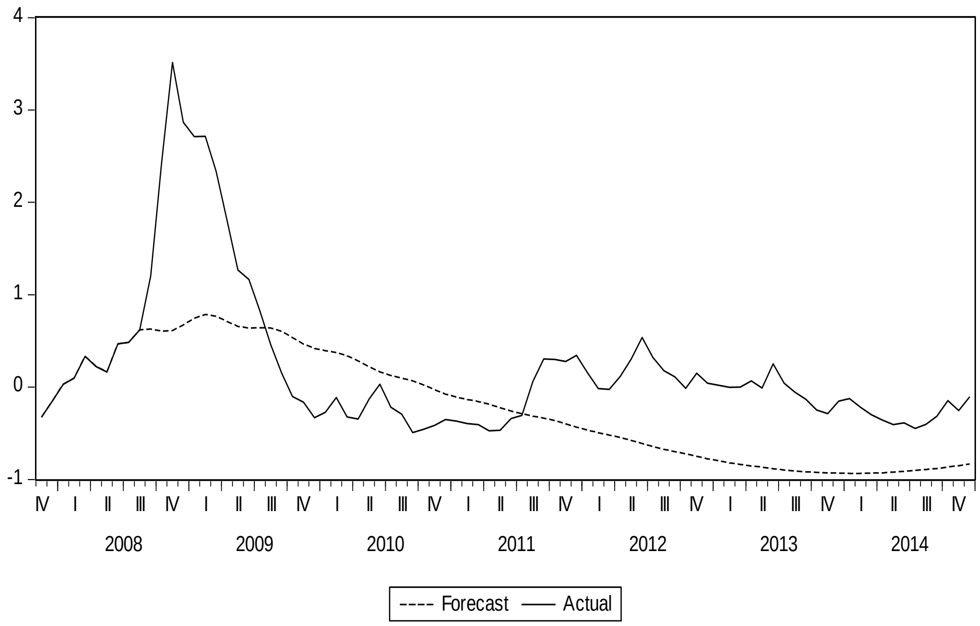


Figure 9.15: Forecasting Australian Financial Stress-VEW Stress Index

9.5.3 Section Summary

In this section of the chapter, this study set out to design a model that forecasts financial stress. The estimated PCA and VEW stress indexes were used to estimate several ARIMA models, which were used to forecast financial stress. Apart from considering the estimated financial stress index, the forecasting potential of four explanatory variables was also investigated. After estimating thirty models, two models were found to be potentially useful in forecasting financial stress. Although, both models showed some promise each model fell short of providing adequate forecasts in financial stress especially at the peak time of the GFC. The findings of this analysis indicate that more research is needed to understand the complex nature of financial crisis, how crises develop, and the techniques (if any) that can be used to predict the onset of financial crises.

9.6 Conclusion

This chapter focuses on combining several stress indicators into a single measure that is a composite stress index. Two stress indexes were constructed using the PCA and VEW aggregation techniques. The performance of the estimated indexes was assessed with respect to the ability of the stress index to monitor the prevailing level of financial stress and the usefulness of the indexes in predicting future episodes of financial stress. The VEW stress index was found to perform better than the PCA stress index when monitoring the level financial stress. This supports the hypothesis that the choice of index aggregation approach would affect the performance of the stress index. However, neither the VEW nor the PCA stress index was useful in predicting the stress during the GFC. These findings suggest that the models proposed in this chapter are useful tools for monitoring the level of financial stress within Australia. However, at present the tools presented in this study are not sufficiently developed to be forward looking in predicting financial stress. The chapter that follows provides a summary of the findings of this research and discusses the implications of the findings for future research. The limitations of the estimated financial stress indexes developed are also discussed.

