Second-Tier Stock Market Efficiency and Dynamic Impacts on Macroeconomic Development: Evidence from Tropical Economies

Thesis submitted by

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Statement of Original Authorship

The work presented in this thesis has not been previously submitted to meet the requirements for the Degree of Doctor of Philosophy at James Cook University or any other higher education institution. To the best of my knowledge and belief, the thesis contains no material previously published or written by another person except where due reference is made.

Nguyen Thi Minh Trang

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Contribution of Others to this Thesis

Nature of Assistance	**Role / Contribution**	**Names, Titles, and Affiliations of Co-Contributors**
Supervision	Primary Supervisor Secondary Supervisor Associate Supervisor	Associate Professor Taha Chaiechi, James Cook University (JCU) Professor Lynne Eagle, James Cook University (JCU) Professor David Low, Charles Darwin University (CDU)
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Publications and Presentations from this Thesis

Publications

Chapter number	Details of publications on which chapter is based	Nature and extent of the intellectual input of each author
1, 2, 3	Nguyen, T., Chaiechi, T., Eagle, L., and Low, D. (2020). SME stock markets in tropical economies: evolving efficiency and dual long memory. *Economic Papers,* 39(1), 28-47. Nguyen, T., Chaiechi, T., Eagle, L., and Low, D. (2020). Growth Enterprise Market in Hong Kong: Efficiency Evolution and Long Memory in Return and Volatility. *Journal of Asian Business and Economic Studies, 27(1), 19-34.*	Nguyen and her primary supervisor Associate Professor Chaiechi co-developed the research questions. Nguyen designed the methodological framework, collected the data, performed the data analyses, interpreted the results and drafted the manuscripts. Associate Professor Chaiechi provided a critical review of the final manuscripts. Professor Eagle provided comments on the final manuscripts with editorial input.
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Chapter number	Details of publications on which chapter is based	Nature and extent of the intellectual input of each author
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The PDF proofs of the first page of all refereed journal articles and conference proceedings are presented in the following pages.

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Special Section: ACE Special Conference 2018

SME Stock Markets in Tropical Economies: Evolving Efficiency and Dual Long Memory[1]

Trang Nguyen,* Taha Chaiechi,* Lynne Eagle* and David Low†

This paper examines the evolving efficiency and the joint effects of thin trading, structural breaks and inflation on dual long memory in Small and Medium Enterprise stock markets in Hong Kong, Singapore, Thailand and Malaysia. The state-space GARCH-M, ARFIMA-FIGARCH, ARFIMA-FIAPARCH and ARFIMA-HYGARCH models are adopted. The results determine that the Hong Kong and Singapore markets exhibit potential tendencies towards efficiency, implying the efficacy of several institutional reforms. The three aforementioned factors jointly have reducing effects on the magnitude and/or statistical significance of long-memory estimates. The Thailand and Malaysia markets show a smaller degree of volatility persistence, indicating a good hedge for portfolio risk management.

Keywords: SME stock market, evolving efficiency, inflation, long memory, structural break, thin trading.

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[1]BRIC refers to Brazil, Russia, India, and China, which are deemed to be newly advanced economies.

[2]State of the Tropics () Report is the initiation of collaboration among prominent research organisations with an interest in tropical issues. This report brings in a wide range of indicators and aspects of the ecosystem, human system and economy to shed light on a unique set of characteristics of the Tropics.

JEL classifications: G14, G15

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Growth enterprise market in Hong Kong

Efficiency evolution and long memory in return and volatility

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David Low
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Abstract

Purpose – Growth enterprise market (GEM) in Hong Kong is acknowledged as one of the world's most successful examples of small and medium enterprise (SME) stock market. The purpose of this paper is to examine the evolving efficiency and dual long memory in the GEM. This paper also explores the joint impacts of thin trading, structural breaks and inflation on the dual long memory.

Design/methodology/approach – State-space GARCH-M model, Kalman filter estimation, factor-adjustment techniques and fractionally integrated models: ARFIMA–FIGARCH, ARFIMA–FIAPARCH and ARFIMA–HYGARCH are adopted for the empirical analysis.

Findings – The results indicate that the GEM is still weak-form inefficient but shows a tendency towards efficiency over time except during the global financial crisis. There also exists a stationary long-memory property in the market return and volatility; however, these long-memory properties weaken in magnitude and/or statistical significance when the joint impacts of the three aforementioned factors were taken into account.

Research limitations/implications – A forecasts of the hedging model that capture dual long memory could provide investors further insights into risk management of investments in the GEM.

Practical implications – The findings of this study are relevant to market authorities in improving the GEM market efficiency and investors in modelling hedging strategies for the GEM.

Originality/value – This study is the first to investigate the evolving efficiency and dual long memory in an SME stock market, and the joint impacts of thin trading, structural breaks and inflation on the dual long memory.

Keywords Inflation, Structural breaks, Thin trading, Dual long memory, Evolution towards efficiency

Paper type Research paper

1. Introduction

As a Special Administrative Region of the People's Republic of China with high degree of autonomy in political and economic systems, Hong Kong is renowned for its extent of trade openness and dynamic economic structure. Over the last seven decades, the economic success of Hong Kong is undisputable due to the fact that its economy has been experiencing structural transformation from a regional hub for industrial manufacturing to a major international financial centre. This successful transformation is largely attributable to the liberal economic policies, effective corporate governance, and free and transparent flow of information.

Being a trade gateway to Mainland China and having strong business relations with many other Asian economies, Hong Kong is strategically situated in a high growth region and has now become one of the world's most unfettered economies. According to WTO (2018) and UNCTAD (2018), Hong Kong is the world's seventh largest exporter of merchandise trade and

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Dynamic transmissions between main stock markets and SME stock markets: Evidence from tropical economies

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ABSTRACT

This paper investigates the dynamic return and asymmetric volatility transmissions between main stock markets and Small and Medium Enterprise (SME) stock markets in Hong Kong, Singapore, Thailand, and Malaysia under the joint impacts of volatility breaks, thin trading, and trading volume. For the analysis, a linear state-space AR model with Kalman filter and an augmented bivariate VAR asymmetric BEKK-GARCH model were adopted. The results reveal that only Hong Kong showed evidence of return transmission from the SME market to the main market. Controlling for the joint effects of the three factors considerably reduced the magnitude and significance level of this return transmission and, in essence, eliminates the volatility transmission. Moreover, Hong Kong's main market return exhibited a causal relationship and a long-run equilibrium relationship with the country's economic development. Therefore, the SME market arguably can make an indirect contribution to economic development in Hong Kong via its return transmission across the main market. Consequently, any policies that facilitate the development of the SME market in this country would promote long-term economic stimulation indirectly through its transmission mechanism with the main market.

1. Introduction

Acting as a second-tier listing option to the main stock market in a country, a Small and Medium Enterprise (SME) stock market, also known as an alternative stock market, provides a new fundraising channel and a credible identity for SMEs that are unqualified to be listed on the main market. Although SME stock markets are a significant component of the SME financing ecosystem (World Federation of Exchanges, 2015) and are increasingly being established worldwide, they have received limited academic attention. On the other hand, several studies have documented the influence of the main stock market return and volatility on economic development. A legal bond also exists between the main stock market and SME stock market, in which the SME market is often housed under the main market and serves as a pathway for SMEs to become listed on the main market (Harwood & Konidaris, 2015). Accordingly, given the existing contribution of the main stock market to economic development and the legal relationship between the two stock markets, the SME stock market could potentially make an indirect contribution to economic development through its return and volatility transmissions across the main market channel. However, these dynamic transmissions between the two stock markets have been disregarded in the financial economics literature.

Furthermore, it is noted that financial time series often encounter large shocks that can instigate changes in the unconditional variance, also known as structural breaks in volatility or volatility breaks. The existence of deterministic volatility breaks in the return series may cause the underlying volatility persistence to be overestimated by a standard Generalised Autoregressive Conditional Heteroscedasticity (GARCH) model (Lamoureux & Lastrapes, 1990b). Thin trading, which occurs when stocks are traded at low volume due to a lack of buy or sell orders, can cause spurious autocorrelation in the return series (Lo & MacKinlay, 1990). Neglecting to adjust for thin trading can induce biased empirical outcomes.

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Return and Asymmetric Volatility Transmissions between Main Stock Market and Second-Tier Stock Market: The Case of Hong Kong

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This study aims to investigate the dynamic return and asymmetric volatility transmissions between the main stock market and the Growth Enterprise Market in Hong Kong. Unlike previous studies, this study examines the cross-market transmissions under the joint impacts of volatility breaks, thin trading, and trading volume. A linear state-space AR model with Kalman filter estimation and an augmented bivariate VAR asymmetric BEKK-GARCH model are employed for empirical analysis. The results determine that under the joint impacts of volatility breaks, thin trading, and trading volume, a unidirectional return transmission from the GEM to the main market survives with the diminishing magnitude and significant level. However, the underlying volatility transmission from the GEM to the main market, in essence, is eliminated. This paper aims to be a *proof-of-concept* to provide sufficient evidence of methodological viability, which can then be used in larger scale research or replicated in new settings.

Keywords: Return and asymmetric volatility transmissions, Volatility break, Thin trading, Trading volume, Augmented bivariate VAR asymmetric BEKK-GARCH

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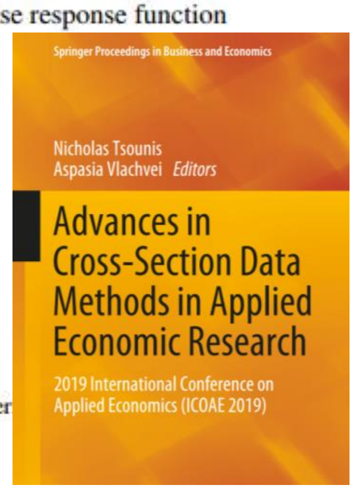
Chapter 35
Feedback of Macroeconomic Indicators to Shocks in Second-Tier Stock Market Development and Innovation Within Kaleckian Framework: Hong Kong Case Study

Trang Nguyen, Taha Chaiechi, Lynne Eagle and David Low

Abstract Despite the importance of second-tier stock markets in supporting SMEs (Small and Medium Enterprise) development and innovation, the dynamic impacts of second-tier stock markets development and innovation on macroeconomic indicators remain under-explored. This study aims to bridge the gap both theoretically and empirically. Accordingly, the theoretical model of Kaleckian–Post-Keynesian macroeconomics is extended and an empirical model is specified and estimated for the case of Hong Kong. A Structural Vector Error Correction (SVEC) estimation technique and impulse response function are adopted for empirical analysis. The results determine that Hong Kong's macroeconomic indicators exhibit small but positive feedback to shocks in the second-tier market development and innovation in the short run. Specifically, various channels of growth including private investment, domestic savings, and productivity growth are found to be responsive to shocks in the second-tier market development indicators. Meanwhile, shocks to innovation indicators effectively induce responses of the following growth channels: private investment, domestic savings, productivity growth, and employment.

Keywords Second-tier stock market · Innovation · Kaleckian–Post-Keynesian economics · Structural VEC (SVEC) model · Impulse response function

JEL Classifications E62 · G32



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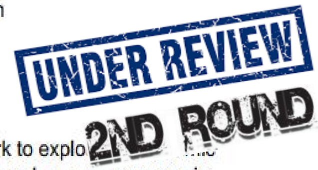

Abstract

This study draws on the principles of Kaleckian-Post-Keynesian macroeconomic framework to explo
impacts of SME (Small and Medium Enterprise) stock market development and innovation on key macroeconomic variables in Hong Kong, Singapore, Thailand, and Malaysia. For empirical analysis, a Structural Vector Error Correction (SVEC) model and an impulse response function (IRF) were adopted. The evidence shows that SME stock market development and/or innovation have small but positive impacts on economic stimulation in the short run. The SME stock market development promotes economic growth through the combination of the following channels: private investment, domestic savings, and productivity growth in Hong Kong, Singapore, and Thailand. Innovation, on the other hand, fosters growth through the combination of these channels and the employment channel in all four countries.

Keywords	SME stock market; Innovation; Kaleckian-Post-Keynesian economics; Structural VEC (SVEC) model; Impulse response function
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Presentations

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Abstract of this Thesis

Background: The Tropics has recently emerged as an important geopolitical region with an economic growth rate outperforming the rest of the world. Second-tier stock markets are well-acknowledged as a critical alternative source of funding for Small and Medium Enterprises (SMEs) and can be seen as a key catalyst for innovation. These markets, which offer several benefits for both SMEs and investors, have been increasingly established across the world since the 1990s. This thesis, therefore, centres around second-tier stock markets in the Tropics.

Objectives and Scope of the Research**:** This thesis presents findings from the following three research studies: (1) Evolution of second-tier stock market efficiency and dual long memory in the market under the joint impacts of thin trading, structural breaks, and inflation; (2) Dynamic return and asymmetric volatility transmissions between main stock market and second-tier stock market while accounting for the effects of thin trading, volatility breaks and trading volume; and (3) Dynamic impacts of second-tier stock market development and innovation on macroeconomic indicators within a Kaleckian-Post-Keynesian growth model. Regarding the scope of the research, Hong Kong, Singapore, Thailand and Malaysia were selected for empirical analysis since these four economies are not only Asian ‘tigers’ and ‘tiger cubs’ but also levers for growth in the tropical region.

Methodology: Study One adopted a State-Space Non-linear Generalized Autoregressive Conditional Heteroscedasticity in Mean (GARCH-M) model with Kalman Filter estimation to depict the evolution of weak-form market efficiency. A set of fractionally integrated models such as Autoregressive Fractionally Integrated Moving Average (ARFIMA), Fractionally Integrated GARCH (FIGARCH), Fractionally Integrated Asymmetric Power ARCH (FIAPARCH), and Hyperbolic GARCH (HYGARCH) were used to estimate dual long memory properties in return and volatility. The joint impacts of thin trading, structural breaks and inflation on dual long memory were examined using relevant adjustment techniques that involve an Iterated Cumulative Sum of Squares (ICSS) algorithm and a State-Space Linear AR model with Kalman Filter estimation.

In Study Two, a Bivariate Vector Autoregressive (VAR) Asymmetric Baba-Engle-Kraft-Kroner (BEKK) GARCH model was adopted to investigate the dynamic transmissions of return

and asymmetric volatility between main stock market and second-tier stock market. The ICSS algorithm was applied to detect multiple volatility breaks in the two stock markets and the State-Space Linear AR model with Kalman Filter estimation was used to adjust for thin trading in second-tier stock market. To control for the joint effects of thin trading, volatility breaks and trading volume, the Bivariate VAR Asymmetric BEKK-GARCH model was extended with a dummy variable indicating volatility breaks, an aggregate trading volume variable, and a de-thinned return variable.

Study Three was grounded on the Kaleckian-Post-Keynesian theoretical model of growth and distribution to explore the macroeconomic impacts of second-tier stock market development and innovation. This theoretical model is renowned for its effective demonstration of the integrated relationships among behavioural functions of an economy including private investment, domestic savings, income distribution, productivity growth, net exports and employment. In this study, the functions of private investment, domestic savings, productivity growth, and employment were extended with the indicators of second-tier stock market development and innovation. A Structural Vector Error Correction (SVEC) model with short-run restrictions and SVEC Impulse Response Function were adopted to delineate the dynamic impacts of second-tier stock market development and innovation on macroeconomic functions.

Results: Study One reports that second-tier stock markets in Hong Kong, Singapore, Thailand and Malaysia are still weak-form inefficient; however, those in Hong Kong and Singapore show tendencies towards efficiency. These tendencies appear to align with the increasing market capitalisation and traded value and several institutional reforms. The inefficiency of the markets is mainly owing to the presence of stationary long memory in return and/or volatility. Thin trading, structural breaks and inflation jointly have diminishing effects on the magnitude and/or statistical significance of dual long memory estimates.

In Study Two, Hong Kong shows return transmission from second-tier stock market to the main stock market, while Singapore, Thailand and Malaysia show return transmission in the reverse direction. Only Singapore exhibits volatility transmission from the main stock market to second-tier stock market. Thin trading, volatility breaks and trading volume jointly decrease (increase) the magnitude and significance level of return transmission from second-tier (main) market to the main (second-tier) market. The underlying volatility transmissions dissipate or strengthen in magnitude and significance level. Furthermore, the evidence exposes a causality and a long-run equilibrium relationship from Hong Kong's main market returns to the country's economic development. Given the aforementioned return transmission from second-tier market to the main market in Hong Kong, its second-tier market thus can make an indirect contribution to economic development through the main market channel.

Study Three reports that second-tier stock market development and/or innovation in Hong Kong, Singapore, Thailand and Malaysia have small but positive effects on the economic growth process in the short run. Second-tier stock markets in Hong Kong, Singapore and Thailand foster growth through the combination of the following three channels: private investment, domestic savings, and productivity growth. On the other hand, innovation in all four countries promotes growth through the combination of the following four channels: private investment, domestic savings, productivity growth and employment.

Conclusions: The results of Study One implies the efficacy of institutional reforms and the importance of market development to the tendency towards efficiency in second-tier stock markets of Hong Kong and Singapore. Ignoring thin trading, structural breaks and inflation while modelling dual long memory in return and volatility may overestimate the corresponding true values. Study Two and Study Three indicate that second-tier stock market in Hong Kong can make contribution to economic development directly and indirectly via return transmission with the main market channel. Meanwhile, second-tier stock markets in Singapore and Thailand can only make direct contributions to the economic growth process. Moreover, failure to account for thin trading, volatility breaks and trading volume may distort the transmissions of return and volatility between main markets and second-tier markets. Study Three also indicates a major role of innovation in Hong Kong, Singapore, Thailand and Malaysia in the process of macroeconomic development. Accordingly, this thesis contains many important implications for academics, policymakers and professional practitioners in developing and investing in second-tier stock markets.

Keywords: The Tropics; Second-tier Stock Market; Evolving Market Efficiency; Dual Long Memory; Dynamic Transmission; Macroeconomic Impact.

Table of Contents

List of Tables

List of Figures

Abbreviations and Acronyms used in the Body of this Thesis

ACE	Access, Certainty, and Efficiency Market
ADB	Asian Development Bank
AIC	Akaike Information Criterion
AIM	Alternative Investment Market in the United Kingdom
APARCH	Asymmetric Power Autoregressive Conditional Heteroscedasticity
APT	Arbitrage Pricing Theory
AR	Autoregressive
ARCH	Autoregressive Conditional Heteroscedasticity
ARFIMA	Autoregressive Fractionally Integrated Moving Average
ARIMA	Autoregressive Integrated Moving Average
ARMA	Autoregressive Moving Average
ATP	Alternative Trading Platform
BEKK	Baba-Engle-Kraft-Kroner
BIS	Bank for International Settlements
BM	Bursa Malaysia
BRIC	Brazil, Russia, India, and China
CPI	Consumer Price Index
DCC	Dynamic Conditional Correlation
EMH	Efficient Market Hypothesis
FBMEMAS	Financial Times Stock Exchange Bursa Malaysia Emas Index
FIAPARCH	Fractionally Integrated Asymmetric Power Autoregressive Conditional Heteroscedasticity
FIEC	Fractionally Integrated Error Correction
FIGARCH	Fractionally Integrated Generalized Autoregressive Conditional Heteroscedasticity
FPE	Final Prediction Error
FSTAS	Financial Times Stock Exchange Strait Times All-Share Index
FTSE	Financial Times Stock Exchange
G20	The Group of Twenty
GARCH	Generalized Autoregressive Conditional Heteroscedasticity
GARCH-M	Generalized Autoregressive Conditional Heteroscedasticity in Mean
GDP	Gross Domestic Product
GEM	Growth Enterprise Market
GFC	Global Financial Crisis 2007-2009
GII	Global Innovation Index
HKEX	Hong Kong Exchange
HQ	Hannan-Quinn Information Criterion
HSI	Hong Kong Hang Seng Composite Index
HYGARCH	Hyperbolic Generalized Autoregressive Conditional Heteroscedasticity
IADB	Inter-America Development Bank
ICSS	Iterative Cumulative Sum of Squares
IFC	International Finance Corporation
IFS	International Financial Statistics
IMF	International Monetary Fund
IPO	Initial Public Offering
LR	Sequentially Modified Likelihood Ratio
MA	Moving Average
MAI	Market for Alternative Investment
MDH	Mixture of Distributions Hypothesis

MESDAQ	Malaysian Exchange of Securities Dealing & Automated Quotation
MGARCH	Multivariate Generalized Autoregressive Conditional Heteroscedasticity
MoU	Memorandum of Understanding
MVHR	Minimum-Variance Hedge Ratio
OECD	Organization for Economic Cooperation and Development
OHR	Optimal Hedge Ratio
OLS	Ordinary Least Squares
PRC	People's Republic of China
R&D	Research and Development
RMB	Renminbi, the Chinese currency
S&P	Standard and Poor
SAR	Special Administrative Region
SIC	Schwarz Information Criterion
SESDAQ	Stock Exchange of Singapore Dealing and Automated Quotation
SET	Stock Exchange of Thailand
SETI	Stock Exchange of Thailand Index
SGX	Singapore Exchange
SIAH	Sequential Information Arrival Hypothesis
SME	Small and Medium Enterprise
SPO	Secondary Public Offering
SVEC	Structural Vector Error Correction
UNCTAD	United Nations Conference on Trade and Development
US$	United State Dollar
VAR	Vector Autoregressive
VCM	Volatility Control Mechanism
WDI	World Development Indicator
WFE	World Federation of Exchanges
WIPO	World Intellectual Property Organisation
WTO	World Trade Organisation

Glossary of Terms used in the Body of this Thesis

'A' Shares: the shares of Chinese Mainland firms that are traded on the Shanghai Stock Exchange and the Shenzhen Stock Exchange (see also 'H' shares)

Agency Problem: a conflict of interest which occurs when one party is expected to act in another's best interests.

Alternative Trading Platform: a separate board which is managed by a regulated market operator (i.e. management of the main stock market) and adheres to less stringent regulations compared to the main stock market

Arbitrage Pricing Theory: a theory that describes a linear relationship between the expected stock market returns and various macroeconomic indicators that accounts for market risk or un-diversifiable risk.

ARFIMA Model: a fractionally integrated model that measures long memory component in return

Asset Bubble: a situation when prices escalate rapidly over a short period but are not supported by an increase in demand for the asset itself

Credit Gap: a shortage in the supply of debt capital

FIAPARCH Model: an extended version of the FIGARCH model that accounts for the asymmetric effect in the conditional variance.

FIGARCH Model: a fractionally integrated model that measures long memory component in return volatility

Fundamental Analysis: an approach of evaluating a stock's intrinsic value by considering all relevant qualitative and quantitative factors such as economic, financial, and political factors

'H' Shares: the shares of firms that are incorporated in Mainland China and traded on the HKEX (see also 'A' Shares)

Hedging: an investment strategy to mitigate the risk of adverse price changes in an asset by investing in an offsetting position in a related securities

HYGARCH Model: a generalised version of the FIGARCH model that releases the unit-amplitude restriction to capture both characteristics of volatility persistence and covariance stationarity

Information Asymmetry: a situation occurs when one party to an economic transaction owns a larger amount of material information than the other party

Initial Public Offering: an activity in which the shares of a company are offered on a public stock exchange for the first time

Innovation: a process that involves research and development activities and acquisition of necessary resources to develop the firms' core value propositions

Iterated Cumulative Sum of Squares (ICSS): an algorithm to identify multiple structural breaks in the unconditional variance of returns (volatility breaks)

Kaleckian-Post-Keynesian Model of Growth and Distribution: an integrated model of behavioural functions of the real sector such as private investment, domestic savings, income distribution, productivity growth, net export and employment

Kalman Filter: an estimation that provides a set of time-varying measurements to estimate an unknown parameter

Long Memory: a common property of financial time series, also known as long-range persistence, occurs when the autocorrelation in a stock market return and/or return volatility decay slowly over time

Market Efficiency: a market in which security prices quickly respond to new information by accurately incorporating this information into the prices and reaching a new equilibrium

Market Return Volatility: a degree of variation of returns for a given market index over time, as measured by the standard deviation of logarithmic returns

Market Return: a change in prices of a given market index over time, often measured in logarithmic form

Marxian Reserve Army Effect: a situation that higher unemployment diminishes the bargaining power of workers and therefore stimulates higher profits

Mixture of Distributions Hypothesis: a supposition that conditional variance of return (or return volatility and trading volume are determined simultaneously by a stream of information

Process Innovation: an implementation of a new method that significantly improves production process

Prospectus: a legal document issued by firms that are offering securities for sale to the public; it is required by and filed with the Securities and Exchange Commission (SEC)

Random Walk: a stochastic or random process in which the movement of stock prices is independent of each other and unpredictable

Return Transmission: an effect that return of one market can have on the return of other markets; also known as return spillover

Return Volatility Transmission: an effect that return volatility of one market can have on the return volatility of other markets; also known as return volatility spillover

Secondary Public Offering: issuance of new shares by a company that has already made an initial public offering

Second-Tier Stock Market: a market that was established to support SMEs with growth potential but which are ineligible to be listed on the main stock market since they cannot fulfil the main market's profitability and track-record requirements; also known as SME stock market or alternative stock market

Semi-Strong Form Efficient Market Hypothesis: a market that current stock prices, at any moment, reflect all the past information and quickly captures without biases any new publicly available information

Sequential Information Arrival Hypothesis: a supposition that new information appears in the market in a sequential random manner and is not obtained by all market participants instantaneously

Small and Medium Enterprises: independent enterprises that have 100 employees or fewer, and total sales up to US$3 million, as defined by Inter-American Development Bank

South Asia: a region that consists of Bangladesh*, India*, Maldives, and Sri Lanka. (* These nations have large areas that bestride the Tropics and a total population of 1.50 billion as of 2017, according to World Bank Database)

South-East Asia: a region consists of Brunei, Cambodia, China*, Hong Kong, Macau, Indonesia, Laos, Malaysia, Myanmar, Singapore, Thailand, Vietnam, and Timor-Leste. (* This nation has Southern part that bestrides the Tropics and total population of 1.39 billion as of 2017, according to World Bank Database)

Spillover: an effect that apparently unrelated events in one market can have on the other markets

State of the Tropics Report: a report that was published in 2014 by James Cook University on behalf of prominent research organisations from Singapore, Thailand, Papua New Guinea, United States, Ecuador, Brazil, Costa Rica, United Kingdom, Ghana, and Kenya with an interest in tropical issues; this report brings in a wide range of indicators and aspects of the ecosystem, human system, and economy to shed light on a unique set of characteristics of the Tropics

State-Space AR Model: a model that uses to adjust for thin trading characteristic in a stock market

State-Space GARCH-M Model: a model that captures the evolving weak-form efficiency by allowing for time-varying dependencies in the return and volatility processes

Strong Form Efficient Market Hypothesis: a market in which all available information including historical market data, public information, and private information is fully incorporated into the current stock prices

Structural Break: a phenomenon that occurs when a time series encounters an abruptly change at a point in time

Technical Analysis: a prominent technique used to forecast stock prices and suggest trading rules based on trends and regular cycles

The ACE Market: a second-tier stock market for SME listings in Malaysia (formerly MESDAQ)

The CATALIST Market: a second-tier stock market for SME listings in Singapore (formerly SESDAQ)

The G20: a global forum for the governments of 19 nations and the European Union

The GEM Market: a second-tier stock market for SME listings in Hong Kong

The MAI Market: a second-tier stock market for SME listings in Thailand

The Tropics: a geopolitical region that is situated between the Tropic of Cancer and the Tropic of Capricorn and which accommodates 40% of the world's population

Thin trading: also known as infrequent trading, occurs when stocks are traded at low volume due to a lack of buy or sell orders

Tiger Economy: the economy of a country which experiences rapid economic growth, often associated with raising standards of living

Underwriting: a service delivered by large financial institutions such as banks or investment banks whereby they evaluate and assume other party's risk for a fee

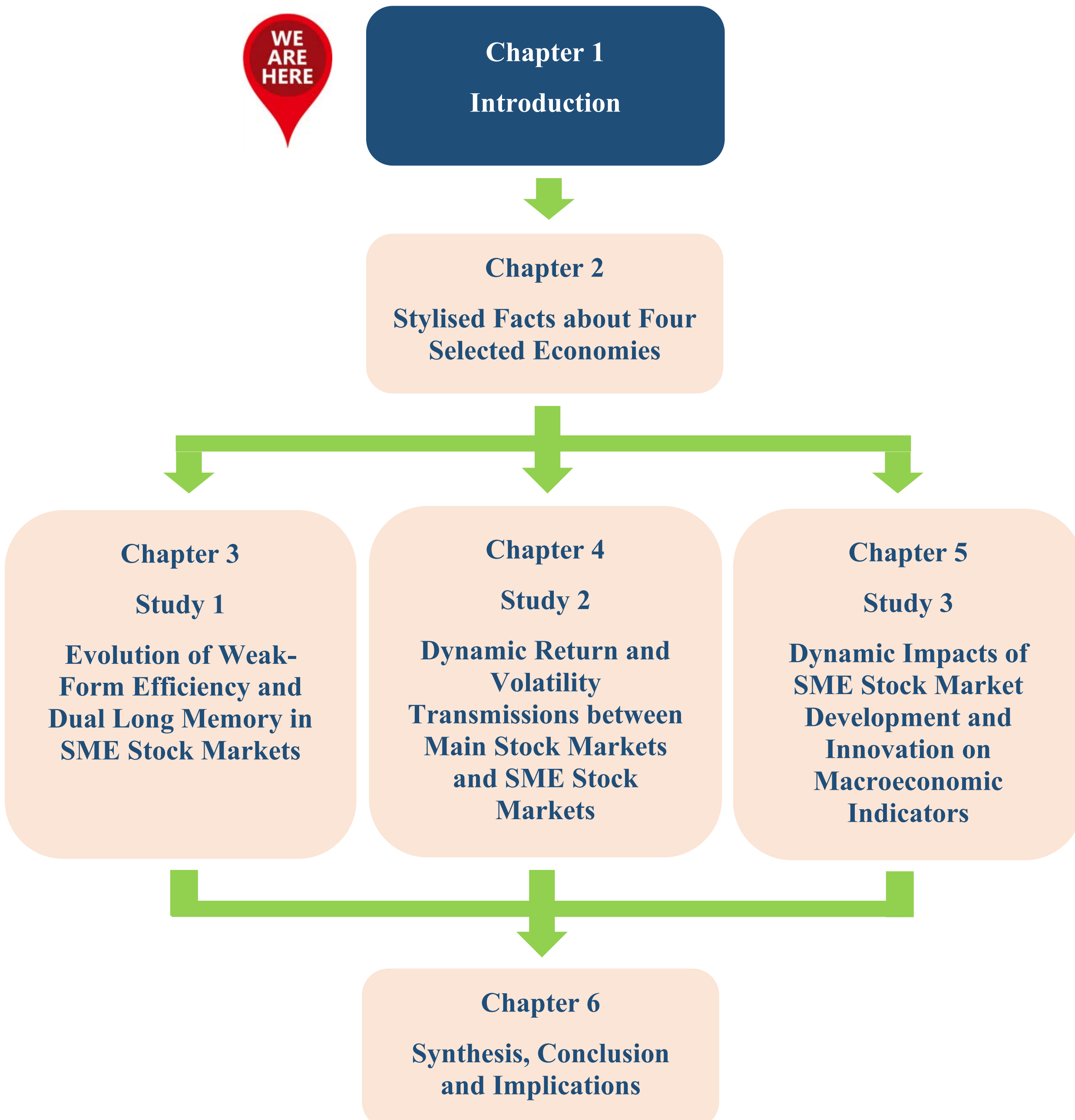
Volatility Break: a phenomenon that occurs when a time series encounters large shocks that can instigate changes in the unconditional variance; also called a structural break in volatility

Volatility Clustering: a tendency of large changes in prices of a market index to cluster together, which leads to the persistence of volatility

Weak Form Efficient Market Hypothesis: a market in which current stock prices, at any moment, incorporate all historical market data (i.e. sequences of price and return)

Weak-Instrumental Problem: a situation that impulse response function is not consistently estimable for an I(0) time series that is parameterised as local to unity

Thesis Structure



Chapter One: Introduction

Overview

Chapter One provides an overview of this thesis. First, the importance of the Tropics to the global economy, and the significance of second-tier stock markets to Small and Medium Enterprises finance, are discussed. Second, the concepts of market efficiency and long memory are briefly described before the three research gaps are identified and the corresponding research studies and questions are discussed. The research studies underpinning this thesis and their associated research questions centre around the evolution of market efficiency and long memory in the second-tier stock market, and the direct and indirect contributions of the market to macroeconomic development. Third, the scope of research is defined, stating that four tropical economies including Hong Kong, Singapore, Thailand, and Malaysia have been employed as case studies. Fourth, the research methodology and data used in each study underpinning the thesis are discussed. Fifth, the significance of the thesis is elaborated, showing its contributions to the empirical and theoretical literatures, as well as the implications for policymakers and professional practitioners. Finally, the chapter ends with an outline of the remaining chapters that make up the thesis.

Chapter Outline

Some sections of the material in this chapter were adapted for publication in the following refereed journal articles along with findings from the individual studies conducted for the thesis:

Nguyen, T., Chaiechi, T., Eagle, L., and Low, D. (2020). SME stock markets in tropical economies: evolving efficiency and dual long memory. *Economic Papers*, 39 (1), 28-47.

Nguyen, T., Chaiechi, T., Eagle, L., and Low, D. (2020) Dynamic transmissions between main stock markets and SME stock markets: evidence from tropical economies. *Quarterly Review of Economics and Finance*, 75, 308-324.

Nguyen, T., Chaiechi, T., Eagle, L., and Low, D. (Under review). Dynamic impacts of SME stock market development and innovation on macroeconomic indicators: A structural VEC approach. *Economic Analysis and Policy*.

1.1 Background

For centuries, geopolitical regions have striven to become important forces for the enhancement of global stability by strengthening their balance-of-power systems (Cohen, 2003). In the 1990s, political and economic shifts emanating from the collapse of the former Soviet Union and the growth of Asia and BRIC[1] economies led to multi-dimensional perspectives on the geopolitical landscape. Recent decades have witnessed further substantial changes in the global political economy as the world reformulates its global development agenda. Among these changes, the Global Financial Crisis (GFC) of 2007-2009, the Paris agreement on climate change action in 2015, and the trade policies enacted by Donald Trump's administration since 2017 have further diversified the multifaceted perceptions of the world geopolitical system. While the world's geopolitical regions are classified primarily into East and West, North and South, and developed and developing areas, the lateral perception of world geopolitical regions has been emphasised in the recent State of the Tropics (2014) Report[2]. This report acknowledges the Tropics as a critical geopolitical entity owing to its unique features and contribution to the future global economy.

Situated between the Tropic of Cancer and the Tropic of Capricorn (see Figure 1.1), the tropical zone consists of 60 countries and currently accommodates 40% of the world's population. This percentage is expected to increase to 50% by 2050 (United Nations, 2015). This sizeable zone with a rapidly expanding population offers great opportunities for business and investment thanks to growing consumption and the innovative potential of a diverse workforce. Tropical economies are diverse and cover a broad spectrum at different stages of development, including developed, emerging, and developing countries. This diversity can exert an increasing influence on the global economy. In fact, tropical economies contributed US$12 trillion to global Gross Domestic Products (GDP) in 2010, almost one-fifth of global GDP. This contribution is predicted to be US$40 trillion by 2025 (Harding, 2011), accounting for nearly a quarter of the corresponding global GDP (PricewaterhouseCoopers, 2015).

[1] BRIC refers to Brazil, Russia, India, and China, which are deemed to be newly advanced economies.
[2] State of the Tropics Report was published in 2014 by James Cook University on behalf of prominent research organisations from Singapore, Thailand, Papua New Guinea, United States, Ecuador, Brazil, Costa Rica, United Kingdom, Ghana, and Kenya with an interest in tropical issues. This report brings in a wide range of indicators and aspects of the ecosystem, human system, and economy to shed light on a unique set of characteristics of the Tropics.

Remarkably, tropical economies have grown 20% faster than the rest of the world over the past three decades and even maintained a positive growth rate during the GFC (State of the Tropics, 2014). The growth of tropical economies has largely been driven by the two best-known economic zones: Southeast Asia[3] and South Asia[4], which have collectively been responsible for 10.3% of the world economy (State of the Tropics, 2014). Moreover, almost half of the Group of Twenty (G20) members are located completely or partially in the Tropics; this dynamic grouping of countries is known to represent 85% of the global economy (Hockey, 2014). As part of its growth agenda, the G20 has committed to promoting sustainable and balanced growth of tropical economies through significant increases in investment, structural reforms, and resilience (Hockey, 2014). Thereby, the enormous economic potential of the Tropics can be realised in the foreseeable future.

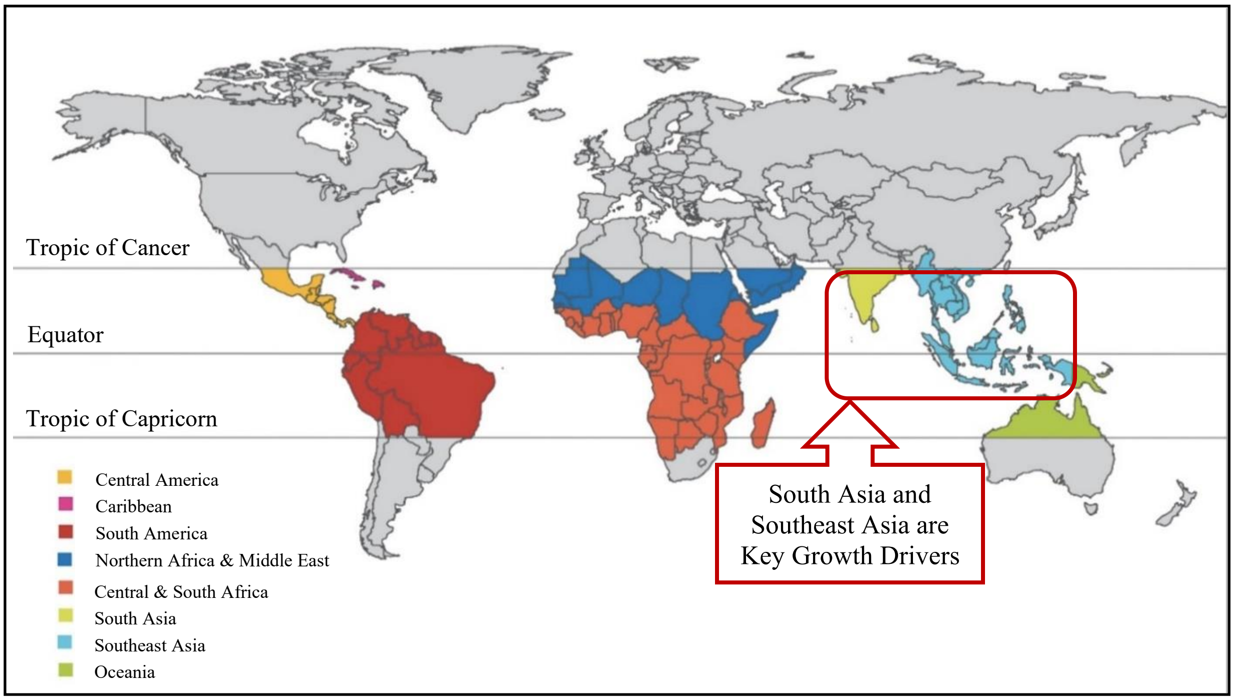


Figure 1.1: The Tropical Economies
Source: State of the Tropics (2014) Report

[3] Southeast Asia consists of Brunei, Cambodia, China*, Hong Kong, Macau, Indonesia, Laos, Malaysia, Myanmar, Singapore, Thailand, Vietnam, and Timor-Leste. (* Bangladesh and India have large areas that bestride the Tropics while only China's southern part straddles the Tropics)
[4] South Asia consists of Bangladesh*, India*, Maldives, and Sri Lanka.

Governments around the world have long recognised Small and Medium Enterprises (SMEs)[5] as a true economic powerhouse of the global economy. Globally, nine out of ten businesses are SMEs, contributing 63% of employment and almost 50% of the world's GDP (World Bank, 2015). In the Tropics, where most members are developing countries, SMEs account for 89-99% of all companies, offer 45% of all jobs and contribute 33% to GDP (World Bank, 2015). After the GFC, the important role of SMEs was further emphasised as an engine of economic recovery and sustainable growth (Robu, 2013). Nonetheless, these growing aspirant enterprises are facing a significant credit gap due to the issues of information asymmetries, low credit-worthiness, and a high level of risk associated with small businesses.

The International Finance Corporation - IFC (2013) estimated the credit gap to be US$3.2 trillion worldwide and US$196.3 billion in the Tropics. That is equivalent to 30% of the total outstanding balance of SME lending. This gap is one of the major obstacles to realising the economic potential of small businesses. Moreover, although bank loans remain a primary source of finance for SMEs, they have been restricted due to the substantial regulatory reform in the global banking sector after the GFC (Asian Development Bank - ADB, 2014). Consequently, academics and policymakers are paying increasing attention to promoting a dynamic financing landscape for SMEs, with a major focus on equity financing such as stock markets.

According to the World Federation of Exchanges (2015), second-tier stock markets, also known as SME stock markets or alternative stock markets, are perceived to be a critical component of the financing ecosystem of SMEs. These markets have been established to support SMEs with growth potential but are ineligible to be listed on the main stock market since they cannot fulfil the main market's profitability and track-record requirements. Acting as a second-tier listing alternative to the main stock market, SME stock markets serve as a new channel for fundraising and a credible identity for SMEs. During 2000-2014, US$185 billion was raised through initial public offerings (IPOs) and secondary public offerings (SPOs) on SME stock exchanges around the world (Organisation for Economic Cooperation and Development - OECD, 2015). This equates to a significant 5.8% of the global SME credit gap. Moreover, compared to SMEs with debt

[5] While the definition of SMEs varies across countries, Inter-American Development Bank (IADB) defines SMEs as independent enterprises having 100 employees or fewer, and total sales up to US$3 million. The IADB definition has been adopted for this thesis.

financing, SMEs funded by equity capital are apt to be more stable and resilient in the event of external financial disturbances (Sestanovic, 2016). Harwood and Konidaris (2015) also demonstrated the benefits of having a second-tier stock exchange in place for both companies and investors:

(i) The stock exchange can help SMEs become less dependent on the restraints of bank lending by providing long-term equity capital without requiring the founders of the SMEs to make interest and principal repayments or to waive their majority control.

(ii) With a flexible and less prescriptive regulatory framework, the stock exchange allows growing enterprises to raise funds on a continuous and cost-effective basis while offering protection for investors.

(iii) Due to the requirements of transparency and corporate governance, being listed on the stock exchange also helps SMEs improve their credit ratings and prevent over-leveraging at different stages of growth, which in turn increases the business resilience.

(iv) Listed SMEs will be covered by analysts in their reports to investors and financial media, thereby improving the company's market visibility, credentials, investor base, and market valuation.

(v) The stock exchange also offers an exit route for early-stage investors such as angel investors, and venture capitalists to realise their investments, thereby encouraging them to supply more seed funds to SMEs.

While the companies listed on the main stock markets operate across a wide range of business sectors, those listed on SME stock markets are primarily involved in innovative sectors (Sestanovic, 2016). Some examples of innovative sectors that engage SMEs are information technology, media, telecommunications, biotechnology, environmental protection, and renewable energy. As such, SME stock markets increasingly appear to be a critical source of finance for SMEs that may have limited access to traditional sources of finance for innovation. By definition, innovation can be viewed as a process that involves research and development (R&D) activities and acquisitions of necessary resources to develop firms' core value propositions (Grossman & Helpman, 1994). More flow of capital into innovation potentially leads to an increase in the number of patents and trademarks registered by SMEs (Pradhan, Arvin, Nair, Bennett, Bahmani, & Hall, 2018). This consequently arouses the demand for outputs and stimulates growth.

Therefore, the growth of SME stock markets can be seen as a key catalyst for innovation. The more innovation, the more economic growth is fuelled.

Since the 1990s, SME stock markets have increasingly been established in different parts of the world. By 2016, 51 markets were operating, of which nearly a quarter was in the Tropics (see Figure 1.2). In this region, the SME stock markets in Hong Kong – Growth Enterprise Market (GEM), Singapore – CATALIST Market, Thailand – Market for Alternative Investment (MAI), and Malaysia – Access, Certainty, and Efficiency Market (ACE), effectively dominate peers in terms of active operation and the number of listings.

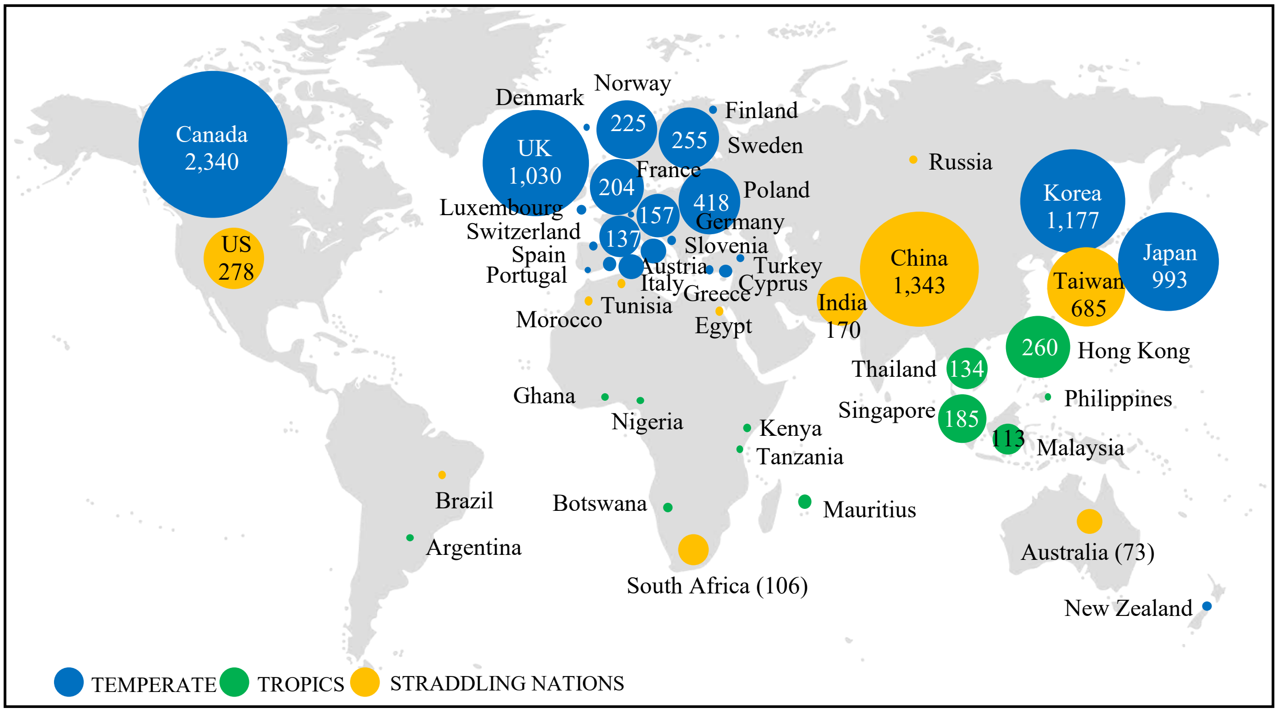


Figure 1.2: SME Stock Markets Worldwide
(Figures represent the number of listed companies as of December 2016)
Source: Author generated using data derived from the World Federation of Exchanges and the stock exchanges' public domains

Although second-tier stock markets play a pivotal role in bridging the credit gaps for SMEs and are growing worldwide, they have been under-researched. Specifically, the efficiency of these markets and their important roles in stimulating economic growth have been disregarded in the finance and growth literature. Accordingly, the overarching aim of this research is to explore the efficiency of second-tier markets and their direct and indirect contributions to macroeconomic development, which are elaborated in Section 1.3 – Research Gaps and Section 1.4 – Research

Studies and Questions. The four second-tier stock markets of Hong Kong, Singapore, Thailand, and Malaysia, namely the GEM, CATALIST, MAI, and ACE, respectively, are employed as cases for empirical analysis. This is mainly due to their prominent roles in SMEs' finance and growth stimulation for tropical economies, as discussed in Section 1.5 – Scope of Research. This research has several implications for academics, policymakers and professional practitioners in making improvements and investments in second-tier stock markets. These implications are justified in Section 1.7 – Significance of the Research.

The author has been unable to locate any prior research in this area. Therefore, this research, to the best of the author's knowledge, is the first to investigate the efficiency of second-tier stock markets and their contribution to macroeconomic development with case studies in tropical economies.

1.2 Concept of Market Efficiency and Long Memory

Fama (1970), in his seminal work, presented a formal concept of market efficiency. He defined a market as efficient when all relevant information is fully reflected in prices. In such a market, security prices quickly respond to new information by accurately incorporating this information into prices and reaching a new equilibrium. Therefore, it is impossible to earn an abnormal return using the given set of information, and the return should be independent and unpredictable.

Basically, the concept of market efficiency is grounded in the following assumptions: (i) all investors are economically rational and attempt to maximize return on investment; (ii) all relevant information is freely available to all investors; (iii) new information is released to the market randomly; and (iv) there are no transaction costs in trading (Roberts, 1959; Roberts, 1967; Fama, 1970). According to Fama (1970), the relevant set of information consists of historical market data, public information, and private information. As such, he divided market efficiency into three levels corresponding with three efficient market hypotheses (EMH), as follows:

(i) *Weak Form EMH* posits that current stock prices, at any moment, incorporate all historical market data, i.e., sequences of price and return. If the weak form holds, it is impossible for investors to gain a superior return based on the historical market data. Thus, technical analysis, which can predict stock price by observing charts, patterns, and technical indicators, yields no extra profit. Weak form EMH is consistent with a random walk in which price movements are independent of each other.

(ii) *Semi-strong Form EMH* presumes that current stock prices, at any moment, reflect all past information and quickly capture without biases any new publicly available information, i.e., economic events, political events, or announcement of earnings, dividend payouts, new issuances, mergers, and acquisitions. If the semi-strong form holds, investors cannot gain an abnormal return based on technical and fundamental analysis. Fundamental analysis is an approach to evaluating a security's intrinsic value by considering all relevant qualitative and quantitative factors such as economic, financial, and political factors.

(iii) *Strong Form EMH* states that all available information including historical market data, public information, and private information is fully incorporated into the current stock prices. In such a market, monopolistic access to private information does not exist, and investors thus cannot beat the market in any way.

The three forms of efficient market hypothesis are illustrated in Figure 1.3 below.