CHAPTER 10

CONCLUSION

10.1 Introduction

This thesis sought to develop a country-specific stress index that can monitor and forecast financial stress or crisis in Australia. Because Australia has limited experience of endogenous financial crises, Chapter 2 of this thesis investigated the concept of financial stress as an early indicator of financial crisis as proposed by Illing and Liu (2006). The general premise is that the lowest levels of financial stress are recorded during tranquil periods and financial stress begins to rise in the early stages of a financial crisis. A financial crisis is observed when financial stress has reached a crescendo. In order to identify some factors that could contribute to financial stress or crises in Australia, Chapters 4-8 of this thesis investigated the theoretical and empirical factors that contributed to the occurrence of past crises in other countries as identified in literature (Balakrishnan et al., 2011; Caramazza et al., 2004; Dabrowski, 2010; Kaminsky & Reinhart, 1999; Kindleberger & Aliber, 2005; Reinhart & Rogoff, 2009a; Reinhart & Rogoff, 2013; Sykes, 2010). Factors that can be used to develop stress variables which track the various stages of a financial crisis were of particular interest; the stages of financial crises that are the pre-crisis, crisis, and post crisis stages. To this end, this study identifies variables to gauge the stress level in Australia’s equity, bond, currency, money, and property markets. Moreover, several studies indicate that the collapse of a country’s banking sector was an indicator of increased probability of a financial crisis in a country in the near future (Claessens & Kose, 2013; Kaminsky, Lizondo, & Reinhart, 1998; Kaminsky & Reinhart, 1999; Laeven & Valencia, 2008). Therefore, variables that gauge the level of stress in the banking sector were also estimated. Given the importance of the mining industry to Australia as highlighted in Chapter 7 of this thesis, this thesis proposed the use of a variable to gauge the level of financial stress in the mining sector. This study also explored how foreign-based variables could be used to predict future movements in the Australian equity markets. This chapter will now focus on highlighting what this research found, the limitations of this study, and avenues for future research. The chapter is organised as follows. First, Section 10.2 discusses the findings of this research in response to the research gap and questions outlined in Chapter 1. A brief discussion of the research methods is also given in this section. The main emphasis, in this chapter, is on addressing whether there is evidence to support the hypotheses highlighted in Chapter 3. Second, the key findings of this research are discussed in Section 10.3. Third, Section 10.4 provides the implications of the research findings. Fourth, the main contributions made by this study to the existing knowledge are outlined in Section 10.5. This chapter concludes with a discussion of the limitations of this research and some recommendations for future work in Section 10.6.

10.2 Research Gap, Questions and Methods

10.2.1 Research Gap

In Chapter 1 of this thesis, this study notes that few studies have sought to construct a composite stress index for Australia (Balakrishnan et al., 2011; Cardarelli et al., 2011; Duca & Peltonen, 2013; Vašíček et al., 2017; Vermeulen et al., 2015). And, those studies have focused on the use of (at most) seven variables and the variance-equal-weights-index-aggregation method. Even though there is growing body of literature suggesting that property bubbles are a precursor to financial crises, none of these studies developed or included a stress variable to measure the level of stress in the Australian property markets (Alessi & Detken, 2011; Claessens & Kose, 2013; Kindleberger & Aliber, 2005; Luc & Valencia, 2008). Another issue of concern is that past studies did not consider the important role that mining plays in the Australian economy. Australia is primarily a resource-based economy and the export of mined resources is Australia's top revenue earner (DFAT, 2010, 2011, 2012, 2013, 2014, 2015c, 2016b). Because of the important role that the mining sector plays in the Australian economy a consideration of resource-based bubbles and the potential impact of a shock to the Australian mining sector is important. However, a variable to gauge the level of stress in the mining sector has not been incorporated into past composite measures of Australian financial stress. This study addressed these research gaps by developing a composite stress index that explores the use of 22 variables, including variables to gauge stress in Australia's mining sector and property market. In addition to the variance-equal weights method of index aggregation, this study explored the use of the principal components approach to index aggregation when constructing the composite stress index.

10.2.2 Research Questions

The discussion in this subsection is geared towards addressing the research questions that were asked in Section 1.6 of Chapter 1. The research questions and subsidiary questions are reproduced here for the readers' convenience. Thereafter, this section summarises responses to each of these questions based on the findings of this study.

The following were the research questions raised in this study:

A) What are the primary stress indicators in Australia?

B) How can the stress indicators in question A be combined to a composite index for Australian financial stress?

C) What environmental, structural, institutional, and other key factors can contribute to the incidence of an Australian financial crisis?

D) Is a comprehensive stress index for Australia an efficient and effective way to model and predict Australian financial stress?