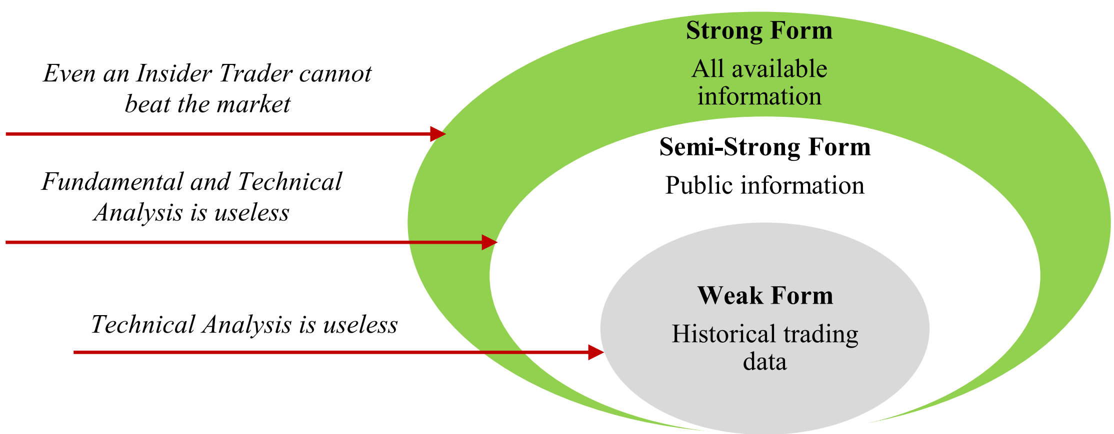


Figure 1.3: Three Forms of Efficient Market Hypothesis
Source: Author adapted from Latif, Arshad, Fatima, and Farooq (2011)

Lagoarde-Segot and Lucey (2008) asserted that an informationally efficient stock market is vital for a favourable stock market-growth nexus. Market efficiency is critical because it effectively reduces the problem of information asymmetry, improves investor confidence, and mobilises savings into productive investments, which then leads to optimal resource allocation and long-term economic stimulation (Caporale, Howells, & Soliman, 2005). In contrast, deviations from efficiency create abnormal profits for well-notified investors at the expense of less-notified investors, resulting in large market inefficiency expenses (Guidi & Gupta, 2011). Policymakers thus have a responsibility to mitigate such expenses and protect investors by improving information distribution technology and regulations. More importantly, an efficient stock market can uphold economic growth by making the stock market resistant to external shocks and providing an attractive investment channel for domestic and international capital (Rakic & Radjenovic, 2013).

One of the major statistical concepts that is used to test for market efficiency is long memory. Long memory, also known as long-range persistence, is a common property of financial time series. Long memory occurs when the autocorrelation in a stock market return series and/or return volatility decays slowly over time. The presence of long memory in both returns and volatility provides evidence against random walk behaviour (Caporale, Gil-Alana, & Plastun, 2019). This implies predictability and is inconsistent with the Efficient Market Hypothesis (EMH) since abnormal profits can be made using trading strategies based on trend analysis. To unpack this more clearly, the presence of long memory indicates that the market does not absorb new information arriving in the market immediately but rather captures the information and adjusts the price gradually over a period of time. Therefore, historical price changes can be employed as material information for predicting future price changes, implying market inefficiency. Long memory is also considered a cause of an asset bubble, when prices escalate rapidly over a short period but are not supported by an underlying demand for the asset itself. This may induce inefficient allocation of capital in the economy and consequently economic stagnation. Moreover, the degree of long-range persistence in market return and/or return volatility is also a key determinant of financial stability and can make portfolio allocation decisions sensitive to investment horizons.

1.3 Research Gaps

As discussed in Section 1.1 – Background, second-tier stock markets or SME stock markets are acknowledged as a critical source of long-term equity financing for SMEs. Over the past two decades, second-tier stock markets have rapidly been instituted both in developed and emerging countries and have fulfilled 5.8% of the global SME credit gap. These stock markets also serve as a pathway for SMEs to be listed on the main stock markets, thereby supplying liquidity to the main stock markets. Moreover, there exists a dynamic relationship between the main stock markets and economic development wherein the main stock markets' return and volatility exhibit short-run and long-run causal relationships with macroeconomic indicators. Putting these together, the author identifies three important research gaps related to the efficiency of SME stock markets and their dynamic contribution to macroeconomic development in both direct and indirect ways through the channel of main stock markets. The research gaps are depicted in Figure 1.4 and elaborated in the following sections.

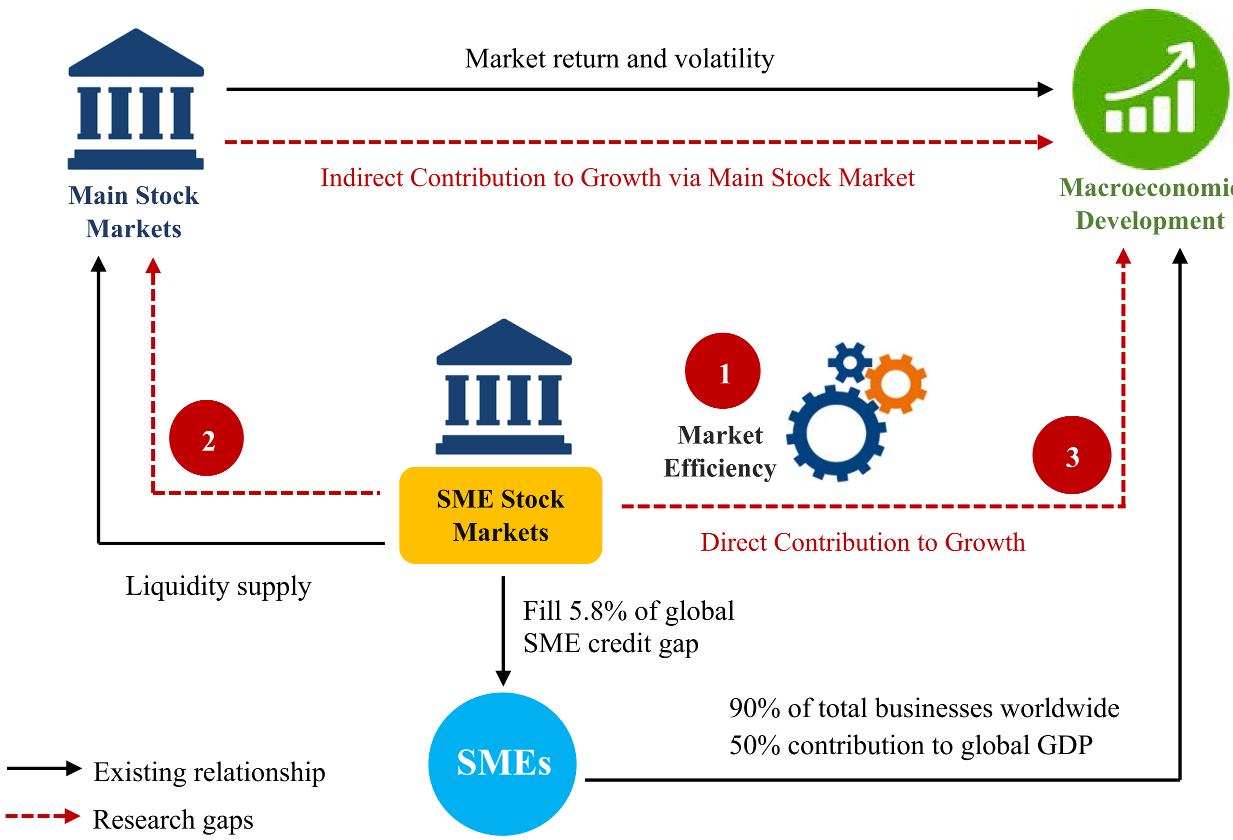


Figure 1.4: Overview of Research Gaps

1.3.1 Research gap 1: SME Stock Market Efficiency and Long Memory

Since the seminal work of Fama (1970), empirical studies on market efficiency have been increasing rapidly. Earlier studies primarily focused on the main stock markets, both in developed and emerging countries, yet results differ owing to discrepancies in the methodology applied, frequency of data and sample period (for example, see Guidi, Gupta, and Maheshwari (2011) and

Shaker and Towhid (2013)). Meanwhile, SME stock markets, which are important for SME finance and growing their footprints worldwide, receive limited academic attention. In addition, many market efficiency studies have examined whether a stock market is efficient in the weak form, assuming that market efficiency remains static over the sample period (for example, see Li and Liu (2012), Dragotă and Țilică (2014), and Singh, Leepsa, and Kushwaha (2016)). Such studies could have hidden a potential tendency towards efficiency in the market or the sub-periods in which the market is actually efficient. Therefore, this thesis explores the evolution of weak-form efficiency in SME stock markets to examine whether these markets are efficient in certain periods or exhibit a tendency towards efficiency.

Furthermore, long memory, which is one of the major the major statistical concepts that used to test for market efficiency, has widely been examined in the literature on stock market behaviours. However, a large body of literature has just focused on the main stock markets and overlooked SME stock markets. It has also failed to control for the joint impacts of factors such as thin trading, structural breaks, and inflation on long memory. Thin trading or infrequent trading occurs when stocks are traded at low volume due to a lack of buy or sell orders. Structural breaks appear when a time series encounters an abrupt change at a point in time. Ignoring these factors may induce biased long memory estimates that mislead professional practitioners. This thesis is thus intended to examine the presence of long memory in SME stock market returns and return volatilities under the joint impacts of thin trading, structural breaks, and inflation.

1.3.2 Research gap 2: Dynamic Transmissions between Main Stock Markets and SME Stock Markets

Several studies have documented the influence of the main stock market return and volatility on economic development (for examples, see Kanas and Ioannidis (2010), Forson and Janrattanagul (2014) and Guo (2015)). Meanwhile, a legal relationship exists between main stock market and second-tier stock market, in which second-tier market is often housed under the main market and supplies new listings to the main market (Harwood & Konidaris, 2015). As such, acting as a liquidity pump for the main market, second-tier market could potentially make an indirect contribution to economic development through its return and volatility transmissions across the main market channel. Nonetheless, these dynamic transmissions between the two stock markets have been disregarded in the literature on spillovers[6] among stock markets.

Financial time series often encounter large shocks that can instigate changes in unconditional variance, also known as structural breaks in volatility or volatility breaks. The existence of deterministic volatility breaks in the return series may cause the underlying volatility persistence to be overestimated by a standard Generalised Autoregressive Conditional Heteroscedasticity (GARCH) model (Lamoureux & Lastrapes, 1990b). Moreover, thin trading can induce a spurious autocorrelation in a return series (Lo & MacKinlay, 1990) and trading volume can affect price movements and the clustering pattern of return volatility (Clark, 1973; Copeland, 1976). Although studies on return and volatility transmissions among size-based stock portfolios are numerous, few of them accounted for either volatility breaks or trading volume when examining these transmission effects. As such, there is a paucity of research on cross-market transmissions of return and volatility that accounts for the joint effects of thin trading, volatility breaks, and trading volume. Neglecting the effects of these factors while modelling cross return and volatility transmissions may distort the true corresponding estimates that mislead policymakers and professional practitioners.

Hence, the objective of this thesis is to investigate the dynamic return and volatility transmissions between main stock markets and second-tier stock markets while controlling for the joint impacts of thin trading, volatility breaks and trading volume. Such an investigation provides further knowledge about the potential indirect influence of the second-tier stock markets on economic development through the main market channels.

1.3.3 Research gap 3: Dynamic Impacts of SME Stock Market Development and Innovation on Macroeconomic Indicators

An extensive body of empirical studies on the nexus between stock market development and economic growth has emerged since the 1990s. Nevertheless, the results remain contradictory and inconclusive across different countries. Several studies reported a positive causal nexus between the stock market and economic growth for the economies where the stock markets are

[6] Spillover is an effect that apparently unrelated events in one market can have on the other markets.

well-developed, such as Hong Kong, Singapore, Thailand, and Malaysia (for examples, see Hoque and Yakob (2017), Ho (2018) and Samsi, Cheok, and Yusof (2019)). Meanwhile, other studies showed negative results for countries where the financial sector is dominated by banks or the stock markets are relatively young, such as Saudi Arabia, Nigeria, and Bangladesh (for examples, see Owusu (2016), Banerjee, Ahmed, and Hossain (2017) and Rehman (2018)). These inconclusive results indicate further empirical works in this area.

Although the above-mentioned studies have covered both developed and emerging economies, they have only examined the main stock markets. This is primarily due to the main markets being larger in term of capitalisation and liquidity compared to the second-tier markets. In terms of methodological approach, most existing studies fail to test the dynamic nexus between stock market and economic development in a structural macroeconomic framework. This, therefore, reveals a paucity of research on the finance-growth nexus focusing on second-tier stock markets and a lack of research on the dynamic interaction between stock markets and economic development within an integrated model of key macroeconomic functions.

As discussed earlier in Section 1.1, the development of second-tier stock markets can be considered a key catalyst for innovation. The notion that innovation has a substantial impact on economic growth is advocated by voluminous studies; for instance, see Kirchhoff, Newbert, Hasan, and Armington (2007), Agénor and Neanidis (2015), and Pradhan, Arvin, Hall, and Nair (2016). Nonetheless, this body of research fails to examine the innovation-growth relationship within an integrated macroeconomic framework. On the other hand, the Kaleckian-Post-Keynesian model of growth and distribution is renowned as an integrated system of behavioural functions of real sectors. The model effectively demonstrates the functional interrelationship between private investment, domestic savings, income distribution, productivity growth, net export, and employment. While the model has recently been extended by Chaiechi (2012) with the effect of financial market development, the role of innovation in the system has yet to receive adequate attention. This inspires the modelling approach in the thesis together with some of the theoretical assumptions to further improve the specification of the Kaleckian macroeconomic model.

This thesis thus explores the dynamic impacts of second-tier stock market development and innovation on major macroeconomic indicators within a Kaleckian-Post-Keynesian framework. Such an exploration provides a further understanding of potential contributions of the second-tier stock market development and innovation to different channels of economic growth.

1.4 Research Studies and Questions

Following the three research gaps identified in the previous section, three research studies and the corresponding questions are defined in the following sections.

1.4.1 Study 1: Evolution of Weak-form Efficiency and Dual Long Memory in SME Stock Markets

To address the research gap one, an examination of evolving weak-form efficiency and long memory property in SME stock markets is required. Since SME stock markets are still at an early stage of development, it is time-consuming for their price discovery processes to fully incorporate new information. Therefore, examining the evolution of weak-form market efficiency is essential, rather than just addressing the issue of whether the markets are weak-form efficient. Weak-form EMH is the first to be tested because it is the lowest level of market efficiency and is encompassed within the semi-strong form EMH and strong form EMH. Additionally, as a common source of market inefficiency, the presence of long memory in the return and volatility of SME stock markets is also diagnosed. To avoid biased estimation of the dual long memory, the joint impacts of thin trading, structural breaks, and inflation are taken into account.

Accordingly, three research questions are stated and depicted in

Q1.1: Do SME stock markets evolve towards weak-form market efficiency?
Q1.2: Is long memory property present in SME stock markets' return and volatility?
Q1.3: What are the joint impacts of thin trading, structural breaks, and inflation on long memory property in SME stock markets' return and volatility?

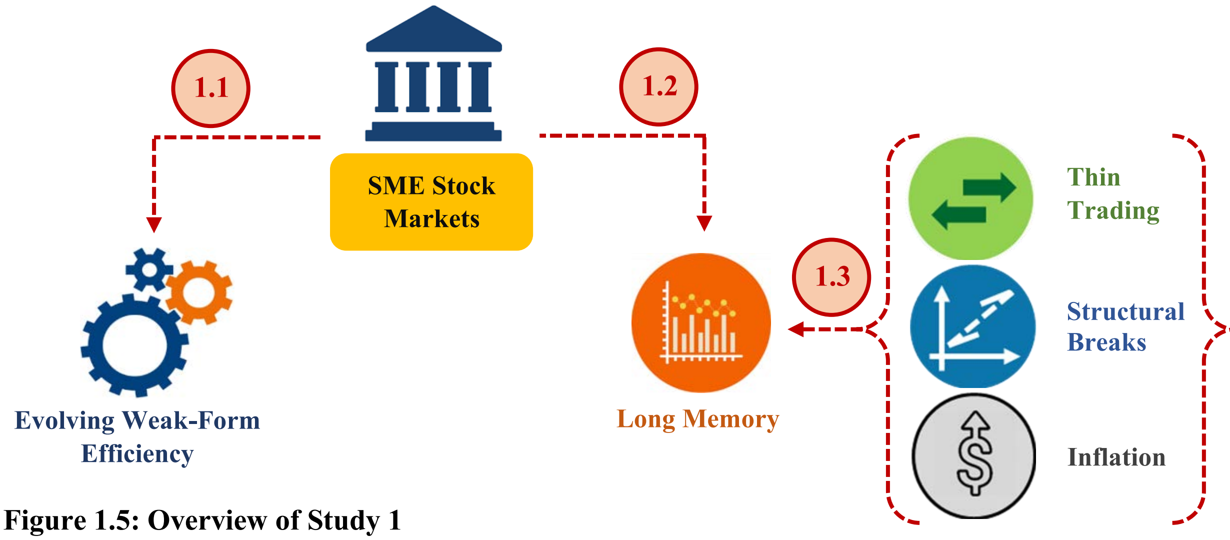


Figure 1.5: Overview of Study 1

1.4.2 Study 2: Dynamic Return and Volatility Transmissions between Main Stock Markets and SME Stock Markets

To address research gap two, it is essential to explore the dynamic return and volatility transmissions between the main stock markets and SME stock markets. To avoid spurious estimates, the joint impacts of thin trading, volatility breaks and trading volume are accounted for while modelling cross-market return and volatility transmissions. The outcomes of this study offer further understanding of potential indirect contributions of SME stock markets to macroeconomic development through their transmission mechanisms with the main stock markets.

Accordingly, two research questions are defined and portrayed in Figure 1.6 as follows:

Q2.1: Are there return and volatility transmissions between main stock markets and SME stock markets?
Q2.2: What are the joint impacts of thin trading, volatility breaks, and trading volume on the return and volatility transmissions between main stock markets and SME stock markets?

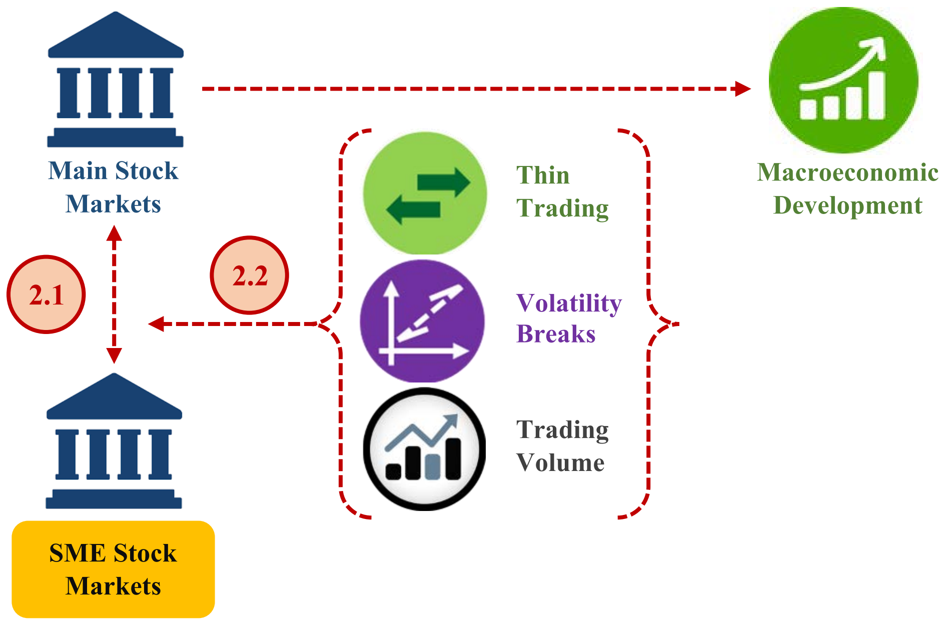


Figure 1.6: Overview of Study 2

1.4.3 Study 3: Dynamic Impacts of SME Stock Market Development and Innovation on Macroeconomic Indicators

To bridge research gap three, an investigation of dynamic impacts of SME stock market development and innovation on macroeconomic indicators within a Kaleckian-Post-Keynesian growth model has been undertaken. Such an investigation provides further knowledge about the potential contribution of SME stock market development and innovation to different channels of economic growth such as private investment, domestic savings, productivity growth, and employment. The outcomes of this study are also intended to improve the model specification and further extend the theoretical framework of the Kaleckian-Post-Keynesian economics.

Accordingly, two research questions are developed and illustrated in Figure 1.7 as follows:

Q3.1: Are there dynamic impacts of SME stock market development on macroeconomic indicators within a Kaleckian-Post-Keynesian growth model?
Q3.2: Are there dynamic impacts of innovation on macroeconomic indicators within a Kaleckian-Post-Keynesian growth model?

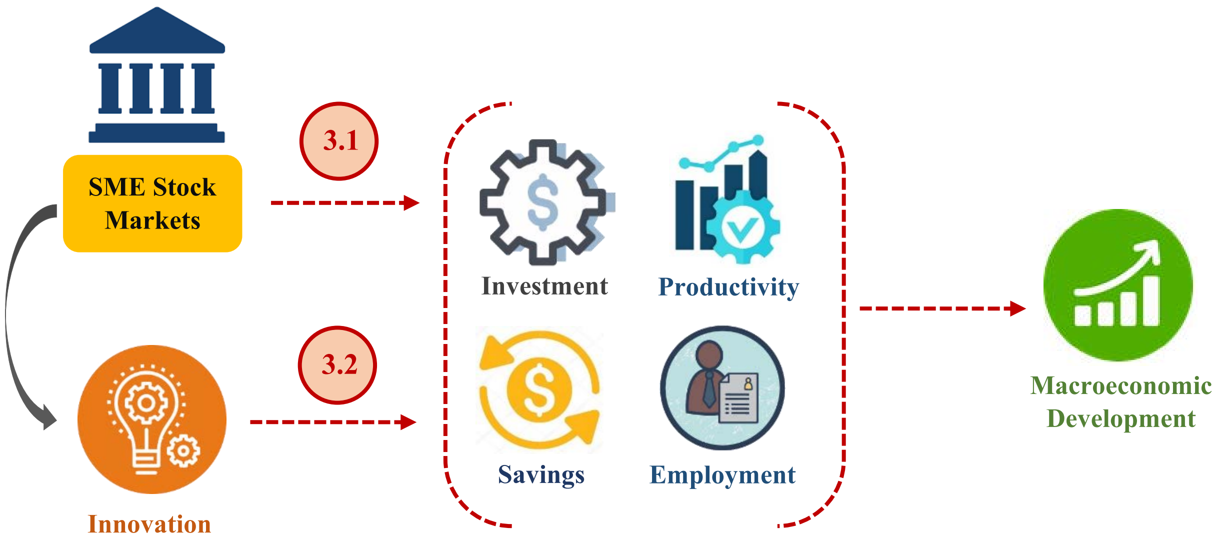


Figure 1.7: Overview of Study 3

1.5 Scope of the Research

Generally, stock markets in Hong Kong, Singapore, Thailand, and Malaysia have been recognised as the primary sources of capital for the Asia region and have played a critical role in driving economic growth in the region (Ong & Lipinsky, 2014). The four countries are also developed and emerging economies in Southeast Asia, which is one of the key growth drivers of the Tropics as mentioned in Section 1.1. Consequently, the stock markets of these countries (including the main market and SME market) could be a major source of funding and a critical driving force for tropical economies.

Indeed, capital mobilisation from SME stock markets of these countries over the period 1999-2016 was approximately US$28.1 billion, which effectively fulfilled 75.8% of SMEs credit gaps in the four countries or 14.3% of SMEs credit gaps in the Tropics. Although SME stock markets in China and Korea are the second and third largest in the world regarding the number of listed companies, they cover just 26.2% and 11.5% of SME credit gaps in China and Korea, respectively. Therefore, arguably, the GEM (Hong Kong), CATALIST (Singapore), MAI (Thailand), and ACE (Malaysia), given their activeness and significant contribution to closing the credit gap for SMEs in the Tropics, play a prominent role in SME finance and growth stimulation in the region.

Moreover, the GEM (Hong Kong) is endorsed as one of the world's most successful examples of an SME stock market together with the Alternative Investment Market (the United Kingdom), the Toronto Venture Exchange (Canada), the Mothers (Japan), and the AlterNext (Europe) (Peterhoff, Romeo, & Calvey, 2014). A successful SME stock market can elevate the contribution of SMEs to the host country's overall GDP by 0.1-0.2% each year (Peterhoff et al., 2014). Therefore, SME stock markets in Hong Kong, Singapore, Thailand, and Malaysia were selected for study, namely the GEM, CATALIST, MAI, and ACE, respectively. The scope of this research also presents a diverse comparison landscape, from developed markets such as Hong Kong and Singapore, to emerging markets such as Thailand and Malaysia.

1.6 Research Methodology and Data

1.6.1 Research Methodology

This thesis applied quantitative methodology to address the identified research studies and questions. Specifically, the studies that underpin this thesis used time series analysis, consisting of a series of methods and econometric techniques for analysing and modelling time series data to uncover important statistical properties and inferences. The time series analysis is a powerful tool to analyse a sequence of discrete-time data such as stock market data and macroeconomic data.

To address the first study of evolving market efficiency and long memory, a set of return and volatility models was utilised. A State-Space Non-linear Generalized Autoregressive Conditional Heteroscedasticity in Mean (GARCH-M) model with Kalman filter estimation was used to capture the evolution of weak-form market efficiency. Three fractionally integrated return – volatility models such as Autoregressive Fractionally Integrated Moving Average (ARFIMA) – Fractionally Integrated GARCH (FIGARCH), ARFIMA – Fractionally Integrated Asymmetric Power ARCH (FIAPARCH), and ARFIMA – Hyperbolic GARCH (HYGARCH) were used to test for the presence of long memory property in the stock market return and volatility. To assess the joint impacts of thin trading, structural breaks and inflation on the dual long memory, an

Iterated Cumulative Sum of Squares (ICSS) algorithm for multiple breaks test, a State-Space Linear AR model with Kalman filter estimation for thin trading adjustment, and other pertinent adjustment techniques were applied. Details of the econometric techniques and models are provided in Chapter Three, Section 3.3.

To conduct the second study of dynamic return and volatility transmissions between main stock markets and SME stock markets, a Bivariate Vector Autoregressive (VAR) Asymmetric Baba-Engle-Kraft-Kroner (BEKK) GARCH model was adopted. The joint effects of thin trading, volatility breaks and trading volume on these cross-market transmissions were evaluated using the State-Space Linear AR model with Kalman filter estimation for thin trading adjustment and the ICSS algorithm for multiple breaks test. Subsequently, a standard Bivariate VAR Asymmetric BEKK-GARCH model was augmented with a dummy variable indicating volatility breaks, an aggregate trading volume variable and a de-thinned return variable. Some econometric issues such as stationarity, asymmetric return volatility, and cross-correlation of returns and residuals were also observed and dealt with. The econometric techniques and models used in this study are described in Chapter Four, Section 4.3.

The third study of dynamic impacts of SME stock market development and innovation on macroeconomic indicators drew on the Kaleckian-Post-Keynesian theoretical model of growth and distribution. This theoretical model was augmented by integrating the indicators of SME stock market development and innovation into different functions of the model such as private investment, domestic savings, productivity growth, and employment. For the empirical estimation, a Structural Vector Error Correction (SVEC) model was adopted and short-run restrictions were imposed following the Kakeckian theory of growth and distribution. A SVEC Impulse Response Function was employed to visually examine the dynamic interaction among the variables in the SVEC system. Preliminary analysis such as stationarity, lag order selection, cointegration analysis, and block exogeneity test were also taken into account. The augmented Kaleckian macroeconomic model and SVEC model identification are presented in Chapter Five, Section 5.3.

1.6.2 Data

The three studies reported in this thesis used time series data for stock markets, macroeconomic development, and innovation in Hong Kong, Singapore, Thailand, and Malaysia.

The study period was from July 2009 to December 2016, starting from the launch of new SME stock market in Malaysia. The new SME stock market in Malaysia replaced the former MESDAQ[7] and improved the quality of listed companies and market liquidity.

Stock market data are daily index closing prices, market capitalisation, and trading volume and value of the main stock markets and the SME stock markets in the four countries. The daily data were retrieved from Stock Exchange Publications, Central Bank Reports, and the Bloomberg Database. The main stock markets and the SME stock markets in Hong Kong, Singapore, Thailand, and Malaysia are represented by four pairs of market-value-weighted indices as follows:

- Hong Kong Hang Seng Composite Index (HSI) and S&P/HKEX GEM Index
- FTSE Strait Times All-Share Index (FSTAS) and FTSE Strait Times CATALIST Index
- Stock Exchange of Thailand Index (SETI) and MAI Index
- FTSE Bursa Malaysia EMAS Index (FBMEMAS) and FTSE Bursa Malaysia ACE Index

Macroeconomic data include a set of monthly indicators representing physical capital stock, gross fixed capital formation, capital depreciation rate, gross domestic savings, net export, gross domestic product (GDP), consumer price index (CPI), labour force, wage rate, and unemployment rate. Innovation data are monthly patent applications, trademark applications, and high-technology export. Monthly data were retrieved from various issues of National Statistics Departments, International Financial Statistics (IFS-IMF), and World Bank Databases (WDI). In the case of indicators for which only quarterly or annual data were available, monthly data were generated using frequency conversion techniques, where appropriate, quadratic with sum or average matched to the source data.

Details on variable definitions and characteristics for each study are provided in the data and variables section of Chapters 3, 4, and 5. A summary of data and time series analysis used to address the research studies and questions are presented in the below Table 1.1.

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[7] MESDAQ stands for Malaysian Exchange of Securities Dealing and Automated Quotation System

Table 1.1: Summary of Research Studies and Questions, Data and Time Series Analysis

Research Studies and Questions	Data	Time Series Analysis
Study 1: Evolution of Weak-Form Efficiency and Long Memory in SME Stock Markets		
Q1.1: Do SME stock markets evolve towards weak-form market efficiency?	Daily index closing price of SME stock markets;	State-Space GARCH-M model with Kalman filter
Q1.2: Is long memory property present in SME stock markets' return and volatility?	Monthly CPI	ICSS algorithm; State-Space AR model with Kalman filter; adjustment techniques
Q1.3: What are the joint impacts of thin trading, structural breaks, and inflation on long memory property in SME stock markets' return and volatility?		ARFIMA-FIGARCH model ARFIMA-FIAPARCH model ARFIMA-HYGARCH model
Study 2: Dynamic Return and Volatility Transmissions between Main Stock Market and SME Stock Market		
Q2.1: Are there return and volatility transmissions between main stock markets and SME stock markets?	Daily index closing price and trading volume of the main stock markets and SME stock markets	Stationarity test; Test of asymmetric return volatility; Test of cross-correlation of returns and residuals
Q2.2: What are the joint impacts of volatility breaks, thin trading, and trading volume on the return and volatility transmissions between main stock markets and SME stock markets?		ICSS algorithm; State-space Linear AR model with Kalman filter Augmented VAR Asymmetric BEKK-GARCH model
Study 3: Dynamic Impacts of SME Stock Market Development & Innovation on Macroeconomic Indicators		
Q3.1: Are there dynamic impacts of SME stock market development on macroeconomic indicators within a Kaleckian-Post-Keynesian growth model?	Monthly macroeconomic data Monthly market capitalisation and trading value of SME stock markets	Stationarity test; Lag order selection; Cointegration analysis; Block exogeneity test Augmented Kaleckian-Post-Keynesian model of growth and distribution
Q3.2: Are there dynamic impacts of innovation on macroeconomic indicators within a Kaleckian-Post-Keynesian growth model?	Monthly innovation data	SVEC model; SVEC impulse response analysis

1.7 Significance of the Research

The research reported in this thesis is expected to make many contributions to the empirical literature on SME stock markets and to the Kaleckian-Post-Keynesian theoretical model of growth and distribution. The findings of the studies undertaken should benefit academics, policymakers, investors, and other professional practitioners, as elaborated in the following sections.

1.7.1 Empirical Contributions

Despite the importance of SME stock markets to SME finance, there is a paucity of empirical literature on these markets. The first study of this research, therefore, contributes an investigation of the evolution of weak-form efficiency and dual long memory property in the SME stock markets. Unlike prior studies, this study examines dual long memory property under the joint impacts of structural breaks, thin trading, and inflation.

The second study of this research provides an exploration of dynamic return and volatility transmissions between main stock markets and SME stock markets. This study is also the first to account for the joint effects of thin trading, volatility breaks, and trading volume on cross-market transmissions. The augmented model used in this study further enhances existing empirical models by incorporating both volatility breaks and trading volume into a standard bivariate VAR asymmetric BEKK-GARCH process.

The third study of this research presents an examination of the dynamic impacts of SME stock market development and innovation on macroeconomic indicators. This study is unique in its way of incorporating indicators of SME stock market development and innovation into various functions of the Kaleckian-Post-Keynesian macroeconomic model.

1.7.2 Theoretical Contribution

Although the Kaleckian-Post-Keynesian's theoretical model of growth and distribution is renowned for its representation of functional interrelationships among several macroeconomic indicators, the model has just been augmented with general financial development indicators. The third study of this research thus further extends the model with SME stock market development and innovation (the development of SME stock markets can be considered an important catalyst for innovation, as discussed in Section 1.1). Specifically, based on theoretical justifications, indicators of SME stock market development are included in the functions of private investment, domestic savings, and productivity growth. On the other hand, indicators of innovation are incorporated into the functions of private investment, domestic savings, productivity growth, and employment. The integration of SME stock market development and innovation into the

Kaleckian-Post-Keynesian macroeconomic model helps improve the model specification and further enhances the theoretical framework of Kaleckian-Post-Keynesian economics.

1.7.3 Implications for Policymakers

The findings of the studies in this thesis are of great relevance to policymakers. The first study examining the evolution of weak-form efficiency of the SME stock markets exposes a tendency towards efficiency and sheds light on the underlying causes. This finding can assist policymakers in making institutional reforms and enacting effective regulation in order to improve market efficiency, thereby optimising capital allocation in the economy.

The analysis of the second study reveals an indirect contribution of the SME stock market to economic development via its dynamic transmissions with the main stock market. Such a finding implies that any policies that facilitate SME stock market development would indirectly promote long-term economic stimulation through its transmission mechanisms with the main stock market.

The outcome of the third study exhibits a direct contribution of the SME stock market and innovation to different channels of economic growth. This suggests that if policymakers provide policies that foster the development of the SME stock market and innovation, they could potentially stimulate economic growth.

Furthermore, this thesis, which employs the four tropical economies as case studies, further promotes the significance of the Tropics to the future global economy and calls for additional attention of world leaders to the tropical zone.

1.7.4 Implications for Professional Practitioners

An examination of the evolving efficiency of SME stock markets in the first study can assist investors and portfolio managers in devising appropriate investment strategies for these markets. Such strategies may involve either passively holding the markets or actively beating the markets. Also, in this study, the findings of long memory property in SME stock markets are highly important to investors and portfolio managers in formulating an effective hedging strategy[8] for these markets.

The estimation of volatility transmissions between the main stock markets and the SME stock markets in the second study also has crucial implications for investors and portfolio managers in minimizing the risk of a portfolio. In particular, the estimation of volatility transmissions can be used to determine an optimal hedge ratio to minimize the risk of a small- and large-cap stock portfolio.

In addition, investment advisors and fund-raisers can use the findings of the first and the second studies in their propositions to potential clients, who are interested in SME stock market investing.

1.8 Outline of the Thesis

This thesis consists of six chapters as outlined below.

Chapter One – Introduction

Chapter Two – Stylised Facts about Four Selected Economies: presents the characteristics and development of second-tier stock markets and innovation in Hong Kong, Singapore, Thailand, and Malaysia, as well as the institutional features of these economies.

Chapter Three – Evolution of Weak-form Efficiency and Long Memory in SME Stock Markets (Study 1) discusses the existing literature, data sources, definitions and statistical descriptions of variables, time series analysis and models such as a State-Space GARCH-M model with Kalman filter and a set of fractionally integrated models (i.e. ARFIMA-FIGARCH, ARFIMA-FIAPARCH, and ARFIMA-HYGARCH), findings and discussion, and implications.

Chapter Four – Dynamic Return and Volatility Transmissions between Main Stock Markets and SME Stock Markets (Study 2) provides a literature review, data sources, variables definitions

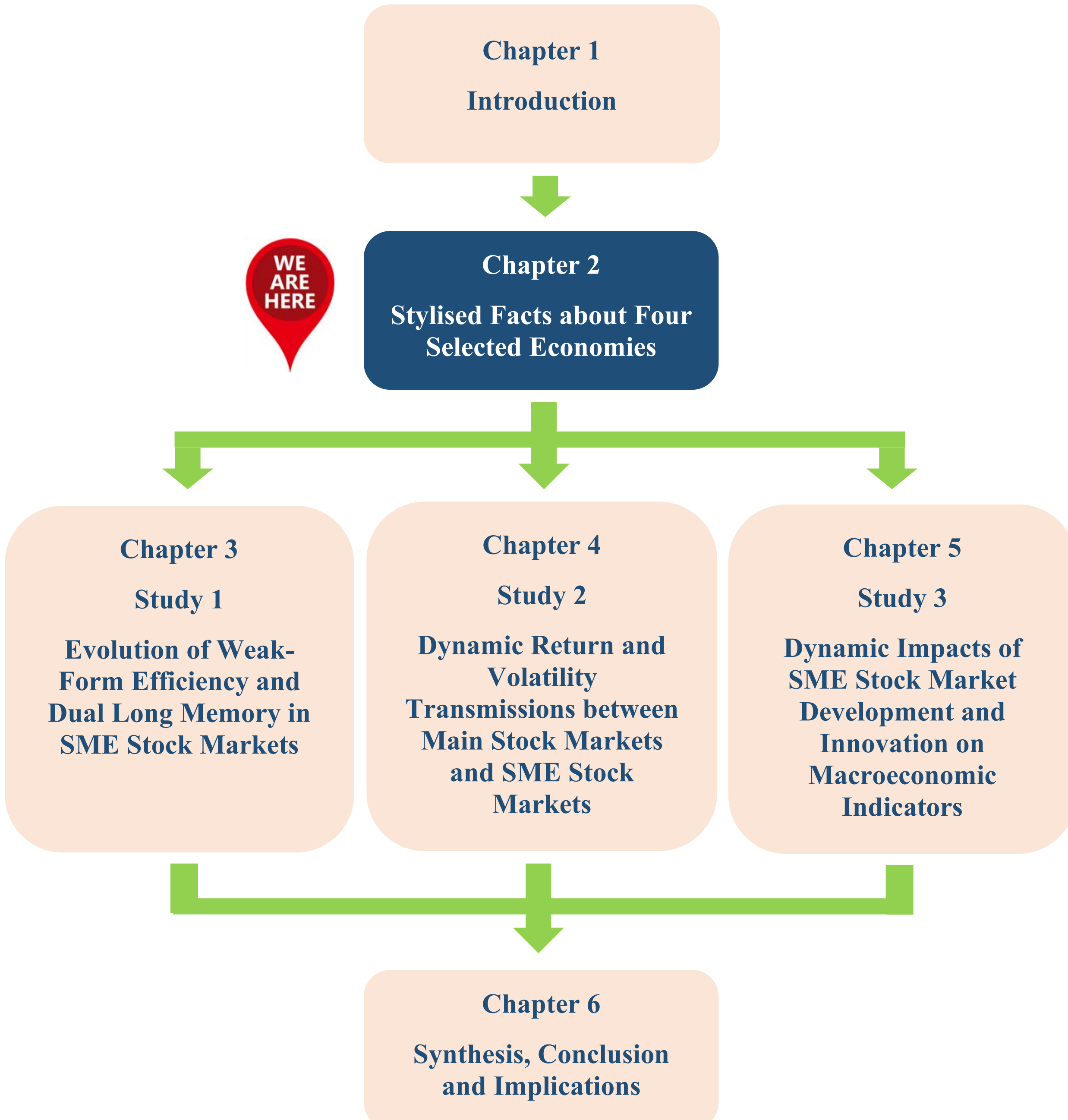
[8] Hedging is an investment strategy to mitigate the risk of adverse price changes in an asset by investing in an offsetting position in related securities.

and characteristics, time series analysis and an augmented VAR Asymmetric BEKK-GARCH model with volatility breaks and trading volume, findings and discussion, and implications.

Chapter Five – Dynamic Impacts of SME Stock Market Development and Innovation on Macro-economic Indicators (Study 3) presents the existing literature, data sources, variables definitions and characteristics, an augmented Kaleckian theoretical model of growth and distribution with SME stock market development and innovation, time series analysis and models such SVEC model and SVEC impulse response analysis, findings and discussion, and implications.

Chapter Six – Synthesis, Conclusion and Implications concludes the thesis by addressing the research studies and questions identified in Chapter One, emphasising research contributions to the empirical and theoretical literatures, and implications for policymakers and professional practitioners, as well as providing recommendations for future research.

Thesis Structure



Chapter Two: Stylised Facts about Four Selected Economies

Abstract

This chapter presents facts and figures that are stylised for the economy, SME stock market, and innovation in Hong Kong, Singapore, Thailand, and Malaysia. An understanding of the characteristics and development of SME stock markets and innovation greatly assists an investigation of market efficiency and the relationship between the two variables and economic development. As discussed in the previous chapter, SME stock markets in the four countries have prominent roles in SME finance for tropical economies. They are also deemed a stimulus for innovation through the process of directing capital into innovative SMEs. In this chapter, these markets are described as small capitalisation and thin trading markets since they are still at an early stage of development. The markets are operating on the principle of caveat emptor (buyer beware), thus they can expose investors to high investment risk. While relaxing the listing requirements compared to the main markets, the markets adopt a sponsor-driven model in which listing candidates must have an accredited sponsor to ensure their listing quality.

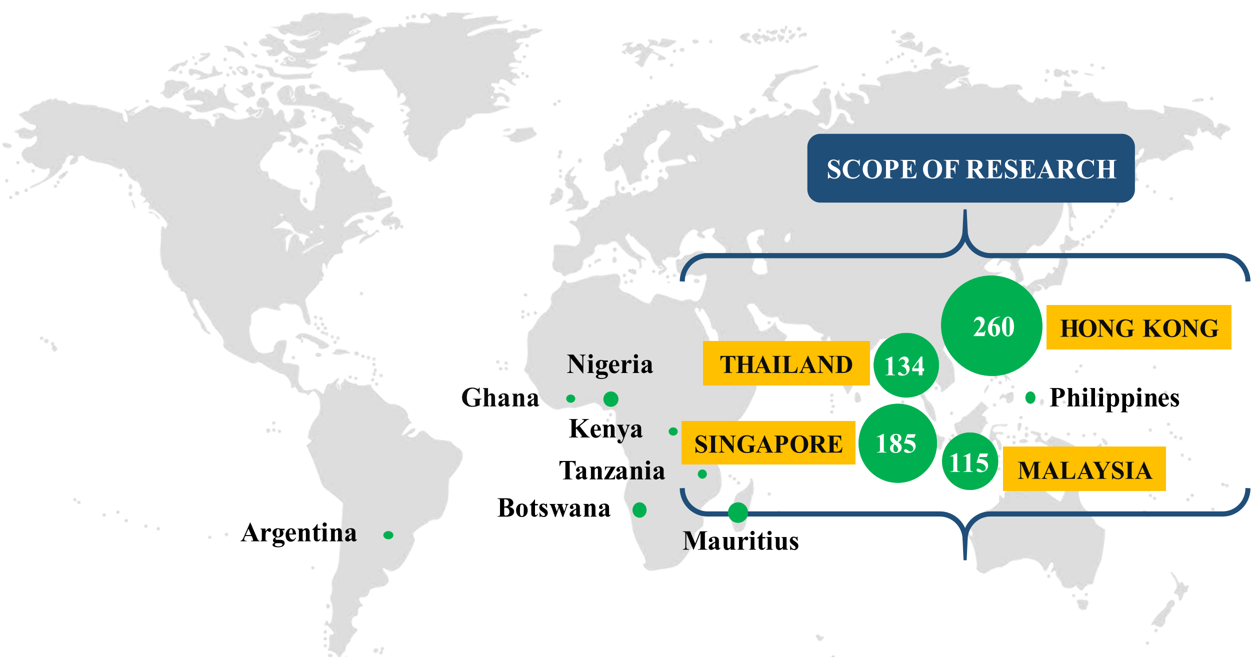


Figure 2.1: SME Stock Markets in the Tropics
(Figures represent the number of listed companies as of December 2016)
Source: Author generated using data derived from the World Federation of Exchanges and the stock exchanges' public domains

Chapter Outline

Some sections of the material in this chapter were adapted for publication in the following refereed journal articles along with findings from the individual studies conducted for the thesis:

Nguyen, T., Chaiechi, T., Eagle, L., and Low, D. (2020). SME stock markets in tropical economies: evolving efficiency and dual long memory. *Economic Papers*, 39(1), 28-47.

Nguyen, T., Chaiechi, T., Eagle, L., and Low, D. (2020). Growth Enterprise Market in Hong Kong: Efficiency Evolution and Long Memory in Return and Volatility. *Journal of Asian Business and Economic Studies*, 27(1), 19-34.

Nguyen, T., Chaiechi, T., Eagle, L., and Low, D. (2020). Dynamic transmissions between main stock markets and SME stock markets: evidence from tropical economies. *Quarterly Review of Economics and Finance*, 75, 308-324.

Nguyen, T., Chaiechi, T., Eagle, L., and Low, D. (Under review). Dynamic impacts of SME stock market development and innovation on macroeconomic indicators: A structural VEC approach. *Economic Analysis and Policy*.

2.1 Introduction

While Hong Kong and Singapore are recognised as 'Asian Tigers'[9], Thailand and Malaysia are referred to as 'Asian Tiger Cubs'. By the second decade of the 21st century, Hong Kong and Singapore had developed into advanced economies, specialising in areas of competitive advantages such as international finance, trade and transportation. Thailand and Malaysia, unsurprisingly, have been replicating the export-driven model of economic development pursued by the Asian Tigers. The four countries are also the top trading partners of each other. In 2018, their international trades recorded 1.2–3.7 times the corresponding GDP (World Bank, 2019c, 2019a, 2019b).

According to the World Intellectual Property Organisation - WIPO (2019), the 2019 Global Innovation Index (GII) of Singapore and Hong Kong were ranked first and third in South East Asia, East Asia, and Oceania, respectively. Meanwhile, the 2019 GII of Malaysia and Thailand were placed second and fourth among the upper-middle income economies, respectively. In 2016, Singapore's high-technology exports made a substantial contribution of US$126 billion or 42.5% to the country's GDP, largely doubling that of Malaysia and tripling that of Thailand (see Table 2.1).

As discussed in Chapter One, second-tier stock markets are recognised as an essential element of the SME financing ecosystem and can be seen as a major catalyst for innovation. The second-tier stock markets in Hong Kong, Singapore, Thailand, and Malaysia, given their activeness and substantial contribution to filling the credit gap for SMEs in the Tropics, have a critical role to play in SME finance and growth stimulation in the region. These second-tier markets are the GEM, CATALIST, MAI and ACE, which were established as a second board under the main boards of the Hong Kong Stock Exchange (HKEX), the Singapore Exchange (SGX), the Stock Exchange of Thailand (SET), and Bursa Malaysia (BM), correspondingly.

Compared to the main boards, the GEM (Hong Kong), CATALIST (Singapore), MAI (Thailand), and ACE (Malaysia) adhere to less stringent rules and regulations, have lower requirements for listing and information disclosure, a narrower investor base, and a higher

[9] A tiger economy refers to the economy of a country which experiences rapid economic growth, often associated with rising standards of living.

investment risk. The SMEs listed on these markets largely operate in innovative sectors such as biotechnology, information and communication technology, financial technology, and materials technology. The markets are characterised by small capitalisation and thin trading because they represent a very small fraction of the main boards in terms of capitalisation and traded value (see Table 2.1). Relative to other SME stock markets in the Tropics, the GEM in Hong Kong can be seen as the largest and the most liquid SME stock market and the one that makes the most significant contribution to its country's GDP (12.6%) (see Figure 2.1 and Table 2.1).

Table 2.1: Facts and Figures (2016)

	Hong Kong	Singapore	Thailand	Malaysia
SME stock markets	GEM	CATALIST	MAI	ACE
Market opened	1999	2007	2001	2009
No. of listed companies	260	185	134	113
Percentage of main index	15.2%	32.3%	25.7%	14.3%
Market capitalisation (a)	40.1	6.4	11.9	2.3
Percentage of GDP	12.6%	2.3%	3.0%	0.8%
Percentage of main index	2.3%	1.5%	3.1%	0.7%
Traded value (a)	19.0	4.9	15.5	3.2
Percentage of GDP	6.0%	1.7%	3.9%	1.1%
Percentage of main index	2.5%	2.8%	4.5%	3.1%
Traded volume (b)	231.9	88.5	200.6	55.3
Percentage of main index	54.6%	53.8%	15.5%	38.7%
Innovation				
No. of patent applications (c)	14,092	10,980	7,820	7,236
Percentage of labour force	0.36%	0.30%	0.02%	0.05%
No. of trademark applications (c)	36,181	22,740	51,613	39,107
Percentage of labour force	0.92%	0.61%	0.13%	0.26%
High-technology export (a)	0.42	126.3	34.2	52.1
Percentage of GDP	0.13%	42.5%	8.5%	18.8%

Source: Exchanges' factbooks and various issues of National Statistics Departments
Notes: (a) in US$ billion; (b) in billion shares; (c) data include residents and non-residents

To provide further insights into the four selected economies, their institutional features and the stylised facts about SME stock markets and innovation in Hong Kong, Singapore, Thailand, and Malaysia are demonstrated in the following sections.

2.2 Hong Kong

As a Special Administrative Region (SAR) of the People's Republic of China (PRC), Hong Kong is renowned for a high level of sovereignty in political and economic systems as well as its trade openness and dynamic economic structure. Over the past seven decades, Hong Kong's indisputable economic success has been due to the fact that its economy has experienced structural transformation from a regional hub for industrial manufacturing to a major international financial centre. This successful transformation is mainly attributable to liberal economic policies, effective corporate governance, and free and transparent flow of information.

Being a trade gateway to Mainland China and having strong business relations with many other Asian economies, Hong Kong is situated in a strategic growth region and has become one of the world's most unfettered economies. According to the World Trade Organisation - WTO (2018) and the United Nations Conference on Trade and Development - UNCTAD (2018), Hong Kong is the world's seventh-largest exporter of merchandise and the world's second-largest investor and host. This service-oriented economy is also noted as the fourth largest foreign exchange market and the biggest offshore RMB (Renminbi, the Chinese currency) clearing centre in the world (Bank for International Settlements - BIS, 2018). For decades, Hong Kong has striven to become the world's leading global financial centre. The Hong Kong Stock Exchange (HKEX) has developed into the world's sixth-largest stock market and the third in Asia, providing equity-funding opportunities for several multinational firms and conglomerates.

In addition, Hong Kong has weathered several critical shocks since the 2000s such as the Global Financial Crisis (GFC), stock market crashes, Chinese market turmoil, typhoons, chaos, and the transfer of sovereignty from London to Beijing (Scobell & Gong, 2017). With an average growth rate of 5.2% during 2000-2018, Hong Kong has proven to be a resilient economy.

2.2.1 Growth Enterprise Market (GEM)

Introduced in 1999, the GEM follows rules and regulations designed to promote a practice of self-compliance by the listed enterprises and sponsors in the discharge of their responsibilities. A GEM sponsor is a qualified advising agent approved by the HKEX. The sponsor is required to conduct due diligence to ensure the quality of listing applicants to the best of its knowledge and make appropriate disclosures. While the main market follows the philosophy of neoclassical growth theory, the GEM pursues the philosophy of classical growth theory. Specifically, the main market allows for government intervention whereas the GEM operates on the two principles of caveat emptor (buyer beware) and let the market decide, together with a robust disclosure regime.