Regarding research question A, Chapters 4-8 identified 22 primary stress indicators that were used to model stress in the Australian financial markets. Relating to research question B, two index aggregation methods were identified in Chapter 9 as suitable techniques that could be used to construct a stress index; these are the variance-equal weights and the principal components approach. For this reason, the researcher chose to estimate composite stress indexes using both techniques. Relating to research question C, this study examined key factors that contributed to the onset and spread of financial crises in other countries in order to identify factors that could cause an Australian financial crisis. Based on this premise, this study found that a several factors (such as information asymmetry, moral hazard, lax regulation, and risk taking behaviour) interact in a manner that causes the onset and spread of financial crises from one sector to another. For example, an examination of the 2007-2009 GFC revealed that the combination of information asymmetry and moral hazard created an environment where it was possible for American credit rating agencies to assign favourable ratings to financially engineered securities such as CDOs even though these securities were actually ‘toxic assets’ (Crotty, 2009; Edgar, 2009). In this manner, the rating agencies facilitated the acquisition of ‘toxic assets’ by unsuspecting investors and investment banks. During the same crisis Australian financial institutions fared better compared to financial institutions in the US and the UK, in part because strict regulation and supervisory practices that were implemented, in Australia, by APRA. These measures fostered a culture of less risky behaviour among Australian financial institutions (Edwards, 2010). In the absence of such stringent regulations, close supervision, and intervention by regulatory authorities such as the RBA, levels of stress in various sectors of Australia could reach a crisis point. For research question D, this study found that the composite stress index proposed in this study was an effective and efficient way to model Australian financial stress. This is because the composite stress index proposed in this thesis is comprised of stress indicators which track rising asset prices and levels of credit in different sectors of the Australian economy. By monitoring the aggregate rise in asset prices and credit it is possible to identify a developing asset or credit bubble. Because asset bubbles are often a prelude to financial crises, higher than usual rises in several asset prices and/or credit would be reflected by a corresponding rise in the composite measure for Australian financial stress. Therefore, monitoring the aggregate level of financial stress would help policy makers to gauge when the overall rise in asset prices and credit is an issue of concern that requires policy intervention. The composite stress index proposed in this study was not found to be a suitable tool for predicting future episodes of Australian financial stress or crisis.

The following were the subsidiary questions raised in this study:

A) Potential uses of being able to predict the occurrence, extent, and magnitude of future periods of stress in Australia?

B) Limitations and risks of using stress indicators to forecast financial crises?

C) Policy implications of a stress index for Australia?

In relation to the subsidiary questions, this study found that predictions the level of financial stress would provide policy makers and regulators with information about the future climate in the financial markets. If forecasts of a composite financial stress index predict a financial crisis in the Australian financial markets based on the prevailing financial and economic environment then policy makers and regulators can implement policies that could forestall the onset of a crisis or mitigate the negative effects of a crisis on the Australian economy as it unfolds (Minsky, 1986). It is important to note that stress indicators are heavily reliant on historical data. As a consequence, composite measures of stress will predict crises if the historical pattern that led to the onset of historical crises are replicated in the future. The policy implications of a stress index for Australia are discussed in detail in Section 10.4 of this chapter.

10.2.3 Research Methods

Three hypotheses were presented in Section 3.3 of Chapter 3 of this thesis. The first hypothesis was that there exist bilateral short-term movements between Australia and its key trading partners that can be used to gauge the potential for stress in Australian financial markets. This study used pairwise Granger causality tests and a five percent level of significance to examine the causal relationships between stock returns of Australia, China, Japan, the US and the republic of Korea. The test results indicated that in the short-run, movements in the Chinese and American equity markets lead those in the Australian markets. Moreover, movements in the Chinese equity market are a more important predictor of movements in the Australian equity markets than the movements in the American equity market. Based on these findings, this research used information from the lagged values of the Chinese and American stock indexes to develop stress indicators which could predict the potential for stress in the Australian equity market. The second hypothesis was that the choice of index aggregation method would affect the performance of the composite stress index. This study used two index aggregation methods, the variance equal weighting (VEW) and the principal components analysis (PCA) method to construct composite stress indexes. The VEW stress index was found to perform better than the PCA stress index when monitoring the level Australian financial stress. Both indexes were found to be unsuitable for forecasting the level of Australian financial stress. The third hypothesis was that a significant decline in exports of the mining industry for a prolonged period would translate to increased vulnerability to stress in the Australian mining sector. This study found that the downward trend of the prices of mined resources from March 2011 to January 2016 was associated with rising levels in the stress indicator for the mining sector. In particular, the estimated stress indicator for the mining sector which is the inverted CMAX for the metals and mining index, recorded rising levels of stress from November 2015 to February 2016. Overall, it can be concluded that the results of this study support the three hypotheses raised in this study.

10.3 Research Findings

This section of the chapter discusses the main findings of this study with particular reference to the research objective and questions outlined in chapter one. The overall objective of this thesis has been to develop a stress index to monitor and forecast Australian financial stress. Unlike other studies that examine a limited number of stress indicators or variables, this study identified and examined a wide array of variables that gauge developing stress in different sectors of the Australian economy (Balakrishnan et al., 2011; Cardarelli et al., 2011; Duca & Peltonen, 2013; Vašíček et al., 2017; Vermeulen et al., 2015). A stress index was constructed using twenty two stress indicators that gauged developing stress in the Australian financial markets[93] and the banking sector. This study estimated the stress index at a monthly frequency since there is limited literature on the performance of the monthly Australian financial stress index. Moreover, a stress index reported at monthly interval would allow policy makers to monitor the level of stress in the Australian economy more closely than a stress index reported at quarterly interval. In addition to the variance-equal weighting

[93] These include the equity, currency, bond, and money markets.

method, this study explored the use of the principal components analysis method of aggregation. The former was found to provide more reliable measure of stress than the latter. While this study successfully designed a composite measure of stress that gauged the level of Australian stress, it failed to develop a suitable tool for forecasting Australian financial stress. Consequently it can be concluded that the stress index developed in this study is not a suitable barometer for financial stress in Australia and extreme caution should be used if the index is used to forecast future episodes of financial stress. Nevertheless, practitioners can benefit from the use of the stress index developed in this study. The section that follows discusses the implications of this research's findings.

10.4 Implications of Research Findings

This research successfully estimated a composite stress index for Australia that is useful for monitoring the prevailing level of financial stress at a monthly interval. Policy makers could make use of composite stress index proposed in this study to track the health of the Australian economy and determine two things. First, the index can be used to gauge when the levels of stress are about to approach a crisis point (e.g., if the stress index is trending upwards and financial stress levels are nearly exceeding two standard deviations above the long-term mean value of the stress index, it is possible that Australia is in the early stages of a crisis). At this point it is up to the policy makers to determine whether to intervene order to reduce distress in the Australian financial markets or to do nothing with the expectation that the period of high levels of stress may 'self-correct' and soon be followed by periods of lower levels of financial stress.

Economists could use the stress index proposed in this study to compare the level of stress in Australia with other countries. If this were to be done, the index designed in this study should be compared with country-specific stress indexes of other countries. This study posits that this is the more prudent approach to undertake when comparing the index prepared in this study against others for the following reason. Considering country-specific factors when constructing a country-specific stress index would yield an index which is a better measure of stress than a generic-stress index. Comparing generic stress indexes for other countries with this study's stress index would not be appropriate since it is probable that stress indicators that contribute to the incidence of financial stress in the other countries could have been ignored. Nevertheless, this could be done as a last resort due to time and resource constraints.

In the lead up to the construction of the composite stress indexes this study made use of four subindexes for the equity market, bond market, currency market, and banking sector. These subindexes are designed to signal developing stress in different sectors of the Australian economy. Additionally the subindexes are designed to cater for the specialised needs of various stakeholders in the financial market. For instance, buyers of shares may be interested in observing the prevailing level of stress in the Australian financial markets in order make a decision as to whether to alter the composition of their portfolios to reflect their individual risk preferences. Investors of bond and currency markets could adopt a similar approach. The Australian Prudential Regulator Authority may be interested in examining the subindex for the banking sector in order to assess the level of stress in the Australian banking sector.

10.5 Contribution to Knowledge

Some unique contributions of this study include: The addition of country specific factors that could contribute to the incidence of financial stress in the Australian economy which were ignored in previous studies. In particular, even though Australia is, to a large degree, a resource-driven economy, past studies have overlooked the importance of resource sector when considering stress indicators for Australia. Unlike previous studies, this thesis gives due consideration to the relevance of resource sector in measuring the level of financial stress in Australia. Accordingly, this study included information from the S&P/ASX300 metals and mining index in the composite stress index.

The importance of property prices was also overlooked by previous studies. Pais and Stork (2011) noted that Australian banks were particularly vulnerable to inter-sector contagion of risks from the Australian property sector and the risk of contagion increased during periods of crises such as the 2007-2009 GFC. Similarly, Kindleberger and Aliber (2005) found that a collapse in a property market could render banks bankrupt especially if it coincides with the collapse of the stock market as was the case in 1992 Japanese banking crises. Despite the evidence in the literature that property bubbles often precede crises, previous studies have failed to incorporate a stress indicator that tracks the level stress in the Australian property sector when estimating an Australian stress index (Hakkio & Keeton, 2009; Kaminsky & Reinhart, 1999; Reinhart & Rogoff, 2013; Scott, 2010). This study attempts to remedy this oversight by including a stress indicator for the Australian property market—which was also absent in previous Australian stress indexes. In particular, information from the S&P/ASX200 Australia Real Estate Investments Trusts (A-REITs) was incorporated into the composite measure for stress used in this study.