As mentioned in Chapter One, the GEM has been acknowledged as one of the world's most successful examples of an SME stock market for its standout fund-raising activity and effective regulatory framework. During 1999-2016, the total funds raised on the GEM were about US$22.7 billion, fourfold greater than the total raised on the CATALIST, MAI and ACE combined. To list on the GEM, a candidate is required to meet relaxed conditions on track record, market capitalisation and operating cashflow, while candidates for the main market must satisfy additional conditions on profit (see Table 2.2). Nonetheless, GEM listed companies have to designate a compliance officer for the period starting from initial listing until the publication of financial results for two years after listing.

Table 2.2: Listing Requirements – Hong Kong Main Market versus Growth Enterprise Market

Main Market	Growth Enterprise Market
▪ Track record of no less than three years	▪ Track record of no less than two years
▪ Profits of HK$20 million (US$2.6 million) for the latest year and HK$30 million (US$3.8 million) for the first two years	▪ No profit requirement
▪ Market capitalisation of HK$500 million (US$64 million) at the time of listing	▪ Market capitalisation of HK$150 million (US$19.2 million) at the time of listing
▪ Positive cashflow generated from operating activities of HK$100 million (US$12.8 million) for the three previous years	▪ Positive cashflow generated from operating activities of HK$30 million (US$3.8 million) for the two previous years

Source: Hong Kong Stock Exchange's public domain

The GEM has been tracked by the S&P/HKEX GEM Index since 2000. Up to 2016, the market held 260 listed firms and exhibited at least a fourfold increase in market capitalisation and traded value, reaching US$40.1 billion and US$19.2 billion, respectively (see Figure 2.2). Over nearly two decades, 86 companies moved their listing from the GEM to the main board.

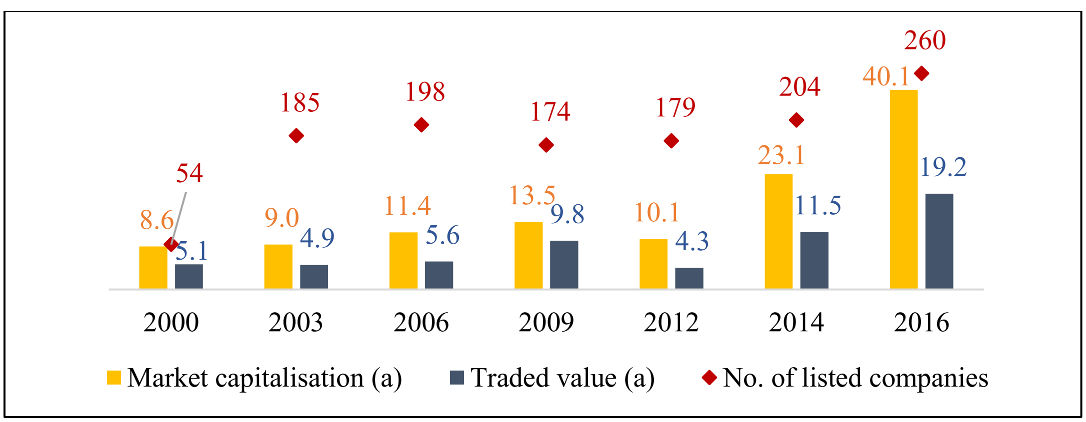


Figure 2.2: Growth Enterprise Market in Hong Kong Since Opened
Sources: Hong Kong Exchange factbooks and Bloomberg database
Notes: (a) in US$ billion

Another interesting feature of the GEM is that it exhibits a higher under-pricing level of IPOs than that of the main board. Vong and Zhao (2008) pointed out that such a high level of IPO under-pricing (approximately 20%) in the GEM is attributable to the ex-post volatility of after-market returns, timing effects, and geographic locations (i.e. H shares[10]). On the other hand, the under-pricing of IPOs in ChiNext, which is a SME stock market in China, is driven by offline oversubscription, issue size, market momentum (Deng & Zhou, 2015), ongoing litigation risk, and trademark infringement risk (Hussein, Zhou, & Deng, 2019).

2.2.2 Innovation

Hong Kong's GII 2019 was ranked third in South East Asia, East Asia, and Oceania and thirteenth in the world (WIPO, 2019). Its Shenzhen innovation park is also the world's second-largest science and technology cluster after the Tokyo-Yokohama innovation district in Japan (WIPO, 2019). Shenzhen Innovation Park is renowned for its space to grow, accessibility to supply chains, production capabilities, and its pool of R&D experts from around the world.

With enormous potentials brought by the Guangdong-Hong Kong-Macao Bay Area, the governments of China and Hong Kong have together committed a significant US$13.5 billion since 2017 to further capitalise its innovation capabilities and technological infrastructure. This strategic commitment aims to provide an effective platform for international R&D companies to access the mainland market or for mainland R&D companies to go international. Accordingly, two innovation hubs will be established focusing on healthcare technologies and artificial intelligence and robotics. A funding scheme for reindustrialisation will also be set up to promote high-end manufacturing development (WIPO, 2019).

In general, the strategic development of innovation and technology in Hong Kong is grounded in the following schemes: (i) growing the resources and funding for R&D; (ii) pooling technology expertise; (iii) building infrastructure for innovation research; (iv) scrutinising legislative frameworks; (v) sharing government data; (vi) improving government procurement procedures; and (vii) fostering science education. Hong Kong's innovation research largely

[10] H shares refer to the shares of firms that are incorporated in Mainland China and traded on the HKEX while A shares refer to the shares of Chinese Mainland firms that are listed on the Shanghai Stock Exchange and the Shenzhen Stock Exchange.

focuses on information and communication technologies (ICT), data analytics, artificial intelligence (AI), robotics, virtual reality (VR), augmented reality (AR), biotechnology, financial technology, smart city, and new materials (WIPO, 2019).

In 2017, there were more than 2,800 innovative start-ups in Hong Kong, offering significant 6,500 jobs to the local workforce (WHup, 2018). During 2000-2016, while the number of patent applications and trademarks applications in Hong Kong was steadily increasing, the city's high-technology export exhibited a downtrend (see Figure 2.3). This is probably due to the effects of prolonged economic slowdown and the rising number of labour strikes and protests in Mainland China, which is the largest trading partner of Hong Kong.

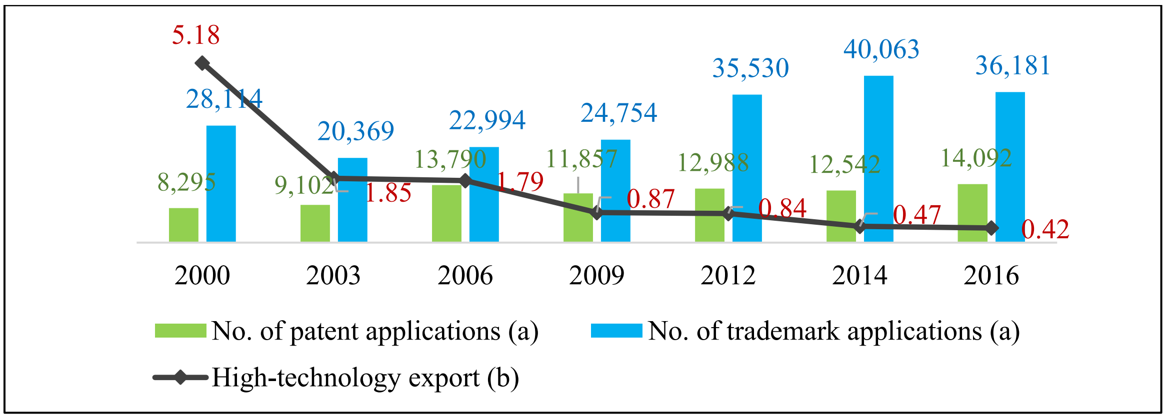


Figure 2.3: Hong Kong Innovation Indicators
Sources: Various issues of Hong Kong Census and Statistics Department
Notes: (a) Data include both residents and non-residents; (b) in US$ billion

2.3 Singapore

Located at the crossways of China, India and Southeast Asia, the world's three economic dynamos, Singapore is a highly developed free-market economy. According to the 2019 Index of Economic Freedom, Singapore is the second freest economy in Asia Pacific and across the globe after Hong Kong (The Heritage Foundation, 2019). This success is largely attributed to its extraordinarily liberated and corruption-free business environment, farsighted monetary and fiscal policies, and a transparent regulatory framework. Singapore has maintained its economic growth via a sagacious policy that effectively upholds incentives, public investment, highly skilled workforce, and economic diversification. Moreover, strong protection of tangible and intangible property rights supports entrepreneurship, innovation and productivity growth. The rule of law is also reinforced by a corruption-intolerant society.

Singapore is not only a service-dominated economy but also an industry-driven economy. This Lion City is a major exporter of electronic and chemical products and operator of one of the world's largest ports. With widespread transport connections within Asia Pacific, it acts as a canal for large flows of merchandise, services, investments, people and innovative ideas into the region. These advantages have encouraged an increasing number of multinational firms to place head offices in Singapore managing their Southeast Asia and Asia Pacific operations. This results in growing foreign direct investment, intellectual property, and robust human resources in the country. Additionally, the unemployment rate of this city-state is remarkably among the lowest in developed nations (on average 2.1% in 2018).

Being a regional commercial and trading hub, Singapore has sophisticated and well-regulated financial markets. Singapore stock exchange is considered the most internationalised exchange in Asia since more than 40% of its listed firms are from overseas, whereas for the Hong Kong stock exchanges, this portion is just 10%, excluding mainland firms. Singapore is also the world's greatest offshore market for Asian equity futures market wherein China, India, and Japan are the key players (UNCTAD, 2018). Moreover, Singapore maintains the top position in the foreign exchange market in Asia Pacific and third position globally, after London and New York (BIS, 2018).

2.3.1 CATALIST market

The CATALIST market was introduced in late 2007 as a substitute for SESDAQ to enhance investor confidence and quality of listing SMEs. The name "CATALIST" is derived from two words "catalyst" and "listing" to manifest the idea that the second-tier market is a catalyst to drive the growth of small firms upon listing.

Following the model of the Alternative Investment Market (AIM) in the United Kingdom, which has proved successful, CATALIST transformed the SESDAQ into a sponsor-supervised listing platform. In this model, listing candidates must appoint a sponsor who is approved by the SGX to facilitate the IPO process. Specifically, CATALIST sponsors act as corporate advisors to conduct due diligence on listing candidates, to support the production of a prospectus[11], provide underwriting services[12], and advise whether the candidate is qualified to be listed on CATALIST. After the listing, the sponsors remain involved in advising on posting-listing compliance and corporate governance as well as reviewing public disclosures. To ensure market quality, the sponsors are also obliged to report to the SGX any suspected or actual breaches of listing rules and regulations.

While the GEM in Hong Kong only requires listing applicants to appoint a qualified sponsor until listing admission, CATALIST requires companies to have a sponsor at all times; those without a sponsor for three months will be delisted. Operating in accordance with the rule of buyer beware, CATALIST successfully raised nearly US$1 billion during 2009-2016, equivalent to more than 14% of the credit gap of SMEs in Singapore. Unlike the main board, CATALIST requires no track record, profit or market capitalisation for a firm to be listed on the market (see Table 2.3). Nonetheless, the sufficiency of working capital needed for at least one year post listing must be confirmed.

Table 2.3: Listing Requirement – Singapore Main Market versus CATALIST Market

Main Market	CATALIST Market
▪ Consolidated pre-tax profits of S$30 million (US$21.6 million) for the most recent year and operating track record of at least 3 years; or ▪ Market capitalisation of S$150 million (US$108 million) if profitable in the most recent year and operating track record of at least 3 years; or ▪ Market capitalisation of S$300 million (US$216 million) if only have operating revenue in the most recent year	▪ No track record, profit or market capitalisation required ▪ The firm and the sponsor must confirm the adequacy of working capital for its present purposes for at least 12 months after listing

Source: Singapore Exchange's public domain

CATALIST has been tracked by the FTSE Strait Times CATALIST Index since 2009. Up to 2016, the number of listed firms had steadily increased to 185 and 21 firms switched their listings to the main board. The surge and plunge in the market's traded value in 2013 and 2014 (as depicted in Figure 2.4) were likely due to the contagion effect of the 2013 penny stock manipulation in the main board. Later, a growing number of Chinese firms listed on the SGX, also

[11] Prospectus is a legal document issued by firms that are offering securities for sale to the public. It is required by and filed with the Securities and Exchange Commission (SEC).
[12] Underwriting services are delivered by large financial institutions such as banks or investment banks whereby they evaluate and assume the other party's risk for a fee.

known as S-chips, had left the market either voluntarily or after failing to meet the listing requirements. This probably induced a decline in market capitalisation and traded value of the CATALIST board in 2015 and 2016.

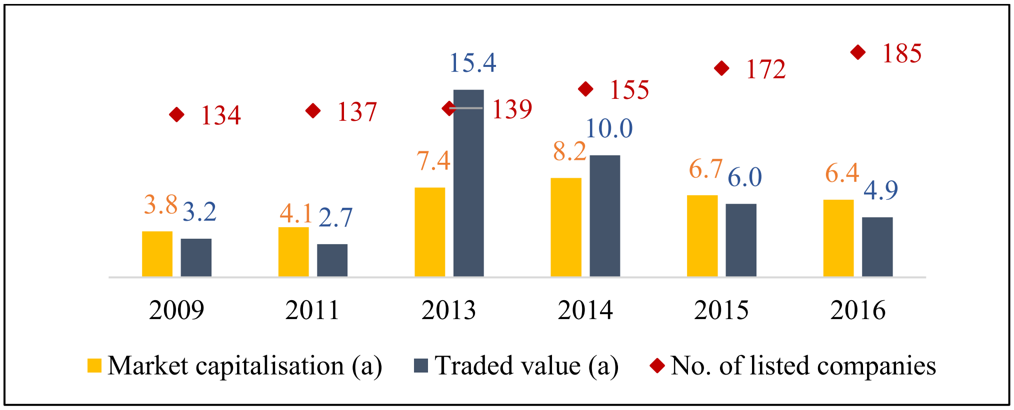


Figure 2.4: CATALIST Market in Singapore Since Opened
Sources: Singapore Exchange factbooks and Bloomberg database
Notes: (a) in US$ billion

2.3.2 Innovation

Singapore ranked eighth worldwide for the GII 2019 and topped this ranking in South East Asia, East Asia, and Oceania (WIPO, 2019). It also held the top position in Asia for best protection of intellectual property according to the Global Competitiveness Report 2015-2016 by the World Economic Forum (2016). This Asian Tiger aims to become a critical junction in the global innovation supply chain where companies prosper on the grounds of intellectual property and intangible assets (World Economic Forum, 2016). To achieve this strategic goal, its action plan is to enhance the innovation ecosystem and to advance international connections, intellectual property commercialisation, and a skilled workforce.

In 2016, a funding scheme of US$14 billion was introduced by the Singapore government to facilitate research, innovation, and entrepreneurship development. The scheme recognises four strategic fields for research funding till 2020: (i) advanced manufacturing and engineering; (ii) health and biomedical sciences; (iii) services and digital economy; and (iv) urban solutions and sustainability. Newer fields such as financial technology are also supported by a lightly regulated environment called a “regulatory sandbox”. This is to encourage enterprises in the field to take risks without being impeded by too many rules. Moreover, thanks to the strategic location and small land area, Singapore is an ideal centre for products to be tested before launching them into other Asian markets and beyond (World Economic Forum, 2016).

Being among the global leaders for innovation, Singapore possesses one of the fastest-growing start-up communities in the world. Technology start-ups have flourished in recent years, rising by more than a quarter from 3,400 in 2012 to 4,300 in 2016 (ForbesCustom, 2018). Interestingly, the size of this community approximately doubles that of Hong Kong. Singaporean entrepreneurs are the youngest in the world, with an average age of 28 years, while the world average is 40 years (Yahoo News, 2018). High-technology exports of Singapore showed insignificant fluctuations and recorded US$126.3 billion in 2016 (see Figure 2.5), which effectively left Hong Kong (US$0.42 billion), Thailand (US$34.2 billion), and Malaysia (US$52.1 billion) far behind (see Table 2.1).

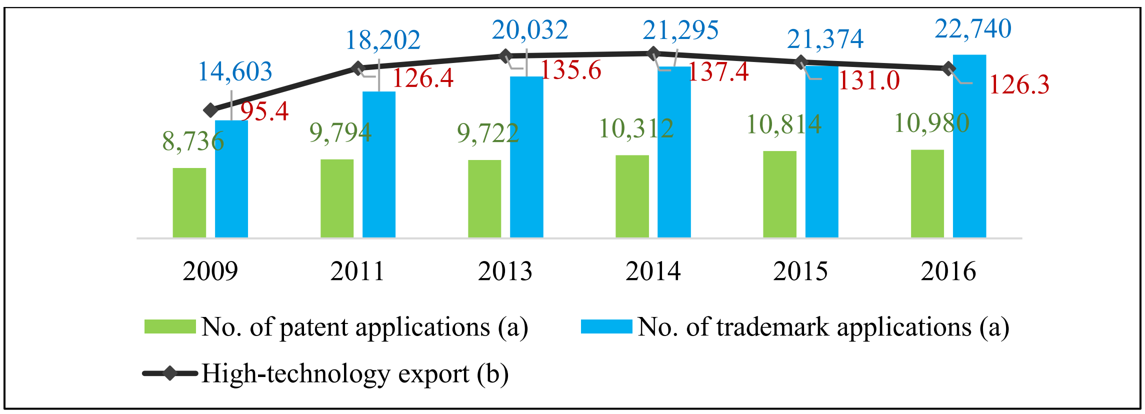


Figure 2.5: Singapore Innovation Indicators
Sources: Various issues of Singapore Department of Statistics (DOS)
Notes: (a) Data include both residents and non-residents; (b) in US$ billion

2.4 Thailand

Thailand is an extraordinary economic success story. Within only four decades, it has greatly improved its socio-economic development, evolving from a low-income nation to an upper-middle-income nation. The Thai economy posted a significant growth of 7.5% on average during the boom period of 1960-1996 and 5% after the 1997 Asian Financial Crisis during 1999-2005 (World Bank, 2019c). After a lower growth of 3.5% over 2006-2016, the country is now on track to a revival with 4.1% growth in 2018, the highest pace since 2012. Sustained growth rates have enabled the country's poverty rate to reduce from 67% in 1986 to 7.8% in 2017 (World Bank, 2019c).

The level of economic freedom of Thailand is graded tenth in the Asia-Pacific region and forty-third in the world, according to The Heritage Foundation (2019). The military-controlled government has implemented several reforms to sustain growth and integrate the local economy into the global economy. The reforms mainly focus on economic stability, human resources, sustainable development, international competitiveness, and legal frameworks. In particular, the government has recently increased investments in public infrastructure, streamlined business formation procedures, improved state-owned enterprise governance and enforced property rights, and opened the financial sector to competition.

Thailand is an export-driven economy since over three-quarters of its GDP is derived from exports. It is the second-largest exporter of foodstuffs in Asia, after China. The Thai stock market has been the most liquid market in Southeast Asia since 2012, making it one of the Asian stock markets that have been attracting a growing number of international investors in recent years (World Bank, 2019c).

2.4.1 Market for Alternative Investments (MAI)

Established in 2001, MAI has a mission to provide a channel for innovative entrepreneurs and SMEs to access long-term capital and enhance competitiveness through transparency and corporate governance. Similar to Hong Kong's GEM, the MAI operates under a sponsor-driven model in which the applicant is required to have an approved sponsor until listing admission only. It also advises investors that they buy shares in the listed companies at their own risk. To list on the MAI, applicants must have a minimum paid-in capital and satisfy either the net profit test or market capitalisation test. These tests are less rigorous than those of the main market (see Table 2.4).

The MAI market has been growing rapidly since the MAI index started tracking it in 2002. The significant growth in the number of listed companies in 2004 and 2005 is mainly due to the corporate income tax reduction from 30% to 20% for five financial years for newly listed companies in the market. As of December 2016, 134 enterprises were listed on the MAI, with total market capitalisation of US$11.9 billion and total traded value of US$15.5 billion (see Figure 2.6). Notably, since 2011, the traded value of the MAI has surpassed the CATALIST due to high transaction costs and the speculating mindset of traders in the SGX. During 2002-2016, total funds raised on the MAI market were around US$3.1 billion, which substantially filled 26.2% of the credit gap of the Thai SMEs. Over the same period, 19 listed firms were successfully transferred from the MAI to the main board.

Table 2.4: Listing Requirements – Thailand Main Market versus MAI Market

Main Market	MAI Market
▪ Paid-in capital of at least THB300 million (US$9.9 million); and ▪ Market capitalisation of at least THB7.5 billion (US$247.2 million); earnings before interest and tax (EBIT) in the most recent year; and an accumulated EBIT prior to the filing of the application; or ▪ Total net profit in the latest 2 or 3 years of at least THB50 million (US$1.65 million); net profit in the most recent year of at least THB30 million (US$1 million); and an accumulated net profit prior to filling the application	▪ Paid-in capital of at least THB50 million (US$1.65 million); and ▪ Market capitalisation of at least THB1 billion (US$32.9 million); EBIT in the most recent year; and an accumulated EBIT prior to filing the application; or ▪ Total net profit in the last 2 years of at least THB10 million (US$0.33 million); and an accumulated net profit prior to filing the application

Source: Stock Exchange of Thailand's public domain

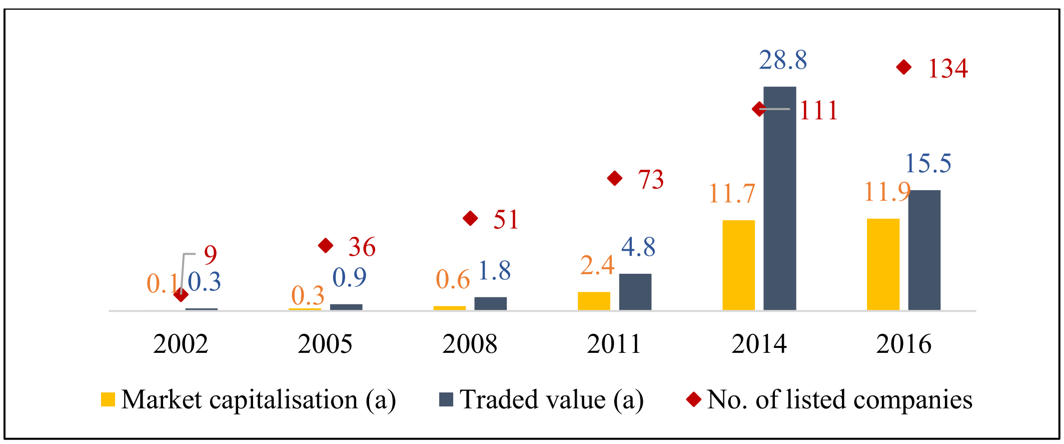


Figure 2.6: MAI Market in Thailand Since Opened
Sources: Stock Exchange of Thailand's factbooks and Bloomberg database
Note: (a) in US$ billion

Intriguingly, in April 2019, a memorandum of understanding (MoU) was signed between the Stock Exchange of Thailand and the Shenzhen Stock Exchange to promote collaboration between China and Thailand SME capital markets. Under this MoU, a network called "ChiNext-MAI Alliance" will be established to facilitate the corporation between enterprises listed on the MAI and the ChiNext and to cultivate cross-border innovation capital formation. The network also aims to nurture technology start-ups and explore new mechanisms for mutual funding and investment between China and Thailand.

2.4.2 Innovation

The World Intellectual Property Organization ranked Thailand fourth among 34 upper-middle-income economies and forty-third in the world in its report of GII 2019. Thailand has been steadily escalating in the rankings during the past five years. This Tiger Cub has consistently improved its performance in four out of seven pillars that capture the factors empowering innovative activities: (i) institutions; (ii) human capital and research; (iii) business sophistication; and (iv) knowledge and technology outputs.

Thailand is considered an innovation achiever since it has outstanding achievements in innovation in relation to its stage of development. Its trademark and patent applications have been rapidly increasing since the 2000s (see Figure 2.7). In 2016, this total (59,433) was nearly double those in Singapore (33,720) and almost 20% higher than those in Hong Kong (50,273) (see Table 2.1). Thailand is remarkably robust in creative goods exports and high-technology exports, where it ranked first and fourth, respectively, relative to other ASEAN economies (WIPO, 2019).

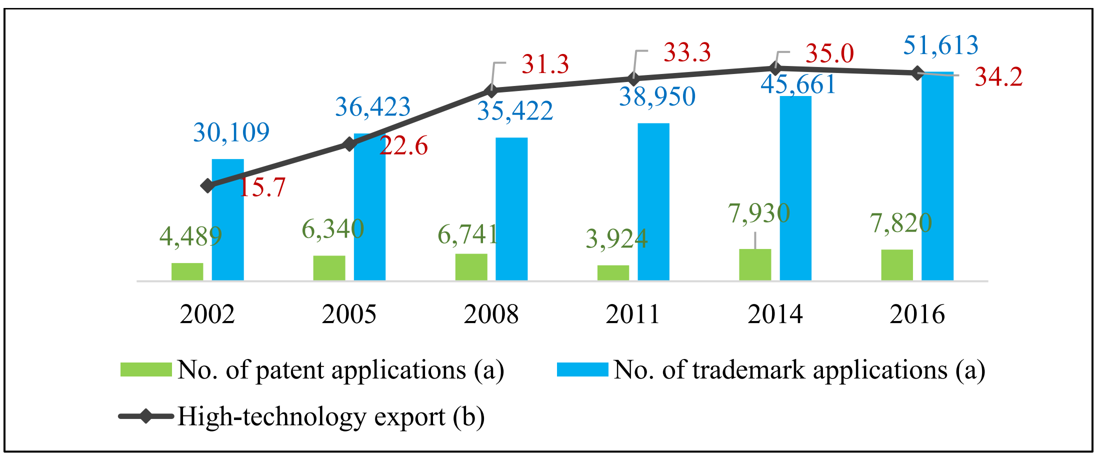


Figure 2.7: Thailand Innovation Indicators
Sources: Various issues of the National Statistical Office of Thailand
Notes: (a) Data include both residents and non-residents; (b) in US$ billion

The Thai government has placed emphasis on innovation as a critical component of its 20-year National Strategy with the goal of transforming Thailand into a developed economy by 2037.

Under a new scheme called Thailand 4.0, introduced in 2016, this Land of Smiles aims to become an innovation-driven nation where life sciences and industrial biotechnology take the lead. The government has assigned US$45 billion to establish the Eastern Economic Corridor (EEC), a strategic hub of smart cities with extensive infrastructure, to boost innovation and advanced technology. The two smart cities in this hub have already contributed more than 10% to the country's GDP.

2.5 Malaysia

Malaysia is one of the world's most open economies, with trade value accounting for more than 135% of its GDP since 2010. The 2019 Index of Economic Freedom of Malaysia is well above Thailand and the world averages, making its economy the sixth and the twenty-second freest in Asia Pacific and in the world, respectively (The Heritage Foundation, 2019). The country has successfully diversified its economy from an agriculture and commodity economy to an industrial and service economy. It has become the global leading exporter of palm oil, electronics, petroleum, and chemicals. Export activities account for a significant 40% of total employment in Malaysia thanks to its openness to trade and investment.

Malaysia is also among the countries that quickly recovered from the 2008 Global Financial Crisis, with 5.4% average growth rate since 2010. The government aims to further enhance competitiveness in 2019 by consolidating high public debts, increasing investments in high-technology sectors, implementing tax reform, and narrowing income disparity (World Bank, 2019a). This market-oriented and diversified nation is expected to have a transformation from an upper-middle-income nation into a high-income nation by 2024 (World Bank, 2019a).

The Malaysian financial sector has been further liberalised by easing restrictions on foreign ownership to attract international investors. Bursa Malaysia was awarded the "Best Islamic Exchange Asia 2016" and the "Best Islamic Finance Facilitation Platform Asia 2016" for the second year in a row by the Global Banking and Finance Review. It is also one of the few international exchanges that offer investment opportunities in the listed subsidiaries of several large multinational corporations such as Carlsberg, Heineken, and British American Tobacco.

2.5.1 Access, Certainty, and Efficiency (ACE)

In 2009, ACE was launched to replace the former MESDAQ for better quality and liquidity of the listed companies. The name "Access, Certainty, and Efficiency" implies that the market is designed to offer SMEs more efficient and certain access to long-term capital. The ACE market also follows a sponsorship model like CATALIST in Singapore with less rigid requirements. While CATALIST listed firms must have a qualified sponsor at all times, ACE listed firms must retain the same sponsor at the time of listing approval for at least three years following listing approval.

Similar to the GEM in Hong Kong, CATALIST in Singapore, and MAI in Thailand, ACE in Malaysia also operates on the principle of buyer beware. Unlike the other three markets, ACE has no listing requirements of operating track record, net profit or market capitalisation. Instead, it provides listing admission based on the recommendation of authorised sponsors regarding the appropriateness and prospects of the applicant.

Table 2.5: Listing Requirements – Malaysia Main Market versus ACE Market

Main Market	ACE Market
▪ Market capitalisation of at least RM500 million (US$119.6 million); and operating revenue for at least one year prior to application; or ▪ Uninterrupted net profit of 3 to 5 years of at least RM20 million (US$4.8 million); net profit in the most recent year of at least RM6 million (US$1.4 million); or ▪ Right to build and operate an infrastructure project in or outside Malaysia, with minimum project costs of RM500 million (US$119.6 million); and the project licence period of at least 15 years	▪ No minimum operating track record, profit, or market capitalisation requirement

Source: Bursa Malaysia's public domain

The ACE market, which has been traced by FTSE Bursa Malaysia ACE Index, held 113 listed companies at the end of 2016. Total market capitalisation and total traded value were US$2.3 billion and US$3.2 billion, respectively (see Figure 2.8), making it the smallest and least liquid market compared to GEM, CATALIST, and MAI. Over eight years to 2016, approximately US$1.3 billion was successfully raised through the ACE market, equating to 16.3% of the SME credit gap in Malaysia. Over the same period, 11 listings of the ACE market passed on to the main market.

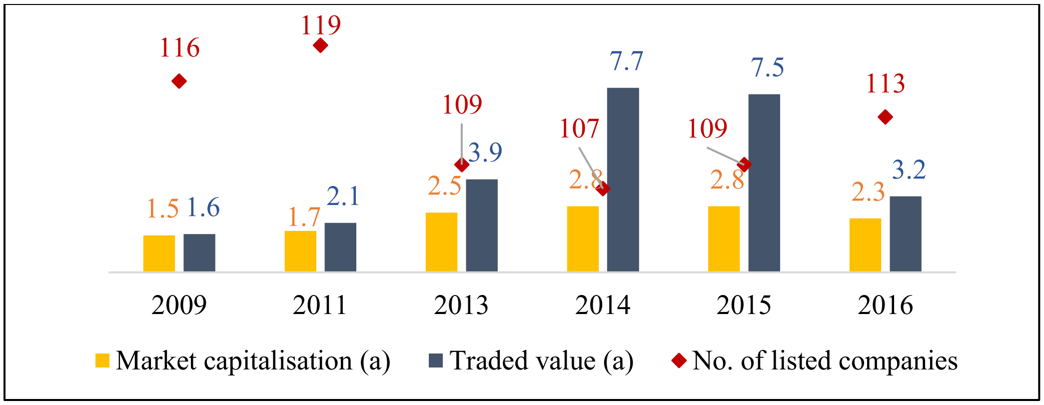


Figure 2.8: ACE Market in Malaysia Since Opened
Sources: Bursa Malaysia's factbooks and Bloomberg database
Notes: (a) in US$ billion

2.5.2 Innovation

The 2019 GII of Malaysia was second among 34 upper-middle-income nations and the thirty-fifth in the world, considerably outperforming Thailand (WIPO, 2019). The most substantial improvements in its ranking were due to the following four pillars: (i) institutions; (ii) infrastructure; (iii) business sophistication; and (iv) creative outputs. Malaysia's high-technology exports, despite a mild decrease since 2014, were still 52% greater than those of Thailand and accounted for almost one-fifth of the country's GDP in 2016 (see Table 2.1). Its total applications for patents and trademarks also experienced a steady rise during 2009-2016 (see Figure 2.9) and were nearly 40% higher than those in Singapore.

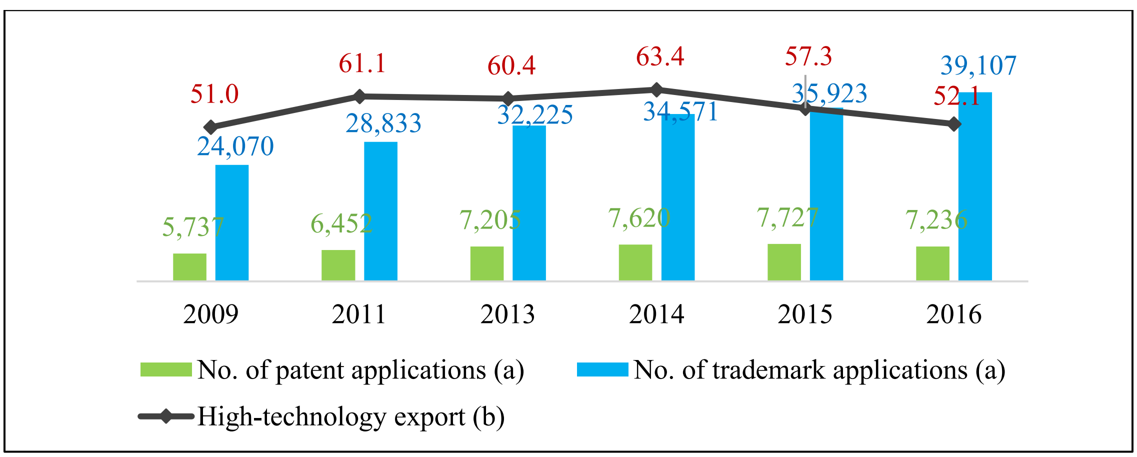


Figure 2.9: Malaysia Innovation Indicators
Sources: Various issues of the Department of Statistics Malaysia
Notes: (a) Data include both residents and non-residents; (b) in US$ billion

The Malaysian government has promoted the digital economy as a new driver of economic development and a source of expansion for Malaysia. The Malaysian digital economy notably grew 9% in value-added terms during 2010-2016, almost doubling the overall GDP growth of 5.4% on average. As of December 2018, the internet penetration rate of Malaysia was 85.7%, nearly twice as great as the rate of the Asia-Pacific region of 45.8%. By 2022, more than 21% of Malaysia's GDP is expected to be digitalised relative to the 2016 level of 18% and Malaysia will become one of the leading ASEAN techno and digital hubs (World Bank, 2019a).

2.6 Conclusion

This chapter described the characteristics and development of SME stock markets and innovation in Hong Kong, Singapore, Thailand, and Malaysia, as well as the institutional features of the economies. The information provided in this chapter points out the fact that Hong Kong and Singapore are highly developed and the most unfettered economies in the world. Thailand and Malaysia are classified as upper-middle-income economies with rapid growth and high economic freedom. On the specific aspect of stock market development, Hong Kong and Singapore possess sophisticated and well-regulated markets and have long been the world's leading global capital markets. Meanwhile, a growing number of international investors have been attracted to the stock markets in Thailand and Malaysia in recent years because of their market liquidity and the room for foreign ownership.

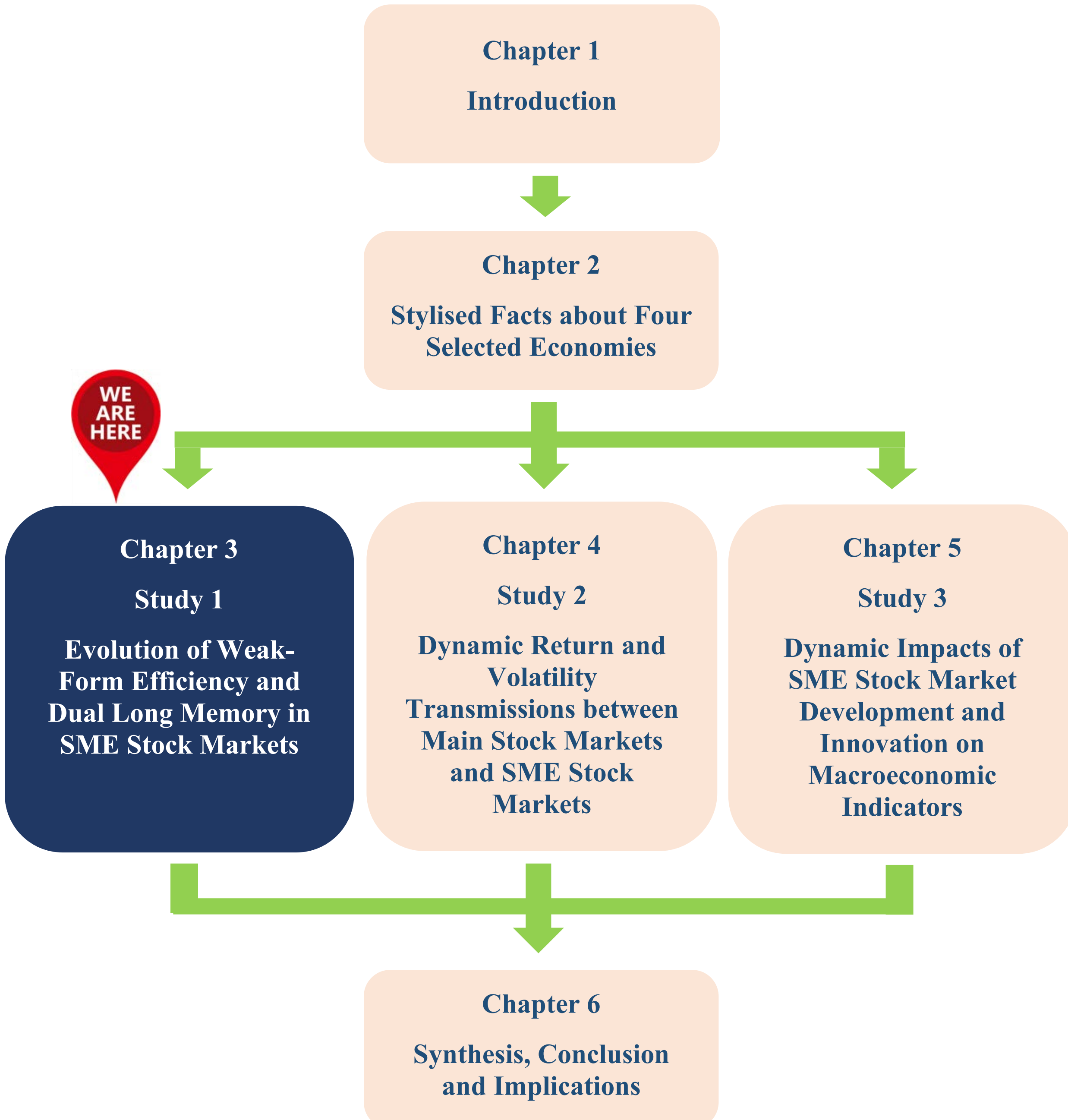
Second-tier stock markets in Hong Kong, Singapore, Thailand, and Malaysia, i.e. the GEM, CATALIST, MAI, and ACE, respectively, have an important role to play in SME financing in the Tropics. All four markets operate on the principle of caveat emptor (buyer beware) and pursue a sponsor-driven model. In this model, a sponsor that is approved by the exchange authority acts as a corporate finance advisor to ensure the quality of listing applicant by conducting a due diligence process. While GEM and MAI require applicants to have a sponsor until listing admission only, CATALIST and ACE require applicants to have one at all times or for three years following listing admission, respectively. In this case, the sponsor continues its advisory role on posting-listing compliance, corporate governance, and public disclosures of the listed firm.

While GEM and MAI have retained their brands since establishment, CATALIST and ACE are replacements for the former SESDAQ and MESDAQ markets, and were established to improve the quality and liquidity of the listed companies. Being at an early stage of development, the four markets are characterised by small capitalisation and thin trading with a narrow investor base and high investment risk. They comply with requirements for listing and information disclosure that are less rigorous than the main boards. Remarkably, GEM has been acknowledged as one of the most successful SME stock markets in the world and can be seen as the largest and the most liquid market in the Tropics.

The SME stock markets in Hong Kong, Singapore, Thailand, and Malaysia also foster innovation in the countries by providing a long term fundraising channel for listed SMEs whose businesses mostly engage with innovative sectors. Singapore and Hong Kong are among the world's most innovative economies and were ranked high on the Global Innovation Index, eighth and thirteenth, respectively, in 2019. Hong Kong is famous for its Shenzhen innovation park, the world's second-largest science and technology cluster, whereas Singapore holds the top position in Asia for best protection of intellectual property. Malaysia and Thailand have been steadily improving their GII rankings over the past five years to be thirty-fifth and forty-third, respectively, in 2019. The two countries are now in transition to become innovation-driven economies while maintaining their current export-driven model of economic development.

Understanding the key features and stage of development of second-tier stock markets and innovation in the four selected economies greatly benefits subsequent empirical studies on the market efficiency and dynamic impacts on macroeconomic development. The outcomes of the empirical chapters 3 to 5 were rationalised based on the facts and figures provided in this chapter.

Thesis Structure



Chapter Three: Evolution of Weak-Form Efficiency and Dual Long Memory in SME Stock Markets

Abstract

The previous chapter provided an overview of the characteristics and development of SME stock markets in Hong Kong, Singapore, Thailand and Malaysia. This chapter reports on the findings from Study 1 of this thesis that examined the evolving efficiency and joint effects of thin trading, structural breaks, and inflation on dual long memory in the four SME stock markets. The state-space GARCH-M model with Kalman Filter estimation, factor adjustment techniques and fractionally integrated models (including ARFIMA-FIGARCH, ARFIMA-FIAPARCH, and ARFIMA-HYGARCH) were adopted. The results determine that all four markets are weak-form inefficient yet those in Hong Kong and Singapore exhibit tendencies towards efficiency, implying the efficacy of several institutional reforms. SME stock markets in Hong Kong and Thailand show a stationary long memory in return and volatility while those in Singapore and Malaysia exhibit this property in volatility only. The three aforementioned factors jointly have reducing effects on the magnitude and/or statistical significance of long memory estimates. SME stock markets in Thailand and Malaysia show a smaller degree of volatility persistence, indicating a good hedge for portfolio risk management.

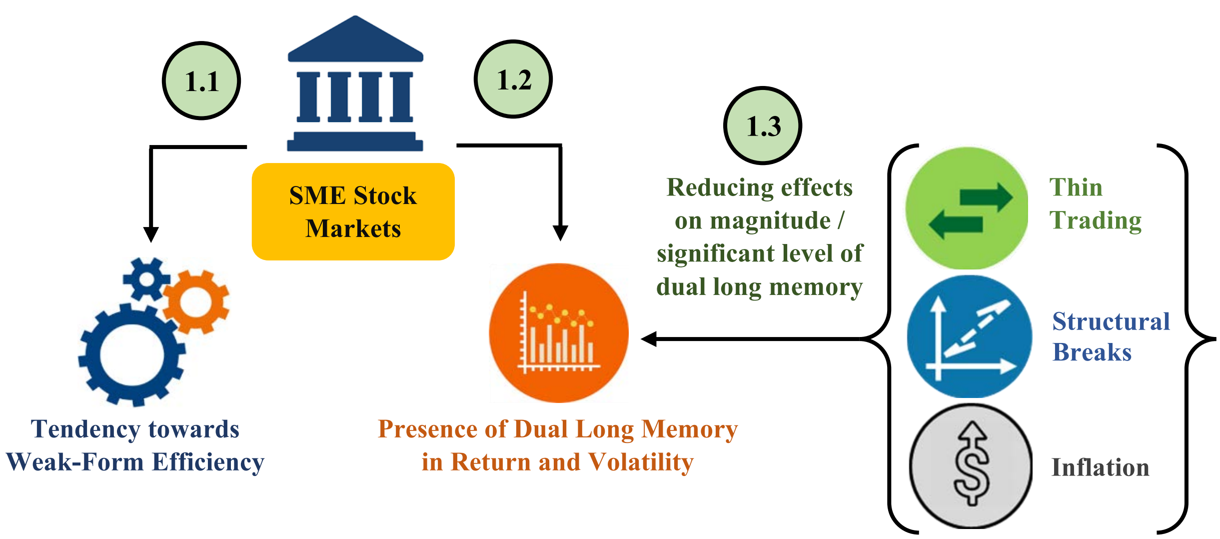


Figure 3.1: Summary of Findings from Study 1

Chapter Outline

This chapter was adapted for publication in the following refereed journal articles:

Nguyen, T., Chaiechi, T., Eagle, L., and Low, D. (2019). SME stock markets in tropical economies: evolving efficiency and dual long memory. *Economic Papers*, 39(1), 28-47.

Nguyen, T., Chaiechi, T., Eagle, L., and Low, D. (2019). Growth Enterprise Market in Hong Kong: Efficiency Evolution and Long Memory in Return and Volatility. *Journal of Asian Business and Economic Studies*, 27(1), 19-34.

3.1 Introduction

SME stock markets, while being important to SME financing and growing in population, have been overlooked when academics began to investigate the efficiency and properties of stock markets four decades ago. Existing body of literature on stock market efficiency mainly focuses on the main stock markets and tests for whether the markets are efficient in the weak form[13], which is the lowest level of market efficiency (for example, see Li and Liu (2012), Dragotă and Ţilică (2014), and Singh et al. (2016)). Testing the static state of market efficiency over a sample period may conceal potential inclination towards efficiency in the market or the sub-periods in which the market is actually efficient. On the other hand, long memory[14], which is a common property of stock markets that gives rise to market inefficiency, has largely been studied for main stock markets in the literature (for examples, see DiSario, Saraoglu, McCarthy, and Li (2008), Kumar and Maheswaran (2013), and Duppati, Kumar, Scrimgeour, and Li (2017)). Nonetheless, these studies fail to examine long memory property under the joint impacts of factors such as thin trading, structural breaks, and inflation. Neglecting these factors may falsify the estimation of dual long memory in stock market returns and volatility.

Therefore, this study investigates the evolution of weak-form market efficiency and the presence of dual long memory components in return and volatility in SME stock markets. When examining the dual long memory, the joint effects of thin trading, structural breaks, and inflation were also taken into account. An investigation into the evolving efficiency of SME stock markets can assist policymakers in making institutional reforms to improve investor confidence in small-capitalisation stocks investment, thereby optimising capital allocation to productive investments of SMEs and stimulating economic growth. This investigation is also relevant to investors or portfolio managers in choosing an appropriate trading approach of either passively holding the market or actively beating the markets. The examination of dual long memory in SME stock

[13] Weak Form market efficiency posits that current stock prices, at any moment, incorporate all historical market data, i.e., sequences of price changes and returns. If the weak form holds, it is impossible for investors to gain a superior return based on the historical market data. Thus, technical analysis yields no extra profit.

[14] The presence of long memory in stock market indicates that the market does not absorb new information arriving in the market immediately but rather captures the information and adjusts the price slowly over a period of time. Thus, historical price changes can be used to predict future price changes, which implying the market inefficiency.

markets also gives assistance to investors and portfolio managers in determining an optimal hedge ratio for these markets.

Following are the three research questions that Study 1 aimed to address.

Q1.1: Do SME stock markets evolve towards weak-form market efficiency?
Q1.2: Is long memory property present in SME stock markets' return and volatility?
Q1.3: What are the joint impacts of thin trading, structural breaks, and inflation on long memory property in SME stock markets' return and volatility?

Hong Kong, Singapore, Thailand, and Malaysia are selected for empirical analysis since they are among the key growth drivers of the Tropics. Known as Asian Tigers, Hong Kong and Singapore are highly developed economies with global competitiveness in international finance, trade and transportation. Thailand and Malaysia, also identified as Asian Tiger Cubs, are among the world's most open and fast-growing economies. In regard to stock market development, Hong Kong and Singapore have been leading the global stock markets while the stock markets in Thailand and Malaysia are attractive because of their liquidity and openness to foreign investors. More importantly, SME stock markets in the four countries have prominent roles to play in SME finance and growth stimulation in the tropical economies, as discussed in Chapter One, Section 1.5.

3.2 Literature Review

A large number of conventional efficiency studies have concentrated on testing whether a stock market is efficient in the weak form, assuming that market efficiency remains static over the sample period. Nonetheless, the state of market efficiency may be different in each sub-period such that it can be efficient in some sub-periods then depart from efficiency in some other sub-periods and vice versa. Moreover, understanding the factors leading to market efficiency is also important. Therefore, Antoniou, Ergul, and Holmes (1997), Hassan, Al-Sultan, and Al-Saleem (2003), and Lim and Brooks (2009) employed the non-overlapping sub-samples approach to split the study period into sub-periods based on the postulated factors or predetermined events such as trading system improvements, regulation changes, and financial chaos. Nevertheless, this approach was criticised for its assumption of a discrete change in market efficiency at the predetermined breakpoint. It is rational to expect market efficiency to evolve over time, yet this dynamic feature should not be captured in irrationally selected sub-samples.

Prompted by this concern, Emerson, Hall, and Zalewska-Mitura (1997) introduced the State-Space Generalised Autoregressive Conditional Heteroskedastic in the Mean (GARCH-M) model with a Kalman filter estimation to track evolving efficiency over time. In this model, a time-varying autocorrelation coefficient is used to capture a continuous and smooth change in the state of market efficiency without splitting the sample based on predetermined events. While the non-overlapping sub-samples approach selects specific events as a basis to divide the sample, the time-varying parameter model initially detects the periods of efficiency, and researchers can then seek associated events to justify the findings in these periods. Consequently, several researchers revisited the weak-form efficiency in many main stock markets of emerging economies and analysed the evolving efficiency using the proposed model. For examples, Pošta (2008) concluded that stock markets of Bulgaria, Hungary, Czech, Poland, Russia, and Romania were still inefficient but showed a steady convergence towards efficiency. Abdmoulah (2010) documented that the efficiency paths for 11 Arab stock markets did not clearly improve over time except for the Saudi Arabian market. Later, according to Charfeddine and Khediri (2016), these Arab stock markets exhibited different levels of time-varying efficiency and experienced periods of efficiency improvement.

A large body of literature on long memory in stock market returns have evolved since the 1990s but these studies appeared to reach diverging conclusions. Ambrose, Ancel, and Griffiths (1993) found no evidence of long memory in the US stock market, whereas DiSario et al. (2008) provided supporting evidence for this market using the wavelets and aggregate series methods. Kang and Yoon (2006) revealed the presence of volatility persistence and asymmetry in stock markets of Japan, South Korea, Hong Kong, and Singapore using the Fractionally Integrated Exponential GARCH (FIEGARCH) model. Cheah and Lee (2008) failed to report any evidence of long memory in the UK stock market using spectral regression methods. Kumar and Maheswaran (2013) documented long memory in return volatility process in stock markets of Portugal, Ireland, Italy, Greece, and Spain employing the GARCH family of models. Recently, Duppati et al. (2017) found volatility persistence in stock markets of China, Japan, Korea, Singapore, and India using the FIGARCH and FIAPARCH models.

Moreover, while the individual impacts of thin trading, structural breaks, and inflation on the long memory have been examined in a number of studies, the joint effect of these factors has yet been dealt with. Dimson (1979) and Lo and MacKinlay (1990) asserted that thin trading can induce spurious autocorrelations in returns and may falsify long memory pattern in the return series. Miller, Muthuswamy, and Whaley (1994) thus proposed fitting an AR(1) model to obtain a thin-trading adjustment. However, their assumption of a fixed AR coefficient is unlikely to hold in emerging markets or newly established markets. Later, Harrison and Moore (2012) suggested a better model to adjust for thin trading, i.e. a State-Space AR(1) model because it captures the evolution of the AR parameter and reflects the evolving nature of these markets.

Financial time series often encounter sporadic structural breaks triggered by various events such as macroeconomic and political events, major changes in market sentiments, and financial crisis. Diebold and Inoue (2001) postulated that infrequent stochastic breaks may cause the autocorrelation function to decay hyperbolically, leading to an erroneous estimate of long memory. Researchers suggest that a failure to incorporate structural breaks in long memory modelling probably results in an overestimated volatility persistence (Lamoureux & Lastrapes, 1990b; Cheung, 1993). Moreover, long memory pattern may be fabricated partially by the existence of structural breaks (Granger & Hyung, 2004). A stationary short memory process that is subject to occasional structural breaks exhibits a slow rate of decline in autocorrelation structure and other properties of fractionally integrated processes (Cappelli & D'Elia, 2006).

Cecchetti and Debelle (2006) examined the inflation persistence in dominant industrial economies and concluded that conditional on a break in the mean, the degree of inflation persistence is much smaller than neglecting the break. Morana and Bagliano (2007) reported that the US inflation exhibits long memory component and regime switching persistence. Belkhouja and Boutahar (2009) reported a lower estimate of long memory in the US inflation when regime shifts are accounted for using the ARFIMA model. Since inflation is an important factor to consider when measuring the investment return in real terms, Ngene, Tah, and Darrat (2017) recently investigated the impact of inflation on long-range persistence in the returns of African stock markets. They contended that the long memory estimates for inflation-adjusted returns decrease in magnitude or in statistical significance using the semiparametric long memory tests.

Overall, the existing body of empirical literature exposes two knowledge gaps. First, while the studies of evolving market efficiency and long memory are rapidly growing in number, most of them centre around the main stock markets. The alternative markets which are critical for SME finance, have largely been neglected. Second, the joint effect of factors such as thin trading, structural breaks, and inflation on long memory property has yet to be examined in the literature.

3.3 Methodology

As mentioned earlier, for newly developed markets such as GEM (Hong Kong), CATALIST (Singapore), MAI (Thailand), and ACE (Malaysia), an examination of the evolving efficiency is more appropriate than just addressing the issue of whether the markets are efficient. To capture the evolving efficiency, a State-Space nonlinear GARCH-M model was adopted. Moreover, dual long memory components in return and volatility of these markets were investigated under the joint impacts of thin trading, structural breaks, and inflation (since ignoring these factors may distort the long memory results). To avoid the pitfall of long memory instigated by the above-mentioned factors, the return series were initially de-thinned and then adjusted for structural breaks and inflation using factor-adjustment techniques. The adjusted return series were sequentially fitted into a set of fractionally integrated models: ARFIMA-FIGARCH, ARFIMA-FIAPARCH, and ARFIMA-HYGARCH to estimate the long memory components in return and volatility. The econometric techniques and models employed are demonstrated in the following subsections.

3.3.1 Testing Multiple Breakpoints

Inclan and Tiao (1994) introduced an Iterated Cumulative Sum of Squares (ICSS) algorithm to detect multiple structural breaks in the unconditional variance of returns (volatility breaks). The ICSS algorithm offers the beginning and the end of return volatility regimes and is robust to heteroscedasticity. Suppose that r_t is a return series with zero mean and unconditional variance (σ_t^2). Within each interval between the breaks, the variance is given by σ_j, where $j =$

$1, 2, \dots, N_T$ and N_T is the total number of volatility breaks in the T observations. A set of breakpoints is given by $1 < K_1 < K_2 < \cdots < K_{N_T}$. The unconditional variance over the N_T intervals is written as

$$\sigma_t^2 = \begin{cases} \sigma_0^2 \; for \; 1 < t < K_1 \\ \sigma_1^2 \; for \; K_1 < t < K_2 \\ \vdots \\ \sigma_{N_T}^2 \; for \; K_{N_T} < t < T \end{cases} \tag{3.1}$$

To estimate the number of volatility breaks, the cumulative sum of squared observations from the start of the series to the kth point in time is determined as

$$C_k = \sum_{t=1}^{k} r_t^2 , \quad for \; k = 1, 2, \dots, T \tag{3.2}$$

where ε_t is the residuals series obtained from the AR(1) process of return series (R_t),

$$R_t = \beta_0 + \beta_1 R_{t-1} + \varepsilon_t \tag{3.3}$$

The D_k statistic is then defined as

$$D_k = \left(\frac{C_k}{C_T}\right) - \frac{k}{T}, \quad with \; D_0 = D_T = 0 \tag{3.4}$$

where C_T is the cumulative sum of squared observations for the entire sample.

The statistic D_k will oscillate around zero if there are no volatility breaks. When plotting the D_k against k, it is a horizontal line. In contrast, if there are volatility breaks, the D_k statistic departs from zero. Critical values achieved from the distribution of D_k are used to identify the significant breaks in the variance under the null hypothesis of constant variance. When the maximum absolute value of D_k exceeds the critical value, the null hypothesis is rejected. Thus, if $\{\max_k \sqrt{T/2}|D_k|\}$ is greater than the predetermined boundary, then $k*$, which is the value at which $max_k|D_k|$ is reached, is considered as an estimate of volatility breakpoint.

3.3.2 Modelling Evolving Efficiency

To capture the evolving weak-form efficiency, the State-Space GARCH-M(1,1) model with Kalman filter estimation was adopted (Emerson et al., 1997). This model not only allows for time-varying dependencies in the return and volatility processes, but also measures the degree of volatility persistence and risk premium. The model is expressed in a dynamic system of state and space equations as follows:

$$r_t = \beta_0 + \beta_{1t} r_{t-1} + \beta_2 h_t + e_t \tag{3.5}$$

$$h_t = \alpha_0 + \alpha_1 h_{t-1} + \alpha_2 e_{t-1}^2 \tag{3.6}$$

$$\beta_{1t} = \beta_{1t-1} + v_{it} \tag{3.7}$$

where $e_t \sim N(0, h_t)$ and $v_{it} \sim N(0, \sigma_i^2)$.

Equation (3.5) is the space equation, in which parameter β_{1t} represents the time-varying AR(1) coefficient, and parameter β_2 represents the risk premium.

Equation (3.6) is the state equation to estimate the conditional variance of return or return volatility (h_t). This is a function of the ARCH term (e_{t-1}^2) and GARCH term (h_{t-1}). The degree of volatility persistence is measured by the sum ($\alpha_1 + \alpha_2$).

Equation (3.7) is the state equation where the dynamics of AR(1) coefficient is estimated using a powerful recursive algorithm known as the Kalman filter (Kalman & Bucy, 1961). Basically, the Kalman filter updates the one-step-ahead coefficient estimates sequentially to generate a set of β_{1t} and corresponding standard deviations over time. In other words, the Kalman filter provides a set of measurements observed over time to estimate the unknown parameter β_{1t}. The time path of this parameter is an indicator of time evolving market efficiency. Whenever it converges towards zero and become insignificant, it suggests an improvement in efficiency.

3.3.3 Adjustment for Thin Trading, Structural Breaks, and Inflation

SME stock market return series were adjusted for thin trading to ensure that the long memory result is not contaminated by the thin trading-induced autocorrelation (Miller et al., 1994). To obtain de-thinned returns, the time-varying coefficient and residuals were extracted from the

State-Space AR(1) model, as suggested by Harrison and Moore (2012). This model only involves Equation (3.5) without the conditional variance (h_t) and Equation (3.7), as described above. Accordingly, the time-varying coefficient (β_{1t}) and residuals (e_t) were then used to estimate the de-thinned return series (r_t^d) as follows:

$$r_t^d = \frac{e_t}{1 - \beta_{1t}} \tag{3.8}$$

As mentioned before, a short memory pattern with structural breaks may spuriously reflect a long memory pattern. Therefore, to avoid this pitfall, structural breaks-adjusted return series (r_t^{db}) were generated using the procedure of Choi, Yu, and Zivot (2010), which involves the estimated mean returns for each break regime ($\widehat{c_\iota}$) and de-thinned return series (r_t^d), as below:

$$r_t^{db} = r_t^d - \widehat{c_\iota} \tag{3.9}$$

Subsequently, the returns adjusted for thin trading and structural breaks (r_t^{db}) were further adjusted for inflation (i) to assess the joint effect of these factors on long memory, using the following equation:

$$r_t^{dbi} = \frac{1 + r_t^{db}}{1 + i} - 1 \tag{3.10}$$

The unadjusted return series (r_t) and adjusted return series ($r_t^d, r_t^{db}, r_t^{dbi}$) were used sequentially to estimate long memory components in return and volatility using a set of fractionally integrated models, as presented in the next subsection.

3.3.4 Fractionally Integrated Models

3.3.4.1 ARFIMA

To model long memory in return series, Granger and Joyeux (1980) and Hosking (1981) developed the ARFIMA(p, d_m, q) model by incorporating the notion of fractional integration into an ARMA model. In this model, p and q are AR and MA lag orders, capturing the short memory component, while d_m represents long memory component in returns. The polynomial specification of ARFIMA(p, d_m, q) model can be written as

$$\Phi(L)(1-L)^{d_m}(r_t-\mu)=\Theta(L)\epsilon_t \tag{3.11}$$

$$\epsilon_t = z_t\sigma_t, \quad z_t \sim N(0,1) \tag{3.12}$$

where μ is unconditional mean; ϵ_t is a white noise process; $\Phi(L) = 1 - \phi_1 L - \phi_2 L^2 - \cdots - \phi_p L^p$ and $\Theta(L) = 1 + \theta_1 L + \theta_2 L^2 + \cdots + \theta_q L^q$ are AR and MA polynomials, which assumed to have all roots outside the unit circle; and $(1-L)^{d_m}$ is the fractional differencing operator defined as

$$(1-L)^{d_m} = \sum_{k=0}^{\infty} \frac{\Gamma(d_m+1)L^k}{\Gamma(d_m-k+1)\Gamma(k+1)} \tag{3.13}$$

where $\Gamma(\cdot)$ denotes the gamma (generalised factorial) function.

ARFIMA(p, d_m, q) model allows parameter d_m to take on fractional values, where return series (r_t) is interpreted as follows:

- $-0.5 < d_m < 0$: r_t is stationary intermediate memory (anti-persistence).
- $d_m = 0$: r_t is stationary short memory, corresponding to an ARMA process.
- $0 < d_m < 0.5$: r_t is stationary long memory (strong persistence).
- $0.5 \leq d_m < 1$: r_t is nonstationary long memory.
- $d_m = 1$: r_t is nonstationary and has a unit root, conforming to an ARIMA process.

It is noted that d_m parameter estimate is sensitive to the choice of lag order for AR and MA terms. Therefore, an ARMA model was initially fitted to select the optimal lag orders using the Akaike information criterion (AIC). The final AR and MA terms were then determined following the principle of the parsimonious model and the convergence of parameters estimation.

3.3.4.2 FIGARCH

To model long memory in the return volatility, Baillie, Bollerslev, and Mikkelsen (1996) developed FIGARCH model based on the premise of GARCH model. Accordingly, the degree of volatility persistence is estimated by a non-integer d_v parameter ($0 < d_v < 1$). The polynomial form of FIGARCH(p, d_v, q) model is written as:

$$[1-\beta(L)](1-L)^{d_v}\epsilon_t^2 = \omega + [1-\alpha(L)]v_t \quad (3.14)$$

where ω is a constant; $\alpha(L) = \alpha_1 L + \alpha_2 L^2 + \cdots + \alpha_q L^q$ and $\beta(L) = \beta_1 L + \beta_2 L^2 + \cdots + \beta_p L^p$ are ARCH and GARCH polynomials, whose roots are constrained to stay outside the unit circle to ensure covariance stationarity of residuals; v_t represents serially uncorrelated, zero-mean residuals, measured by $v_t = \epsilon_t^2 - \sigma_t^2$; and $(1-L)^{d_v}$ is a fractional differencing operator, defined by similar gamma function as stated in Equation (3.13). When $d_v = 0$ $(d_v = 1)$, FIGARCH process becomes GARCH (Integrated GARCH) process.

3.3.4.3 FIAPARCH

Tse (1998) extended FIGARCH model to capture the asymmetric effect in the conditional variance. Tse proposed FIAPARCH process by introducing the function $(|\epsilon_t| - \gamma\epsilon_t)^\delta$ to Asymmetric Power ARCH (APARCH) process of Campbell, Grossman, and Wang (1993). The polynomial form of FIAPARCH$(p, \gamma, \delta, d_v, q)$ model can be written as

$$\sigma_t^\delta = \omega + \left\{1 - \frac{\phi(L)(1-L)^{d_v}}{[1-\beta(L)]}\right\}(|\epsilon_t| - \gamma\epsilon_t)^\delta \quad (3.15)$$

where $\delta > 0$ is the power term of volatility process; $-1 < \gamma < 1$ is asymmetry parameter; parameters ϕ and β represent ARCH and GARCH terms. A positive γ indicates that negative shocks have a greater impact on volatility structure than positive shocks and vice versa. When $0 < d_v < 1$, long memory is present in return volatility. When $d_v = 0$ $(d_v = 1)$, FIAPARCH model becomes APARCH (Integrated APARCH) model. FIAPARCH model collapses to FIGARCH model if $\gamma = 0$ and $\delta = 2$.

3.3.4.5 HYGARCH

Davidson (2004) introduced Hyperbolic GARCH (HYGARCH), which is a generalised version of FIGARCH model. Superior to FIGARCH, HYGARCH releases the unit-amplitude restriction to capture both characteristics of volatility persistence and covariance stationarity. The polynomial form of HYGARCH(p, λ, d_v, q) process is described as

$$\sigma_t^2 = \omega + \left\{1 - \frac{\alpha(L)}{\beta(L)}\left(1 + \lambda((1-L)^{d_v} - 1)\right)\right\}\epsilon_t^2 \tag{3.16}$$

where $\lambda \geq 0$ is amplitude parameter; parameters α and β represent ARCH and GARCH terms. If $\lambda = 0$ ($\lambda = 1$), HYGARCH model reduces to GARCH (FIGARCH) model. If $\lambda > 1$, it is a legitimate case of non-stationarity. When $0 < d_v < 1$, volatility structure follows a hyperbolic decaying pattern or a long memory pattern. When $d_v = 1$, parameter λ declines to an autoregressive root, and the model reduces to either GARCH or IGARCH process, depending on whether $\lambda < 1$ or $\lambda = 1$.

The model parameters are estimated by Quasi-maximum Likelihood Estimation (QMLE) method, allowing for asymptotic Gaussian distribution. The likelihood function is defined as

$$LL = -\frac{1}{2}\log(2\pi) - \frac{1}{2}\sum_{t=1}^{T}\left[\log(\sigma_t^2) + \frac{\epsilon_t^2}{\sigma_t^2}\right] \tag{3.17}$$

Conrad and Karanasos (2005) documented that dual long memory models (ARFIMA-FIGARCH, ARFIMA-FIAPARCH, and ARFIMA-HYGARCH) have been used widely since they retain the analytical sophistication of ARMA-GARCH process while augmenting its dynamics with a fractionally integrated structure. The fractional integration is more flexible than the knife-edge 0 or 1 integration orders. More importantly, these models offer a simultaneous estimation of the long memory components in the return and volatility series.

3.4 Data Sources and Characteristics

The data used are daily closing prices of the S&P/HKEX GEM Index (Hong Kong), FTSE Strait Times CATALIST Index (Singapore), MAI Index (Thailand), and FTSE Bursa Malaysia ACE Index (Malaysia). Data were obtained from the Bloomberg Database for the period 01/07/2009 to 30/12/2016 and then filtered for valid trading days (because there exist several non-trading days which duplicate the values of the previous trading day in the raw series). The sample period started from the launch of the ACE market which replaced the former MESDAQ market. Monthly consumer price indices of the four countries were collected from the IMF's International Financial Statistics (IFS) and then converted to daily series using frequency conversion technique[15]. The data were analysed using Oxmetrics 7.2, which is among the most prevailing econometrics software packages and, importantly, offers integrated solutions for time series analysis.

The daily price series were transformed into daily logarithmic return series as, $r_t = ln\ (P_t/P_{t-1})$, where P_t and P_{t-1} denotes index closing prices at day t and $t-1$.

Table 3.1: Descriptive Statistics of Logarithmic Returns

	GEM (Hong Kong)	CATALIST (Singapore)	MAI (Thailand)	ACE (Malaysia)
No. obs.	1,853	1,884	1,832	1,849
Mean	-0.0003	-0.0005	0.0006	0.0001
Median	0.0003	-0.0005	0.0014	0.0001
Maximum	0.2707	0.0726	0.0805	0.0551
Minimum	-0.1584	-0.0883	-0.0789	-0.0765
Std. Dev.	0.0152	0.0147	0.0125	0.0118
Skewness	0.96	-0.28	-0.87	-0.47
Kurtosis	75.28	6.96	9.85	7.16
Jarque-Bera	403,695*	1,255*	3,816*	1,399*
Q(10)	79.59*	80.86*	25.52*	31.58*
Q(20)	108.85*	91.72*	32.00*	46.21*
$Q^2(10)$	502.32*	416.07*	329.01*	313.87*
$Q^2(20)$	509.60*	771.42*	337.96*	351.72*
ARCH (5)	78.14*	44.83*	38.51*	31.75*
ARCH (10)	40.06*	24.66*	19.36*	19.19*

Note: * indicates the test statistic is significant at 1%; $Q(q)$ and $Q^2(q)$ are the Ljung-Box test statistics for serial correlation up to lag q in logarithmic returns and squared logarithmic returns, respectively; ARCH(q) is the Engle ARCH test statistic for unconditional heteroscedasticity up to lag q in logarithmic returns.

Table 3.1 displays the descriptive statistics for the logarithmic returns of GEM (Hong Kong), CATALIST (Singapore), MAI (Thailand), and ACE (Malaysia). Compared to MAI and ACE, GEM and CATALIST experienced negative mean returns but higher standard deviations. All returns, except for GEM, have fatter tails and longer left tails compared to the Gaussian distribution due to negative skewness. The substantial kurtosis indicated that all returns are leptokurtic and have a sharp peak. The Jarque-Bera statistics further confirmed that all returns are non-Gaussian distributed. The significant Ljung-Box Q and Q^2 statistics up to lag 10 and 20 indicated long-range dependencies in the mean and variance of all returns. The Engle ARCH statistics up to lag 5 and 10 provided the evidence of conditional heteroscedasticity in all returns.

[15] Frequency conversion is a technique that involves converting a time series data from high to low frequencies (e.g. from monthly to quarterly), or from low to high frequencies (e.g. quarterly to annual).

3.5 Findings and Discussion

3.5.1 Evidence of Structural Breaks

Before modelling the evolving efficiency and long memory, the presence of structural breaks in return series was tested using the procedure of ICSS algorithm. The results revealed two breakpoints in GEM and ACE, and one breakpoint in CATALIST and MAI. The identified breakpoints appear to correspond to major political, macroeconomic and financial events (see Table 3.2). One should note that the reported regimes include periods that have breakpoint and no breakpoint as well, making up the whole sample period (01/07/2009 – 30/12/2016).

Table 3.2: Structural Breakpoints

Market	Breakpoint	Corresponding events	Regime	$\widehat{c_i}$
GEM			02/07/2009 – 10/11/2010	0.0011
(Hong Kong)	11/11/2010	Chinese Central Bank announced an	11/11/2010 – 08/07/2015	-0.0006
		increase in the monetary policy rate	09/07/2015 – 21/08/2015	0.0051
	24/08/2015	Black Monday of Chinese stock market	24/08/2015 – 13/06/2016	-0.0013
			14/06/2016 – 30/12/2016	-0.0009
CATALIST			01/07/2009 – 25/09/2009	0.0051
(Singapore)	28/09/2009	Singapore's unemployment rate peaked	28/09/2009 – 24/06/2016	-0.0008
		at 3.3%	27/06/2016 – 30/12/2016	0.0001
MAI	07/04/2010	Thai Prime Minister ordered a state of	02/07/2009 – 05/04/2010	0.0006
(Thailand)		emergency	07/04/2010 – 16/08/2013	0.0008
			19/08/2013 – 30/12/2016	0.0005
ACE			01/07/2009 – 12/09/2012	0.0001
(Malaysia)	13/09/2012	S&P warned to cut Malaysia's	13/09/2012 – 12/12/2014	0.0004
		sovereign credit rating	15/12/2014 – 26/08/2015	-0.0007
	27/08/2015	Malaysian government declared the	27/08/2015 – 28/03/2016	0.0010
		Bersih rallies* illegal	29/03/2016 – 30/12/2016	-0.0009

Notes: $\widehat{c_i}$ represents the estimated mean returns for each regime; *Bersih rallies are political protests held by a non-governmental organisation to strengthen the parliamentary democracy system in Malaysia.

3.5.2 Evolution Towards Efficiency

Before fitting the State-Space GARCH-M(1,1) model, the stationarity of all returns was assessed to avoid the problem of spurious regression. Due to the presence of structural breaks, the Modified Augmented Dickey-Fuller unit root test (Perron, 1989; Zivot & Andrews, 1992; Vogelsang & Perron, 1998), which allows for a single break in the data with trend and non-trend, was applied. For GEM and ACE, which exhibited two breakpoints, these series were split into two periods and the test was applied separately. As shown in Table 3.3, the null of having a unit root was strongly rejected for all return series, implying their stationarity.

Table 3.3: Single Breakpoint Unit Root Test

	GEM (Hong Kong)		CATALIST (Singapore)	MAI (Thailand)	ACE (Malaysia)	
	Period 1	Period 2	Full period	Full period	Period 1	Period 2
Intercept break	-17.46*	-19.49*	-50.83*	-39.30*	-17.81*	-22.60*
Trend break	-17.46*	-21.00*	-51.18*	-39.28*	-17.81*	-22.60*
Intercept and Trend break	-17.46*	-20.84*	-50.81*	-39.30*	-17.83*	-23.20*

Notes: * indicates the test statistic is significant at 1%; For GEM, period 1: 02/07/2009-08/07/2015, period 2: 09/07/2015-30/12/2016; For ACE, period 1: 01/07/2009-12/12/2014, period 2: 15/12/2014-30/12/2016

Table 3.4 reports the State-Space GARCH-M(1,1) model estimation for the GEM, CATALIST, MAI, and ACE. In this model, parameter β_0 represents non-measurable factors such as political events, macro effects, and external shocks (such interpretation of parameter β_0 can be seen in the studies of Charfeddine and Khediri (2016) and Abdmoulah (2010)). Although these factors are immaterial for GEM and ACE, they are important for CATALIST and MAI. Parameters β_1 at the final state were significantly different from zero for all returns, indicating weak-form inefficiency in all markets. The ARCH and GARCH effects (represented by parameters α_2 and α_1) were highly significant, implying that all markets are highly sensitive to past shocks. Furthermore, the sum $(\alpha_1 + \alpha_2)$ was close to unity for all markets, suggesting the persistence of volatility. The model specification is also adequate since serial correlation and heteroscedasticity in the residuals were almost eliminated.

Table 3.4: State-Space GARCH-M(1,1) Model Estimation

Coefficient	GEM (Hong Kong)	CATALIST (Singapore)	MAI (Thailand)	ACE (Malaysia)
β_0	0.00	0.004***	0.004***	0.00
β_1 (final state)	0.06**	-0.08*	0.10*	0.05***
β_2	2.53	-0.85	3.28	0.01
α_0	0.00**	0.00**	0.00*	0.00*
α_1	0.14*	0.10*	0.21*	0.16*
α_2	0.82*	0.89*	0.73*	0.79*
Diagnostics				
$\alpha_1 + \alpha_2$	0.96	0.99	0.94	0.94
Log-likelihood	5,783.22	5,580.51	5,673.19	5,744.70
AIC	-6.24	-5.92	-6.19	-6.21
Q(10)	30.14***	33.03***	25.22	26.08
Q(20)	40.33	37.64	29.80	32.96
$Q^2(10)$	10.57	12.94	6.23	9.23
$Q^2(20)$	14.46	22.15	11.24	14.91
ARCH(10)	1.07	1.26	0.63	0.94
ARCH(20)	0.73	1.13	0.55	0.76

Notes: *, **, *** indicate the test statistic is significant at 1%, 5%, and 10%, respectively; $Q(q)$ and $Q^2(q)$ are the Ljung-Box test statistics for serial correlation up to lag q in the residuals and squared residuals, respectively; ARCH(q) is the Engle ARCH test statistic for conditional heteroscedasticity up to lag q in the residuals.

Figure 3.2 to Figure 3.5 depict the evolving efficiency in GEM, CATALIST, MAI, and ACE. They illustrate the time paths of AR(1) coefficient (β_{1t}) (red line) together with 95% confidence interval (black lines), obtained from Kalman filter estimation. When the time path approaches zero, a tendency towards efficiency is implied and vice versa.

The time paths of AR(1) coefficient for GEM and CATALIST showed a steady movement towards zero (see Figure 3.2 and Figure 3.3), suggesting that these markets are still weak-form inefficient, yet exhibit tendencies towards efficiency. These tendencies were observed to align with growing market capitalisation and turnover value of the two markets (see Figure 2.2 and Figure 2.4). This seems to be consistent with previous findings in the studies of Jefferis and Smith (2005), Lagoarde-Segot and Lucey (2008), and Abdmoulah (2010). Growing turnover value means that more transactions are executed, thus offering more opportunities for market prices to adjust and reflect new information. This is a requisite for a stock market to be weak-form efficient. Moreover, the tendencies towards efficiency can be supported by several institutional reforms in operational efficiency undertaken by the HKEX and SGX authorities (see Table 3.5). As mentioned earlier, non-measurable factors are important for CATALIST. Thus, its tendency towards efficiency would be possibly attributed to non-measurable factors such as a stable political structure, a well-established legal system, and robust corporate governance practices.

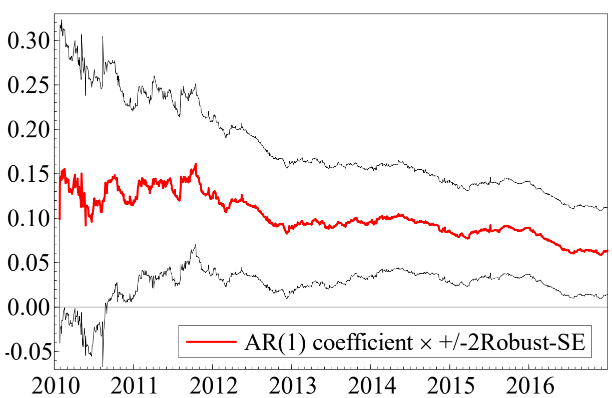


Figure 3.2: Evolving Efficiency of GEM

Source: Authors generated using Oxmetrics 7.2

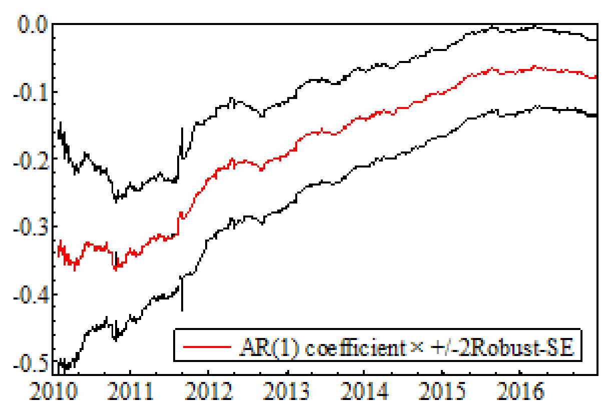


Figure 3.3: Evolving Efficiency of CATALIST

Table 3.5: Major Institutional Reforms in Operational Efficiency

Exchange	Date	Event
HKEX (Hong Kong)	05/12/2011	The Automatic Order Matching and Execution System was upgraded to version 3.8. (Processing capacity increased from 3,000 to 30,000 orders per second; Response time reduced to 2 milliseconds from 0.15 seconds)
	01/11/2014	The 10% reduction in Securities and Futures Commission's transaction fees took effect.
	25/07/2016	Closing Auction Session for securities market was implemented to extend the closing time up to 10 minutes.
	22/08/2016	Volatility Control Mechanism (VCM) was introduced to prevent extreme price volatility stemming from trading errors or unusual incidents.
SGX (Singapore)	17/08/2011	A new trading platform, SGX's Reach, went live, offering the lowest response time of 90 microseconds.
	24/02/2014	VCM was introduced where any matching prices exceeding 10% from reference prices will trigger a circuit break.
	01/06/2014	The clearing fee per transaction value was reduced from 0.04% to 0.0325%. SGX Market Maker and Liquidity Provider Program was executed.
	24/02/2016	Millennium Post Trade, a real-time clearing, settlement and depository platform, was implemented.
SET (Thailand)	03/09/2012	SET CONNECT, a new trading engine considered as efficient as the system of world-leading stock markets, went live.
	27/10/2014	A smart-listing system was launched to speed up the listing procedures of securities.
	24/08/2015	A new clearing system, which can efficiently manage risk and connect to the real-time transaction, was implemented.
BM (Malaysia)	03/01/2012	A comprehensive Corporate Disclosure Guide was introduced to improve the quality of information for financial reporting.
	02/12/2013	A new trading system, Bursa Trade Securities 2, was launched, offering 10 times higher in processing capacity and several risk control mechanisms.
	27/04/2015	A new listing information network system (Bursa LINK) and an online listing enquiry service (AskListing@Bursa) were introduced.

Source: The stock exchanges' factbooks and public domains

Regarding MAI, AR(1) coefficient was very close to zero only for a short period in 2011 (see Figure 3.4), implying a transient bout of weak-form efficiency. As mentioned previously, non-measurable factors can influence this market. Therefore, this transient efficiency could be rationalised by a critical political event, that is, Yingluck Shinawatra was elected Prime Minister on 04/07/2011. This event notably boosted investor confidence in political stability in Thailand and led to another peak in the Thai bourse since 1996. Nevertheless, for the remaining periods, MAI showed a deviation from efficiency regardless of institutional reforms in operational efficiency (see Table 3.5) and the growing market capitalisation and trading turnover (see Figure 2.6). This deviation from efficiency might be due to the prolonged political instability in the country since 2012.

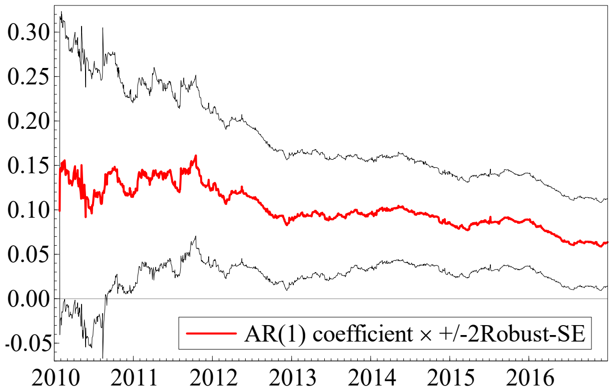


Figure 3.4: Evolving Efficiency of MAI

Source: Authors generated using Oxmetrics 7.2

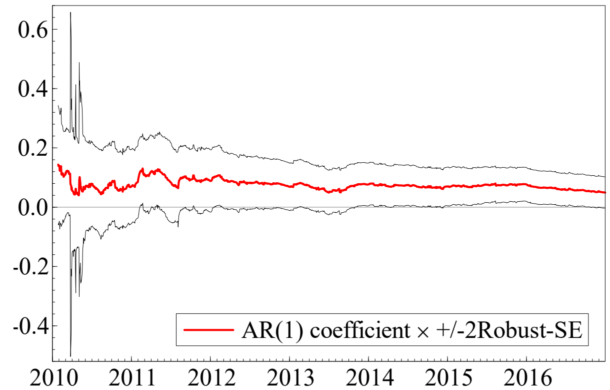


Figure 3.5: Evolving Efficiency of ACE

In the case of ACE, the movement of AR(1) coefficient was fairly stable throughout the study period (see Figure 3.5) and significantly different from zero. As such, this market is weak-form inefficient and has no potential movement towards efficiency despite a moderate increase in the market capitalisation (see Figure 2.8) and institutional reforms in operational efficiency (see Table 3.5). This outcome may be due to the unstable political environment in Malaysia, which has encountered continuous confrontations between the government and opposition parties since 2011.

3.5.3 Modelling Dual Long Memory

Due to the high degree of volatility persistence in GEM, CATALIST, MAI, and ACE as stated above, long memory properties in both return and volatility were further investigated. Such investigation may provide further evidence for the identified state of inefficiency in these markets. Accordingly, to model dual long memory, a joint estimate of long memory parameters in the first and second moments of return series was conducted using three models: ARFIMA-FIGARCH, ARFIMA-FIAPARCH, and ARFIMA-HYGARCH. Being superior to FIGARCH, FIAPARCH allows for asymmetric volatility, while HYGARCH releases the unit-amplitude restriction. As noted earlier, the joint effect of thin trading, structural breaks, and inflation on long memory was assessed by fitting the models using unadjusted returns (r_t) and adjusted returns ($r_t^d, r_t^{db}, r_t^{dbi}$). To begin with, lag 2 was selected for AR and MA terms, and lag 1 was determined for ARCH and GARCH terms for all markets based on the following three criteria: minimum AIC value, the parsimony of the model, and the convergence of parameters estimation.

Table 3.6 assembles estimation results of the ARFIMA$(2, d_m, 2)$-FIGARCH$(1, d_v, 1)$ model for GEM, CATALIST, MAI, and ACE. In the mean equation (ARFIMA), parameters d_m for GEM were significant at 10% and declined from 0.131 to 0.083, 0.073, and 0.069 as the returns were adjusted for thin trading, structural breaks, and inflation, respectively. The results indicated the presence of return persistence and persistence reducing effect of these factors in GEM. Regarding MAI, parameters d_m using raw returns and de-thinned returns weakened both in magnitude and statistical significance from 0.119 (significant at 1%) to 0.060 (significant at 10%). As the returns were further adjusted for structural breaks and inflation, these parameters became statistically insignificant, suggesting that the identified long memory may be an artefact of short memory in the presence of these factors. The short memory was also supported by significant AR(1) and MA(1) terms (Φ_1 and Θ_1 parameters). In order words, significant AR and MA terms indicate the presence of short memory in returns and may (or may not) eliminate the presence of long memory in returns. The presence of short memory implies return predictability as the market does not absorb new information arrived instantly but rather delays the price adjustment of new information after a short period of time, thus invalidates the efficient market hypothesis. In contrast, there was no evidence of return persistence in CATALIST and ACE due to their insignificant d_m parameters.

Turning to the variance equation (FIGARCH), parameters d_v for all unadjusted and adjusted returns were highly significant, indicating strong volatility persistence in the four markets. In particular, the values of d_v parameters for all-factor-adjusted returns (r_t^{dbi}) ranged from 0.339 to 0.489. Unsurprisingly, the degree of volatility persistence also reduced monotonically when the returns were adjusted for thin trading, structural breaks, and inflation. For examples, parameters d_v of GEM (MAI) decreased from 0.518 (0.571) to 0.501 (0.537), 0.499 (0.376), and 0.489 (0.339).

Table 3.6: ARFIMA$(2, d_m, 2)$-FIGARCH$(1, d_v, 1)$ Model Estimation

	GEM (Hong Kong)	CATALIST (Singapore)	MAI (Thailand)	ACE (Malaysia)
Panel A: ARFIMA				
μ	0.000	0.000	0.000	0.000
$\boldsymbol{d_m(r_t)}$	**0.131*****	**-0.002**	**0.119***	**0.014**
$\boldsymbol{d_m(r_t^d)}$	**0.083*****	**0.030**	**0.060*****	**-0.010**
$\boldsymbol{d_m(r_t^{db})}$	**0.073*****	**0.025**	**0.059**	**-0.116**
$\boldsymbol{d_m(r_t^{dbi})}$	**0.069*****	**0.020**	**0.056**	**-0.010**
Φ_1	-0.702***	0.115	-0.831*	0.700*
Φ_2	0.270	-0.502**	-0.047	-0.772*
Θ_1	0.719***	-0.185	0.801*	-0.726*
Θ_2	-0.265	0.474***	0.009	0.834*
Panel B: FIGARCH				
ω	4.921**	0.009	1.974*	0.099
$\boldsymbol{d_v(r_t)}$	**0.518***	**0.629***	**0.571***	**0.361****
$\boldsymbol{d_v(r_t^d)}$	**0.501***	**0.604***	**0.537***	**0.357****
$\boldsymbol{d_v(r_t^{db})}$	**0.499***	**0.463***	**0.376***	**0.350****
$\boldsymbol{d_v(r_t^{dbi})}$	**0.489***	**0.459***	**0.339***	**0.342****
α_1	-0.113	0.588*	-0.338	0.036
β_1	0.175	0.786*	-0.162	0.185
Panel C: Post-Estimation Diagnostics				
Log-Likelihood	5,727	5,685	5,511	5,615
AIC	-6.17	-6.03	-6.01	-6.07
Q(10)	12.00	15.69	8.84	14.11
Q(20)	21.22	23.02	13.75	17.94
$Q^2(10)$	6.51	2.70	4.19	6.58
Q^2 (20)	9.50	22.63	10.07	11.39
ARCH(5)	0.19	0.17	0.58	0.42
ARCH(10)	0.64	0.28	0.41	0.71
P(40)	114.47*	60.73*	110.56*	79.10*

Notes: *, **, *** indicate the test statistic is significant at 1%, 5%, and 10%, respectively; For comparison purpose, the table displays d_m and d_v parameters for model estimations using r_t, r_t^d, r_t^{db}, r_t^{dbi} while the other parameters solely pertain to the final model estimation using r_t^{dbi}; P(40) indicates the Pearson Goodness of Fit Test for 40 cells; Q(q) and $Q^2(q)$ are the Ljung-Box test statistics for serial correlation up to lag q in the residuals and squared residuals, respectively; ARCH(q) is the Engle ARCH test statistic for conditional heteroscedasticity up to lag q in the residuals.

Table 3.7 reports estimation results of the ARFIMA$(2, d_m, 2)$-FIAPARCH$(1, \gamma, \delta, d_v, 1)$ model for GEM, CATALIST, MAI, and ACE. Unlike the results from the previous model, both GEM and MAI exhibited return persistence given the significant d_m parameters for all returns. The magnitude of parameters d_m also decreased steadily once the factors of thin trading, structural breaks, and inflation were taken into account. In particular, parameters d_m of GEM (MAI) declined from 0.176 (0.131) to 0.167 (0.118), 0.164 (0.115), and 0.161 (0.105). Nevertheless, in the case of CATALIST, the d_m parameter became insignificant after the three factors were sequentially adjusted. Meanwhile, according to the estimation of FIAPARCH process, all four markets presented robust evidence of volatility persistence and the degree of persistence also diminished as return series are adjusted for the three factors. For instances, parameters d_v of CATALIST (ACE) declined from 0.707 (0.519) to lower corresponding values of 0.513 (0.485), 0.498 (0.420), and 0.493 (0.346). In addition, parameters γ of GEM and MAI were significant and positive, suggesting that negative events (such as market turbulence and national state of emergency, see Table 3.2) inflict higher volatility in these markets than positive events.

Table 3.7: ARFIMA$(2, d_m, 2)$-FIAPARCH$(1, \gamma, \delta, d_v, 1)$ Model Estimation

	GEM (Hong Kong)	CATALIST (Singapore)	MAI (Thailand)	ACE (Malaysia)
Panel A: ARFIMA				
μ	0.000	0.000	-0.001	0.000
$d_m(r_t)$	**0.176****	**0.264****	**0.131****	**0.009**
$d_m(r_t^d)$	**0.167****	**0.031**	**0.118****	**-0.013**
$d_m(r_t^{db})$	**0.164****	**0.025**	**0.115****	**-0.115**
$d_m(r_t^{dbi})$	**0.161*****	**0.020**	**0.105****	**-0.012**
Φ_1	-0.390*	0.150	-0.891*	0.700*
Φ_2	0.577*	-0.506**	-0.088	-0.757*
Θ_1	0.322*	-0.221	0.822*	-0.725*
Θ_2	-0.659*	0.482***	0.010	0.821*
Panel B: FIAPARCH				
ω	1.632	0.010	7.142	4.880
$d_v(r_t)$	**0.473***	**0.707***	**0.408***	**0.519****
$d_v(r_t^d)$	**0.469***	**0.513***	**0.293***	**0.485****
$d_v(r_t^{db})$	**0.466***	**0.498***	**0.293***	**0.420****
$d_v(r_t^{dbi})$	**0.454***	**0.493***	**0.281***	**0.346****
ϕ_1	0.016	0.560*	-0.272***	0.066
β_1	0.284	0.796*	-0.123	0.224
γ	0.232**	-0.093	0.426*	0.026
δ	1.485*	1.993*	1.679*	1.863*
Panel C: Post-Estimation Diagnostics				
Log-Likelihood	5,739	5,686	5,534	5,616
AIC	-6.18	-6.03	-6.03	-6.07
Q(10)	10.50	15.61	5.81	14.34
Q(20)	20.29	23.07	12.09	18.39
$Q^2(10)$	12.82	3.57	7.57	7.36
Q^2 (20)	16.40	25.75	14.03	12.51
ARCH(5)	1.57	0.26	1.32	0.47
ARCH(10)	1.17	0.36	0.77	0.78
P(40)	108.68*	62.89*	101.21*	71.91*

Notes: *, **, *** indicate the test statistic is significant at 1%, 5%, and 10%, respectively; For comparison purpose, the table displays d_m and d_v parameters for model estimations using r_t, r_t^d, r_t^{db}, r_t^{dbi} while the other parameters solely pertain to the final model estimation using r_t^{dbi}; P(40) indicates the Pearson Goodness of Fit Test for 40 cells; Q(q) and $Q^2(q)$ are the Ljung-Box test statistics for serial correlation up to lag q in the residuals and squared residuals, respectively; ARCH(q) is the Engle ARCH test statistic for conditional heteroscedasticity up to lag q in the residuals.

Table 3.8 displays the ARFIMA$(2, d_m, 2)$-HYGARCH$(1, d_v, 1)$ model estimation for GEM, CATALIST, MAI, and ACE. When fitting the model with raw returns, parameters d_m were found to be significant for GEM, CATALIST and MAI, suggesting a long memory component in the returns of these markets. When modelling with the three adjusted returns, parameters d_m of GEM maintained its magnitude (0.070) but decreased in significance level from 5% to 10%. In contrast, parameters d_m of CATALIST and MAI became insignificant as their returns were adjusted for thin trading, structural breaks, and inflation. The results imply that in the presence of these factors, what appears to be long memory may be in fact the existence of short memory. The existence of short memory was also supported by the statistical significance of AR(2) and MA(2) terms (Φ_2 and Θ_2 parameters) for CATALIST, and AR(1) and MA(1) terms (Φ_1 and Θ_1 parameters) for MAI.

Table 3.8: ARFIMA$(2, d_m, 2)$-HYGARCH$(1, \lambda, d_v, 1)$ Model Estimation

	GEM (Hong Kong)	CATALIST (Singapore)	MAI (Thailand)	ACE (Malaysia)
Panel A: ARFIMA				
μ	0.000	0.000	0.000	0.000
$\boldsymbol{d_m(r_t)}$	**0.070****	**0.271*****	**0.162****	**-0.075**
$\boldsymbol{d_m(r_t^d)}$	**0.070*****	**0.028**	**0.108*****	**0.004**
$\boldsymbol{d_m(r_t^{db})}$	**0.070*****	**0.020**	**0.049**	**-0.001**
$\boldsymbol{d_m(r_t^{dbi})}$	**0.070*****	**0.026**	**0.048**	**0.000**
Φ_1	-0.819	0.086	-0.827*	0.656*
Φ_2	0.155	-0.488**	-0.131	-0.697*
Θ_1	0.828	-0.159	0.790*	-0.695*
Θ_2	-0.159	0.456**	0.090	0.761*
Panel B: HYGARCH				
ω	0.166**	-0.015	0.294**	0.032
$\boldsymbol{d_v(r_t)}$	**0.598***	**0.617****	**0.661***	**0.576****
$\boldsymbol{d_v(r_t^d)}$	**0.596***	**0.442****	**0.448***	**0.339****
$\boldsymbol{d_v(r_t^{db})}$	**0.595***	**0.435****	**0.444***	**0.335*****
$\boldsymbol{d_v(r_t^{dbi})}$	**0.578***	**0.392****	**0.439***	**0.333*****
α_1	-0.086	0.643*	-0.299	0.020
β_1	0.265	0.791*	-0.088	0.201
$Log\lambda$	-0.113***	0.054	-0.088**	0.043**
Panel C: Post-Estimation Diagnostics				
Log-Likelihood	5,747	5,687	5,618	5,684
AIC	-6.19	-6.03	-6.12	-6.14
Q(10)	11.20	15.69	11.05	10.92
Q(20)	21.80	22.34	16.19	16.45
$Q^2(10)$	8.18	2.43	4.19	5.99
Q^2 (20)	11.64	22.26	9.40	9.93
ARCH(5)	0.30	0.14	0.59	0.47
ARCH(10)	0.82	0.25	0.42	0.66
P(40)	108.64*	68.42*	40.44**	46.03**

Notes: *, **, *** indicate the test statistic is significant at 1%, 5%, and 10%, respectively; For comparison purpose, the table displays d_m and d_v parameters for model estimations using r_t, r_t^d, r_t^{db}, r_t^{dbi} while the other parameters solely pertain to the final model estimation using r_t^{dbi}; P(40) indicates the Pearson Goodness of Fit Test for 40 cells; $Q(q)$ and $Q^2(q)$ are the Ljung-Box test statistics for serial correlation up to lag q in the residuals and squared residuals, respectively; ARCH(q) is the Engle ARCH test statistic for conditional heteroscedasticity up to lag q in the residuals.

With respect to the estimates of volatility persistence using HYGARCH process, parameters d_v for all markets were statistically significant but declined steadily in magnitude when using the three adjusted return series. For examples, parameters d_v of GEM (ACE) declined from 0.598 (0.576) to 0.596 (0.339), 0.595 (0.335), and 0.578 (0.333) as returns were adjusted for thin trading, structural breaks, and inflation, respectively. Furthermore, parameters d_v of ACE also weakened in statistical significance from 5% to 10%.

Table 3.6 to Table 3.8 also present the post-estimation diagnostics in Panel C, showing no significant serial correlation and heteroscedasticity in the standardised residuals and no evidence of model misspecification in all markets.

All three dual long memory models above showed that parameters d_m and d_v estimated using the returns adjusted for thin trading, structural breaks, and inflation (r_t^{dbi}) of the four markets fell within the interval of [0; 0.5] (except for GEM in ARFIMA-HYGARCH model). As previously mentioned, the presence of long memory in both returns and volatility provides evidence against random walk behaviour (Caporale et al., 2019). This implies predictability and is inconsistent with the Efficient Market Hypothesis (EMH) since abnormal profits can be made using trading strategies based on trend analysis. Given the estimated parameters d_m and d_v being within the interval of [0; 0.5], the results indicate a stationary long memory property in return and volatility, implying that the return and volatility will revert to their means in the long-run. In other words, the current stock price index is heavily dependent on distant past price indexes and it will revert to its long-run equilibrium after the impact of external events has dissipated. If investors are aware of the persistent trend in stock price index, they can yield abnormal returns by buying (selling) index stocks when prices are expected to increase (decrease). Consequently, the presence of stationary long memory in the market is of great importance for investors in formulating trading strategies and investment portfolios.

Furthermore, long memory has a major role to play in hedging[16] effectiveness, which involves the determination of an Optimal Hedge Ratio (OHR), also known as Minimum-Variance Hedge Ratio (MVHR). Specifically, Dark (2007) postulated that when market returns follow a

[16] Hedging is an investment strategy to mitigate the risk of adverse price changes in an asset by investing in an offsetting position in a related securities.

long memory volatility process, the standard models used to estimate OHR such as Ordinary Least Squares (OLS) model, Cointegration model, and GARCH model become mis-specified. Accordingly, Coakley, Dollery, and Kellard (2008) incorporated long memory component into the hedging model and concluded that a joint fractionally integrated, error-correction and multivariate GARCH (FIEC-MGARCH) hedging strategy can outperform the OLS benchmark in terms of variance reduction and hedger utility. Mann (2012) found a FIAPARCH hedge ratio is the most effective among several other GARCH hedge ratios, emphasizing the important role of long memory in hedging effectiveness. More recently, Chkili, Aloui, and Nguyen (2014) asserted that using the Dynamic Conditional Correlation (DCC) - FIAPARCH model enables investors to effectively hedge the risk of stock portfolios at lower costs than using the standard DCC-GARCH model. Therefore, our finding can assist investors to create their hedging strategies and risk management in the sense that dual long memory components should be integrated into the indicated hedging models in order to estimate the optimal hedge ratio for SME stock markets.

In addition, compared to GEM and CATALIST, MAI and ACE had lower values of parameter d_v, implying that their return volatilities have shorter strays from the volatility mean or smaller degree of persistence. Therefore, MAI and ACE may serve as a good hedge for portfolio risk management during a crisis or in a bear market.

Table 3.9: Summary of Study 1 – Evolution of Weak-Form Efficiency and Dual Long Memory in SME Stock Markets

Research Questions	Findings	Implications / Contributions
Q1.1: Do SME stock markets evolve towards weak-form market efficiency?	SME stock markets in Hong Kong, Singapore, Thailand and Malaysia are still weak-form inefficient. SME stock markets in Hong Kong and Singapore exhibit tendencies towards weak-form market efficiency. These tendencies appear to evolve with the market development and institutional reforms in trading operation.	*For policymakers:* The findings can assist policymakers in making institutional reforms and policies to further develop SME stock markets in Hong Kong and Singapore and improve the market efficiency. *For investors and portfolio managers:* The inefficiency of SME stock markets in the four countries implies that investors and portfolio managers can earn abnormal returns by actively beating the markets using technical analysis. *For academics:* The findings contribute to the empirical literature on second-tier stock market efficiency.
Q1.2: Is long memory property present in SME stock markets' return and volatility?	SME stock markets in Hong Kong and Thailand present stationary long memory in return and volatility, while those in Singapore and Malaysia show stationary long memory in volatility only.	*For investors and portfolio managers:* The presence of stationary long memory property in the SME stock markets implies the predictability in the markets which is of great importance to investors and portfolio managers in forming active trading and hedging strategies. *For academics:* This finding contributes to the empirical literature on the characteristics of second-tier stock markets.
Q1.3: What are the joint impacts of thin trading, structural breaks, and inflation on long memory property in SME stock markets' return and volatility?	The three factors: thin trading, structural breaks, and inflation jointly have diminishing effect on the magnitude and/or significance level of dual long memory property in the SME stock markets' return and volatility.	*For investors and portfolio managers:* Failure to account for the joint effects of thin trading, structural breaks, and inflation results in overestimated long memory parameters, leading to false trading and hedging strategies. *For academics:* This finding improves the empirical literature on long memory in stock markets by controlling for the three impact factors to avoid biased estimations.