This study analysed equity market movements of Australia and four of its leading bilateral trading partners (i.e., China, Japan, the USA, and the republic of Korea; DFAT, 2015a, 2015c, 2016a). Linear and nonlinear Granger causality tests were used to investigate the relationship between pairs of the five countries. It was found that past values of leading indexes of the Chinese and American equity markets were useful for predicting movements in the Australian equity market. In response, this study explores the use of foreign-based variables for China and US and estimated inverted CMAX measures of the lagged Chinese Hang Seng and the American S&P 500. Before now, the use of such variables in a composite measure of stress has not been explored in other literature.

LIBOR spreads are often used as a barometer of financial stress. However, it was not possible to use the Australian LIBOR for this purpose since it was discontinued due to allegations of manipulation (Wheatley, 2012). Therefore, this study explored the use of proxy spreads that mimicked some of the movements of LIBOR spreads. Chapter 7 of this study successfully estimated a proxy for the LIBOR-OIS spread (the IOC-OIS spread) which performed relatively well. The use of the IOC-OIS spread has not been explored in previous studies.

In summary, this research has explored the use of stress indicators that were not examined in previous literature. This study provides a deeper understanding of factors that collectively contribute to the development of stress in the Australian financial markets. Instead of focusing on local factors that could lead to stress, this study also includes foreign-based variables that could show the potential for stress transmission from two of Australia's bilateral trading partners (China and the US). The discussion in the section that follows will now turn to the limitation of this research.

10.6 Limitations and Suggestions for Future Research

The stress index developed in this study was comprised of 22 stress indicators and reported at a monthly frequency. Reporting a stress index at the monthly interval presented one key challenge. Specifically, it was it was not possible to obtain large samples of historical data for all the variables that were included in the composite stress index. Monthly data was available for all variables for the months from January 2005 to December 2014. This meant that it was only possible to evaluate the performance of the estimated stress index over one episode of financial crisis; this is the 2007-2009 GFC.

When constructing the credit-to-GDP gap in Chapter 6, monthly values of the GDP were not readily available because GDP is reported at a quarterly frequency. For this reason, this study used quarterly values of GDP and an interpolation method to estimate monthly values of the GDP. Due to the use of interpolated values of GDP, it is possible that an unknown margin of error was introduced into the resulting stress indicator. Since monthly estimates of GDP are unavailable, it is not possible to estimate the exact extent of the margin of error. Thus, this research recommends caution when estimating or interpreting the credit-to-GDP gap variable.

When developing a proxy variable for the LIBOR-OIS spread, the Australian Bank Bill Swap (BBSW) rate was found to be the best proxy for the Australian LIBOR. However, the data for the BBSW was not readily available. Therefore, this study resorted to the use of the interbank overnight cash (IOC) rate instead. This study proposes that researchers with access to historical data for the BBSW could develop a better proxy for the LIBOR-OIS spread; this would be the BBSW-OIS spread.

Since past studies have primarily focused on the development and assessment of generic stress indexes of several countries, this study propose that future research consider country-specific stress-indexes of several countries for the following reasons. First, such an analysis improves the understanding of the country-specific factors that contribute to stress or crises in different countries. Moreover, it sheds light on factors that make some countries more vulnerable to crises than others. Second, a comparative study may reveal relationships between transmission of stress or crises across borders or via trade or financial links.

This study only explored the lead and lag relationship between composite equity indexes of Australia and four of its key bilateral trading partners. It would be interesting to see how other factors could be early predictors of movements in the Australian market. For instance, it may be possible that certain cross-border connections between Australian banks and foreign banks could potentially make Australia more vulnerable to cross-border contagion of a banking crisis in a foreign country; future studies could explore this.

Future studies could explore the use of qualitative data when assessing the level of financial stress in Australia. In particular, researchers could interview Australian industry experts in order to gauge the perceived level of stress in the Australian markets over a period of time. It would be interesting to assess whether there is correlation between qualitative and the quantitative aspects of Australian financial stress. Whereby, the qualitative aspects of financial stress are the perceived levels of stress as gauged by the Australian experts' opinion and the quantitative aspects of financials stress are the estimated levels of financial stress as reported by a composite stress index.

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