3.6 Conclusion and Future Research

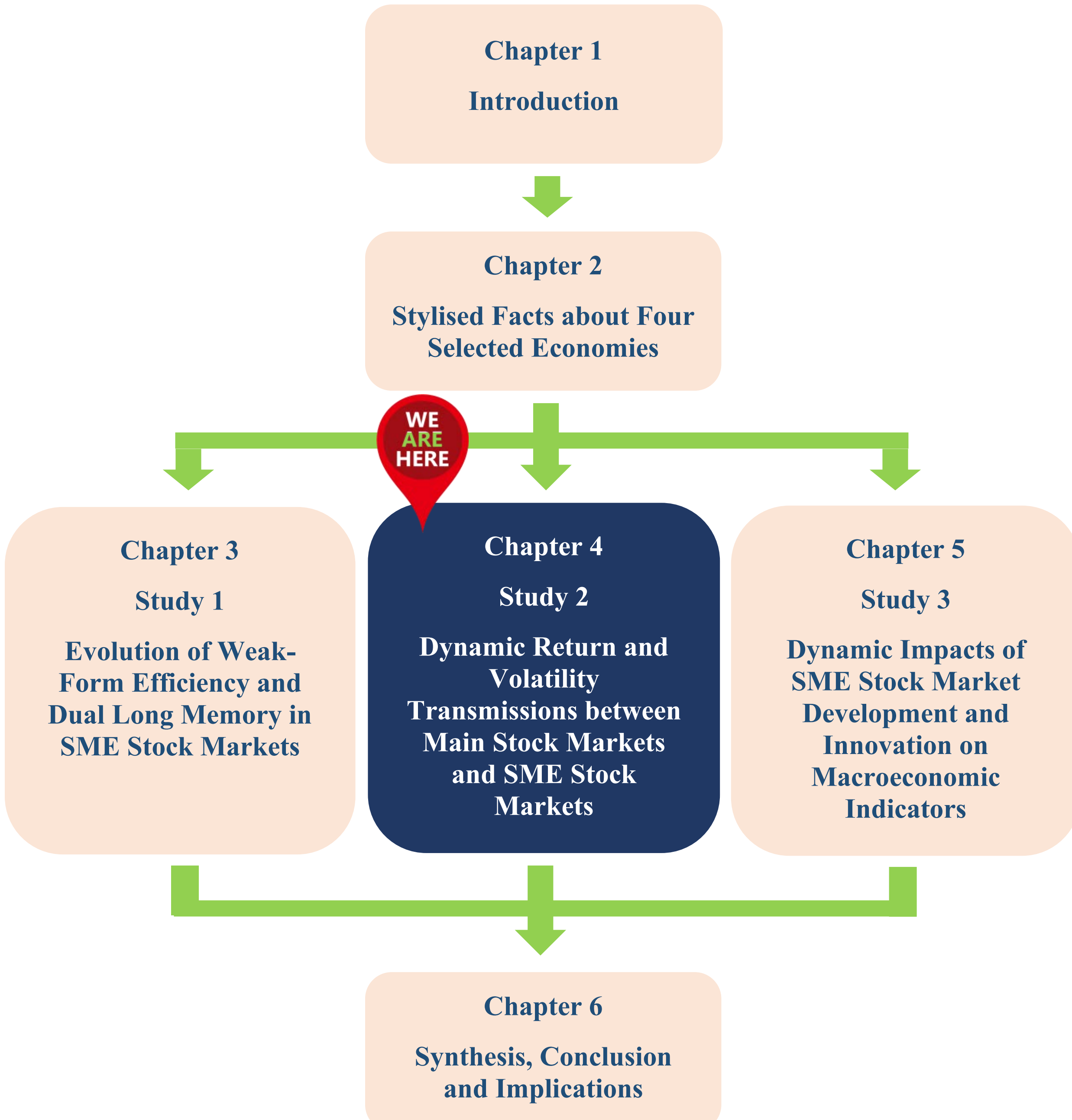
This paper investigated the evolving weak-form efficiency and joint effect of three factors: thin trading, structural breaks, and inflation on dual long memory in SME stock markets in Hong Kong, Singapore, Thailand, and Malaysia during 2009-2016. Accordingly, a set of econometric techniques and models was adopted including the ICSS algorithm to detect potential structural breaks, the State-Space GARCH-M model with Kalman filter estimation to capture the evolving efficiency, the factors adjustment techniques to account for thin trading, structural breaks, and inflation, and a set of fractionally integrated models (including ARFIMA-FIGARCH, ARFIMA-FIAPARCH, and ARFIMA-HYGARCH) to investigate dual long memory.

The results indicated that all four SME stock markets are still inefficient in the weak form, implying that investors and portfolio managers can earn an abnormal return by actively beating the markets using technical analysis. Despite the inefficiency, SME stock markets in Hong Kong and Singapore exhibit tendencies towards efficiency during the sample period. These tendencies are observed to align well with growing market capitalisation and liquidity and several institutional reforms in operational efficiency. This finding can facilitate policymakers in making institutional reforms and policies to further develop SME stock markets in Hong Kong and Singapore and improve their efficiency. In contrast, the markets in Thailand and Malaysia do not show tendencies towards efficiency despite their market development and operational efficiency reforms. This is possibly attributable to the prolonged political instability since 2011 in the two countries.

The results also indicated the presence of stationary long memory properties in return and volatility of SME stock markets in Hong Kong and Thailand, while those in Singapore and Malaysia show stationary long memory in volatility only. The presence of stationary long memory properties in the markets is highly pertinent to investors and portfolio managers in creating active trading strategies and investment portfolios. On the other hand, the long memory properties decreased in magnitude and/or statistical significance as thin trading, structural breaks, and inflation are taken into account. In some instances, long memory in return is effectively reduced to a short memory. Therefore, failure to account for these factors would overestimate the corresponding true values. Additionally, compared to the markets in Hong Kong and Singapore, the markets in Thailand and Malaysia may serve as a good hedge for portfolio risk management during market recessions, due to their smaller degree of volatility persistence. The findings of dual long memory components in SME stock markets give assistance to investors in making an effective hedging strategy wherein dual long memory components should be integrated into hedging model in order to estimate the optimal hedge ratio for these markets.

Finally, while this study investigated the evolution of SME stock market efficiency and rationalised the evolving efficiency by various factors such as market development indicators, institutional reforms, and political events, it was not intended to assess the statistical impact of these factors on the evolving efficiency. Further work is therefore required in this area. Moreover, since SME stock markets are currently functioning without government intervention, it is worthwhile to explore the potential effect of government intervention on the evolving efficiency of these markets.

Thesis Structure



Chapter Four: Dynamic Return and Volatility Transmissions between Main Stock Markets and SME Stock Markets

Abstract

The previous chapter examined the evolving efficiency and joint effects of thin trading, structural breaks, and inflation on dual long memory in SME stock markets of Hong Kong, Singapore, Thailand and Malaysia. This chapter reports on the findings from Study 2 of this thesis that investigated the dynamic return and asymmetric volatility transmissions between the main stock markets and SME stock markets in the four countries. The dynamic transmissions were also examined under the joint impacts of volatility breaks, thin trading, and trading volume. A linear State-Space AR model with Kalman filter was adopted and a standard bivariate VAR asymmetric BEKK-GARCH model was augmented. The results reveal that only Hong Kong show evidence of return transmission from SME stock market to the main stock market. Controlling for the joint effects of the three factors considerably reduces the magnitude and significance level of the return transmission and, in essence, eliminates the underlying volatility transmission. Moreover, Hong Kong's main stock market return exhibits a causal relationship and a long-run equilibrium relationship with the country's economic development. Therefore, SME stock market arguably can make an indirect contribution to economic development in Hong Kong via its return transmission across the main stock market.

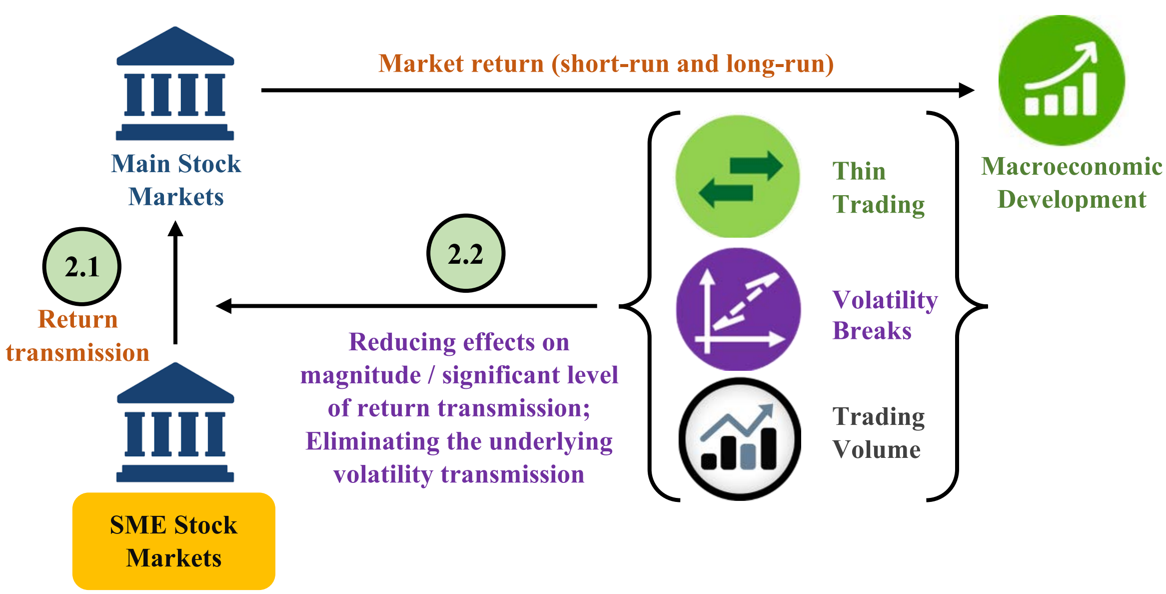


Figure 4.1: Summary of Findings from Study 2

Chapter Outline

This chapter was adapted for publication in the following refereed journal article and conference proceeding:

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Nguyen, T., Chaiechi, T., Eagle, L., and Low, D. (2020). Return and asymmetric volatility transmissions between main stock market and second-tier stock market: The case of Hong Kong. In T. Lee, L. Hock, and T. Foon (Eds.). *Finance and Economics Readings. Selected papers from Asia-Pacific Conference on Economics & Finance, 2019*. Singapore: Springer. In press.

4.1 Introduction

There exists a legal relationship between the main stock market and second-tier stock market (or SME stock market) in a country. Usually, a second-tier stock market is structured as a separate board that is legally housed under the main stock market. This is mainly due to an SME stock market being able to benefit from: (i) the reputation and credentials of the main market, which assures both securities issuers and investors, and (ii) the subsidies from the main market because it needs to maintain low costs for issuers with smaller issue sizes and lower liquidity, which translates into low listing and trading costs (Harwood & Konidaris, 2015). In exchange, the second-tier market acts as a pathway for SMEs to be listed in the main market, thereby increasing the liquidity of the main market (World Federation of Exchanges, 2015). On the other hand, the main stock market return and volatility can have positive effects on various economic development indicators in both developed and emerging countries (for instances, see Kanas and Ioannidis (2010), Forson and Janrattanagul (2014) and Guo (2015)). Putting these together, SME stock market could potentially make an indirect contribution to economic development through its return and volatility transmissions across the main stock market channel. Nonetheless, these dynamic transmissions between the two stock markets have been disregarded in the financial economics literature.

Furthermore, the transmissions of return and volatility between small and large stock markets can be affected by a number of factors such as volatility breaks (i.e. the structural changes in unconditional variance), thin trading, and trading volume. Lamoureux and Lastrapes (1990b) postulated that in the presence of volatility breaks in return series, the underlying volatility persistence can be overestimated by a standard GARCH process. Lo and MacKinlay (1990) placed emphasis on spurious autocorrelation in return series due to the issue of thin trading that occurs when stocks are traded at low volume. Gallo and Pacini (2000) showed evidence of the reducing or eliminating effect of trading volume on volatility persistence. While the body of research focused on dynamic transmissions between small- and large-cap stock portfolios is extensive, very few of the studies controlled for the effects of either volatility breaks or trading volume. Therefore, this gap in knowledge indicates the need for further examination of cross-market transmissions under the joint impacts of volatility breaks, thin trading, and trading volume. Failure to account for these factors may lead to biased estimation of cross-market transmissions.

Therefore, the study reported in this chapter was intended to explore the dynamic return and volatility transmissions between the main stock markets and SME stock markets under the joint impacts of volatility breaks, thin trading, and trading volume. Such an investigation provides further understanding about a potential indirect effect of SME stock markets to economic development via its return and volatility transmissions with the main stock markets. This understanding can assist policymakers in making policies that facilitate the development of SME stock markets since they can stimulate economic growth indirectly through the channel of main stock markets. The estimation of volatility transmission between the main stock markets and SME stock markets is also relevant to investors and portfolio managers in determining an optimal hedge ratio for a small- and large-cap stock portfolio to minimize investment risk.

Following are the two research questions that Study 2 aimed to address.

Q2.1: Are there return and volatility transmissions between main stock markets and SME stock markets?
Q2.2: What are the joint impacts of thin trading, volatility breaks, and trading volume on the return and volatility transmissions between main stock markets and SME stock markets?

This study employed the stock markets of Hong Kong, Singapore, Thailand, and Malaysia for empirical analysis due to their important roles in capital funding for the Asia region. While the stock markets of Hong Kong and Singapore are among the world's most sophisticated and well-regulated markets, those in Thailand and Malaysia are reputed for their fast-growing pace, strong liquidity, and receptivity to competition (as discussed in Chapter Two). Second-tier stock markets of the four economies have also made a substantial contribution to bridging the SME credit gap and driving the development in the tropical region (as discussed in Chapter One). Moreover, since established in the 2000s, these second-tier markets have successfully transferred 137 out of 692 listed companies (equivalent to 20%) to the main markets, thus supplying considerable liquidity to the main markets (as mentioned in Chapter Two).

4.2 Literature Review

Following the principles of Arbitrage Pricing Theory[17] (Ross, 1976), a large body of studies on the dynamic linkage between the main stock market returns and economic development has begun to emerge. For example, Lee (1992) noted that stock market returns affect the macroeconomic indicators in the US using multivariate VAR analysis. Choi, Hauser, and Kopecky (1999) and Nasseh and Strauss (2000) reported a long-run nexus between stock market returns and industrial manufacturing for G7 and six other European countries using VEC model. Mauro (2003) showed a positive correlation between output growth and stock market returns in ten advanced economies and five emerging economies, including Singapore and Thailand. Henry, Olekalns, and Thong (2004), using a panel data of 27 countries including Hong Kong and Singapore, concluded that stock market returns are most helpful in anticipating output growth during recession periods. Tang, Habibullah, and Puah (2008) documented a bidirectional Granger causality between stock market returns and real GDP in China, Hong Kong, Indonesia, Malaysia, and Thailand, as well as a long-term relationship between the two variables in China, the Philippines, Singapore and Taiwan. Liu and Sinclair (2008) reported a unidirectional causality running from stock market returns to economic growth in the short run and a reverse causality in the long run in China, Hong Kong, and Taiwan. Mahmood and Dinniah (2009) found the presence of a long-term equilibrium nexus between stock market indices and economic variables (foreign exchange rates, consumer price index, and industrial production index) in Japan, Korea, Hong Kong, and Australia. Forson and Janrattanagul (2014) also showed a long-term equilibrium nexus between the Stock Exchange of Thailand index and macroeconomic indicators (money supply, industrial production index, and consumer price index).

Since the introduction of ARCH and GARCH models, several studies have adopted a multivariate GARCH model to analyse the dynamic between the main stock market return volatility and economic development. Schwert (1989) indicated that US macroeconomic volatility can be predicted by stock market return volatility. Liljeblom and Stenius (1997) presented evidence of reciprocal spillover between stock market return volatility and macroeconomic

[17] Arbitrage Pricing Theory (APT) refers to a linear relationship between the expected stock market returns and various macroeconomic indicators which accounts for market risk or un-diversifiable risk. This is a helpful mechanism for identifying mispriced assets and formulate a value investing strategy.

volatility using the data from Finland. Caporale and Spagnolo (2003) showed that stock market return volatility has a significant influence on GDP growth volatility in both emerging economies (Thailand, Malaysia, and the Philippines) and developed economies (US, UK, and Canada). Ahn and Lee (2006) employed a bivariate VAR-GARCH process and reported that increased stock market return volatility is likely to instigate high volatility in industrial production and vice versa in the US, UK, Canada, Italy, and Japan. Kanas and Ioannidis (2010) further showed Granger causality from stock market returns to industrial output growth in a relatively low volatile stock market using the Markov switching VAR model and data from the UK. More recently, Guo (2015), who applied a non-uniform weighting two-step causality test and a multivariate GARCH process, revealed one-way causality from real economic growth to stock market returns and from the market return volatility to real economic growth in China.

As mentioned in the previous section, a SME stock market is often legally organised under the main stock market to exploit the eminence of the main market and obtain support from the main market. A main stock market is categorised as a regulated market, which is administered by national securities regulators and conforms to stricter standards for listing and disclosure. A SME stock market is classified as an Alternative Trading Platform (ATP), which is managed by the regulated market operator (management of the main stock market) and adheres to less stringent regulations. A regulated market operator is required to submit a regulatory framework for an ATP to the national securities regulators for approval. An ATP is wholly owned and regulated by the main stock market. As discussed above, the main stock market return and volatility have a significant influence on economic development. A legal relationship also exists between the main stock market and SME stock market. It is thus arguable that SME stock market could potentially make an indirect contribution to economic development through its return and volatility transmissions across the main market channel. However, these dynamic transmissions between the two markets have yet to be explored.

Stock markets often encounter sporadic structural breaks in the unconditional variance. These breaks may have been triggered by various events such as macroeconomic and political events, major changes in market sentiments, or financial crises. The presence of structural breaks in volatility has been proved to have effects on volatility clustering and volatility persistence according to several studies in the literature on financial economics. For examples, Lamoureux and Lastrapes (1990b) postulated that persistence in variance can be overestimated by a standard GARCH process if one fails to account for structural shifts in variance. Mikosch and Starica (2004) emphasised the importance of modelling the changing unconditional variance for long return series due to the fact that long return series usually have a changing volatility structure rather than a constant structure. Hillebrand (2005) provided solid evidence on the strong bias towards unity of the summations of the estimated ARCH and GARCH parameters when breaks in the unconditional volatility are neglected. Stărică and Granger (2005) contended that most of the dynamics of return series are attributed to breaks in the unconditional variance and their nonstationary unconditional model produces better forecasts than the stationary GARCH model. Ewing and Malik (2005) argued that if structural shifts in unconditional variance of one series can affect the volatility persistence in the series itself, then they may also affect the volatility persistence across two series. In addition, the presence of structural breaks in unconditional variance can give rise to volatility asymmetry and volatility clustering (Ewing & Malik, 2005).

Thin trading-induced autocorrelation in the return series, as indicated by Dimson (1979) and Lo and MacKinlay (1990), may lead to seriously biased cross transmissions of return and volatility. Despite numerous studies on the cross-market return and volatility transmissions, there are very few research studies that accounted for the effect of thin trading. For instance, Kuttu (2014) examined the effect of thin trading on return and volatility transmissions between stock markets in Ghana, Kenya, Nigeria, and South Africa. Using a thin-trading adjustment method recommended by Miller et al. (1994), this author concluded that neglect of adjusting for thin trading can lead to inconsistent and unreliable model estimation. Nonetheless, the assumption of Miller et al. (1994) of a fixed AR coefficient for thin-trading adjustment is implausible to hold in emerging markets or newly established markets because these markets are known to be highly volatile. Therefore, to adjust for thin trading while capturing the volatile feature of these markets, Harrison and Moore (2012) suggested using a state-space AR model with Kalman filter that allows for time-varying AR coefficient. Compared to other models, state-space model can identify the temporal dynamics of a system more precisely and be more flexible when modelling univariate and multivariate with structural shifts, missing data or other data abnormalities (Chukhrova & Johannssen, 2017). Kalman filter, which is a distribution-free algorithm, offers the best linear estimators in the sense that mean squared errors are minimised (Kalman, 1960). In addition, the method of adjustment for thin trading suggested by Harrison and Moore (2012) has also been adopted in recent studies on market efficiency and long memory such as Ngene et al. (2017), Abakah, Alagidede, Mensah, and Ohene-Asare (2018), and Robinson, Glean, and Moore (2018).

The volume-volatility nexus is grounded theoretically on the Mixture of Distributions Hypothesis (MDH) and the Sequential Information Arrival Hypothesis (SIAH). The MDH, which was first introduced by Clark (1973) and later modified by Andersen (1996), posits that conditional variance of return or return volatility and trading volume are ascertained simultaneously by a stream of information. This hypothesis indicates a positive concurrent linkage between these two variables, and this linkage is a function of the information stream distribution. In contrast, according to the SIAH, as suggested by Copeland (1976), new information appears in the market in a sequential random manner and is not obtained by all market participants instantaneously. The response of each market participant to new information, i.e., changing their trading positions, stands for one in a set of preliminary market equilibria. The ultimate market equilibrium is determined once all market participants have a similar set of information. The SIAH implies that given the sequential response of traders to information, return volatility can be predicted from trading volume information. Empirically, Lamoureux and Lastrapes (1990a), Gallo and Pacini (2000), and Girard and Biswas (2007) used stock market data from several developed and emerging countries and found that incorporating trading volume into the volatility model decreased or eliminated the persistence in return volatility. Recently, Chakraborty and Kakani (2016) noted that trading volume can provide endogenous dynamic information evolving together with return volatility.

There exists a substantial body of literature on return and volatility transmissions between different size stock portfolios, for examples, McQueen, Pinegar, and Thorley (1996), Harris and Pisedtasalasai (2006), Karmakar (2010), and Hung and Lin (2013). These studies revealed a unidirectional asymmetric return transmission from large-stock portfolios to small-stock portfolios and a bidirectional asymmetric volatility transmission between the two portfolios. Nevertheless, very few studies in this body of literature accounted for either volatility breaks or trading volume when examining these transmission effects. For instances, Ewing and Malik (2005) studied the small- and large-cap stock returns in the New York and American stock markets and showed that volatility breaks significantly weaken the volatility spillover and, in some instances, wipe out the spillover effects. Koulakiotis, Babalos, and Papasyriopoulos (2016) reported volatility transmissions among large-, medium-, and small-cap stocks in the Athens stock market with feedback effect after taking trading volume into account. Therefore, the joint impacts of volatility breaks, thin trading, and trading volume on return and volatility transmissions between size-based stock portfolios have largely been ignored in the literature on dynamic spillovers between small- and large-cap stocks.

Overall, two research gaps have been identified from the existing body of literature. First, dynamic return and volatility transmissions between the main stock market and SME stock market have been neglected. This gap implies a potential indirect influence of SME stock market to economic development via the main stock market channel, given the existing connection between the main stock market and economic development. Second, the joint effects of volatility breaks, thin trading, and trading volume on cross-market return and volatility transmissions have yet to be examined. As previously discussed, failure to address the effects of these factors while modelling cross-market transmissions may result in overestimated volatility persistence. Therefore, this study aims to investigate the dynamic return and asymmetric volatility transmissions between the main stock market and SME stock market while taking into account the joint effects of volatility breaks, thin trading, and trading volume to avoid biased results.

4.3 Methodology

As mentioned in the previous section, this study aims to investigate dynamic transmissions of return and asymmetric volatility between the main stock market and SME stock market under the joint impacts of volatility breaks, thin trading, and trading volume (ignoring these effects may result in overestimated volatility persistence). To test the presence of volatility breaks, the Iterated Cumulated Sum of Squares (ICSS) algorithm was used (see Chapter Three, Section 3.3.1 for detail description). To avoid the pitfall of autocorrelation instigated by thin trading, SME market return series were de-thinned using a linear state-space AR model with Kalman filter estimation. The thin trading-adjusted return series, dummy variables indicating volatility breaks, and trading volume variable were then incorporated into a standard bivariate VAR asymmetric BEKK-GARCH model to investigate the return and asymmetric volatility dynamics between the two markets. The econometric models used in this study are demonstrated in the following subsections.

4.3.1 Linear State-Space AR Model with Kalman Filter Estimation

To adjust the returns of SME stock market (R_{2t}) for thin trading, a linear state-space AR(1) model (Harvey, 1989; Hamilton, 1994; Koopman, Shephard, & Doornik, 1999) with Kalman filter estimation (Kalman & Bucy, 1961) was adopted. This model allows AR(1) coefficient to vary over time and can be expressed in the following space and state equations.

$$R_{2t} = \beta_0 + \beta_{1t}R_{2,t-1} + e_t \tag{4.1}$$

$$\beta_{1t} = \beta_{1t-1} + v_t \tag{4.2}$$

where e_t and $v_t \sim N(0, \sigma_t^2)$.

Parameter β_{1t} in Equation (4.1) represents the time-varying AR(1) coefficient. The dynamics of AR(1) coefficient was estimated using Equation (4.2) with a Kalman recursive filter. Principally, Kalman filter estimates the one-step-ahead coefficient sequentially to produce a set of β_{1t} and the corresponding standard deviations over time. In other words, Kalman filter generates a set of measurements observed through time to estimate the unknown parameter (β_{1t}). The time path of this parameter is an indicator of the time-varying thin-trading adjustment.

As suggested by Harrison and Moore (2012), to obtain de-thinned SME market returns (R_{2t}^d), the time-varying coefficient (β_{1t}) and residuals (e_t) were extracted from the above model and used to estimate the R_{2t}^d as follows:

$$R_{2t}^d = \frac{e_t}{1 - \beta_{1t}} \tag{4.3}$$

4.3.2 Bivariate VAR Asymmetric BEKK-GARCH Model

Multivariate asymmetric BEKK-GARCH model was developed by Engle and Kroner (1995) and Kroner and Ng (1998) to capture the asymmetric volatility transmission across multiple markets. The variance-covariance matrix of this model is built on the vector of innovation term (ε_{it}) of a VAR model. Suppose that $R_t = (R_{1t}, R_{2t})'$ denotes a $(2x1)$ vector of the main stock market return series and the SME stock market return series at day t, and p represents the lag order, a bivariate $VAR(p)$ model can then be stated in the following matrix:

$$\begin{pmatrix} R_{1t} \\ R_{2t} \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix} + \begin{pmatrix} \varphi_{11}^1 & \varphi_{12}^1 \\ \varphi_{21}^1 & \varphi_{22}^1 \end{pmatrix} \begin{pmatrix} R_{1,t-1} \\ R_{2,t-1} \end{pmatrix} + \cdots + \begin{pmatrix} \varphi_{11}^p & \varphi_{12}^p \\ \varphi_{21}^p & \varphi_{22}^p \end{pmatrix} \begin{pmatrix} R_{1,t-p} \\ R_{2,t-p} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix} \tag{4.4}$$

where $\mu_i (i = 1,2)$ denotes constants or drift coefficients for the return series i (where 1 and 2 stands for the main market returns and SME market returns, respectively) and $\varepsilon_{it} (i = 1,2)$ denotes the innovation term (shock) for the return series i at day t. The diagonal parameters $\varphi_{ij}^p (i = j)$ gauge the effect of return spillover within individual return series (own return spillover) whereas the off-diagonal parameters $\varphi_{ij}^p (i \neq j)$ quantify the effect of return spillover between return series (cross return spillover). The vector of error terms is then used to model a bivariate asymmetric BEKK-GARCH(1,1) process, which can be expressed as

$$H_t = C'C + A'(\varepsilon_{t-1}\varepsilon_{t-1}')A + B'H_{t-1}B + D'(\kappa_{t-1}\kappa_{t-1}')D \tag{4.5}$$

where C denotes a $(2x2)$ lower triangular matrix of constants, A denotes $(2x2)$ squared matrix of coefficients measuring the impact of past shocks on present volatility (short-run volatility spillover), B denotes $(2x2)$ squared matrix of coefficients measuring the influence of past volatility on present volatility (long-run volatility spillover), D denotes $(2x2)$ matrix of coefficients capturing the asymmetry of the conditional variance-covariance (asymmetric volatility spillover), H_{t-1} denotes a $(2x2)$ conditional variance matrix, ε_{t-1} denotes a $(2x1)$ vector of squared error terms and cross product of error terms, and κ_{t-1} denotes a $(2x1)$ vector of squared asymmetric terms and cross products of asymmetric terms.

Alternatively, a bivariate asymmetric BEKK-GARCH(1,1) model can be expanded in the following conditional variance equations, which show how past shocks and volatility are transmitted within and across the main market ($h_{11,t}$) and the SME market ($h_{22,t}$).

$$\begin{aligned} h_{11,t} = c_{11}^2 + b_{11}^2 h_{11,t-1} + 2b_{11}b_{21}h_{12,t-1} + b_{21}^2 h_{22,t-1} + a_{11}^2 \varepsilon_{1,t-1}^2 \\ + 2a_{11}a_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}^2\varepsilon_{2,t-1}^2 + \delta_{11}^2\kappa_{1,t-1}^2 + 2\delta_{11}\delta_{21}\kappa_{1,t-1}\kappa_{2,t-1} \\ + \delta_{21}^2\kappa_{2,t-1}^2 \end{aligned} \tag{4.6}$$

$$\begin{aligned} h_{22,t} = c_{21}^2 + c_{22}^2 + b_{12}^2 h_{11,t-1} + 2b_{12}b_{22}h_{12,t-1} + b_{22}^2 h_{22,t-1} + a_{12}^2 \varepsilon_{1,t-1}^2 \\ + 2a_{12}a_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{22}^2\varepsilon_{2,t-1}^2 + \delta_{12}^2\kappa_{1,t-1}^2 + 2\delta_{12}\delta_{22}\kappa_{1,t-1}\kappa_{2,t-1} \\ + \delta_{22}^2\kappa_{2,t-1}^2 \end{aligned} \tag{4.7}$$

As suggested by Kearney and Patton (2000), the standard errors of these coefficients are computed using a first-order Taylor expansion of the function around its mean, which involves the estimated variance-covariance matrix of the coefficients together with vectors of the mean and standard error. Assuming normally distributed errors, the model is estimated using the following maximum-likelihood function.

$$L(\theta) = -\frac{T}{2}\ln(2\pi) - \frac{1}{2}\sum_{t=1}^{T}(\ln|H_t| + \varepsilon_t' H_t^{-1}\varepsilon_t) \quad (4.8)$$

where T indicates the number of observations and θ indicates the vector of estimated coefficients.

4.3.3 Augmented Bivariate VAR Asymmetric BEKK-GARCH Model

To observe the joint impacts of volatility breaks, thin trading, and trading volume on the dynamic transmissions between the main stock market and SME stock market, a standard bivariate VAR asymmetric BEKK-GARCH model was augmented with these factors. As discussed in the literature review section, there were very few studies on the dynamic spillovers between large- and small-cap stocks portfolios that accounted for either volatility breaks or trading volume in the model. While Ewing and Malik (2005) introduced a set of dummies indicating volatility breaks into a bivariate BEKK-GARCH model, Koulakiotis et al. (2016) included trading volume in a trivariate VAR-EGARCH model. Putting these forward, in this study, both factors, volatility breaks and trading volume were incorporated into a bivariate VAR asymmetric BEKK-GARCH model. Accordingly, our augmented model further contributes to the existing empirical models by including both volatility breaks and trading volume in a standard bivariate VAR Asymmetric BEKK-GARCH procedure. In particular, a set of dummies for volatility breaks in each market was entered into variance equation while the aggregate trading volume of the two markets was included in both mean and variance equations. The aggregate volume series can be a better variable than individual volume series because idiosyncratic buying or selling pressure does not initiate systematic risk for market makers (Campbell et al., 1993). In addition, using a single aggregate series help accounts for a large disparity in trading volume between the main markets and the SME markets in each country (as shown in Table 2.1). This approach has been used in some of studies such as those by Gallant, Rossi, and Tauchen (1992), Hussain (2011), and Koulakiotis et al. (2016).

The augmented model was then used to fit the main market return series (R_{1t}) and the de-thinned SME market return series (R_{2t}^d). It can be written in the following mean and variance equations.

$$\begin{pmatrix} R_{1t} \\ R_{2t}^d \end{pmatrix} = \begin{pmatrix} \mu_1 \\ \mu_2 \end{pmatrix} + \begin{pmatrix} \varphi_{11}^1 & \varphi_{12}^1 \\ \varphi_{21}^1 & \varphi_{22}^1 \end{pmatrix} \begin{pmatrix} R_{1,t-1} \\ R_{2,t-1}^d \end{pmatrix} + \cdots + \begin{pmatrix} \varphi_{11}^p & \varphi_{12}^p \\ \varphi_{21}^p & \varphi_{22}^p \end{pmatrix} \begin{pmatrix} R_{1,t-p} \\ R_{2,t-p}^d \end{pmatrix} + \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{pmatrix} + \begin{pmatrix} \boldsymbol{\gamma_1} \\ \boldsymbol{\gamma_2} \end{pmatrix} \boldsymbol{ATV_t} \quad (4.9)$$

$$H_t = C'C + A'(\varepsilon_{t-1}\varepsilon_{t-1}')A + B'H_{t-1}B + D'(\kappa_{t-1}\kappa_{t-1}')D + \sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \boldsymbol{V_i'(X_iX_i')V_i} + \boldsymbol{T'ATV_tT} \quad (4.10)$$

where $\gamma_i (i = 1,2)$ quantifies the impact of aggregate trading volume on the return spillover in return series i, ATV_t denotes the aggregate trading volume of the main market and the SME market at day t, T denotes $(2x2)$ lower triangular matrix of parameters measuring the effect of aggregate trading volume on the conditional variance of return series i, V_i is a $(2x2)$ lower triangular matrix of parameters measuring the effect of volatility breaks on the conditional variance of return series i, X_i is a $(1x2)$ vector of dummies for volatility breaks in return series i, if the series is subjected to a volatility break at time t, X_i will take a value of 0 before time t and a value of 1 from time t onwards, n is the number of breakpoints detected in variance, all other variables and parameters were described in Section 4.3.2.

4.4 Data Sources and Characteristics

Data used in this study were daily index closing prices and trading volumes of the main stock markets and SME stock markets in Hong Kong, Singapore, Thailand, and Malaysia. The corresponding main markets and SME markets are represented by the following pairs of indices: (i) Hong Kong Hang Seng Composite Index (HSI) and S&P/HKEX GEM Index, (ii) FTSE Strait Times All-Share Index (FSTAS) and FTSE Strait Times CATALIST Index, Stock Exchange of Thailand Index (SETI) and MAI Index, and FTSE Bursa Malaysia EMAS Index (FBMEMAS) and FTSE Bursa Malaysia ACE Index. The datasets were downloaded from the Bloomberg Database from 01/07/2009 to 30/12/2016 and then filtered for valid trading days (because there exist several non-trading days which duplicate the values of the previous trading day in the raw series), yielding 1,832-1,884 observations. The sample period started from the launch of the ACE market, which replaced the former MESDAQ in Malaysia. The data were analysed using RATS9.2 and Eviews10, which are among the most prevalent statistical packages for time series analysis and econometrics.

The daily price series of the main markets (P_{1t}) and SME markets (P_{2t}) were transformed into daily logarithmic return series as, $R_{1t} = ln\left(P_{1t}/P_{1,t-1}\right)$ and $R_{2t} = ln\left(P_{2t}/P_{2,t-1}\right)$, where P_t and P_{t-1} denote the index closing prices on day t and $t-1$. The daily trading volume series of the main markets and SME markets were rescaled and combined into one single aggregate trading volume series (ATV_t) for each country.

Table A1.1 in Appendix 1 presents the characteristics of the returns and trading volumes of the main markets and SME markets in Hong Kong, Singapore, Thailand, and Malaysia. Compared to Thailand and Malaysia, Hong Kong and Singapore experienced negative mean returns but higher standard deviations in the SME markets, suggesting no risk and return trade-off in these markets. Hong Kong and Singapore also exhibited lower mean returns in the main markets than those in Thailand and Malaysia. All return series, except for the R_t^S in Hong Kong, had fatter tails and longer left tails compared to the Gaussian distribution due to negative skewness. In contrast, all trading volume series were highly positively skewed, indicating that they have fatter tails and much longer right tails than the Gaussian distribution. The substantial kurtosis indicated that all return and volume series were leptokurtic and had a sharp peak. The Jarque and Bera (1980) statistics further confirmed that all return and volume series were non-Gaussian distributed. The significant Ljung and Box (1979) Q and Q^2 statistics up to lag 10 and 20 indicated the presence of autocorrelation in the mean and variance of all return and volume series. The Engle (1982) ARCH statistics up to lag 5 and 10 provided evidence of conditional heteroscedasticity in all return and volume series, suggesting that these series should be fit by a model that accommodates the ARCH/ GARCH processes.

4.5 Findings and Discussion

Before modelling the return and volatility transmissions between the main stock markets and SME stock markets in Hong Kong, Singapore, Thailand, and Malaysia, all return and aggregate trading volume series were tested for stationarity to avoid spurious regression (see Table A1.2 in Appendix 1). Tests of the asymmetric return volatility and cross-correlations of the returns and residuals were performed to determine the appropriate mean and variance models that might be a good fit for the data. The presence of structural breaks in volatility of the return series was also tested to identify whether a set of dummy variables representing volatility breaks should be included in the model. The tests results are presented in the following subsections.

4.5.1 Asymmetric Return Volatility

To test the presence of asymmetric return volatility, the size and sign bias tests introduced by Engle and Ng (1993) were applied. Table 4.1 displays the asymmetric test statistics for the return series of the main markets and SME markets in Hong Kong, Singapore, Thailand, and Malaysia. These results showed that in Hong Kong, the GEM exhibited both size bias and sign bias (negative and positive) in return volatility, whereas the HKEX exposed only positive sign bias in return volatility. In Singapore, there was no size bias in return volatility of the SGX and CATALIST, but there existed positive sign bias in the SGX return volatility and negative sign bias in the CATALIST return volatility. In Thailand, the SET and MAI only experienced positive sign bias in return volatility. In Malaysia, the BM return volatility had size bias whereas the ACE return volatility showed negative sign bias. Although the evidence of the individual size and sign bias in return volatility was inconsistent between the main markets and SME markets in the four countries, the joint test of size and sign bias for all market returns was highly significant, indicating the presence of asymmetric return volatility. These results suggest that an asymmetric volatility model might fit the return series of the two markets in all countries.

Table 4.1: Asymmetric Tests for Return Series

	Hong Kong		Singapore		Thailand		Malaysia	
	R_{1t}	R_{2t}	R_{1t}	R_{2t}	R_{1t}	R_{2t}	R_{1t}	R_{2t}
Size bias (t-test)	0.03	2.37**	0.94	0.68	0.30	0.11	2.68*	1.16
Negative sign bias (t-test)	0.63	5.40*	0.97	2.35**	1.10	0.42	0.24	1.38***
Positive sign bias (t-test)	2.16**	1.84***	1.71***	0.81	3.30*	2.16**	0.18	0.75
Joint effect (F-test)	10.37**	33.51*	15.72*	6.21**	20.30*	8.47**	17.68*	2.50**

*, **, *** indicate the test statistic is significant at 1%, 5% and 10%, respectively; R_{1t} and R_{2t} denote daily returns of the main market and SME market, respectively.

4.5.2 Cross-Correlations of Returns and Residuals

Following the procedure proposed by Conrad, Gultekin, and Kaul (1991), the first-order lagged cross-correlation matrices of returns and residuals between the main markets and SME markets in Hong Kong, Singapore, Thailand, and Malaysia were generated from a VAR(1) process (see Table 4.2). As shown in Panel A, the absolute values of the first lagged cross-correlations between the previous day's return on the main market ($R_{1,t-1}$) and the current day's return on the SME market (R_{2t}) were 5.6% (for Hong Kong), 10.6% (for Singapore), 11.2% (for Thailand), and 11.3% (for Malaysia). Meanwhile, the absolute cross-correlations between the previous day's return on the SME market ($R_{2,t-1}$) and the current day's return on the main market (R_{1t}) were only 3.3% (for Hong Kong), 0.5% (for Singapore), 4.1% (for Thailand), and 1.2% (for Malaysia). These results indicate the presence of an asymmetric cross-correlation of returns, which is important because variations in the returns of each individual market may exert a different asymmetric influence on the cross-market correlation of returns. In addition, the return cross-correlations between the two markets in Singapore and Thailand were positive while those in Hong Kong and Malaysia were negative.

Table 4.2: Cross-Correlations of Returns and Residuals

	Hong Kong		Singapore		Thailand		Malaysia	
Panel A: Return cross-correlations	R_{1t}	R_{2t}	R_{1t}	R_{2t}	R_{1t}	R_{2t}	R_{1t}	R_{2t}
$R_{1,t-1}$	-0.008	-0.056	0.062	0.106	0.063	0.112	0.114	-0.113
$R_{2,t-1}$	0.033	0.168	-0.005	-0.186	-0.041	0.018	0.012	0.100
Panel B: Residual cross-correlations	ε_{1t}	ε_{2t}	ε_{1t}	ε_{2t}	ε_{1t}	ε_{2t}	ε_{1t}	ε_{2t}
$\varepsilon_{1,t-1}$	-0.001	-0.001	-0.002	-0.006	0.000	0.005	-0.011	-0.034
$\varepsilon_{2,t-1}$	-0.005	-0.003	0.003	-0.003	-0.001	-0.007	0.003	0.007

Notes: R_{1t} and R_{2t} denote daily returns of the main market and SME market, respectively; ε_{1t} and ε_{2t} denote residuals from estimates of VAR(1) process for daily returns of the main market and SME market, respectively.

Panel B reports the first lagged cross-correlations of the residuals of the model, in which the returns of the main market and SME market follow a VAR(1) process. The results showed that the asymmetry of residuals between the two markets was reduced dramatically in all four countries. For examples, in Hong Kong, approximately 0.5% of variation in the residual of VAR(1) model for the HKEX return can be explained by that of the GEM lagged return, and 0.1% of variation in the residual of VAR(1) model for the GEM return can be explained by that of the HKEX lagged return. Accordingly, the above results suggest that a VAR process that incorporates asymmetric features might be a good fit for the returns of the main markets and SME markets in Hong Kong, Singapore, Thailand, and Malaysia.

4.5.3 Detected Structural Breaks in Volatility

The presence of volatility breaks in the return series of the main market and SME market was tested using the procedure of the ICSS algorithm. The results are reported in Table 4.3 below. One should note that the reported regimes include periods that have breakpoint and no breakpoint as well, making up the whole sample period (01/07/2009 – 30/12/2016).

Table 4.3: Structural Breaks in Volatility

Market	Breakpoint	Corresponding event	Break regime	SD
HSI			02/07/2009 - 26/11/2009	0.0158
Hong Kong	27/11/2009	Dubai debt standstill due to a massive renovation	27/11/2009 - 18/08/2010	0.0126
		projects and the Great Recession	19/08/2010 - 21/09/2011	0.0122
	22/09/2011	The US Federal Reserve's Operation Twist failed	22/09/2011 - 18/02/2014	0.0122
		to calm financial markets after the crash in August	19/02/2014 - 30/12/2016	0.0115
GEM			02/07/2009 - 10/11/2010	0.0132
Hong Kong	11/11/2010	Chinese Central Bank announced an increase in the	11/11/2010 - 08/07/2015	0.0133
		monetary policy rate	09/07/2015 - 21/08/2015	0.0562
	24/08/2015	Black Monday of Chinese stock market	24/08/2015 - 13/06/2016	0.0167
			14/06/2016 - 30/12/2016	0.0095
FSTAS			01/07/2009 - 14/08/2009	0.0138
Singapore	16/08/2009	Singapore's Prime Minister announced "the worst	17/08/2009 - 29/08/2014	0.0080
		is over for Singapore economy"	01/09/2014 - 30/12/2016	0.0074
CATALIST			01/07/2009 - 25/09/2009	0.0209
Singapore	28/09/2009	Singapore's unemployment rate peaked at 3.3%	28/09/2009 - 24/06/2016	0.0147
		since September 2003 (4.8%)	27/06/2016 - 30/12/2016	0.0089
SET			02/07/2009 - 07/04/2010	0.0150
Thailand	07/04/2010	Thai Prime Minister ordered a state of emergency	08/04/2010 - 14/12/2015	0.0109
			15/12/2015 - 30/12/2016	0.0113
MAI			02/07/2009 - 05/04/2010	0.0094
Thailand	07/04/2010	Thai Prime Minister ordered a state of emergency	07/04/2010 - 16/08/2013	0.0124
			19/08/2013 - 30/12/2016	0.0131
FBMEMAS			01/07/2009 - 26/09/2011	0.0061
Malaysia	27/09/2011	Asian and European stock markets opened lower in	27/09/2011 - 02/08/2012	0.0060
		response to the ongoing sovereign debt crisis in EU	03/08/2012 - 20/01/2016	0.0058
	21/01/2016	Central Bank of Malaysia retained the overnight	21/01/2016 - 07/04/2016	0.0060
		policy rate at 3.25%, meeting the market expectation	08/04/2016 - 30/12/2016	0.0043
ACE			01/07/2009 - 12/09/2012	0.0112
Malaysia	13/09/2012	S&P warned to cut Malaysia's sovereign credit	13/09/2012 - 12/12/2014	0.0115
		rating	15/12/2014 - 26/08/2015	0.0173
	27/08/2015	Malaysian government declared the Bersih rallies	27/08/2015 - 28/03/2016	0.0119
		illegal	29/03/2016 - 30/12/2016	0.0088

Notes: The usual 5% level of significance was used to detect volatility breaks in the return series; SD denotes standard deviation for each break regime.

The results show different volatility breakpoints in the two markets' return series in Hong Kong, Singapore, and Malaysia. In Thailand, there was one common volatility breakpoint in both return series because a critical event would instigate volatility break in different markets simultaneously. The detected breakpoints appear to correspond to major political, macroeconomic and financial events.

4.5.4 Modelling Return and Volatility Transmissions

Following preliminary analysis, a bivariate VAR asymmetric BEKK-GARCH model was used to model the dynamic transmissions of return and asymmetric volatility between the main markets and SME markets in Hong Kong, Singapore, Thailand, and Malaysia. As mentioned before, the presence of volatility breaks can reduce or even remove volatility spillover effects, thin trading can induce spurious autocorrelation in the return series, and trading volume can affect the price movements and the pattern of volatility clustering. Ignoring these factors would most likely lead to biased estimation of dynamic return and volatility transmissions. Therefore, the joint impacts of volatility breaks, thin trading (a characteristic of SME markets), and aggregate trading volume (of the main markets and SME markets) on the return and asymmetric volatility dynamics were accounted for using the augmented bivariate VAR asymmetric BEKK-GARCH model.

To begin with, the optimal lag lengths in the mean model (VAR) and variance model (Asymmetric BEKK-GARCH) were selected based on the following three criteria: minimum AIC value, parsimonious model, and the convergence of coefficient estimation. Accordingly, in the VAR model, lag 2 was selected for Hong Kong and Malaysia whereas lag 3 was chosen for Singapore and Thailand. In the Asymmetric BEKK-GARCH model, order 1 was selected for both ARCH and GARCH terms for all four countries. Since this study was intended to explore a dynamic relationship between the main market and SME market, the statistical significance, sign, and size of coefficients for the mean, conditional variance, covariance, and squared error terms which represent direct and indirect cross-market transmissions were on the focus in the subsequent analysis. Table 4.4 to Table 4.6 report the model estimations for Hong Kong, Singapore, and Thailand in the following four cases:

- Case 1: an analysis using raw return series in modelling;
- Case 2: an analysis incorporating detected volatility breaks into the model;
- Case 3: an analysis using thin trading adjusted return series and incorporating detected volatility breaks into the model;
- Case 4: an analysis using thin trading adjusted return series and incorporating detected volatility breaks and aggregate trading volume into the model.

Table 4.7 reports the model estimation for Malaysia up to Case 3 only, Case 4 was not reported because the model did not satisfy the condition of covariance stationarity and the ARCH effect persisted in the residuals (see Table 4.8).

The results indicate that in Hong Kong, there was a unidirectional return transmission from the GEM to the HKEX and its magnitude and significance level declined from 0.049 (1%) to 0.034 (5%) (equation $R_{1,t}$, coefficients of $R_{2,t-2}$) when volatility breaks, thin trading, and aggregate trading volume were included in the model. By contrast, Singapore and Thailand exhibited a reverse return transmission from the SGX and the SET to the CATALIST and the MAI, respectively, after the inclusion of the three factors. Malaysia also showed a reverse return transmission from the BM to the ACE after accounting for volatility breaks and thin trading. Interestingly, the size and/or significance level of these return transmissions increased from 0.138 (1%) to 0.146 (1%) for Singapore (equation $R_{2,t}$, coefficient of $R_{1,t-3}$), from 0.049 (5%) to 0.070 (1%) for Thailand (coefficient of $R_{1,t-1}$), and from 0.158 (1%) to 0.180 (1%) for Malaysia (coefficient of $R_{1,t-2}$). Among the countries, the return transmission from the SME market to the main market is only visible in Hong Kong mainly because the GEM is much larger in size and has higher liquidity compared to the CATALIST, MAI, and ACE (see Table 2.1). In addition, cross-market transmission effect is often attributed to hedging activities between large and small markets and the sharing of common information between these two markets as suggested by Fleming, Kirby, and Ostdiek (1998).

Turning to variance equations ($h_{11,t}$ and $h_{22,t}$), the results reveal no short- and long-run volatility spillovers and asymmetric volatility spillover between the main market and the SME market in Thailand and Malaysia. In Hong Kong, direct short-run volatility spillover from the GEM to the HKEX became insignificant after controlling for the three factors (equation $h_{11,t}$, coefficient of $\varepsilon^2_{2,t-1}$), making cross-market volatility dynamics invisible in Hong Kong as well. However, in Singapore, while there was no short- and long-run volatility spillovers between the two markets, the asymmetric volatility spillover from the SGX to the CATALIST was getting stronger in significance level and larger in magnitude from 0.070 (10%) to 0.108 (5%) (equation $h_{11,t}$, coefficient of $\varepsilon^2_{2,t-1}$). This asymmetric volatility transmission implies that volatility in the CATALIST responding to a negative shock in the SGX is higher than that responding to a positive shock in the SGX. The presence of an asymmetric response in volatility of the small-cap stocks in the CATALIST may have been due to the infamous 2013 penny stock manipulation in the SGX that wiped out S$8 billion (US$5.8 billion) in less than two days of trade.

Table 4.4: Augmented Bivariate VAR Asymmetric BEKK-GARCH Model Estimation for Hong Kong

Case 1: Raw return series											
R_{1t}	=	-5E-06	+ $0.021R_{1,t-1}$	+ $0.01R_{2,t-1}$	− $0.036R_{1,t-2}$	+ $0.049R_{2,t-2}$					
		(-0.03)	(1.00)	(0.45)	(-1.65)***	(2.59)*					
R_{2t}	=	-0.0004	+ $0.025R_{1,t-1}$	+ $0.067R_{2,t-1}$	− $0.004R_{1,t-2}$	+ $0.058R_{2,t-2}$					
		(-1.51)	(1.34)	(3.11)*	(-0.23)	(2.25)**					
$h_{11,t}$	=	3E-06	+ $0.939h_{11,t-1}$	− $0.014h_{12,t-1}$	+ 5E-05$h_{22,t-1}$	+ $0.001\varepsilon^2_{1,t-1}$	+ $0.003\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+ $0.003\varepsilon^2_{2,t-1}$	+ $0.076\kappa^2_{1,t-1}$	− $0.0002\kappa_{1,t-1}\kappa_{2,t-1}$	+ 2E-07$\kappa^2_{2,t-1}$
		(3.13)*	(75.99)*	(-0.33)	(0.82)	(0.28)	(0.09)	(1.75)***	(3.60)*	(-0.02)	(0.01)
$h_{22,t}$	=	6E-06	+ 4E-06$h_{11,t-1}$	+ $0.004h_{12,t-1}$	+ $0.809h_{22,t-1}$	+ $0.004\varepsilon^2_{1,t-1}$	− $0.041\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+ $0.120\varepsilon^2_{2,t-1}$	+ $0.013\kappa^2_{1,t-1}$	+ $0.055\kappa_{1,t-1}\kappa_{2,t-1}$	+ $0.055\kappa^2_{2,t-1}$
		(1.68)***	(0.05)	(0.08)	(19.05)*	(0.44)	(-0.51)	(4.67)*	(0.48)	(0.30)	(1.10)
Case 2: Volatility breaks in volatility incorporated											
R_{1t}	=	1.5E-05	+ $0.019R_{1,t-1}$	+ $0.010R_{2,t-1}$	− $0.037R_{1,t-2}$	+ $0.047R_{2,t-2}$					
		(0.07)	(1.12)	(0.70)	(-1.87)***	(3.62)*					
R_{2t}	=	-0.0004	+ $0.024R_{1,t-1}$	+ $0.065R_{2,t-1}$	− $0.005R_{1,t-2}$	+ $0.057R_{2,t-2}$					
		(-1.28)	(1.31)	(3.90)*	(-0.43)	(3.00)*					
$h_{11,t}$	=	4E-06	+ $0.944h_{11,t-1}$	− $0.019h_{12,t-1}$	+ 1E-04$h_{22,t-1}$	+ $0.0004\varepsilon^2_{1,t-1}$	+ $0.002\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+ $0.004\varepsilon^2_{2,t-1}$	+ $0.072\kappa^2_{1,t-1}$	+ $0.002\kappa_{1,t-1}\kappa_{2,t-1}$	+ 9E-06$\kappa^2_{2,t-1}$
		(3.23)*	(76.49)*	(-0.27)	(1.19)	(0.19)	(0.09)	(2.16)**	(2.88)*	(0.06)	(0.09)
$h_{22,t}$	=	1E-05	+ $0.0001h_{11,t-1}$	+ $0.018h_{12,t-1}$	+ $0.789h_{22,t-1}$	+ $0.006\varepsilon^2_{1,t-1}$	− $0.054\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+ $0.127\varepsilon^2_{2,t-1}$	+ $0.008\kappa^2_{1,t-1}$	+ $0.046\kappa_{1,t-1}\kappa_{2,t-1}$	+ $0.066\kappa^2_{2,t-1}$
		(1.85)***	(0.21)	(0.20)	(18.38)*	(0.43)	(-0.34)	(4.64)*	(0.24)	(0.26)	(1.08)
Case 3: Volatility breaks in volatility incorporated and Thin trading adjusted											
R_{1t}	=	3.5E-06	+ $0.019R_{1,t-1}$	+ $0.009R_{2,t-1}$	− $0.036R_{1,t-2}$	+ $0.040R_{2,t-2}$					
		(0.02)	(0.86)	(0.76)	(-1.87)***	(2.56)*					
R_{2t}	=	-0.0002	+ $0.028R_{1,t-1}$	− $0.079R_{2,t-1}$	− $0.003R_{1,t-2}$	+ $0.040R_{2,t-2}$					
		(-0.58)	(0.99)	(-3.56)*	(0.99)	(1.62)					
$h_{11,t}$	=	4E-06	+ $0.944h_{11,t-1}$	− $0.016h_{12,t-1}$	+ 7E-05$h_{22,t-1}$	+ $0.0005\varepsilon^2_{1,t-1}$	+ $0.002\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+ $0.003\varepsilon^2_{2,t-1}$	+ $0.072\kappa^2_{1,t-1}$	+ $0.001\kappa_{1,t-1}\kappa_{2,t-1}$	+ 2E-06$\kappa^2_{2,t-1}$
		(2.82)*	(71.79)*	(-0.19)	(0.88)	(0.27)	(0.07)	(2.47)**	(2.90)*	(0.04)	(0.06)
$h_{22,t}$	=	1.5E-05	+ $0.0002h_{11,t-1}$	+ $0.021h_{12,t-1}$	+ $0.789h_{22,t-1}$	+ $0.007\varepsilon^2_{1,t-1}$	− $0.061\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+ $0.127\varepsilon^2_{2,t-1}$	+ $0.010\kappa^2_{1,t-1}$	+ $0.052\kappa_{1,t-1}\kappa_{2,t-1}$	+ $0.065\kappa^2_{2,t-1}$
		(1.72)***	(0.20)	(0.18)	(15.81)*	(0.45)	(-0.36)	(4.25)*	(0.25)	(0.26)	(1.11)
Case 4: Volatility breaks in volatility and Aggregate trading volume incorporated and Thin trading adjusted											
R_{1t}	=	0.001	+ $0.020R_{1,t-1}$	+ $0.006R_{2,t-1}$	− $0.027R_{1,t-2}$	+ $0.034R_{2,t-2}$					
		(1.16)	(0.92)	(0.29)	(-1.31)	(2.00)**					
R_{2t}	=	0.0002	+ $0.025R_{1,t-1}$	− $0.074R_{2,t-1}$	+ $0.007R_{1,t-2}$	+ $0.031R_{2,t-2}$					
		(0.22)	(1.11)	(-2.67)*	(0.38)	(1.45)					
$h_{11,t}$	=	4.4E-07	+ $0.946h_{11,t-1}$	− $0.031h_{12,t-1}$	+ 3E-04$h_{22,t-1}$	+ $0.001\varepsilon^2_{1,t-1}$	− $0.003\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+ $0.002\varepsilon^2_{2,t-1}$	+ $0.074\kappa^2_{1,t-1}$	+ $0.015\kappa_{1,t-1}\kappa_{2,t-1}$	+ $0.001\kappa^2_{2,t-1}$
		(0.44)	(42.05)*	(-0.23)	(0.77)	(0.16)	(-0.06)	(1.55)	(2.50)**	(0.14)	(0.54)
$h_{22,t}$	=	6E-06	+ $0.002h_{11,t-1}$	+ $0.081h_{12,t-1}$	+ $0.714h_{22,t-1}$	+ $0.004\varepsilon^2_{1,t-1}$	− $0.037\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+ $0.084\varepsilon^2_{2,t-1}$	+ $0.001\kappa^2_{1,t-1}$	− $0.022\kappa_{1,t-1}\kappa_{2,t-1}$	+ $0.169\kappa^2_{2,t-1}$
		(0.41)	(0.31)	(0.31)	(5.66)*	(0.19)	(-0.30)	(3.18)*	(0.04)	(-0.11)	(1.10)

Notes: *, **, *** indicate the t-statistic is significant at 1%, 5% and 10%, respectively; R_{1t} and R_{2t} are the mean equations for the main market return series and the SME market return series, respectively; $h_{11,t}$ and $h_{22,t}$ are the conditional variance equations for the main market return series and the SME market return series, respectively. Numbers below the estimated coefficients are the corresponding t-statistics (in parentheses).

Table 4.5: Augmented Bivariate VAR Asymmetric BEKK-GARCH Model Estimation for Singapore

Case 1: Raw returns											
R_{1t}	=	-8E-05	+ $0.053R_{1,t-1}$	+ $0.0003R_{2,t-1}$	+ $0.028R_{1,t-2}$	+ $0.004R_{2,t-2}$	+ $0.058R_{1,t-3}$	− $0.010R_{2,t-3}$			
		(-0.60)	(2.51)**	(0.03)	(1.45)	(0.34)	(3.98)*	(-1.37)			
R_{2t}	=	-0.001	+ $0.042R_{1,t-1}$	− $0.078R_{2,t-1}$	+ $0.145R_{1,t-2}$	− $0.001R_{2,t-2}$	+ $0.138R_{1,t-3}$	+ $0.019R_{2,t-3}$			
		(-4.08)*	(1.35)	(-2.20)**	(3.58)*	(-0.04)	(7.60)*	(0.88)			
$h_{11,t}$	=	8.4E-07	+ $0.934h_{11,t-1}$	− $0.028h_{12,t-1}$	+ $0.0002h_{22,t-1}$	+ $0.002\varepsilon_{1,t-1}^2$	+ $0.004\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+ $0.003\varepsilon_{2,t-1}^2$	+ $0.126\kappa_{1,t-1}^2$	− $0.011\kappa_{1,t-1}\kappa_{2,t-1}$	+ $0.0002\kappa_{2,t-1}^2$
		(3.39)*	(109.08)*	(-0.40)	(1.44)	(0.40)	(0.08)	(1.97)**	(3.97)*	(-0.11)	(0.19)
$h_{22,t}$	=	2.8E-06	+ $0.0001h_{11,t-1}$	− $0.022h_{12,t-1}$	+ $0.876h_{22,t-1}$	+ $0.0002\varepsilon_{1,t-1}^2$	− $0.009\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+ $0.111\varepsilon_{2,t-1}^2$	+ $0.072\kappa_{1,t-1}^2$	− $0.014\kappa_{1,t-1}\kappa_{2,t-1}$	+ $0.001\kappa_{2,t-1}^2$
		(1.68)***	(0.64)	(-0.38)	(24.35)*	(0.60)	(-0.09)	(2.77)*	(1.59)	(-0.25)	(0.30)
Case 2: Volatility breaks incorporated											
R_{1t}	=	-7E-05	+ $0.052R_{1,t-1}$	+ $0.001R_{2,t-1}$	+ $0.027R_{1,t-2}$	+ $0.004R_{2,t-2}$	+ $0.058R_{1,t-3}$	− $0.010R_{2,t-3}$			
		(-0.51)	(2.17)**	(0.07)	(1.88)***	(0.51)	(3.53)*	(-1.45)			
R_{2t}	=	-0.001	+ $0.039R_{1,t-1}$	− $0.079R_{2,t-1}$	+ $0.145R_{1,t-2}$	− $0.002R_{2,t-2}$	+ $0.140R_{1,t-3}$	+ $0.018R_{2,t-3}$			
		(-3.25)*	(1.04)	(-1.64)	(7.65)*	(-0.09)	(3.71)*	(0.82)			
$h_{11,t}$	=	1E-06	+ $0.933h_{11,t-1}$	− $0.028h_{12,t-1}$	+ $0.0002h_{22,t-1}$	+ $0.002\varepsilon_{1,t-1}^2$	+ $0.004\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+ $0.003\varepsilon_{2,t-1}^2$	+ $0.128\kappa_{1,t-1}^2$	− $0.010\kappa_{1,t-1}\kappa_{2,t-1}$	+ $0.0002\kappa_{2,t-1}^2$
		(2.55)**	(96.42)*	(-0.34)	(1.53)	(0.41)	(0.08)	(2.14)**	(3.50)*	(-0.11)	(0.14)
$h_{22,t}$	=	3E-06	+ $0.0001h_{11,t-1}$	− $0.019h_{12,t-1}$	+ $0.873h_{22,t-1}$	+ $0.0001\varepsilon_{1,t-1}^2$	− $0.007\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+ $0.110\varepsilon_{2,t-1}^2$	+ $0.070\kappa_{1,t-1}^2$	− $0.013\kappa_{1,t-1}\kappa_{2,t-1}$	+ $0.001\kappa_{2,t-1}^2$
		(1.69)***	(0.51)	(-0.71)	(28.68)*	(0.05)	(-0.09)	(3.44)*	(1.68)***	(-0.17)	(0.31)
Case 3: Volatility breaks incorporated and Thin trading adjusted											
R_{1t}	=	-6E-05	+ $0.052R_{1,t-1}$	− $0.008R_{2,t-1}$	+ $0.029R_{1,t-2}$	− $0.002R_{2,t-2}$	+ $0.056R_{1,t-3}$	− $0.013R_{2,t-3}$			
		(-0.43)	(2.37)**	(-0.73)	(1.73)***	(-0.23)	(3.19)*	(-1.23)			
R_{2t}	=	-0.0003	+ $0.029R_{1,t-1}$	− $0.043R_{2,t-1}$	+ $0.139R_{1,t-2}$	− $0.054R_{2,t-2}$	+ $0.134R_{1,t-3}$	+ $0.011R_{2,t-3}$			
		(-1.51)	(0.91)	(-1.61)	(7.13)*	(-1.85)***	(5.01)*	(0.57)			
$h_{11,t}$	=	9E-07	+ $0.935h_{11,t-1}$	− $0.026h_{12,t-1}$	+ $0.0002h_{22,t-1}$	+ $0.002\varepsilon_{1,t-1}^2$	+ $0.004\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+ $0.002\varepsilon_{2,t-1}^2$	+ $0.136\kappa_{1,t-1}^2$	− $0.022\kappa_{1,t-1}\kappa_{2,t-1}$	+ $0.0009\kappa_{2,t-1}^2$
		(1.97)**	(62.28)*	(-0.21)	(1.20)	(0.29)	(0.07)	(1.54)	(4.42)*	(-0.17)	(0.53)
$h_{22,t}$	=	2E-06	+ $2E\text{-}05h_{11,t-1}$	− $0.008h_{12,t-1}$	+ $0.861h_{22,t-1}$	+ $0.001\varepsilon_{1,t-1}^2$	+ $0.025\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+ $0.105\varepsilon_{2,t-1}^2$	+ $0.085\kappa_{1,t-1}^2$	− $0.034\kappa_{1,t-1}\kappa_{2,t-1}$	+ $0.003\kappa_{2,t-1}^2$
		(2.08)**	(0.18)	(-0.25)	(34.64)*	(0.26)	(0.20)	(4.19)*	(1.81)***	(-0.28)	(0.74)
Case 4: Volatility breaks and Aggregate trading volume incorporated and Thin trading adjusted											
R_{1t}	=	-0.0003	+ $0.051R_{1,t-1}$	− $0.009R_{2,t-1}$	+ $0.030R_{1,t-2}$	− $0.002R_{2,t-2}$	+ $0.059R_{1,t-3}$	− $0.014R_{2,t-3}$			
		(-1.36)	(2.37)**	(-0.81)	(1.39)	(-0.20)	(3.47)*	(-1.64)			
R_{2t}	=	-0.003	+ $0.042R_{1,t-1}$	− $0.068R_{2,t-1}$	+ $0.145R_{1,t-2}$	− $0.062R_{2,t-2}$	+ $0.146R_{1,t-3}$	− $0.006R_{2,t-3}$			
		(-10.37)*	(1.38)	(-3.07)*	(3.78)*	(-1.61)	(7.33)*	(-0.30)			
$h_{11,t}$	=	6E-07	+ $0.939h_{11,t-1}$	− $0.030h_{12,t-1}$	+ $0.0002h_{22,t-1}$	+ $0.001\varepsilon_{1,t-1}^2$	+ $0.003\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+ $0.002\varepsilon_{2,t-1}^2$	+ $0.139\kappa_{1,t-1}^2$	− $0.027\kappa_{1,t-1}\kappa_{2,t-1}$	+ $0.001\kappa_{2,t-1}^2$
		(1.37)	(57.22)*	(-0.19)	(1.70)	(0.17)	(0.06)	(1.53)	(5.58)**	(-0.20)	(0.97)
$h_{22,t}$	=	1E-06	+ $2E\text{-}05h_{11,t-1}$	− $0.009h_{12,t-1}$	+ $0.860h_{22,t-1}$	+ $0.002\varepsilon_{1,t-1}^2$	+ $0.025\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+ $0.097\varepsilon_{2,t-1}^2$	+ $0.108\kappa_{1,t-1}^2$	− $0.053\kappa_{1,t-1}\kappa_{2,t-1}$	+ $0.007\kappa_{2,t-1}^2$
		(0.42)	(0.17)	(-0.17)	(30.36)*	(0.22)	(0.18)	(4.31)*	(2.40)**	(-1.58)	(0.89)

Notes: *, **, *** indicate the t-statistic is significant at 1%, 5% and 10%, respectively; R_{1t} and R_{2t} are the mean equations for the main market return series and the SME market return series, respectively; $h_{11,t}$ and $h_{22,t}$ are the conditional variance equations for the main market return series and the SME market return series, respectively. Numbers below the estimated coefficients are the corresponding t-statistics (in parentheses).

Table 4.6: Augmented Bivariate VAR Asymmetric BEKK-GARCH Model Estimation for Thailand

Case 1: Raw returns											
R_{1t}	=	0.0004	$+\ 0.014R_{1,t-1}$	$+\ 0.007R_{2,t-1}$	$+\ 0.013R_{1,t-2}$	$+\ 0.006R_{2,t-2}$	$+\ 0.034R_{1,t-3}$	$-\ 0.022R_{2,t-3}$			
		(2.27)**	(0.58)	(0.33)	(0.93)	(0.36)	(1.61)	(-1.12)			
R_{2t}	=	0.0005	$+\ 0.049R_{1,t-1}$	$+\ 0.090R_{2,t-1}$	$+\ 0.022R_{1,t-2}$	$+\ 0.038R_{2,t-2}$	$+\ 0.022R_{1,t-3}$	$+\ 0.044R_{2,t-3}$			
		(1.84)***	(1.96)**	(2.87)**	(1.17)	(2.30)**	(0.77)	(2.02)**			
$h_{11,t}$	=	3E-06	$+\ 0.917h_{11,t-1}$	$-\ 0.081h_{12,t-1}$	$+\ 0.002h_{22,t-1}$	$+\ 0.044\varepsilon_{1,t-1}^2$	$+\ 0.016\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	$+\ 0.001\varepsilon_{2,t-1}^2$	$+\ 0.099\kappa_{1,t-1}^2$	$+\ 0.030\kappa_{1,t-1}\kappa_{2,t-1}$	$+\ 0.002\kappa_{2,t-1}^2$
		(3.52)*	(32.27)*	(-0.30)	(0.85)	(1.89)***	(0.14)	(0.34)	(1.84)***	(0.21)	(0.50)
$h_{22,t}$	=	1E-05	$+\ 0.001h_{11,t-1}$	$+\ 0.051h_{12,t-1}$	$+\ 0.719h_{22,t-1}$	$+\ 0.003\varepsilon_{1,t-1}^2$	$-\ 0.028\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	$+\ 0.067\varepsilon_{2,t-1}^2$	$+\ 0.019\kappa_{1,t-1}^2$	$+\ 0.102\kappa_{1,t-1}\kappa_{2,t-1}$	$+\ 0.137\kappa_{2,t-1}^2$
		(2.22)**	(0.99)	(0.24)	(9.85)*	(0.48)	(-0.20)	(1.43)	(0.59)	(0.47)	(2.84)*
Case 2: Volatility breaks incorporated											
R_{1t}	=	0.0004	$+\ 0.016R_{1,t-1}$	$+\ 0.005R_{2,t-1}$	$+\ 0.012R_{1,t-2}$	$+\ 0.004R_{2,t-2}$	$+\ 0.036R_{1,t-3}$	$-\ 0.023R_{2,t-3}$			
		(2.13)**	(0.58)	(0.27)	(0.63)	(0.32)	(1.67)***	(-1.21)			
R_{2t}	=	0.0005	$+\ 0.054R_{1,t-1}$	$+\ 0.088R_{2,t-1}$	$+\ 0.021R_{1,t-2}$	$+\ 0.034R_{2,t-2}$	$+\ 0.024R_{1,t-3}$	$+\ 0.045R_{2,t-3}$			
		(2.07)**	(1.79)***	(3.35)*	(0.97)	(1.58)	(1.06)	(2.49)**			
$h_{11,t}$	=	4E-06	$+\ 0.913h_{11,t-1}$	$-\ 0.092h_{12,t-1}$	$+\ 0.002h_{22,t-1}$	$+\ 0.039\varepsilon_{1,t-1}^2$	$+\ 0.017\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	$+\ 0.002\varepsilon_{2,t-1}^2$	$+\ 0.126\kappa_{1,t-1}^2$	$+\ 0.021\kappa_{1,t-1}\kappa_{2,t-1}$	$+\ 0.0009\kappa_{2,t-1}^2$
		(2.54)**	(25.34)*	(-0.32)	(0.68)	(1.92)***	(0.14)	(0.39)	(2.07)**	(0.18)	(0.30)
$h_{22,t}$	=	1E-05	$+\ 0.001h_{11,t-1}$	$+\ 0.062h_{12,t-1}$	$+\ 0.685h_{22,t-1}$	$+\ 0.004\varepsilon_{1,t-1}^2$	$-\ 0.032\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	$+\ 0.063\varepsilon_{2,t-1}^2$	$+\ 0.032\kappa_{1,t-1}^2$	$+\ 0.130\kappa_{1,t-1}\kappa_{2,t-1}$	$+\ 0.133\kappa_{2,t-1}^2$
		(1.41)	(1.21)	(0.27)	(8.72)*	(0.59)	(-0.20)	(1.41)	(0.74)	(0.50)	(3.07)*
Case 3: Volatility breaks incorporated and Thin trading adjusted											
R_{1t}	=	0.0004	$+\ 0.016R_{1,t-1}$	$+\ 0.007R_{2,t-1}$	$+\ 0.011R_{1,t-2}$	$+\ 0.004R_{2,t-2}$	$+\ 0.032R_{1,t-3}$	$-\ 0.019R_{2,t-3}$			
		(1.87)***	(0.74)	(0.40)	(0.73)	(0.32)	(1.27)	(-0.95)			
R_{2t}	=	-0.0001	$+\ 0.064R_{1,t-1}$	$+\ 0.019R_{2,t-1}$	$+\ 0.023R_{1,t-2}$	$+\ 0.033R_{2,t-2}$	$+\ 0.017R_{1,t-3}$	$+\ 0.053R_{2,t-3}$			
		(0.24)	(3.03)*	(0.98)	(1.38)	(1.49)	(0.55)	(2.47)**			
$h_{11,t}$	=	4E-06	$+\ 0.908h_{11,t-1}$	$-\ 0.081h_{12,t-1}$	$+\ 0.002h_{22,t-1}$	$+\ 0.041\varepsilon_{1,t-1}^2$	$+\ 0.014\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	$+\ 0.001\varepsilon_{2,t-1}^2$	$+\ 0.125\kappa_{1,t-1}^2$	$+\ 0.022\kappa_{1,t-1}\kappa_{2,t-1}$	$+\ 0.001\kappa_{2,t-1}^2$
		(2.86)*	(31.57)*	(-0.30)	(0.82)	(1.93)	(0.14)	(0.37)	(2.16)**	(0.19)	(0.39)
$h_{22,t}$	=	1E-05	$+\ 0.001h_{11,t-1}$	$+\ 0.058h_{12,t-1}$	$+\ 0.683h_{22,t-1}$	$+\ 0.002\varepsilon_{1,t-1}^2$	$-\ 0.025\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	$+\ 0.062\varepsilon_{2,t-1}^2$	$+\ 0.031\kappa_{1,t-1}^2$	$+\ 0.136\kappa_{1,t-1}\kappa_{2,t-1}$	$+\ 0.149\kappa_{2,t-1}^2$
		(1.61)	(1.04)	(0.27)	(9.64)*	(0.43)	(-0.21)	(1.49)*	(0.65)	(0.50)	(3.54)*
Case 4: Volatility breaks and Aggregate trading volume incorporated and Thin trading adjusted											
R_{1t}	=	0.001	$+\ 0.029R_{1,t-1}$	$-\ 0.003R_{2,t-1}$	$+\ 0.008R_{1,t-2}$	$+\ 0.010R_{2,t-2}$	$+\ 0.031R_{1,t-3}$	$-\ 0.007R_{2,t-3}$			
		(2.40)**	(1.40)	(-0.19)	(0.42)	(0.56)	(1.82)***	(-0.33)			
R_{2t}	=	0.0003	$+\ 0.070R_{1,t-1}$	$+\ 0.002R_{2,t-1}$	$+\ 0.022R_{1,t-2}$	$+\ 0.040R_{2,t-2}$	$+\ 0.003R_{1,t-3}$	$+\ 0.081R_{2,t-3}$			
		(0.73)	(3.82)*	(0.10)	(0.71)	(1.40)	(0.11)*	(3.66)*			
$h_{11,t}$	=	4E-06	$+\ 0.900h_{11,t-1}$	$-\ 0.107h_{12,t-1}$	$+\ 0.003h_{22,t-1}$	$+\ 0.055\varepsilon_{1,t-1}^2$	$-\ 0.061\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	$+\ 0.017\varepsilon_{2,t-1}^2$	$+\ 0.169\kappa_{1,t-1}^2$	$+\ 0.048\kappa_{1,t-1}\kappa_{2,t-1}$	$+\ 0.003\kappa_{2,t-1}^2$
		(2.10)**	(28.17)*	(-0.37)	(1.14)	(2.75)*	(-0.32)	(0.97)	(3.44)*	(0.24)	(0.64)
$h_{22,t}$	=	6E-06	$+\ 0.002h_{11,t-1}$	$+\ 0.062h_{12,t-1}$	$+\ 0.626h_{22,t-1}$	$+\ 0.004\varepsilon_{1,t-1}^2$	$-\ 0.017\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	$+\ 0.017\varepsilon_{2,t-1}^2$	$+\ 0.046\kappa_{1,t-1}^2$	$+\ 0.181\kappa_{1,t-1}\kappa_{2,t-1}$	$+\ 0.177\kappa_{2,t-1}^2$
		(2.18)**	(0.83)	(0.30)	(11.71)*	(0.35)	(-0.14)	(0.43)	(1.38)	(0.52)	(3.43)*

Notes: *, **, *** indicate the t-statistic is significant at 1%, 5% and 10%, respectively; R_{1t} and R_{2t} are the mean equations for the main market return series and the SME market return series, respectively; $h_{11,t}$ and $h_{22,t}$ are the conditional variance equations for the main market return series and the SME market return series, respectively. Numbers below the estimated coefficients are the corresponding t-statistics (in parentheses).

Table 4.7: Augmented Bivariate VAR Asymmetric BEKK-GARCH Model Estimation for Malaysia

Case 1: Raw returns																					
R_{1t}	=	0.0001	+	$0.121R_{1,t-1}$	+	$0.009R_{2,t-1}$	+	$0.074R_{1,t-2}$	−	$0.006R_{2,t-2}$											
		(1.17)		(6.93)*		(0.82)		(3.15)*		(-0.38)											
R_{2t}	=	-1E-04	−	$0.070R_{1,t-1}$	+	$0.079R_{2,t-1}$	+	$0.158R_{1,t-2}$	+	$0.026R_{2,t-2}$											
		(-0.39)		(-1.61)		(3.75)*		(3.69)*		(1.12)											
$h_{11,t}$	=	1E-06	+	$0.903h_{11,t-1}$	−	$0.045h_{12,t-1}$	+	$0.001h_{22,t-1}$	+	$0.011\varepsilon_{1,t-1}^2$	+	$0.012\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+	$0.003\varepsilon_{2,t-1}^2$	+	$0.141\kappa_{1,t-1}^2$	−	$0.005\kappa_{1,t-1}\kappa_{2,t-1}$	+	4E-05$\kappa_{2,t-1}^2$
		(3.38)*		(39.78)*		(-0.27)		(0.75)		(0.71)		(0.16)		(1.40)		(2.23)**		(-0.10)		(0.11)
$h_{22,t}$	=	9E-06	+	$0.0003h_{11,t-1}$	−	$0.031h_{12,t-1}$	+	$0.781h_{22,t-1}$	+	$0.001\varepsilon_{1,t-1}^2$	−	$0.021\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+	$0.138\varepsilon_{2,t-1}^2$	+	$0.201\kappa_{1,t-1}^2$	+	$0.045\kappa_{1,t-1}\kappa_{2,t-1}$	+	$0.002\kappa_{2,t-1}^2$
		(1.55)		(0.20)		(-0.19)		(9.94)*		(0.19)		(-0.17)		(4.02)*		(1.63)		(0.37)		(0.25)
Case 2: Volatility breaks incorporated																					
R_{1t}	=	0.0001	+	$0.121R_{1,t-1}$	+	$0.009R_{2,t-1}$	+	$0.075R_{1,t-2}$	−	$0.006R_{2,t-2}$											
		(1.30)		(6.46)		(1.01)		(3.10)*		(-0.48)											
R_{2t}	=	-0.0001	−	$0.072R_{1,t-1}$	+	$0.080R_{2,t-1}$	+	$0.160R_{1,t-2}$	+	$0.026R_{2,t-2}$											
		(-0.46)		(-1.84)		(4.40)*		(3.89)*		(1.38)											
$h_{11,t}$	=	1E-06	+	$0.910h_{11,t-1}$	−	$0.045h_{12,t-1}$	+	$0.001h_{22,t-1}$	+	$0.008\varepsilon_{1,t-1}^2$	+	$0.011\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+	$0.004\varepsilon_{2,t-1}^2$	+	$0.141\kappa_{1,t-1}^2$	−	$0.006\kappa_{1,t-1}\kappa_{2,t-1}$	+	$0.0001\kappa_{2,t-1}^2$
		(4.46)*		(43.15)*		(-0.27)		(0.87)		(0.44)		(0.12)		(1.17)		(1.80)***		(-0.10)		(0.15)
$h_{22,t}$	=	9E-06	+	$0.0002h_{11,t-1}$	−	$0.025h_{12,t-1}$	+	$0.784h_{22,t-1}$	+	$0.001\varepsilon_{1,t-1}^2$	−	$0.022\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+	$0.135\varepsilon_{2,t-1}^2$	+	$0.200\kappa_{1,t-1}^2$	+	$0.045\kappa_{1,t-1}\kappa_{2,t-1}$	+	$0.003\kappa_{2,t-1}^2$
		(1.57)		(0.16)		(-0.17)		(10.00)*		(0.16)		(-0.16)		(3.40)*		(1.64)		(0.45)		(0.31)
Case 3: Volatility breaks incorporated and Thin trading adjusted																					
R_{1t}	=	0.0001	+	$0.125R_{1,t-1}$	+	$0.007R_{2,t-1}$	+	$0.073R_{1,t-2}$	−	$0.004R_{2,t-2}$											
		(1.15)		(6.21)*		(0.93)		(2.62)**		(-0.35)											
R_{2t}	=	-0.0003	−	$0.063R_{1,t-1}$	−	$0.004R_{2,t-1}$	+	$0.180R_{1,t-2}$	+	$0.016R_{2,t-2}$											
		(-0.99)		(-1.41)		(-0.19)		(6.02)*		(0.75)											
$h_{11,t}$	=	1E-06	+	$0.915h_{11,t-1}$	−	$0.042h_{12,t-1}$	+	$0.0005h_{22,t-1}$	+	$0.005\varepsilon_{1,t-1}^2$	+	$0.008\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+	$0.003\varepsilon_{2,t-1}^2$	+	$0.132\kappa_{1,t-1}^2$	+	$0.002\kappa_{1,t-1}\kappa_{2,t-1}$	+	1E-05$\kappa_{2,t-1}^2$
		(4.73)*		(32.50)*		(-0.24)		(0.69)		(0.22)		(0.10)		(0.81)		(1.53)		(0.07)		(0.05)
$h_{22,t}$	=	1E-05	+	2E-05$h_{11,t-1}$	−	$0.008h_{12,t-1}$	+	$0.775h_{22,t-1}$	+	$0.003\varepsilon_{1,t-1}^2$	−	$0.041\varepsilon_{1,t-1}\varepsilon_{2,t-1}$	+	$0.146\varepsilon_{2,t-1}^2$	+	$0.212\kappa_{1,t-1}^2$	+	$0.071\kappa_{1,t-1}\kappa_{2,t-1}$	+	$0.006\kappa_{2,t-1}^2$
		(1.45)		(0.05)		(-0.09)		(10.82)*		(0.24)		(-0.24)		(4.06)*		(1.31)		(0.38)		(0.41)

Notes: *, **, *** indicate the t-statistic is significant at 1%, 5% and 10%, respectively; R_{1t} and R_{2t} are the mean equations for the main market return series and the SME market return series, respectively; $h_{11,t}$ and $h_{22,t}$ are the conditional variance equations for the main market return series and the SME market return series, respectively. Numbers below the estimated coefficients are the corresponding t-statistics (in parentheses). Case 4 (analysis using thin trading adjusted return series and incorporating detected volatility breaks and aggregate trading volume into the model) is not reported because the model did not satisfy the condition of covariance stationarity and the ARCH effect in the residuals persists (see Table 4.8).

Post-estimation diagnostics for Hong Kong, Singapore, Thailand, and Malaysia are shown in Table 4.8. The results reveal that multivariate portmanteau statistics of Ljung-Box test (M-Q) and Engle ARCH test (M-ARCH) up to lag 10 and 20 were insignificant in Case 4 for Hong Kong, Singapore, and Thailand. This indicates the absence of serial correlation and heteroscedasticity in the residuals after incorporating volatility shifts, thin trading, and aggregate trading volume into the model. Covariance stationarity of the models for those three countries are also ensured because the summation of ($\alpha_{ii}^2 + \beta_{ii}^2$) were all less than unity (α_{ii} and β_{ii} are diagonal elements of the A and B matrices of the model). The models were thus well-specified for Hong Kong, Singapore, and Thailand. For Malaysia, the model specification is valid in Cases 1 to 3 because the residuals contained no serial correlation and satisfied the condition of covariance stationarity; the ARCH effect in the residuals also dissipated when the test was performed up to lag 20. The model estimation for Malaysia was thus reported up to Case 3 as in Table 4.7.

Table 4.8: Augmented Bivariate VAR Asymmetric BEKK-GARCH Model Diagnostics

Country	Case	M-Q(10)	M-Q(20)	M-ARCH(10)	M-ARCH(20)	$\alpha_{11}^2 + \beta_{11}^2$	$\alpha_{22}^2 + \beta_{22}^2$
Hong Kong	1	41.14	91.42	133.73*	210.21***	0.94	0.93
	2	45.06	94.83	131.35*	202.34	0.94	0.92
	3	45.39	95.43	131.68*	202.52	0.94	0.92
	4	42.82	87.87	104.46	172.45	0.95	0.80
Singapore	1	42.04	70.48	70.81	185.13	0.94	0.99
	2	42.65	71.77	70.38	186.68	0.93	0.98
	3	45.64	72.57	77.90	186.21	0.94	0.97
	4	43.41	71.94	76.85	184.22	0.94	0.96
Thailand	1	41.69	82.74	61.18	106.05	0.96	0.79
	2	39.78	80.94	64.34	108.41	0.95	0.75
	3	41.38	81.91	63.80	108.87	0.95	0.74
	4	36.25	76.13	67.90	111.34	0.96	0.64
Malaysia	1	39.69	77.54	131.37*	202.75	0.91	0.92
	2	39.93	77.65	132.26*	203.23	0.92	0.92
	3	41.49	79.28	132.12*	200.89	0.92	0.92
	4	46.90	86.76	162.85*	258.33*	1.06	0.25

*, *** indicate the test statistic is significant at 1% and 10%, respectively; Case 1 refers to analysis using raw return series in modelling; Case 2 refers to analysis incorporating detected volatility breaks into the model; Case 3 refers to analysis using thin trading adjusted return series and incorporating detected volatility breaks into the model; Case 4 refers to analysis using thin trading adjusted return series and incorporating detected volatility breaks and aggregate trading volume into the model; M-Q(q) is multivariate statistics of the Ljung-Box test for serial correlation up to lag q in the residuals; M-ARCH(q) is multivariate statistics of the Engle ARCH test for conditional heteroscedasticity up to lag q in the residuals; α_{ii} and β_{ii} are diagonal elements of the A and B matrices of the model.

Thus far, the study found that SME stock market can exert influence on the main stock market through the effect of return transmission and this influence is visible in the case of Hong

Kong only. As previously discussed in the literature review section, a causal relationship and a long-run equilibrium relationship exist between the main market return and economic development in Hong Kong. To ensure the existence of these relationships in Hong Kong during the studied period, Pairwise Granger Causality test and Johansen Cointegration Rank test were performed. A set of different macroeconomic indicators including GDP growth (YG), growth of physical capital stock (KG), productivity growth (PG), and wage growth (WG)[18] were used as the proxies for economic development. The results of Pairwise Granger Causality test, as reported in Table 4.9, show a one-way causality running from the main market return to each of the four economic development indicators in Hong Kong. The results of Johansen Cointegration Rank test (see Table 4.10) also provide evidence that the pairs of variables are cointegrated, implying the presence of a long-run equilibrium nexus between the main market return and economic development in Hong Kong.

Table 4.9: Pairwise Granger Causality Test for Hong Kong

Null Hypothesis	Observation (monthly)	F-Statistic	Causal relation
RM does not Granger Cause YG	75	1.98**	RM → YG
YG does not Granger Cause RM		0.52	
RM does not Granger Cause KG	74	2.14**	RM → KG
KG does not Granger Cause RM		0.63	
RM does not Granger Cause PG	75	1.83***	RM → PG
PG does not Granger Cause RM		0.77	
RM does not Granger Cause WG	88	2.85***	RM → WG
WG does not Granger Cause RM		1.95	

, * indicate the test statistic is significant at 5% and 10%, respectively; RM is the main market return; YG is nominal GDP growth; KG is the growth of physical capital stock; PG is productivity growth; WG is wage growth.

Table 4.10: Johansen Cointegration Rank Test for Hong Kong

Hypothesised No. of Cointegration Equation(s)	RM – YG		RM – KG		RM – PG		RM – WG	
	Trace Statistic	Max-Eigen Statistic	Trace Statistic	Max-Eigen Statistic	Trace Statistic	Max-Eigen Statistic	Trace Statistic	Max-Eigen Statistic
None	34.59*	25.61*	28.92*	24.73*	46.37*	27.39*	42.43*	26.12*
At most 1	8.98*	8.98*	4.19**	4.19**	18.98*	18.98*	16.31*	16.31*

*, ** indicate the test statistic is significant at 1% and 5%, respectively; RM is the main market return; YG is nominal GDP growth; KG is the growth of physical capital stock; PG is productivity growth; WG is wage growth. Both Trace test and Max-eigenvalue test indicate 2 cointegrating equations at 5% level.

[18] Productivity is measured by dividing nominal GDP by labour force. The data were obtained from various issues of Hong Kong Census and Statistics Department, International Financial Statistics (IFS-IMF), World Bank Database (WDI), for the period of 2009:Q2 to 2016:Q4. Quarterly data were adjusted for seasonality and then converted into monthly data using Eviews10 interpolation techniques, where appropriate, quadratic with sum or average matched to the source data.

Overall, only Hong Kong exhibits a return transmission from the SME market (the GEM) to the main market. Moreover, the main market return also exposes a causal relationship and a long-run relationship with the economic development of Hong Kong. Therefore, it can be inferred that the GEM can contribute indirectly to Hong Kong's economic development via the main market channel. This inference is related only to Hong Kong and it can be justified by the fact that the GEM's market capitalisation accounts for a significant 12.6% of Hong Kong's GDP while the ratios for the CATALIST, MAI, and ACE are very modest, ranging from 0.8% to 3.0% of GDP (see Table 2.1). Accordingly, any policies that facilitate the development of the GEM would indirectly promote long-term economic stimulation in Hong Kong through its return transmission mechanisms with the main market.

Furthermore, the estimation of cross-market volatility transmissions has a crucial implication for investors and portfolio manager in minimising the risk of a small- and large-capitalisation stock portfolio. Kroner and Sultan (1993) asserted that the risk of such a portfolio can be minimised should investors short $\$\beta$ of the large-cap stock portfolio that is $1 long in the small-cap stock portfolio. Accordingly, the "risk minimising hedge ratio" β^* is defined as

$$\beta_t^* = \left|\frac{h_{12,t}}{h_{22,t}}\right| \tag{4.11}$$

Table 4.11 presents the estimated risk minimising hedge ratio β^* for Hong Kong, Singapore, Thailand, and Malaysia using our augmented bivariate VAR asymmetric BEKK-GARCH model. The hedging ratio can be interpreted, for example in the case of Hong Kong, as follows: to hedge a long position of $100 in a small-cap stock portfolio, investors should hold a short position of $11.3 in a large-cap stock portfolio.

Table 4.11: Risk Minimising Hedge Ratio

	Hong Kong	Singapore	Thailand	Malaysia
β^*	0.113	0.010	0.099	0.010

Additionally, the estimation of cross-market return and volatility transmissions also benefit several applications in finance which depend on the forecasts of these dynamic relationships such as value-at-risk, options and derivatives pricing.

Table 4.12: Summary of Study 2 - Dynamic Return and Volatility Transmissions between Main Stock Markets and SME Stock Markets

Research Questions	Findings	Implications / Contributions
Q2.1: Are there return and volatility transmissions between main stock markets and SME stock markets?	Hong Kong shows return transmission from SME stock market to the main stock market while Singapore, Thailand and Malaysia show the reverse transmission. Only Singapore exhibits volatility transmission from the main stock market to SME stock market. SME stock market in Hong Kong can make indirect contribution to the country's economic development through return transmission with the main market channel.	*For policymakers:* The indirect contribution of SME stock market in Hong Kong to economic development can support policymakers in making policies that facilitate the development of SME stock market in the country. *For investors and portfolio managers:* The estimation of cross-market return and volatility transmissions can assist investors and portfolio managers in forming hedging strategy. *For academics:* The findings contribute to the empirical literature of dynamic transmissions among stock markets.
Q2.2: What are the joint impacts of thin trading, volatility breaks, and trading volume on the return and volatility transmissions between main stock markets and SME stock markets?	Thin trading, volatility breaks, and trading volume jointly decrease (increase) the magnitude and significance level of return transmission from SME (main) stock market to the main (SME) stock market. In essence, the underlying volatility transmission is eliminated or becomes stronger in magnitude and significance level.	*For investors and portfolio managers:* Ignoring the joint impacts of thin trading, volatility breaks, and trading volume can distort the estimation of cross-market return and volatility transmissions, thus, misleading the investors and portfolio managers in formulating hedging strategy. *For academics:* This finding improves the empirical literature on cross-market transmissions by accounting for the three impact factors to avoid biased estimations. This finding also advances the existing empirical models by augmenting a standard bivariate VAR asymmetric BEKK-GARCH model with the three impact factors.

4.6 Conclusion and Future Research

This chapter reported the results of a study on the return and asymmetric volatility transmissions between the main stock markets and SME stock markets under the joint impacts of volatility breaks, thin trading, and trading volume in Hong Kong, Singapore, Thailand, and

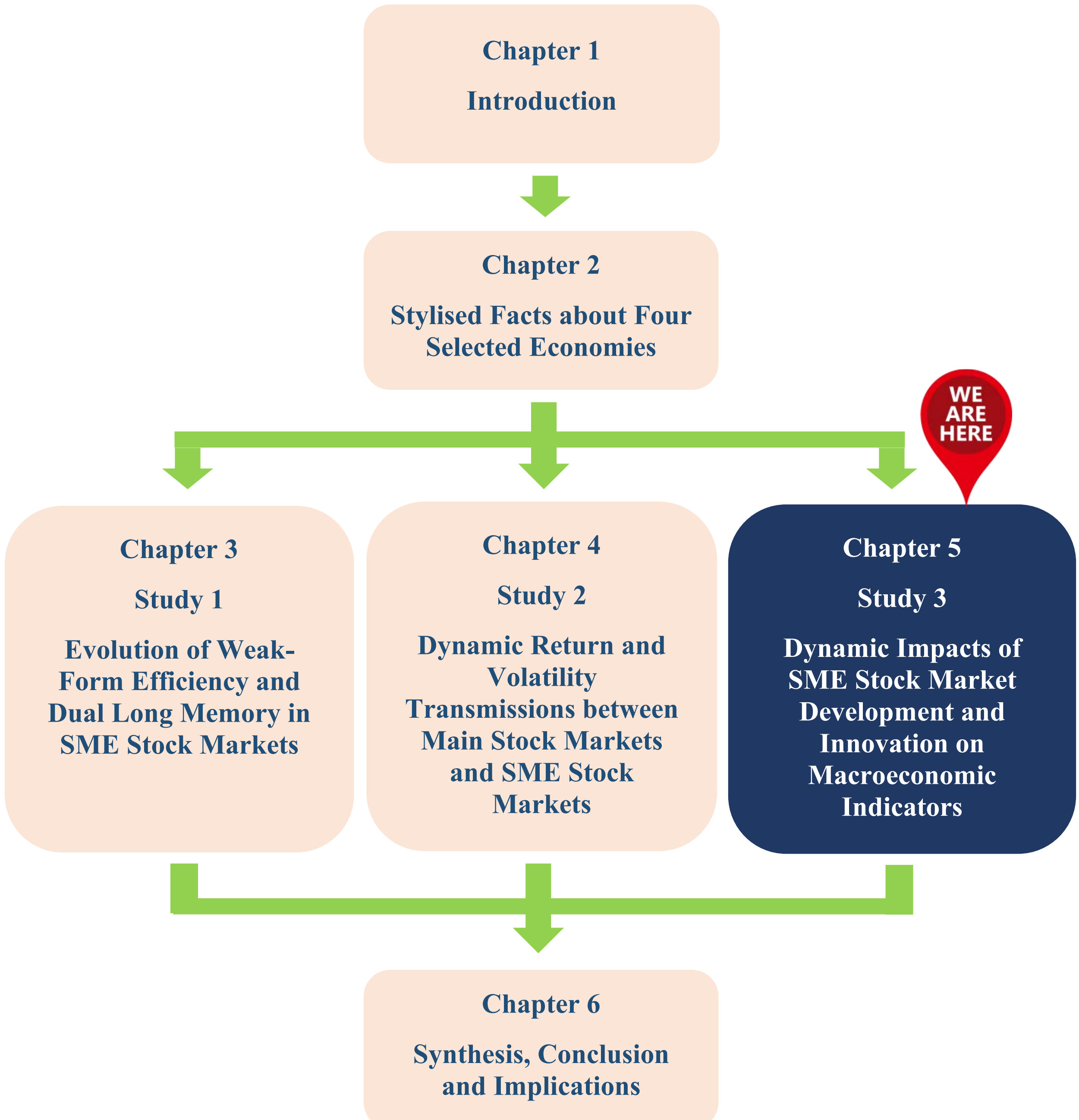
Malaysia. The study has provided a further understanding of an indirect contribution of SME stock markets to macroeconomic stimulation via the channel of main stock market. A set of time series econometrics adopted in this study was: (i) Iterated Cumulated Sum of Squares (ICSS) algorithm to identify volatility breaks (ii) linear state-space AR model with the Kalman filter to adjust for thin trading, and (iii) augmented bivariate VAR asymmetric BEKK-GARCH model to estimate the return and asymmetric volatility transmissions under the joint effects of volatility breaks, thin trading, and trading volume.

The results determined that incorporation of volatility breaks, thin trading, and trading volume in modelling cross-market return and asymmetric volatility transmissions proved to have at least one of the following consequences. First, in Hong Kong, the magnitude and significance level of unidirectional return transmission from SME stock market to the main stock market decreased. Second, however, in Singapore, Thailand, and Malaysia, the magnitude and/or significance level of return transmissions from the main stock markets to SME stock markets increased. Third, in Hong Kong, direct short-run volatility transmission from SME stock market to the main stock market dissipated. Fourth, in Singapore, asymmetric volatility transmission from the main stock market to SME stock market became stronger in significance level and larger in magnitude. Accordingly, several important consequences on return and asymmetric volatility transmissions between the main stock market and SME stock market would be hidden if one fails to consider the joint effects of volatility breaks, thin trading, and trading volume.

The results also indicated that among the studied countries, evidence of return transmission from SME stock market to the main stock market was found to be substantial in Hong Kong only. The main stock market return also exhibited a causal nexus and a long-run equilibrium nexus with economic development in Hong Kong. Consequently, it can be argued that SME stock market can make an indirect contribution to economic development in Hong Kong via its dynamic return transmission with the main stock market. Therefore, any policies that facilitate the development of SME stock market would indirectly promote long-term economic stimulation in Hong Kong through its transmission mechanisms with the main stock market. Moreover, the results of cross-market return and asymmetric volatility transmissions also have important implications for investors and portfolio managers in determining an optimal hedge ratio to minimise the risk of investing in a small- and large-capitalisation stock portfolio.

Finally, while return and asymmetric volatility transmissions between the main stock market and SME stock market were investigated in this study, liquidity transmission between the two markets is also worthwhile to explore. Future research can examine this dynamic effect using different liquidity measures such as Amihud (2002) illiquidity ratio and relative quoted bid-ask spreads. These two measures of liquidity have been proved to be effective in capturing price impact, premium for illiquidity, and spread cost over time as suggested by Goyenko and Ukhov (2009), Goyenko, Holden, and Trzcinka (2009), and Hasbrouck (2009). Moreover, unlike the main stock markets, SME stock markets in Hong Kong, Singapore, Thailand, and Malaysia are currently functioning on the principals of the classical growth theory, which casts out the government intervention. This study was not intended to explore the potential impacts of government intervention on the dynamic cross-market transmissions and the indirect contribution of the SME market to economic development, and these remain areas for future research.

Thesis Structure



Chapter Five: Dynamic Impacts of SME Stock Market Development and Innovation on Macroeconomic Indicators

Abstract

The previous chapter examined the dynamic return and asymmetric volatility transmissions between the main stock markets and SME stock markets in Hong Kong, Singapore, Thailand and Malaysia. The joint effects of volatility breaks, thin trading and trading volume were also taken into account when modelling the transmissions of return and volatility between the two markets. This chapter reports on the findings from Study 3 of this thesis that draws on the principles of Kaleckian-Post-Keynesian macroeconomic framework to explore the dynamic impacts of SME stock market development and innovation on key macroeconomic variables in the four economies. For empirical analysis, a Structural Vector Error Correction (SVEC) model and an impulse response function (IRF) were adopted. The evidence shows that SME stock market development and/or innovation have small but positive impacts on economic stimulation in the short run. The development of SME stock market promotes economic growth through the combination of the following channels: private investment, domestic savings, and productivity growth in Hong Kong, Singapore, and Thailand. Innovation, on the other hand, fosters growth through the combination of these channels and the employment channel in all four countries.

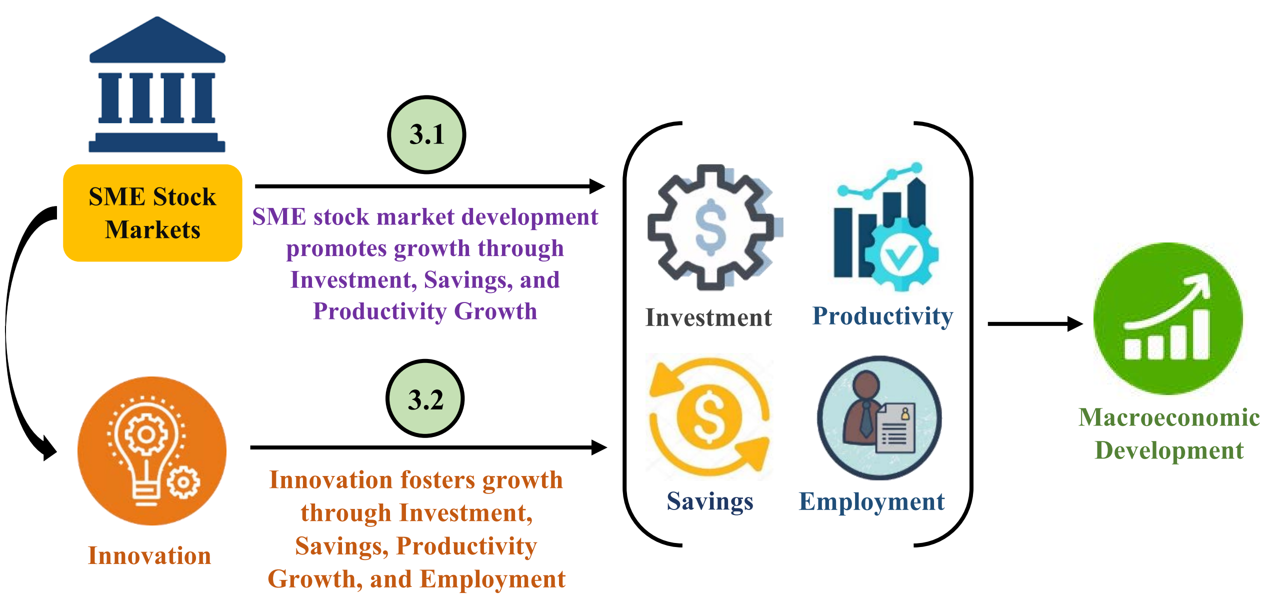


Figure 5.1: Summary of Findings from Study 3

Chapter Outline

This chapter has been adapted for publication in the following refereed conference proceeding and journal article:

Nguyen, T., Chaiechi, T., Eagle, L., and Low, D. (2020). Feedback of macro-economic indicators to shocks in second-tier stock market development and innovation within Kaleckian framework: Hong Kong Case Study. In N. Tsounis, A. Vlachvei (Eds.), *Advances in Cross-Section Data Methods in Applied Economic Research: 2019 International Conference on Applied Economics, pp. 531-552.* Springer.

Nguyen, T., Chaiechi, T., Eagle, L., and Low, D. (Under review). Dynamic impacts of SME stock market development and innovation on macroeconomic indicators: A structural VEC approach. *Economic Analysis and Policy*.

5.1 Introduction

The dynamic relationship between stock market development and economic growth has been extensively studied in both developed and emerging markets. This relationship appears to be positive in the countries that have market-based financial systems such as Hong Kong, Singapore, Thailand and Malaysia (for examples, see Hoque and Yakob (2017), Ho (2018) and Samsi et al. (2019)). It seems, however, to be negative in the countries that have bank-based financial systems such as Saudi Arabia, Nigeria, and Bangladesh (for examples, see Owusu (2016), Banerjee et al. (2017) and Rehman (2018)). On the other hand, this finance-growth relationship was tested using the main stock markets only, whereas SME stock markets, which, as noted earlier in Chapter One, Section 1.1, are recognised as an important constituent of SME financing ecosystem and are increasingly set up around the world, have been overlooked. This may have been due to SME stock markets being smaller in respect of market value and transaction volume compared to the main stock markets. Moreover, with regard to research methodology, most of the aforementioned studies have just examined the relationship based on modelling experiments rather than grounding on a theoretical macroeconomic framework. Therefore, there are apparently two research gaps requiring attention: (i) the finance-growth nexus with a major focus on SME stock markets, and (ii) the dynamic interaction between finance and growth within a theoretical macroeconomic framework.

As discussed earlier in Chapter One, Section 1.1, SME stock market development can be seen as a major stimulus for innovation. This is because SME stock markets increasingly become an important source of finance for SMEs that may have limited access to traditional sources of finance for innovation. Ample research supports the notion that innovation has a significant effect on economic growth, for example, see Kirchhoff et al. (2007), Agénor and Neanidis (2015), and Pradhan et al. (2016). Nonetheless, alike finance-growth nexus, innovation-growth nexus has yet been examined within a systematic macroeconomic framework. Further work is, thus, required in this area. In regard to theoretical macroeconomic framework, the Kaleckian-Post-Keynesian economics is famous for its model of growth and distribution. This model theoretically presents an integrated system of behaviour functions of real sectors, including private investment, domestic savings, income distribution, productivity growth, net export, and employment. While the model has recently been augmented by Chaiechi (2012) with financial market development indicator, the role of innovation indicator in the system has yet been discovered.

Consequently, to address the identified research gaps, this study is intended to investigate the dynamic impacts of SME stock market development and innovation on macroeconomic indicators within the Kaleckian-Post-Keynesian model of growth and distribution. Such an investigation provides further knowledge about a potential contribution of SME stock market development and innovation to different channels of economic growth such as private investment, domestic savings, productivity growth, and employment. This knowledge can give assistance to policymakers in making policies that facilitate the development of SME stock markets and innovation since they could effectively boost the economy. In addition, this study further extends the Kaleckian-Post-Keynesian macro-economic model with SME stock market development and innovation indicators, thus, improving the model specification and the theoretical framework of Kaleckian-Post-Keynesian economics.

Following are the two research questions that Study 3 aimed to address.

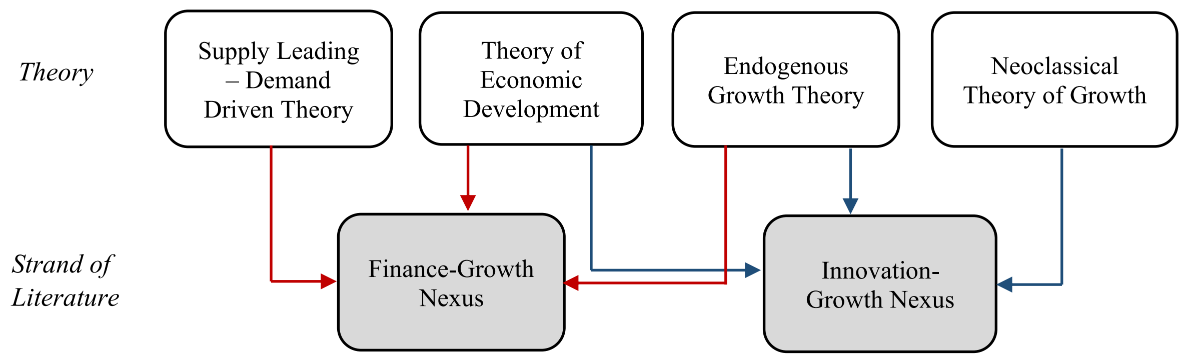
Q3.1: Are there dynamic impacts of SME stock market development on macroeconomic indicators within a Kaleckian-Post-Keynesian growth model?
Q3.2: Are there dynamic impacts of innovation on macroeconomic indicators within a Kaleckian-Post-Keynesian growth model?

For empirical analysis, Hong Kong, Singapore, Thailand, and Malaysia were utilised because they are fast-growing economies with well-developed stock markets and a high level of innovation. As noted in Chapter Two, Hong Kong and Singapore are high-income economies, while Thailand and Malaysia are identified as upper-middle-income economies. The four economies have high ratings for economic freedom and are among the key growth drivers of the Tropics (see Chapter One). Their second-tier stock markets have also made a substantial contribution to filling the credit gap for SMEs, whose businesses largely operate in innovative sectors, thereby effectively upholding innovation in the economies. Indeed, Hong Kong and Singapore were ranked eighth and thirteenth, respectively, on the 2019 Global Innovation Index. Meanwhile, Thailand and Malaysia, with continuous improvements in the past five years, were placed thirty-fifth and forty-third, respectively, in the 2019 ranking.

5.2 Literature Review

To shed light on the investigation of dynamic impacts of SME stock market development and innovation on economic growth, two different strands of literature on finance-growth nexus and innovation-growth nexus are discussed in this section. The corresponding theoretical bases are demonstrated in Figure 5.2 as below.

Figure 5.2: Theoretical Bases of Finance-Growth Nexus and Innovation-Growth Nexus



The theoretical framework relating to the finance-growth nexus can be traced back to the theory of economic development of Schumpeter (1912), who placed emphasis on the importance of financial institutions in determining productive investments. Later, McKinnon (1973) and Shaw (1973) proposed the supply-leading theory, stating that financial assets aggregation enhances economic growth, thus financial market development positively affects growth. On the other hand, Friedman and Schwartz (1963) introduced the demand-driven hypothesis in which economic growth leads to the establishment and development of financial market. Later, the finance-growth nexus is further explained by endogenous growth theory, which was introduced by Lucas (1988) and Romer (1990). Accordingly, financial development endogenously boosts economic growth through capital accumulation, which can be invested in innovation and technology and, consequently, fosters productivity and growth.

Since the financial sector is complex and multi-layered, it becomes extremely challenging to measure its growth using a single indicator, thus several studies have focused on the nexus between one specific segment of financial market and economic development. Stock market is such a segment that has captivated wide academic interests. Greenwood and Jovanovic (1990) and Jbili, Enders, and Treichel (1997) initially described the role of stock market as being to mobilise savings, distribute resources, and promote long-term economic stimulation. Pagano (1993a) proposed three key channels through which stock market development contributes to growth: (i) it increases the proportion of savings that are transmitted to investments; (ii) it may alter the savings rate and thus influence investments; and (iii) it improves the efficiency of capital allocation.

Moreover, a stock market can facilitate growth through additional channels such as liquidity provision, information dissemination, corporate governance control, and risk distribution. A stock market provides liquidity that helps investors enhance the allocation of funds and reduce the risk of losing all of their investment funds in projects that do not pay off for a long time (Bencivenga, Smith, & Starr, 1996). A stock market can reduce the cost of acquiring information by generating and disseminating corporate information to the public. Reducing the information asymmetry[19] problem thus assists investors in the decision-making process and improves the resources allocation (Levine, 2005). A stock market also controls elements of corporate governance by tying managers' compensation to the performance of the company's shares in the market. It aligns the interests of principles (investors) and agents (managers), which improving investors' confidence, thereby fostering efficient resources allocation (Jensen & Murphy, 1990). In addition, a stock market provides a mechanism allowing a transfer of risk from parties who undertake investments to parties who finance the investments, thus, such a distribution of risk can increase the saving rate and allocate resources effectively (Levine, 2005).

A large body of empirical studies on the nexus between stock market and economic development has emerged since the proposition of endogenous growth theory, but the findings remain contradictory across different countries. Several studies reported a positive relationship in the short- and long-run between stock market and growth for the countries where the stock markets are well-established such as Hong Kong, Singapore, Thailand, and Malaysia (for examples, see Hoque and Yakob (2017), Ho (2018), and Samsi et al. (2019)). Meanwhile, other studies showed negative results for the countries where the financial sectors are dominated by banks or the stock markets are relatively young such as Saudi Arabia, Nigeria, and Bangladesh (for examples, see Owusu (2016), Banerjee et al. (2017), and Rehman (2018)). Although the existing studies have

[19] Information asymmetry refers to the situation that one party to an economic transaction has more or better information than the other party. This asymmetry creates an imbalance of power in transactions.

covered both developed and emerging economies, they have just examined the main stock markets mainly because the main markets are larger in term of capitalisation and liquidity compared to the second-tier markets. Additionally, most of these studies tested the relationship without considering it in a theoretical framework.

The focus in this section is now on the literature on the interrelation between innovation and economic growth. In his theory of economic development, Schumpeter (1912) acknowledged innovation as one of the major stimuli to growth. This is because institutions, entrepreneurs, and technology changes are the cores of growth and can be influenced by government policy. According to the neoclassical theory of growth proposed by Solow (1956), technological advances typically increase the productivity of capital and thus induce further investments. As such, the resulting capital formation should be regarded as a facilitator of growth. Romer (1986, 1990) asserted that industrial innovation is the key determinant of economic development due to their direct impacts on the production process and product release procedure. Kirchhoff (1994) and Wennekers and Thurik (1999) further postulated that innovation promotes productivity and growth through motivating new business establishment, which in turn boosts the employment and outputs. Additionally, Grossman and Helpman (1994) laid stress on the important role of innovation in the endogenous growth model in which technology improvements are indispensable to pursuing a rapid and sustainable growth in the face of depletable natural resources.

The empirical works on the innovation-growth nexus, however, exhibit mixed results, which can be synthesised into the following four hypotheses. First, the supply-leading hypothesis posits that innovation upholds marginal productivity and output, thus Granger causes economic growth. Second, the demand-following hypothesis, which is the reverse of the first hypothesis, states that economic growth Granger causes innovation. Third, the feedback hypothesis implies a bidirectional causality between innovation and growth, such that innovation leads to higher growth, which in turn induces further innovation. Fourth, the neutrality hypothesis refers to the case that innovation and economic growth are not causative factors of each other. Although the innovation-growth nexus has been widely examined in the literature (for examples, see Table 5.1), it has never been examined within an integrated system of macroeconomic functions.

Table 5.1: Empirical Studies Supporting Four Hypotheses of Innovation-Growth Nexus

No.	Hypothesis	Empirical studies
1	Supply-leading hypothesis	Kirchhoff et al. (2007), Hasan and Tucci (2010), Agénor and Neanidis (2015), and Pradhan et al. (2016), Pradhan et al. (2018)
2	Demand-following hypothesis	Howells (2005), Sinha (2007), and Sadraoui, Ali, and Deguachi (2014)
3	Feedback hypothesis	Guloglu and Tekin (2012), Cetin (2013), Galindo and Méndez (2014), and Maradana, Pradhan, Dash, Gaurav, Jayakumar, and Chatterjee (2017)
4	Neutrality hypothesis	Cetin (2013)

In summary, two major knowledge gaps have been identified from the current bodies of literature. First, despite the importance of SME stock market in SMEs financing, an intensive body of literature on finance-growth nexus fails to examine the dynamic interaction between SME stock market development and macroeconomic functions. This indicates a potential contribution of SME stock market to different channels of economic growth. Second, there is a need for testing the linkage between innovation and economic growth within a general macroeconomic framework. Such an examination could provide further understanding about the impact of innovation on an integrated system of macroeconomic variables. Accordingly, this study aims to investigate the dynamic impacts of the SME stock market development and innovation on macroeconomic indicators within a Kaleckian-Post-Keynesian theoretical model of growth and distribution.

5.3 Methodology

5.3.1 Extended Kaleckian Model of Growth and Distribution

The Kaleckian model of growth and distribution, which was first proposed by Marglin and Bhaduri (1990), demonstrates the interaction between goods market and labour market. It captures both profit-led and wage-led growth regimes wherein goods market comprises behavioural functions for private investment, domestic savings, and net export. Stockhammer and Onaran (2003) and Onaran and Stockhammer (2006) later complimented the Marglin-Bhaduri model by the functions of distribution, labour productivity, and employment. Accordingly, goods market was augmented by a demand-driven labour market, the Marxian reserve army effect[20], and technological progress.

[20] Marxian reserve army effect refers to a situation that higher unemployment diminishes the bargaining power of workers and therefore stimulates higher profits.

This study extended the model by including exogenous variables of SME stock market development and innovation into the functions of accumulation, savings, productivity growth, and employment to examine their simultaneous impacts on the integrated real sectors. The extended system of equations is presented as follows:

Accumulation
$$g_t^i \equiv \frac{I_t}{K_t} = \alpha_0 + \alpha_1 z_{t-1} + \alpha_2 \pi_{t-1} - \alpha_3 r_t + \alpha_4 g x_{t-1} + \boldsymbol{\alpha_5 smd_t} + \boldsymbol{\alpha_6 inn_t} \quad (5.1)$$

Savings
$$g_t^s \equiv \frac{S_t}{K_t} = \beta_1 z_t + \beta_2 \pi_t + \beta_3 smd_t + \boldsymbol{\beta_4 inn_t} \quad (5.2)$$

Income distribution
$$\pi_t = \gamma_0 + \gamma_1 z_t + \gamma_2 u_t + \gamma_3 g x_t \quad (5.3)$$

Productivity growth
$$g x_t = \tau_0 + \tau_1 g_t^i + \tau_2 z_t + \boldsymbol{\tau_3 smd_t} + \boldsymbol{\tau_4 inn_t} \quad (5.4)$$

Net export
$$n x_t = -\delta_1 z_t + \delta_2 \pi_t \quad (5.5)$$

Unemployment
$$u_t = \lambda_0 - \lambda_1 g_t^i - \lambda_2 \Delta z_t - \lambda_3 \pi_t + \lambda_4 u_{t-1} + \lambda_5 g x_t - \boldsymbol{\lambda_6 inn_t} \quad (5.6)$$

Market equilibrium
$$g_t^i = g_t^{stotal} = g_t^s - n x_t \quad (5.7)$$

where g_t^i is the growth of capital accumulation (such that private investment I_t is normalised by physical capital stock K_t), g_t^s is domestic savings (normalised by physical capital stock), z_t is capacity utilization, π_t is profit share or income distribution, nx_t is net export (normalised by GDP), u_t is unemployment rate, gx_t is productivity growth, r_t is interest rate, smd_t is SME stock market development, and inn_t is innovation.

Equation (5.1) defines the growth of capital accumulation as a result of investment decisions of firms. Investment decisions are affected positively by the expected rate of profit, which is decomposed into the profit share and capacity utilisation, and negatively by interest rate (Kalecki, 1968; Hein, 2004). Kalecki (1968) gave emphasis to the importance of technological progress for investment, thus this factor is reflected in the investment function by a term for productivity growth. Interest rate has a strong influence on investment through its effect on mobilising internally generated funds and external sources of funds. The demand effect of investment arouses further investments while the lagged capacity effect stifles investment decisions. In addition, investment can produce sufficient savings by means of redistribution or by changing the level of capacity utilisation.

Equation (5.2) demonstrates private domestic savings function which is positively influenced by the two important components of profit rate, that is profit share and capacity utilisation. This is a plain Cambridge savings function, supposing that capitalists have a higher marginal propensity to save than workers, whose wages are to be wholly consumed for necessities. This supposition is the cornerstone of Post-Keynesian open economy theory, such that savings are subject to income distribution behaviour of workers and capitalists (Marglin, 1984; Lavoie, 1992).

Equation (5.3) presents the supply-side of the model, delineating income distribution function which is positively affected by capacity utilisation rate, unemployment rate, and productivity growth. The first element is derived from the supposition that firms establish prices based on a mark-up over unit labour cost, which changes pro-cyclically with capacity utilisation rate. The second element signifies the Marxian reserve army effect. The third element is inserted because the distributional struggle may be more about the division of productivity gains than about the output itself. Unpredicted productivity growth can have distributional effects in the short run.

Equation (5.4) postulates that the growth of labour productivity is driven by capital accumulation and capacity utilisation. Technological advancements need to be implemented through the production of new machinery and equipment, thus resulting in physical capital accumulation. This, in turn, increases the ratio of capital over labour. Furthermore, measuring labour productivity relies on the extent to which the existing machinery and equipment are placed in service, thus relating to the rate of capacity utilisation.

Equation (5.5) shows the proposition that net export is a positive function of profit share and a negative function of capacity utilisation. Domestic demand for import gives rise to the negative impact of capacity utilisation on net export. Profit share is considered as an indicator of international competitiveness since it is driven by the unit labour costs (Setterfield, 2002). In other words, a decline in domestic labour costs can be interpreted as an improvement in profit share, which can induce a decrease in export prices and hence boost export volume. Therefore, the impact of international competitiveness on net export can be captured by a positive function of profit share.

Equation (5.6) depicts the labour market where unemployment rate is identified as a function of the growth of capital stock, the change of capacity utilisation, profit share, unemployment persistence, and the growth of labour productivity. The first two elements are goods market variables, also known as standard Keynesian variables. Kalecki (1968) posits that employment depends on effective demand for output. As such, given productive capacity, employment relies on capacity utilisation which is treated as endogenous in the function of capital accumulation. The third element is considered as a non-Keynesian effect, such that if demand for labour mainly depends on wages, then profit share, which is a proxy for wages, can capture the effect of real wage per labour after accounting for labour productivity. As for the last element, if a technological advance does not align with an increase in effective demand for output, then it will engender unemployment. This is a natural consequence of any macroeconomic model with demand restriction and it is reflected in the effect of labour productivity growth.

Equation (5.7) describes the goods market equilibrium in the long run in which the capital stock is established at a certain equilibrium level where investment will be equal to savings for a normal rate of capital utilisation. In such a circumstance, investment and growth can be improved only if savings is increased or the real wage rate is decreased.

The inclusion of SME stock market development and innovation into Equations (5.1), (5.2), (5.4) and (5.6) are theoretically justified as below:

Heterodox economists contend that capital can influence final demand for output through the investment of enterprises and consumption of households (Chaiechi, 2012). Capital may also affect manufacturing firms through the acquisition of materials and recruitment of workers. Stock markets, which are one of the common types of financial intermediary, can accommodate the capital requirement for investment and production (Duménil & Lévy, 1989). Therefore, stock markets can be acknowledged as an important mechanism in fostering investment according to the fundamentals of Keynesian economics. Given the significance of SME stock markets for investment and production activities of SMEs, SME stock market development were entered into the equation of capital accumulation (Equation (5.1)).

Theoretically, stock market development increases the proportion of savings that are transformed into productive investments and thus may change the interest rate on savings (Pagano, 1993a). Stock markets can mobilise savings from individuals, firms and government by offering additional financial instruments that possibly meet their risk appetites and liquidity needs. The availability of various channels for investment may lead to the rise of savings interest rate (Levine & Zervos, 1998). Moreover, stock markets act as a mechanism for risk distribution which can increase the saving interest rate and allocate resources efficiently (Levine, 2005). In addition, stock markets connect net savers (household, individuals) and net investors (firms), thereby reducing the transaction costs related to saving mobilisation and making the savings highly liquid. Therefore, SME stock market development was included in the domestic savings function (Equation (5.2)).

Greenwood and Jovanovic (1990) placed emphasis on the functions of stock markets in improving productivity and fostering growth in the endogenous growth model. Stock markets use public offering requirements to analyse and select prospective firms and allocate funds to the most profitable projects. King and Levine (1993) postulated that stock market development promotes productivity growth through the process of directing capital into productive investments and diversifying investment risks, thereby leading to long-term economic stimulation. As pointed out by Rioja and Valev (2004), stock market development enhances the global economic growth by way of improving productivity for industrial economies and intensifying capital accumulation for developing economies. Accordingly, the equation of productivity growth (Equation (5.4)) was also augmented with the development of SME stock market.

As stated by Aghion and Howitt (1998), innovation and capital accumulation should be acknowledged as two aspects of the growth process rather than distinct causal elements. Technological innovation brings in new economic opportunities for investment in physical and human capital. Meanwhile, physical and human capitals are indispensable inputs for R&D activities and the implementation of new technologies, which are invented from innovation. Zeng (2003) later asserted that long-term economic growth is attributable to innovative technologies and physical and human capital accumulation. Therefore, theoretically, it is essential to incorporate innovation into the equation of capital accumulation (Equation (5.1)).

Aghion, Comin, Howitt, and Tecu (2016) proposed a theory of endogenous domestic savings and growth in an open economy, stating that the growth stemming from innovation allows domestic sectors to easily adopt the advanced technology. For those countries which are distant from the advanced technology, a collaboration between foreign partners who are experts in the technology and the local firms who are acquainted with local conditions is required. In such a situation, domestic savings are vital for innovation and growth since it enables the local firms to have equity stakes in the collaboration. This helps moderate the agency problem[21] that would otherwise discourage foreign partners from involvement in the collaboration. Innovation, in turn, stimulates the domestic savings for further technological collaboration that will spur long-term growth. For those countries which are close to the frontier, domestic firms have no problem of adopting the technology and thus no foreign cooperation is needed. Thus, according to the theory, innovation was entered into the equation of domestic savings (Equation (5.2)).

Innovation results in the invention of new technologies, systems, and procedures that enhance efficiency and productivity in the economy. Technological innovation is essential for the development of new leading-edge products and services, which in turn induce consumptions and growth. Huergo and Jaumandreu (2004) analysed the effect of process innovation[22] on productivity growth over different stages of development of firms and came up with a number of the following conclusions. First, process innovation leads to additional productivity growth throughout the process. Second, productivity growth rate tends to be higher in the early stage and then gradually converge to a normal average growth rate over time. And third, in the case where innovation is halted, additional productivity growth tends to continue for a number of years before the halt, however, it exhibits a below-average growth rate. Therefore, inclusion of innovation in the equation of productivity growth (Equation (5.4)) is desirable.

Theoretically, technological innovation may instigate job destruction in the short run, whereas the impact in the long run is likely to stay positive because the compensation mechanism leads to higher demand for labour. In the long run, technological innovation ultimately creates new economic opportunities for investment in human capital, thus creating more jobs and employment. Furthermore, as posited by Ugur, Churchill, and Solomon (2018), the impact of technological innovation on employment is attributable to several factors such as labour market flexibility, product market competition, types of innovation, national innovation systems, and international

[21] Agency problem is a conflict of interest which occurs when one party is expected to act in another's best interests.
[22] Process innovation refers to the implementation of a new or significantly improved manufacturing or logistic methods.

trade. Since the macroeconomic functions are considered in a system of integrated equations, the long-run impact of innovation is reflected in the unemployment function (Equation (5.6)).

5.3.2 Structural VEC (SVEC) Model Identification

To examine the dynamic effects of SME stock market development and innovation on the integrated system of macroeconomic functions, an SVEC model was used. In the model, only short-run restrictions were imposed while long-run restrictions were not due to reliability concerns. The concerns mainly derive from the problems of finite time series data[23] (Faust & Leeper, 1997), near-observational equivalence of shocks with permanent effects and shocks with persistent effects[24] (Erceg, Gust, & Guerrieri, 2005), and weak-instrumental problem[25] (Gospodinov, 2010).

To impose short-run restrictions on structural innovations of the estimated system, a lower triangular Cholesky decomposition, which orthogonalises the reduced form errors, was applied. All elements above the diagonal are restricted to be zero and the Cholesky order of lower diagonal elements are identified following a recursive structure Wold-causal chain. In such a recursive structure, the first variable is assumed to be the most endogenous and contemporaneously independent of all other variables, while the last variable should be the least endogenous and contemporaneously dependent on all other variables. The ordering of variables is essential for identifying the structural form errors, which allows the orthogonal shocks to be imposed in the impulse response function (IRF). According to the Kaleckian theory of growth and distribution, private investment is presumed to be the powerhouse for economic growth and generates effective circles of growth in domestic savings, income distribution, productivity, net export, and employment. Thus, investment is placed first in the Cholesky ordering. Since the labour market is determined endogenously by other real sectors, unemployment is therefore placed last.

Having determined the order of key macroeconomic variables, the focus moves on to exploring the dynamic responses of key macroeconomic variables to orthogonal shocks imposed

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[23] It is impossible to estimate precisely the long-run behaviour of an economic variable from a finite sample of data.
[24] In the case when the roots of VAR models are close to unity, one may encounter to unwind the shocks with permanent effects from the shocks with persistent but not permanent effect.
[25] Weak-instrumental problem refers to the situation that IRF is not consistently estimable for an I(0) time series that is parameterised as local to unity.

on the SME stock market development and innovation variables. The SME stock market development variable is followed by innovation variable because the SME stock market helps SMEs raise equity capital to implement R&D activities to enhance their technologies or intellectual properties. Initially, a set of indicators of SME stock market development and innovation was introduced into the SVEC model and block exogeneity Wald test was performed. This is to identify which indicators are endogenous to the Kaleckian model of growth and distribution. If the indicators are found to be exogenous, they will be excluded from SVEC modelling and will not be imposed shocks to examine the IRF.

The following vector presents the order of variables that are used for the subsequent analysis. One can find a couple of empirical studies in the current body of literature that may, to some extent, align with this order of variables, for examples, see Chaiechi (2012) and Chaiechi (2014).

$$Y_t = (INV_t, SAV_t, ID_t, PG_t, NX_t, UN_t, SMD_t, INN_t) = (MED_t, SMD_t, INN_t) \tag{5.8}$$

where INV_t is private investment, SAV_t is domestic savings, ID_t is income distribution, PG_t is productivity growth, NX_t is net export, UN_t is unemployment, MED_t is macroeconomic development $MED_t = (INV_t, SAV_t, ID_t, PG_t, NX_t, UN_t)$, SMD_t is SME stock market development, and INN_t is innovation.

The vector is written in an SVEC representation, which allows structural shocks to be imposed in the estimated system, as below:

$$\Delta Y_t = \Pi Y_{t-1} + \Gamma_1 \Delta Y_{t-1} + \cdots + \Gamma_{p-1} \Delta Y_{t-p+1} + B\varepsilon_t \tag{5.9}$$

where $\Pi = \alpha\beta^{\top}$ is cointegration matrix in which α is the loading matrix and β is the matrix of the coefficients of the long-run relationships; the dimension of α and β is Sxr where S is the number of variables and r is the cointegration rank or the number of cointegrating relationships between the variables; $\Gamma_i = -(I - A_1 - \cdots A_i)$ where I is integration order and A_i is SxS coefficient matrices for $i = 1, \dots, p$; $u_t = B\varepsilon_t$ and $\varepsilon_t \sim N(0, I_K)$ is the underlying structural shocks.

To exploit the information on the underlying structural shocks, the Beveridge-Nelson moving average representation of the vector Y_t is used and written as

$$Y_t = \Xi \sum_{i=1}^{t} u_i + \sum_{j=0}^{\infty} \Xi_j^* u_{t-j} + Y_0^* \tag{5.10}$$

where the first term on the right-hand side is the common trends of the system Y_t, the second term is zero order of integration and Ξ_j^* converge to 0 as $j \to \infty$, the last term is the initial values. In modelling an SVEC, the common trends are the key driver of the system Y_t since they capture the long-term effects of shocks. The matrix Ξ is of reduced rank $S - r$ and is defined as

$$\Xi = \beta_\perp \left[\alpha_\perp^\top \left(I_k - \sum_{i=1}^{p-1} \Gamma_i \right) \beta_\perp \right]^{-1} \alpha_\perp^\top \tag{5.11}$$

The contemporaneous effects of the structural innovations are determined by the matrix B whereas the long-run effects of the structural errors are captured by the matrix ΞB. For the SVEC model identification, a number of $S(S-1)/2$ restrictions are required wherein at least a number of $r(r-1)/2$ restrictions must be imposed on the short-run matrix B.

5.4 Data Sources and Variables Definition

Data used in this study are a set of indicators representing the development of macroeconomics, SME stock market, and innovation. The data were retrieved from various issues of the National Statistics Departments, International Financial Statistics (IFS-IMF), World Bank Database (WDI), and Bloomberg Database for the period of 2009:M7 to 2016:M12 for Hong Kong, Singapore, Thailand, and Malaysia. The sample period starts from the launch of the ACE market, which replaced the former MESDAQ in Malaysia. All data have been adjusted for seasonality and in the case of variables for which only quarterly or annually data are available, monthly data were generated using interpolation techniques. The techniques for frequency conversion such as quadratic with sum or average matched to the source data were applied where appropriate. The data was analysed using JMulTi4.24 and Eviews10 econometrics packages which offer comprehensive analysis for time series data. List of variables used and their definitions are shown in Table 5.2.

Table 5.2: Definition of Variables

Variable	Notation	Definition
Macroeconomic indicator	INV	*Investment* is measured by the growth of physical capital stock. Investment = [Physical Capital Stock + (1 – Capital Depreciation Rate) x Gross fixed capital formation] / Physical Capital Stock
	SAV	*Savings* is normalised by physical capital stock.
	ID	*Income Distribution* or *Profit Share* is measured following Dutt (1995) approach. Income Distribution = [1 – (Wage Rate x Labour Force / Nominal GDP)] x Capacity Utilisation | Capacity Utilisation = Nominal GDP / Physical Capital Stock
	PG	*Productivity Growth* is the growth rate of (Nominal GDP / Labour Force).
	NX	*Net Export* is the difference between export and import normalised by nominal GDP.
	UN	*Unemployment Rate*
SME stock market indicator	SCAP	*SME stock market capitalisation* is normalised by nominal GDP.
	STRA	*SME stock market traded value* is normalised by nominal GDP.
	STUR	*SME stock market turnover ratio* is measured by dividing stock market traded value by stock market capitalisation.
Innovation Indicator	PTA	*Patent applications* of residents and non-residents per thousand labours;
	TMA	*Trademark applications* of residents and non-residents per thousand labours;
	HTE	*High-technology export* is normalised by nominal GDP.

The descriptive characteristics of the 12 variables are displayed in Appendix 2, Table A2.1. Variables with positive (negative) skewness imply that their distributions have fatter tails and longer right (left) tails compared to the Gaussian distribution. Most of the variables had kurtosis greater than three, indicating leptokurtic distributions. Jarque-Bera statistics confirmed that most of the variables are non-Gaussian distributed.

5.5 Findings and Discussion

This section presents the empirical estimation of an SVEC model and an impulse response function based on the assumptions of short-run restrictions and the outcomes of cointegration and block exogeneity tests for the selected economies: Hong Kong, Singapore, Thailand, and Malaysia.

5.5.1 Stationarity

To avoid fallacies which allow shocks in the system of equations to accumulate over time, leading to permanent effects, all variables were tested for stationarity before fitting into an SVEC model. Unit root tests such as Augmented Dickey and Fuller (1981), Phillips and Perron (1988), and Ng and Perron (2001) were performed in both orders of integration I(0) and I(1). The results show that the null hypothesis of a unit root (non-stationarity) cannot be rejected for most of the variables at I(0), but it can be easily rejected for all variables at I(1) for all cases (see Appendix 2, Table A2.2 and Table A2.3). This indicates that all variables were integrated at first difference and their first order of integration should be used in subsequent analysis.

5.5.2 Lag Order Selection

Selection of appropriate lag length is an essential part of the analysis of VAR/VEC models because it eliminates any serial correlation from the residuals and avoids over-parameterisation in the system which leads to losing an important degree of freedom for estimation purposes. Lag order selection is vital not only for the estimates of autoregressive coefficients to be consistent and reliable but also for the inferences of IRF to be accurate. A symmetric lag order or a similar lag order is set up for all variables in all equations of the model. It is determined using various statistical information criteria such as LR (Sequentially Modified Likelihood Ratio), FPE (Final Prediction Error), AIC (Akaike Information Criterion), SIC (Schwarz Information Criterion), and HQ (Hannan-Quinn Information Criterion). Table 5.3 shows that three out of five criteria (LR, FPE, and AIC) consistently selected lag 4 for the cases of Hong Kong, Singapore, and Thailand and lag 3 for the case of Malaysia. Therefore, VAR/VEC models with lag 4 were established for Hong Kong, Singapore, and Thailand and that with lag 3 for Malaysia.

Table 5.3: Lag Order Selection Criteria

Lag	Hong Kong	Singapore	Thailand	Malaysia
0	SC	SC	SC, HQ	SC
1	HQ	-	-	HQ
2	-	-	-	-
3	-	HQ	-	LR, FPE, AIC
4	LR, FPE, AIC	LR, FPE, AIC	LR, FPE, AIC	-

Notes: LR is sequentially modified likelihood ratio test statistic (each test at 5% level); FPE is Final Prediction Error; AIC is Akaike Information Criterion; SIC is Schwarz Information Criterion; HQ is Hannan-Quinn Information Criterion. Numerical statistics are reported in Appendix 3, Table A3.1.

5.5.3 Cointegration Analysis

Since all macroeconomic and financial variables for four cases were stationary at I(1), cointegration relationships may exist between the variables. Cointegration relationship can be interpreted as a long-run equilibrium relationship in which variables are likely to exhibit co-movement in the long run. To test for this relationship, a VAR-based cointegration rank test was performed following the method of Johansen (1991, 1995). The method was developed to identify the number of cointegrating vectors and cointegration ranks based on maximum likelihood estimation for the coefficient matrix of a VAR model. The test also included various deterministic trend assumptions of variables (i.e. linear and quadratic).

The test results are reported in Table 5.4, showing the presence of cointegration relationships among the variables for all four cases. Thus, a VEC model that incorporates an error correction term is a good fit for the cointegrated variables. The results, as expected, confirmed our theoretical model specification which is described in Section 5.3.1. It is noted that the maximum eigenvalue statistics may identify fewer cointegrating equations than the trace statistics. This is likely due to the low power of the test when the cointegration relation is rather close to the unit circle or the non-stationary bound (Johansen & Juselius, 1990). The minimum amount of reported cointegrating equations was thus used for subsequent analysis.

Table 5.4: Identification of Johansen Cointegrating Equations

	Hong Kong		Singapore		Thailand		Malaysia	
Statistic	Trace	Max-Eigen	Trace	Max-Eigen	Trace	Max-Eigen	Trace	Max-Eigen
No. of Cointegrating Equation(s)	4	4	4	3	4	4	4	3

Notes: Trace statistic and Max-eigenvalue statistic indicate the number of cointegrating equations at the 5% level of significance. Numerical statistics are displayed in Appendix 3, Table A3.2.

5.5.4 Block Exogeneity Issue

The exogeneity issue really matters the application of SVEC model because without appropriate validation of exogeneity of the variables, the model would become too restrictive and that may mislead the dynamic relationships between the variables in the system (Huh, 2005). The Block Exogeneity Wald test was therefore performed to examine whether incorporating the indicators of SME stock market development and innovation into the model encounters the exogeneity issue.

As shown in Table 5.5, the exogeneity assumption was rejected for all macroeconomic indicators and most of the indicators of SME stock market development and innovation across the four countries. While market capitalisation, traded value, turnover ratio are endogenous variables in the cases of Hong Kong, Singapore, and Thailand, only the last two variables are endogenous in the case of Malaysia. Regarding innovation indicators, patent applications (in Singapore and Malaysia), trademark applications (in Hong Kong, Thailand, and Malaysia), and high-technology exports (in Hong Kong) are valid to be included in the system. These variables are eligible for shock imposition to analyse the impulse response function.

Table 5.5: Block Exogeneity Wald Test

		Hong Kong	Singapore	Thailand	Malaysia
Variable	Notation	Chi-sq (df = 4)	Chi-sq (df = 5)	Chi-sq (df = 5)	Chi-sq (df = 5)
Private investment	INV	68.27**	97.39*	104.77*	41.78*
Domestic savings	SAV	75.26*	182.00*	94.02*	58.80*
Income distribution	ID	61.20**	199.95*	113.68*	81.45*
Productivity growth	PG	70.27*	161.44*	88.13*	88.81*
Net exports	NX	60.95**	90.49*	155.94*	44.37*
Unemployment	UN	106.44*	128.38*	121.89*	39.51**
SME stock market capitalisation	SCAP	106.54*	120.51*	178.35*	23.32
SME stock market traded value	STRA	87.30*	152.00*	91.25*	30.97***
SME stock market turnover ratio	STUR	86.05*	149.90*	97.82*	31.33***
No. of patent applications	PTA	48.48	170.52*	42.73	53.55*
No. of trademark applications	TMA	65.69**	40.76	130.14*	60.46*
High-technology exports	HTE	59.66***	49.70	75.17	33.38

Notes: *, **, *** indicate that Chi-squared statistic is significant at 1%, 5%, and 10%, respectively; df is the degree of freedom.

5.5.5 VEC Residuals Diagnosis and Stability Condition

Following the results of cointegration analysis, lag order selection, and block exogeneity test, VEC models were established for a set of identified endogenous variables for each of the selected countries. To ensure all inferences and further estimations from the VEC models are consistent and reliable, testing for any sign of misspecification of the models is desirable. The presences of serial correlation, non-normality, and heteroscedasticity in the residuals are indications of serious model misspecification. Therefore, model residuals diagnosis were conducted and reported in Table 5.6. The results of serial correlation Lagrange Multipliers test reveal that all models have zero autocorrelation in residuals up to lag 12. The results of normality joint test and heteroscedasticity joint test show that residuals of all models are normally distributed, homoscedastic and independent with the regressors. Accordingly, given the satisfaction of the three conditions on residuals, the models used in each country are well-specified.

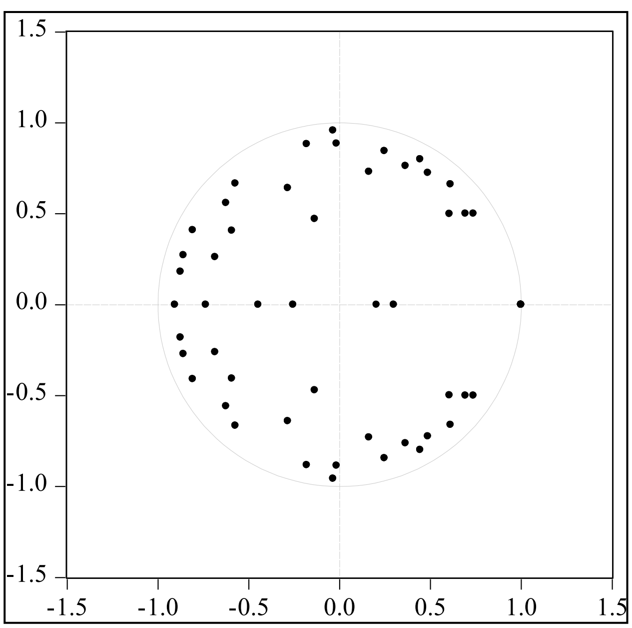
Table 5.6: VEC Residual Diagnostics

	Hong Kong		Singapore		Thailand		Malaysia	
VEC Residual Serial Correlation Lagrange Multipliers Tests								
Lag	Rao F-stat	P-value	Rao F-stat	P-value	Rao F-stat	P-value	Rao F-stat	P-value
2	0.866	0.790	1.049	0.409	0.875	0.740	76.638	0.960
4	0.879	0.764	0.955	0.589	0.935	0.627	102.049	0.424
6	0.976	0.553	1.056	0.398	0.924	0.650	91.009	0.729
8	0.861	0.798	0.785	0.881	1.226	0.169	81.492	0.912
10	0.880	0.763	1.064	0.383	0.835	0.806	101.253	0.446
12	1.176	0.180	1.054	0.400	0.933	0.632	102.396	0.415
VEC Residual Normality Tests								
Joint test:	Jarque-Bera	P-value	Jarque-Bera	P-value	Jarque-Bera	P-value	Jarque-Bera	P-value
	28.522	0.159	14.950	0.779	23.711	0.255	13.621	0.849
VEC Residual White Heteroscedasticity Tests (Levels and Squares)								
Joint test:	Chi-sq	P-value	Chi-sq	P-value	Chi-sq	P-value	Chi-sq	P-value
	4,920.86	0.352	3,642.56	0.438	3,731.34	0.537	3,796.55	0.255

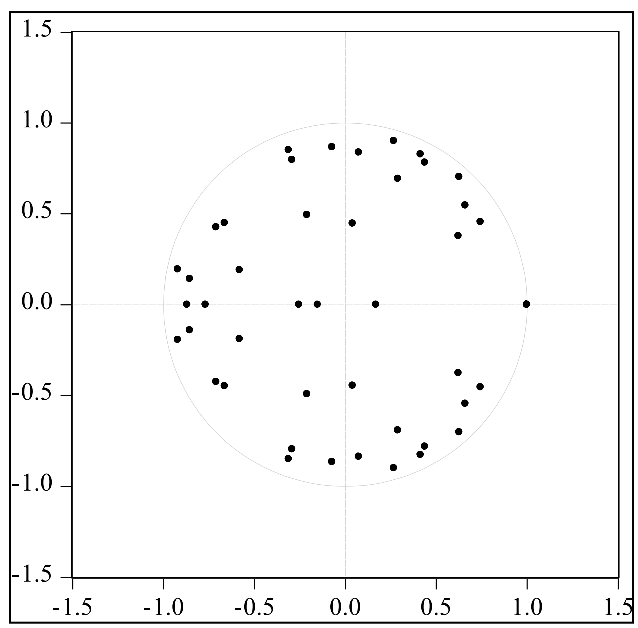
Moreover, the stability condition of VEC models was also examined using the inverse roots of autoregressive (AR) characteristic polynomial. The stability condition holds when all inverse AR roots of the VEC models lie in or on the unit circle rather than outside. As depicted in Figure 5.3, this condition was not violated in all four cases, indicating that our VEC models are covariance-stationary.

Figure 5.3: VEC stability condition – Inverse roots of AR characteristic polynomial

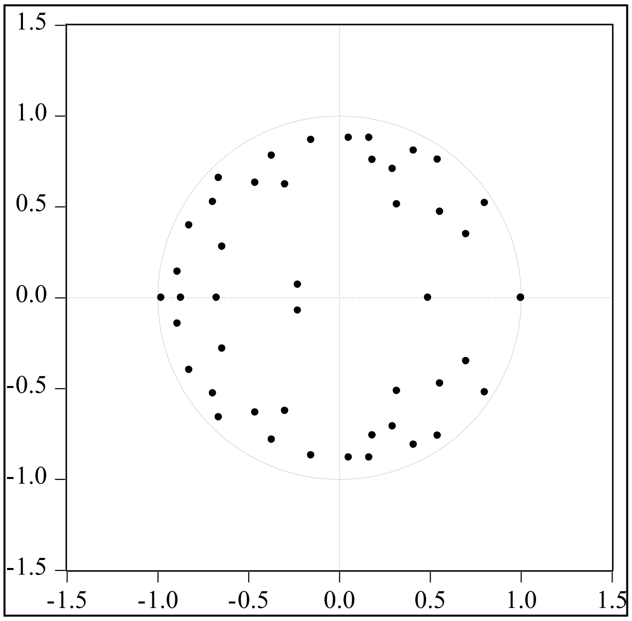
Hong Kong



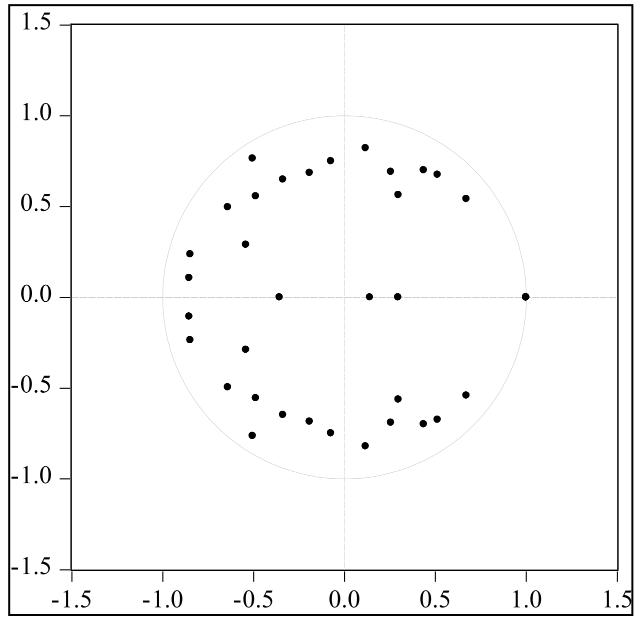
Singapore



Thailand



Malaysia



5.5.6 SVEC Matrices Estimation

Since the VEC models satisfied all conditions for white noise residuals and covariance stationarity (Section 5.5.5), SVEC models were estimated using a lower triangular Cholesky factorisation approach. Following the Cholesky ordering of variables (Section 5.3.2) and the results of block exogeneity tests (Section 5.5.4), SVEC matrices were identified for each case study wherein only endogenous variables were included in the matrices. Accordingly, the structure of the matrices appear as follows:

Hong Kong: $$\Delta Y_t = (MED_t, SCAP_t, STRA_t, STUR_t, TMA_t, HTE_t) \quad (5.12)$$

Singapore: $$\Delta Y_t = (MED_t, SCAP_t, STRA_t, STUR_t, PTA_t) \quad (5.13)$$

Thailand: $$\Delta Y_t = (MED_t, SCAP_t, STRA_t, STUR_t, TMA_t) \quad (5.14)$$

Malaysia: $$\Delta Y_t = (MED_t, STRA_t, STUR_t, PTA_t, TMA_t) \quad (5.15)$$

where $MED_t = (INV_t, SAV_t, ID_t, PG_t, NX_t, UN_t)$. All other variables were defined in Table 5.2.

The results (reported in Appendix 4) appear to align with the Kaleckian theoretical model of growth and distribution (Section 5.3.1). Specifically, investment fosters productivity growth in

Hong Kong, Singapore, and Thailand and net export in Hong Kong and Thailand. Domestic savings is positively affected by investment in all four countries as the theory predicts, such that productive investments effectively promote the mobilisation of domestic savings. Investment and unemployment are negatively related in Singapore as investment creates more job opportunities. The positive influence of investment on income distribution in Hong Kong and Singapore suggests that a higher level of investment is associated with a higher rate of profit share, implying a profit-led system of capital accumulation in the two economies.

Savings affect income distribution through the marginal propensity to save, which is higher for capitalists and lower for workers. It is observed that Hong Kong shows a positive effect while Thailand and Malaysia experience a negative effect, suggesting that the marginal propensity to save of developed/developing economies increases/decreases with the level of savings. Productivity grows together with the level of savings in Hong Kong and Singapore since the technology improvements in the countries were effectively funded by savings. In Malaysia, it seems that technological progress does not keep up with the growing demand for output, thereby instigating unemployment. The last four rows of the estimated matrices indicate contemporaneous relationships among SME stock market development, innovation, and key macroeconomic variables in all four countries.

5.5.7 SVEC Impulse Response Analysis

To explore the dynamic responses of key macroeconomic indicators to shocks in SME stock market development and innovation, shocks were only imposed on endogenous indicators of these variables (identified in Section 5.5.4). The responses of private investment, domestic savings, productivity growth, and unemployment are on the focus since the indicators of SME stock market development and innovation were included in these functions following the theoretical basis (discussed in Section 5.3.1).

Figure 5.4 to Figure 5.7 display the impulse response functions for the selected economies during 30 months ahead with Cholesky one standard deviation shocks imposed on the SVEC system. The null hypothesis that the true response is zero cannot be rejected at the specified level of significance if the confidence interval contains zero. In order words, the response is statistically significant if the zero baselines do not fall within the confidence bands. In the graphs, the grey lines signify the response of the variable to the imposition of Cholesky one standard deviation, while the red lines represent the bootstrapped 95% confidence interval of error bands. The speed of adjustment following a structural shock is measured by the number of months before the grey lines intersect with the zero baselines.

Regarding the case of Hong Kong, investment and savings are responsive to shocks in the GEM market capitalisation and trademark applications in the first 3-4 months. The feedbacks of productive growth to shocks in the GEM market turnover and trademark applications are immediately positive up to four months ahead before die out afterwards. However, productivity growth shows some delays (around four months) in response to shocks in the GEM market traded value and high-technology export and these responses last for just 1-3 months before become insignificant. Shock in trademark applications, at the same time, causes an instant decrease in unemployment, which then bounces back but quickly drops down again.

In the case of Singapore, investment is likely to react instantly to a shock in the CATALIST market traded value for two months ahead while its reaction to a shock in patent applications only begins after three months and lasts for around three months. Savings also exhibit positive feedback for 2-3 months after the shocks in the market turnover ratio and patent applications. Productivity growth immediately responds to a shock in the market capitalisation up to four months but does not respond to a shock in the market turnover ratio until the fifth month and lasts for about a quarter. The impact of a shock in patent applications on productivity growth is satisfying with an increase without any delay. As expected, a growing number of patent applications negatively affects the unemployment rate as more patent applications are filed, more job opportunities become available, thus bringing unemployment down.

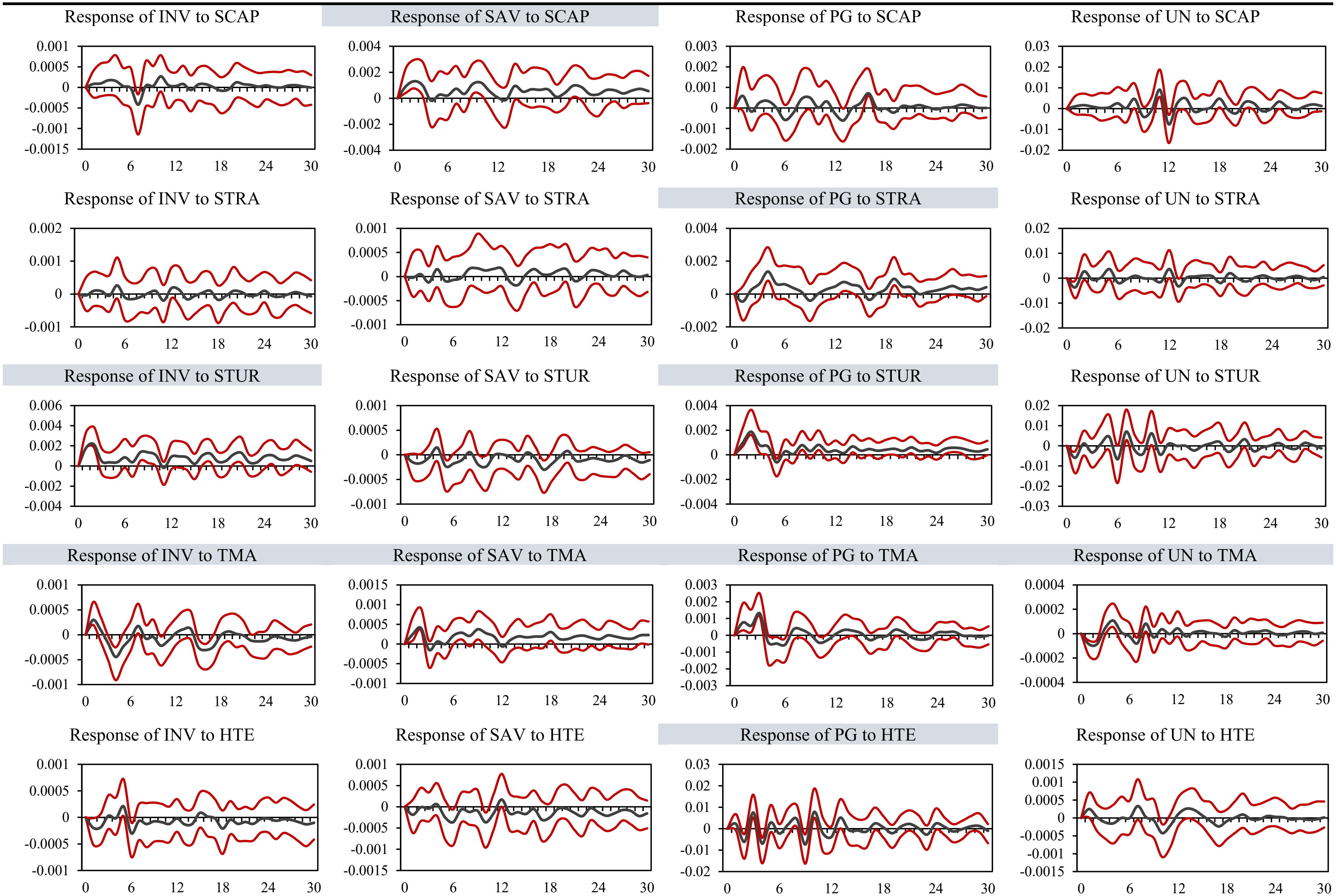
As for the case of Thailand, investment appears to react instantly to a shock in the MAI market turnover ratio and trademark applications within the first two quarters. Savings are responsive to shocks in the market capitalisation and trademark applications up to just a couple of months. The impacts of shocks in the market capitalisation and trademark applications on productivity growth are immediate rises as no surprise. In response to a shock in trademark applications, unemployment is likely to show some significant up- and down-trends within a quarter.

Unlike the previous cases, all considered macroeconomic functions in Malaysia (i.e. investment, savings, productivity growth, and employment) seem to have insignificant reactions to shocks in the ACE market development indicators (i.e. market capitalisation, traded value, and turnover ratio). Nonetheless, they significantly react to a shock in trademark applications, such that after the shock, investment and savings show instant increases and unemployment shows an instant decline while productivity growth exhibits some delays in response.

Overall, the results show that at 5% level of significance, shocks to various indicators of SME stock market development and/or innovation induce small but positive feedbacks in different sources of economic growth in Hong Kong, Singapore, Thailand, and Malaysia. As such, shocks to indicators of SME stock market development trigger responses of private investment, domestic savings, and productivity growth functions in Hong Kong, Singapore, and Thailand. On the other hand, shocks to innovation indicators initiate responses of these functions plus employment function in all four countries. The positive responses appear to be statistically significant in the short run only.

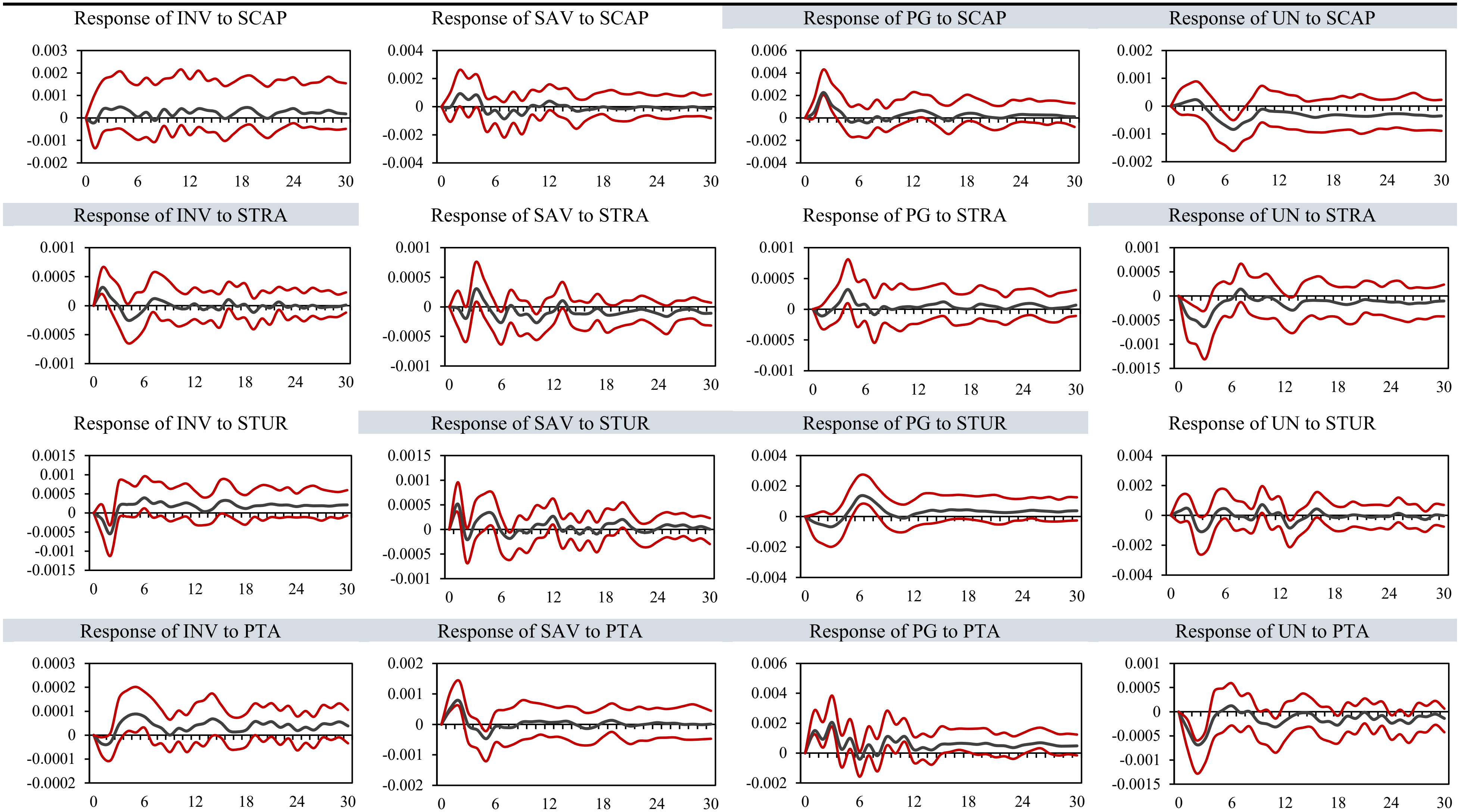
The small contribution of the SME stock markets to economic development is perhaps due to the fact that these stock markets are still at an early stage of development. As reported in Table 2.1 in Chapter Two, the market capitalisation and traded value exhibit a modest range of the proportion of GDP: 2.3%-12.6% and 1.7%-6.0%, respectively. In terms of innovation, the number of patent applications and trademark applications currently account for a very small portion of the labour forces from 0.02% to 0.9%. Regarding high-technology exports' contribution to GDP, Singapore is leading the pace with 42.5%, followed by Malaysia (18.8%), Thailand (8.5%), and Hong Kong (0.1%). Nevertheless, this indicator was treated endogenously in the model for the case of Hong Kong only. Therefore, innovation just shows a small impact on various macroeconomic channels.

Figure 5.4: Impulse Response Analysis for Orthogonal Shocks to SME Stock Market Development and Innovation in Hong Kong



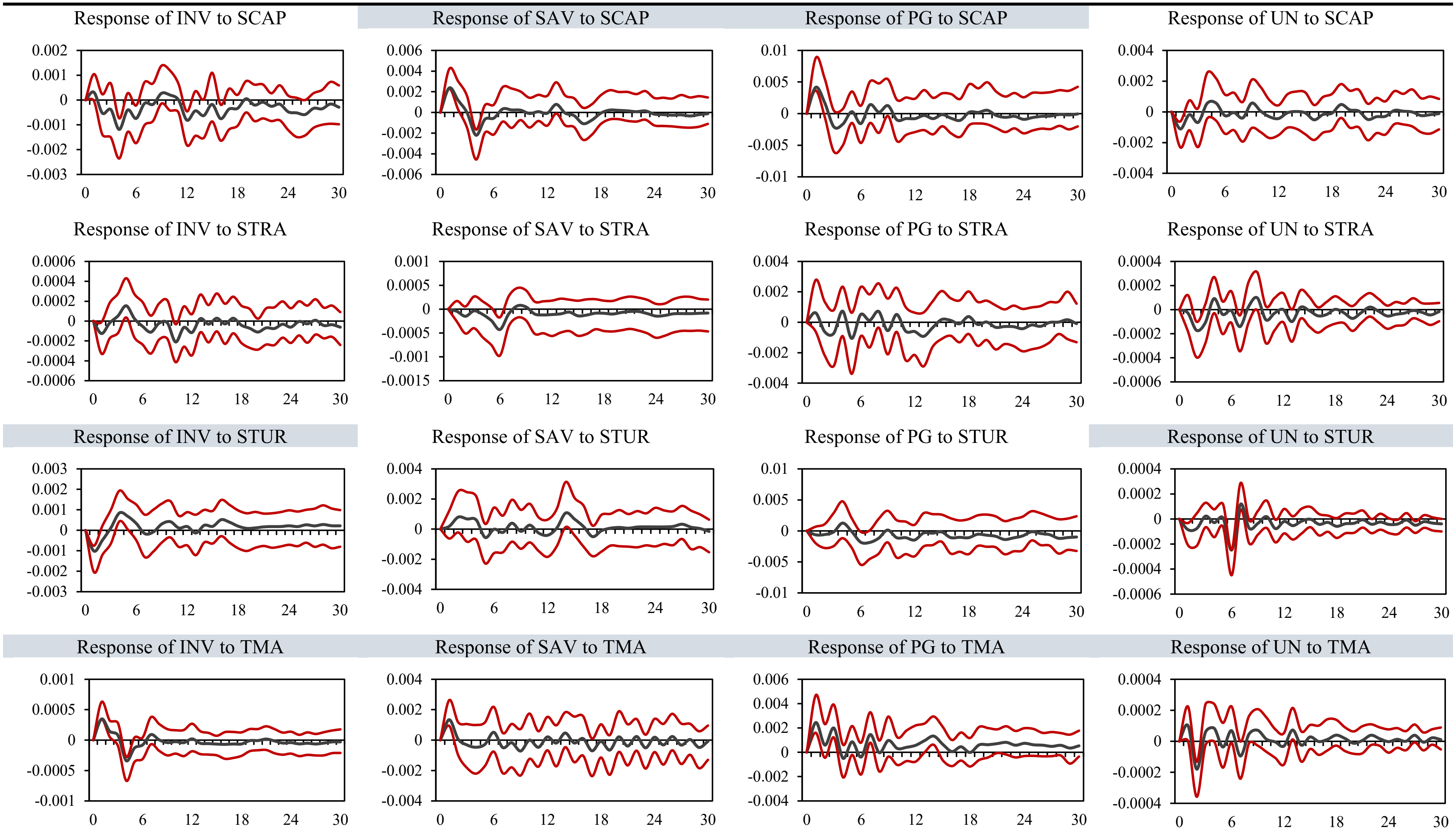
Notes: Grey highlights indicate the impulse response functions are significant at 5%, INV is investment, SAV is savings, PG is productivity growth, UN is unemployment, SCAP is SME stock market capitalization, STRA is SME stock market traded value, STUR is SME stock market turnover, TMA is the number of trademark applications, and HTE is high-technology exports.

Figure 5.5: Impulse Response Analysis for Orthogonal Shocks to SME Stock Market Development and Innovation in Singapore



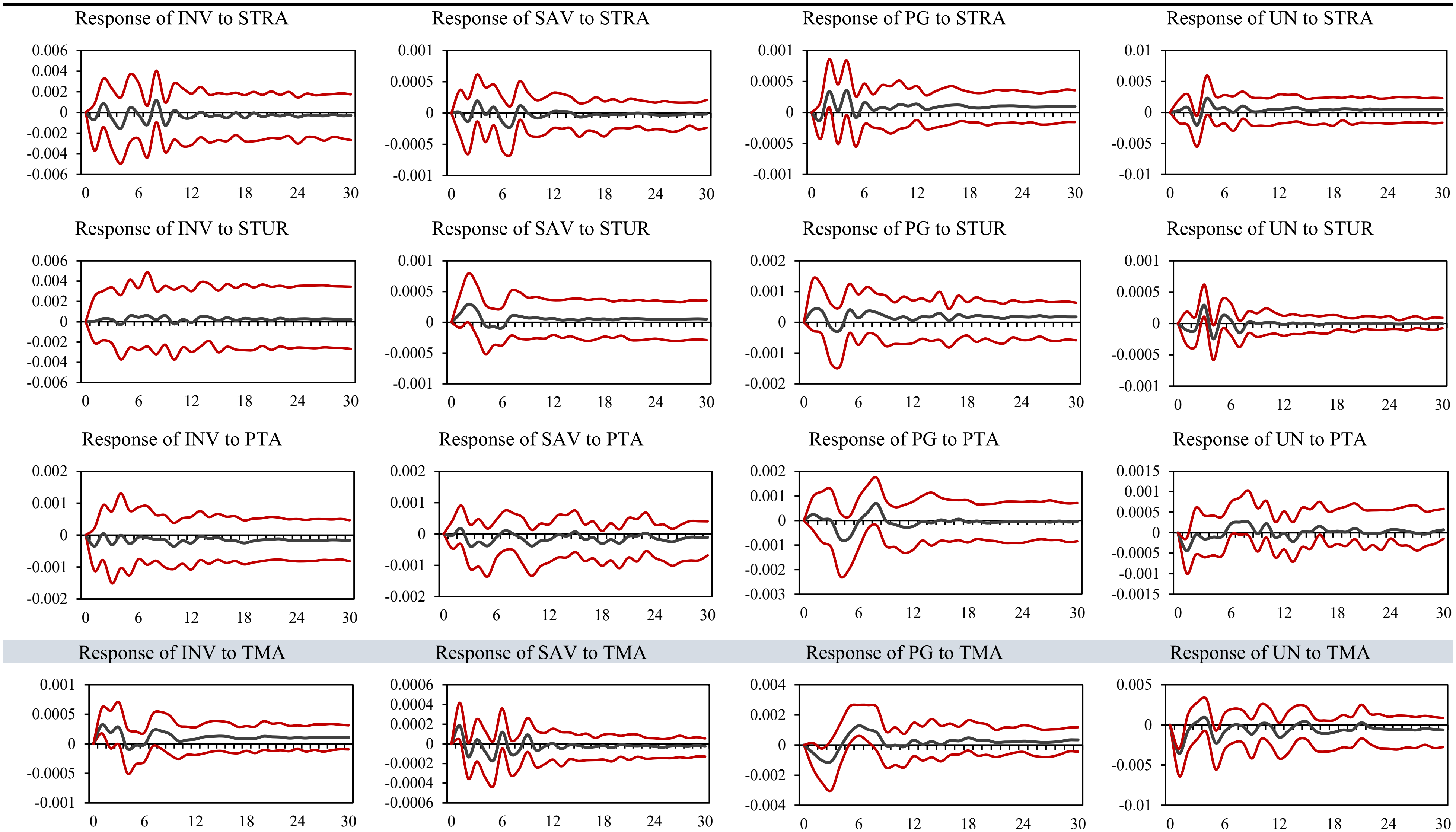
Notes: Grey highlights indicate the impulse response functions are significant at 5%, INV is investment, SAV is savings, PG is productivity growth, UN is unemployment, SCAP is SME stock market capitalization, STRA is SME stock market traded value, STUR is SME stock market turnover, and PTA is the number of patents applications.

Figure 5.6: Impulse Response Analysis for Orthogonal Shocks to SME Stock Market Development and Innovation in Thailand



Notes: Grey highlights indicate the impulse response functions are significant at 5%, INV is investment, SAV is savings, PG is productivity growth, UN is unemployment, SCAP is SME stock market capitalization, STRA is SME stock market traded value, STUR is SME stock market turnover, and TMA is the number of trademark applications.

Figure 5.7: Impulse Response Analysis for Orthogonal Shocks to SME Stock Market Development and Innovation in Malaysia



Notes: Grey highlights indicate the impulse response functions are significant at 5%, INV is investment, SAV is savings, PG is productivity growth, UN is unemployment, STRA is SME stock market traded value, STUR is SME stock market turnover, PTA is the number of patents applications, and TMA is the number of trademark applications.

Table 5.7: Summary of Study 3 – Dynamic Impacts of SME Stock Market Development and Innovation on Macroeconomic Indicators

<table>
<tr><th>Research Questions</th><th>Findings</th><th>Implications / Contributions</th></tr>
<tr><td>Q3.1: Are there dynamic impacts of SME stock market development on macroeconomic indicators within a Kaleckian-Post-Keynesian growth model?</td><td>The development of SME stock markets in Hong Kong, Singapore and Thailand shows small but positive impact to economic growth process in the short run through the combination of the following functions of the Kaleckian-Post-Keynesian growth model: private investment, domestic savings and productivity growth.</td><td rowspan="2">For policymakers: The findings give assistance to policymakers in making policies that facilitate the development of SME stock markets and innovation since they can effectively boost economic growth through different channels of macroeconomics.
For academics: Incorporation of SME stock market development and innovation indicators into the Kaleckian-Post-Keynesian macro-economic model improves the model specification and further extends the theoretical framework of Kaleckian-Post-Keynesian economics.</td></tr>
<tr><td>Q3.2: Are there dynamic impacts of innovation on macroeconomic indicators within a Kaleckian-Post-Keynesian growth model?</td><td>Innovation in Hong Kong, Singapore, Thailand and Malaysia shows small but positive impact to economic growth process in the short run through the combination of the following functions of the Kaleckian-Post-Keynesian growth model: private investment, domestic savings, productivity growth, and employment.</td></tr>
</table>

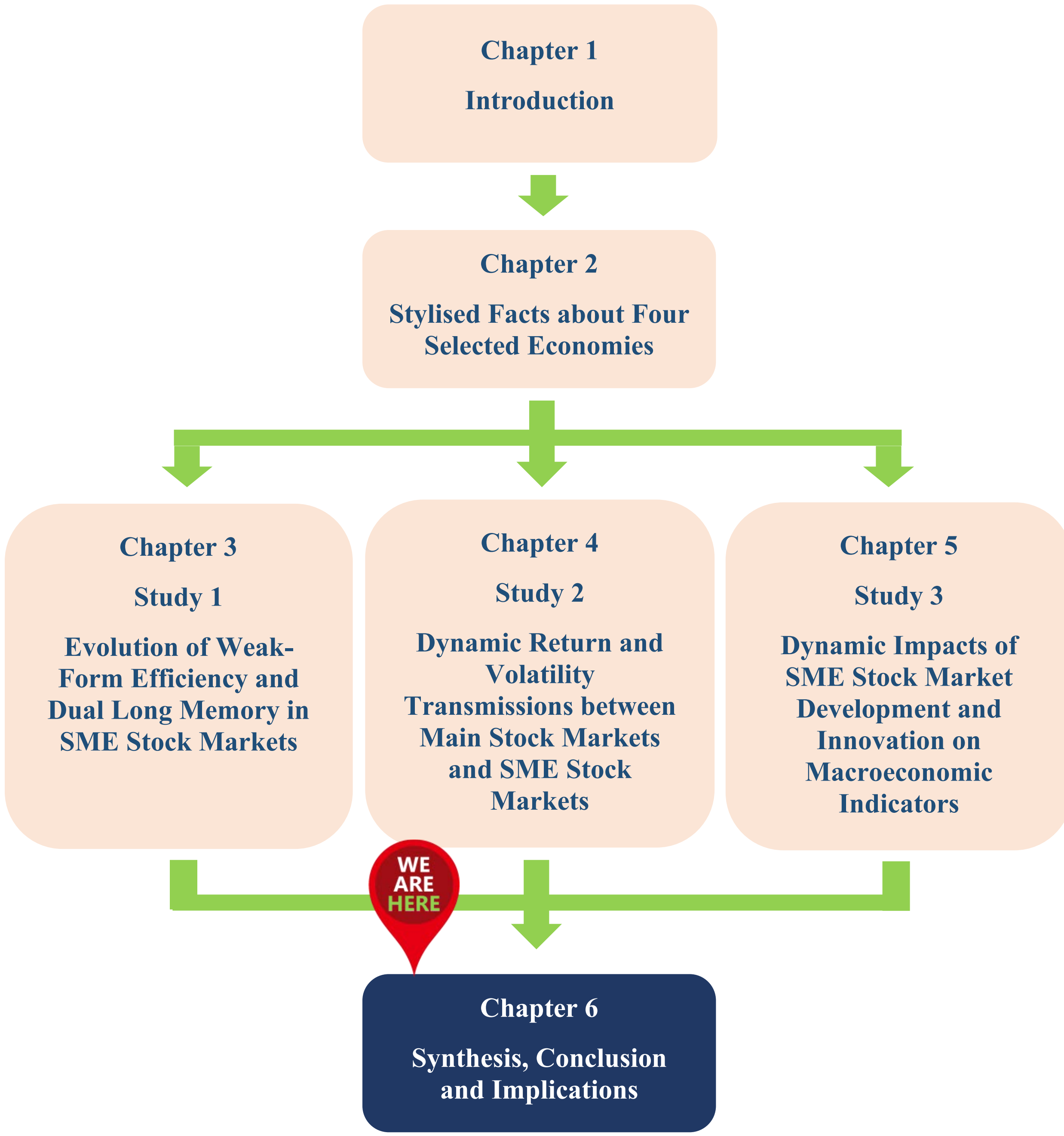
5.6 Conclusion and Future Research

This study extended the Kaleckian-Post-Keynesian theoretical model of growth and distribution in an open economy to investigate the dynamic effects of SME stock market development and innovation on different channels of growth. Accordingly, the indicators of SME stock market development and innovation were integrated into the functions of private investment, domestic savings, productivity growth and employment. Hong Kong, Singapore, Thailand, and Malaysia, which are fast-growing economies with well-developed stock markets and high level of innovation, were selected for empirical study. For the analysis of the simultaneous interactions among the variables, a SVEC model and an Impulse Response Function were used based on the assumptions of short-run restrictions only.

The results determined that various indicators of SME stock market development and/or innovation are proved to have small but positive contributions to economic stimulation in the short run in the four countries. The development of SME stock market influences growth process in Hong Kong, Singapore and Thailand through the combination of following channels: private investment, domestic savings, and productivity growth. Meanwhile, innovation affects growth through the combination of those channels and employment channel in all four economies. Consequently, the findings of this study can give assistance to governments of the four countries studied in making policies that promote the development of SME stock markets and/or innovation since they could potentially induce an overall crowding-in effect on private investment and growth in domestic savings, productivity, and employment. Firms would thus find it easy to gain access to capital and technological innovation in order to capture and satisfy an increase in aggregate demand. Additionally, with respect to theoretical and methodological grounds, inclusion of SME stock market development and innovation into the Kaleckian macroeconomic model helps improve the model specification and widen the theoretical framework of Kaleckian-Post-Keynesian economics.

And finally, governments can facilitate the development process of SME stock markets and innovation possibly by helping to sustain full employment and real wage rates. As such, when employment and real wage rate are secured, the liquidity preferences of firms and individuals are stabilised. This, consequently, affects income distribution and increases the level of savings, which can then be mobilised into productive investments in SME stock market and innovation. Therefore, for future research, it would be worthwhile to explore the impact of government support on the contribution of SME stock market and innovation to the process of economic development.

Thesis Structure



Chapter Six: Synthesis, Conclusion and Implications

Overview

The previous chapters reported three studies that investigated the evolving efficiency of, and dual long memory in, second-tier stock markets; dynamic return and asymmetric volatility transmissions between main stock markets and second-tier stock markets; and dynamic impacts of second-tier stock market development and innovation on macroeconomic indicators. This chapter synthesises the key findings of three studies underpinning this thesis, then draws implications for academics, policymakers and professional practitioners, and provides some recommendations for future research.

Chapter Outline

6.1 Summary of Key Findings

As discussed in Chapter One, Section 1.1, the world's SMEs are now facing a large credit gap which is estimated to be 30% of their total outstanding loan balance. The limited access to bank credit significantly deters SMEs from realising their economic potential. Second-tier stock markets have emerged as an effective alternative source of funding for SMEs and are recognised as a pivotal pillar of the SME financing landscape. Second-tier stock markets provide a platform for SMEs to raise long-term equity capital on a continuous and cost-effective basis, thus making a significant 5.8% contribution to narrow the existing global SME credit gap of US$3.2 trillion. While allowing business founders to retain their controlling interest in their businesses, second-tier stock markets help listed SMEs improve their credit rating and market valuation and become more resilient during periods of financial turbulence. At the same time, second-tier stock markets offer an exit strategy and a secured trading platform for investors as well bringing many opportunities to diversify investors' portfolios into large- and small-capitalisation stocks. Consequently, 51 second-tier stock markets have been constituted around the world since the 1990s. Moreover, second-tier stock markets can also be viewed as a major stimulant for innovation since the SMEs listed on the markets mainly operate in innovative sectors. Given their important roles in SME finance and innovation, second-tier stock markets highly deserve increased research focus.

This thesis, therefore, focused on the following three studies: (1) Evolution of second-tier stock market efficiency and dual long memory in the market under the joint impacts of thin trading, structural breaks, and inflation; (2) Dynamic return and asymmetric volatility transmissions between main stock market and second-tier stock market while controlling for the effects of thin trading, volatility breaks and trading volume; and (3) Dynamic impacts of second-tier stock market development and innovation on macroeconomic indicators within a Kaleckian-Post-Keynesian growth model. For empirical analysis, the cases of Hong Kong, Singapore, Thailand and Malaysia were employed since these four economies are the growth engines of tropical economies along with a high level of economic freedom and innovation.

Summary of key findings of this thesis is depicted in Figure 6.1 as below.

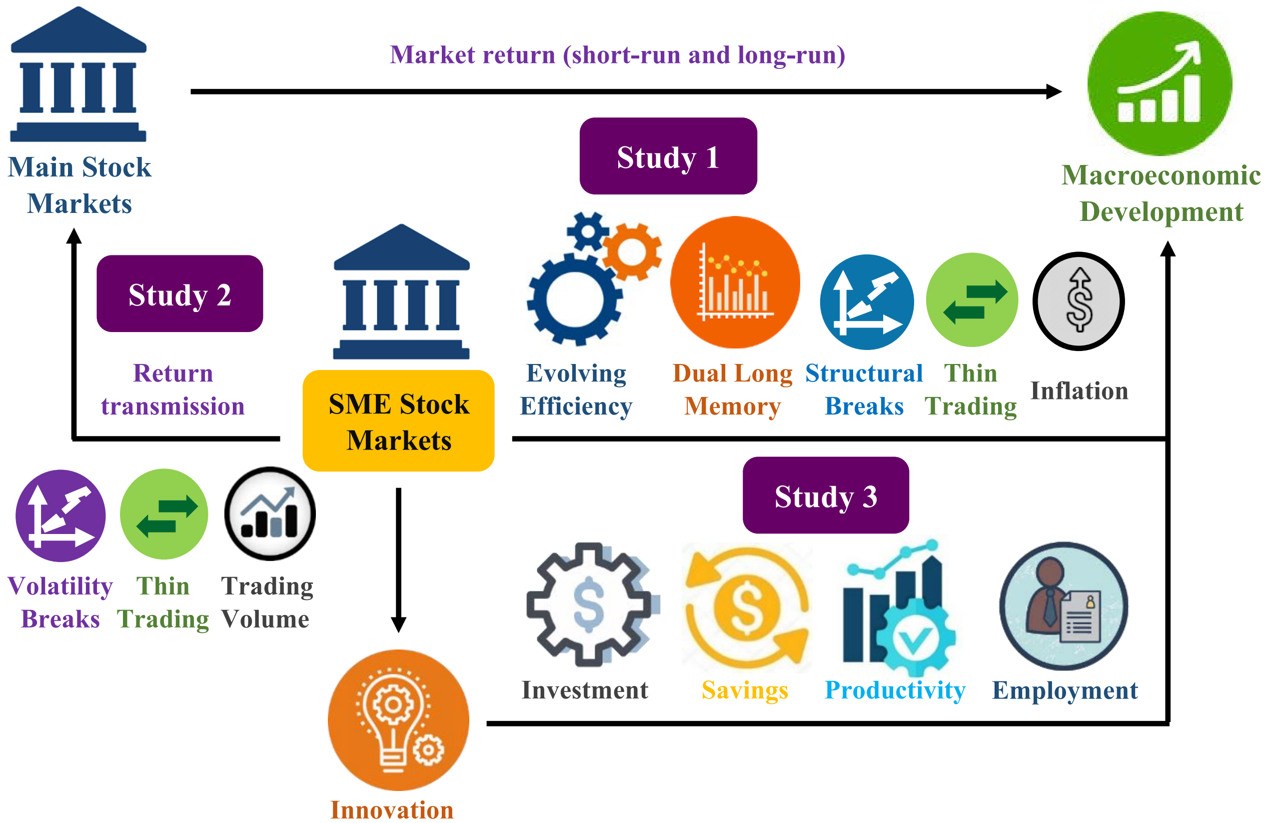


Figure 6.1: Summary of Key Findings

Study One adopted a State-Space GARCH-M model with Kalman Filter estimation and revealed that second-tier stock markets in Hong Kong, Singapore, Thailand and Malaysia were still inefficient in the weak form. However, the markets in Hong Kong and Singapore exhibited tendencies towards efficiency which appeared to align with growing market capitalisation and trading value of the two markets. These tendencies can also be supported by several institutional reforms in operational efficiency undertaken by the HKEX and SGX authorities such as upgrading trading and settlement system, implementing volatility control mechanisms and reducing transaction fees. In contrast, second-tier stock market in Thailand only experienced a transient bout of weak-form efficiency which could be rationalised by a critical political event of Yingluck Shinawatra election in 2011. Other than that, this market saw deviations from weak-form efficiency and this may have been due to the prolonged political instability in Thailand since 2012. The second-tier market in Malaysia also had no potential movement towards efficiency which probably due to the continuous confrontations between the government and opposition parties since 2011.

Study One also examined the presence of dual long memory properties in second-tier stock markets using a set of fractionally integrated models including ARFIMA-FIGARCH, ARFIMA-FIAPARCH and ARFIMA-HYGARCH, and factor adjustment techniques including an ICSS algorithm and a State-Space Linear AR model with Kalman Filter estimation. The results showed that second-tier stock markets in Hong Kong and Thailand exhibited long memory property in return and volatility, while those in Singapore and Malaysia exhibited long memory property in volatility only. Moreover, all three fractionally integrated models consistently reported dual long memory parameters in the four markets being within an interval of [0; 0.5] (except for Hong Kong market in ARFIMA-HYGARCH model). This indicates that the dual long memory in return and volatility are stationary; as such, the return and volatility will revert to their means in the long run. In addition, the three factors: thin trading, structural breaks, and inflation jointly have diminishing effect on the magnitude and/or significance level of dual long memory in return and volatility in the four markets.

Study Two augmented the bivariate VAR asymmetric BEKK-GARCH model with a dummy variable indicating volatility breaks, an aggregate trading volume variable, and a de-thinned return variable to explore the dynamic transmissions between main stock markets and second-tier stock markets. The results determined that there was a return transmission from second-tier market to the main market in Hong Kong while this return transmission reversed its direction in the cases of Singapore, Thailand and Malaysia. Only Singapore exhibited volatility transmission from the main market to second-tier market. Furthermore, inclusion of volatility breaks, thin trading and trading volume in modelling cross-market return and volatility transmissions proved to have at least one of the following effects. First, in Hong Kong, the magnitude and significance level of unidirectional return transmission from second-tier market to the main market decreased. Second, however, in Singapore, Thailand and Malaysia, the magnitude and/or significance level of return transmissions from the main markets to second-tier markets increased. Third, in Hong Kong, direct short-run volatility transmission from second-tier market to the main market dissipated. Fourth, in Singapore, asymmetric volatility transmission from the main market to second-tier market became stronger in significance level and larger in magnitude.

Study Three extended the Kaleckian-Post-Keynesian theoretical model of growth and distribution in an open economy to explore the dynamic effects of second-tier stock market development and innovation on different channels of growth. The analysis of the SVEC Impulse Response Function determined that shocks to various indicators of second-tier stock market development and/or innovation induced small but positive feedbacks in different sources of economic growth in Hong Kong, Singapore, Thailand, and Malaysia. Shocks to indicators of second-tier market development triggered responses of private investment, domestic savings, and productivity growth functions in Hong Kong, Singapore, and Thailand. Meanwhile, shocks to innovation indicators initiated responses of these functions plus employment function in all four countries. The positive responses appeared to be statistically significant in the short run only. The small contribution of the second-tier stock markets and innovation to economic development is perhaps due to the fact that these stock markets are still at an early stage of development and the number of patent and trademark applications currently account for a very small portion of the labour force.

6.2 Implications and Contributions

The findings of the three studies underpinning this thesis provided not only both theoretical and empirical academic contributions but also implications for policymakers and professional practitioners, as discussed in the following sections.

6.2.1 Contributions to Academia

This thesis is the first to contribute to the empirical literature on second-tier stock markets. The first study reported in this thesis contributed an investigation of the evolution of weak-form efficiency and dual long memory properties in second-tier stock markets. This study also improved the empirical literature on long memory in stock markets by investigating this property under the joint impacts of structural breaks, thin trading and inflation to avoid biased estimation.

The second study reported in this thesis provided an examination of the dynamic return and asymmetric volatility transmissions between main stock markets and second-tier stock markets. This study effectively stood out from prior studies on cross-market transmissions since it controlled for the impact factors of thin trading, volatility breaks and trading volume to avoid fallacy in estimation. Moreover, this study also improved the existing empirical models by extending a standard bivariate VAR asymmetric BEKK-GARCH model with de-thinned returns, volatility breaks and aggregate trading volume.

The third study reported in this thesis contributed an exploration of the dynamic effects of second-tier stock market development and innovation on macroeconomic indicators. This study is distinctive in its way of extending the Kaleckian-Post-Keynesian's theoretical model of growth and distribution with indicators of second-tier stock market development and innovation. It provided theoretical justifications and empirical evidence that incorporating indicators of second-tier stock market development and innovation into the functions of private investment, domestic savings, productivity growth and employment effectively improved the model specification. This study thus further expand the theoretical framework of Kaleckian-Post-Keynesian economics, to better elucidate the interactions between various economic functions in an open economy.

6.2.2 Implications for Policymakers

The findings reported in this thesis provide several implications for policymakers. The first study of this thesis found that the tendencies towards weak-form efficiency of second-tier stock markets in Hong Kong and Singapore appeared to evolve with the market development and institutional reforms in trading operation. This finding can assist policymakers in making institutional reforms and policies to further develop second-tier stock markets in Hong Kong and Singapore and improve the efficiency of the markets, thereby optimising capital allocation in the economies.

The second study reported in this thesis provided the evidence of significant return transmission from second-tier stock market to main stock market in Hong Kong. The main stock market return also exhibited a causality and a long-run equilibrium relationship with economic development in Hong Kong. This study thus provides evidence for an inference that second-tier stock market can make an indirect contribution to economic development in Hong Kong via its dynamic return transmission with the main stock market. This finding can support Hong Kong policymakers in making policies that facilitate the development of second-tier stock market since this market can indirectly promote long-term economic stimulation through its transmission mechanisms with the main stock market.

The third study reported in this thesis reported a direct contribution of second-tier stock markets and/or innovation to different channels of economic growth in Hong Kong, Singapore, Thailand and Malaysia. This finding can give assistance to governments of the four countries in forming policies that foster the development of second-tier stock markets and/or innovation since they could potentially induce an overall crowding-in effect on private investment and growth in domestic savings, productivity and employment. Therefore, access to financial capital and technological innovation for SMEs can be improved so that they can capture and satisfy an increase in aggregate demand.

To effectively develop policy that promotes the development of second-tier stock market, it is essential for the government of the four economies to understand the determinants of stock market development. The determinants of stock market development can be classified into two group of factors: macroeconomic factors and institutional factors (Ho & Iyke, 2017), which elaborated in the next two paragraphs.

Macroeconomic factors include, but are not limited to, real income level, foreign direct investment, inflation rate, interest rate and exchange rate. Greenwood and Smith (1997) asserted that there exists a significant fixed cost associated with the establishment of stock markets. A higher level of real income allows more people to participate in stock markets. Thus, a stock market may not become active until real income has reached a certain level, implying a threshold effect in the establishment of stock market. A strong inflow of foreign direct investment may reinforce the participation of firms in stock markets and may increase the liquidity of domestic stock markets through trading of existing equities by foreign investors (Claessens, Demirgüç-Kunt, & Huizinga, 2001). A higher rate of inflation makes a stock market smaller in market capitalisation and liquidity since it depreciates the real rate of return on money and all other assets (Boyd, Levine, & Smith, 2001). An increase in interest rates reduces the present value of future dividend incomes, thus depresses stock prices and discourages investors to borrow and invest in the stock market (Mok, 1993). A currency appreciation can adversely affect the cashflow of companies and their stock prices since it decreases the international competitiveness and the balance of trade position of an economy (Dornbusch & Fischer, 1980).

Institutional factors include, but are not limited to, legal protection, corporate governance, stock market liberalisation, stock market integration and trade openness. As advocated by Pagano (1993b) and La Porta, Lopez-de-Silanes, Shleifer, and Vishny (1997), the existence of transparency, regulations and corporate governance that protect the interests of shareholders and creditors will boost the flow of investments and foster the efficiency of stock markets. Henry (2000) argued that stock market liberalisation fosters risk distribution between domestic and foreign investors, thus reducing the cost of equity of the liberalising market and promoting the market development. According to Bekaert and Harvey (2000), stock market integration, in which projects with identical risks have identical expected returns across different markets, efficiently allows investors to diversify their portfolios into foreign stock markets, thus promoting an efficient allocation of productive resources. Rajan and Zingales (2003) contended that trade openness induces investment propensity and stock market development as it weakens the incentives and the power of groups whose interests are to block entry and decrease competition in stock markets.

In addition, this thesis conducted the three studies above using four tropical economies: Hong Kong, Singapore, Thailand and Malaysia for empirical analysis, thereby increasing global awareness of the importance of tropical region to the global economy.

6.2.3 Implications for Professional Practitioners

In the first study, the finding of the inefficiency of second-tier stock markets in Hong Kong, Singapore, Thailand and Malaysia implies the predictability in the markets; such that investors and portfolio managers can earn abnormal returns by actively beating the markets using technical analysis. The presence of stationary long memory property in the returns and/or volatility of the four second-tier stock markets is highly relevant to investors and portfolio managers in formulating active trading and hedging strategies. As such, dual long memory components in return and volatility should be integrated into hedging model to estimate the optimal hedge ratio for these markets. In addition, failure to account for the joint effects of thin trading, structural breaks and inflation results in overestimated long memory parameters, which leads to false trading and hedging strategies. Moreover, compared to second-tier stock markets in Hong Kong and Singapore, those in Thailand and Malaysia may serve as a good hedge for portfolio risk management during market downturns since they had a smaller degree of volatility persistence.

In the second study, the finding of return and volatility transmissions between the main stock markets and second-tier stock markets in Hong Kong, Singapore, Thailand and Malaysia also has important implications for investors and portfolio managers in minimizing the risk of a portfolio. The estimation of volatility transmissions can be used to determine an optimal hedge ratio to minimize the risk of a small- and large-cap stock portfolio. Moreover, ignoring the joint impacts of thin trading, volatility breaks and trading volume can distort the estimation of cross-market return and volatility transmissions, thus, misleading investors and portfolio managers.

Moreover, investment advisors and fundraisers can use the findings of the first and the second studies in their pitch proposals to potential clients for second-tier stock market investing.

Finally, overview of the thesis and its contributions and implications are summarised in the below Table 6.1.

Table 6.1: Overview of Thesis and its Contributions and Implications

Research Questions	Findings	Contributions to Academia	Implications to Policymakers	Implications to Professional Practitioners
Research Gap 1: SME Stock Market Efficiency and Long Memory → **Study 1: Evolution of Weak-form Efficiency and Dual Long Memory in SME Stock Markets**				
Q1.1: Do SME stock markets evolve towards weak-form market efficiency?	SME stock markets in Hong Kong, Singapore, Thailand and Malaysia are still weak-form inefficient. SME stock markets in Hong Kong and Singapore exhibit tendencies towards weak-form market efficiency. These tendencies appear to evolve with the market development and institutional reforms in trading operation.	This finding contributes to the empirical literature on second-tier stock market efficiency.	This finding can assist policymakers in making institutional reforms and policies to further develop SME stock markets in Hong Kong and Singapore and improve the market efficiency.	The inefficiency of SME stock markets in the four countries implies that investors and portfolio managers can earn abnormal returns by actively beating the markets using technical analysis.
Q1.2: Is long memory property present in SME stock markets' return and volatility?	SME stock markets in Hong Kong and Thailand present stationary long memory in return and volatility, while those in Singapore and Malaysia show stationary long memory in volatility only.	This finding contributes to the empirical literature on the characteristics of second-tier stock markets.		The presence of stationary long memory property in the SME stock markets implies the predictability in the markets which is of great importance to investors and portfolio managers in forming active trading and hedging strategies.
Q1.3: What are the joint impacts of thin trading, structural breaks, and inflation on long memory property in SME stock markets' return and volatility?	The three factors: thin trading, structural breaks, and inflation jointly have diminishing effect on the magnitude and/or significance level of dual long memory property in the SME stock markets' return and volatility.	This finding improves the empirical literature on long memory in stock markets by investigating this property under the joint impacts of structural breaks, thin trading and inflation to avoid biased estimations.		Failure to account for the joint effects of thin trading, structural breaks, and inflation results in overestimated long memory parameters, leading to false trading and hedging strategies.
Research Gap 2: Dynamic Transmissions between Main Stock Markets and SME Stock Markets → **Study 2: Dynamic Return and Volatility Transmissions between Main Stock Markets and SME Stock Markets**				
Q2.1: Are there return and volatility transmissions between main stock markets and SME stock markets?	Hong Kong shows return transmission from SME stock market to the main stock market while Singapore, Thailand and Malaysia show the reverse transmission. Only Singapore exhibits volatility transmission from the main stock market to SME stock market. SME stock market in Hong Kong can make an indirect contribution to the country's economic development through return transmission with the main market channel.	This finding contributes to the empirical literature of dynamic transmissions among stock markets.	The indirect contribution of SME stock market in Hong Kong to economic development can support policymakers in making policies that facilitate the development of SME stock market in the country.	The estimation of cross-market return and volatility transmissions can assist investors and portfolio managers in forming a hedging strategy.

Research Questions	Findings	Contributions to Academia	Implications to Policymakers	Implications to Professional Practitioners
Q2.2: What are the joint impacts of thin trading, volatility breaks, and trading volume on the return and volatility transmissions between main stock markets and SME stock markets?	Thin trading, volatility breaks, and trading volume jointly decrease (increase) the magnitude and significance level of return transmission from SME (main) stock market to the main (SME) stock market. In essence, the underlying volatility transmission is eliminated or becomes stronger in magnitude and significance level.	This finding improves the empirical literature on cross-market transmissions by accounting for the impact factors of thin trading, volatility breaks and trading volume to avoid biased estimations. This finding also advances the existing empirical models by augmenting a standard bivariate VAR asymmetric BEKK-GARCH model with de-thinned returns, volatility breaks and aggregate trading volume.		Ignoring the joint impacts of thin trading, volatility breaks, and trading volume can distort the estimation of cross-market return and volatility transmissions, thus, misleading investors and portfolio managers in formulating hedging strategy.
Research Gap 3: Dynamic Impacts of SME Stock Market Development and Innovation on Macroeconomic Indicators **→ Study 3: Dynamic Impacts of SME Stock Market Development and Innovation on Macroeconomic Indicators**				
Q3.1: Are there dynamic impacts of SME stock market development on macroeconomic indicators within a Kaleckian-Post-Keynesian growth model?	The development of SME stock markets in Hong Kong, Singapore and Thailand shows a small but positive impact to economic growth process in the short run through the combination of the following functions of the Kaleckian-Post-Keynesian growth model: private investment, domestic savings and productivity growth.	Incorporation of SME stock market development and innovation indicators into the Kaleckian-Post-Keynesian macro-economic model improves the model specification and further extends the theoretical framework of Kaleckian-Post-Keynesian economics.	The findings give assistance to policymakers in making policies that facilitate the development of SME stock markets and innovation since they can effectively boost economic growth through different channels of macroeconomics.	
Q3.2: Are there dynamic impacts of innovation on macroeconomic indicators within a Kaleckian-Post-Keynesian growth model?	Innovation in Hong Kong, Singapore, Thailand and Malaysia shows a small but positive impact to economic growth process in the short run through the combination of the following functions of the Kaleckian-Post-Keynesian growth model: private investment, domestic savings, productivity growth, and employment.			

6.3 Recommendations for Future Research

This thesis investigated the evolving efficiency of second-tier stock markets and how these markets influence macroeconomic development both directly and indirectly. Nonetheless, studies contained in this thesis are not without limitations since there are areas that would benefit from further investigation. In particular, the first study of this thesis examined the evolution of second-tier stock market efficiency and rationalised the evolving efficiency by various factors such as market development indicators, institutional reforms and political events. However, it was not intended to examine the statistical impact of these factors on evolving efficiency. Further work using event study methods is thus needed to provide additional assistance to policymakers in improving market efficiency.

While the second study explored the transmissions of return and asymmetric volatility between the main stock market and second-tier stock market, it left out the transmission of liquidity between the two markets. An examination of this liquidity transmission could potentially provide further evidence of an indirect contribution of second-tier stock market to economic development through the main stock market. Future research can use some liquidity indicators such as illiquidity ratio and relative quoted bid-ask spread to examine the transmission of liquidity between the two markets.

Additionally, most of second-tier stock markets are currently operating on the principals of the classical growth theory, which is without government interference. As such, one could be curious about potential effects of government interference on the indirect contribution of second-tier stock market to economic development via the main stock market and the direct contribution of second-tier stock market and innovation to economic growth process. These areas, therefore, are recommended for future research. Researchers can consider extending the empirical models presented in the second and third studies with measures of government intervention such as government spending, policies and regulations, and government ownership.

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Appendix 1: Descriptive Statistics and Stationarity Tests of Returns and Aggregate Trading Volume

Table A1.1: Descriptive statistics of Returns and Aggregate Trading Volume

	Hong Kong			Singapore			Thailand			Malaysia		
	R_{1t}	R_{2t}	ATV_t	R_{1t}	R_{2t}	ATV_t	R_{1t}	R_{2t}	ATV_t	R_{1t}	R_{2t}	ATV_t
Obs.	1,853	1,853	1,853	1,884	1,884	1,884	1,832	1,832	1,832	1,849	1,849	1,849
Mean	0.0001	-0.0003	0.0255	0.0001	-0.0005	0.0118	0.0005	0.0006	0.0058	0.0003	0.0001	0.0081
Median	0.0002	0.0003	0.0229	0.0004	-0.0005	0.0100	0.0009	0.0014	0.0050	0.0005	0.0001	0.0074
Std. Dev.	0.012	0.015	0.011	0.008	0.015	0.006	0.011	0.012	0.003	0.006	0.012	0.003
Skewness	-0.3	1.0	2.5	-0.4	-0.3	2.8	-0.3	-0.9	1.6	-0.4	-0.5	1.2
Kurtosis	5.0	75.3	13.8	5.3	7.0	17.6	6.4	9.9	6.3	6.3	7.2	5.5
Jarque-Bera	332*	403,695*	10,868*	473**	1,254*	19,207*	922*	3,816*	1,592*	884*	1,399*	900*
Q(10)	6.3	79.6*	4,614.0*	22.8*	80.9*	7,980.3*	12.8	25.5*	10,829.5*	41.1*	31.6*	7,086.0*
Q(20)	27.4**	108.9*	6,930.4*	39.1*	91.7*	12,335.1*	26.7**	32.0**	18,892.3*	49.5*	46.2*	10,981.7*
$Q^2(10)$	307.2*	502.3*	2,829.7*	584.5*	416.1*	5,079.7*	408.6*	329.0*	8,238.5*	371.2*	313.9*	5,083.5*
$Q^2(20)$	514.8*	509.6*	4,204.0*	916.5*	771.4*	7,712.1*	515.3*	338.0*	13,590.8*	506.7*	351.7*	7,608.2*
ARCH(5)	24.8*	78.1*	209.6*	40.1*	44.8*	453.9*	38.2*	38.5*	837.0*	38.9*	31.7*	463.7*
ARCH(10)	16.1*	40.1*	108.9*	27.7*	24.7*	270.2*	21.9*	19.4*	432.1*	21.3*	19.2*	235.0*

*, ** indicate the test statistic is significant at 1% and 5%, respectively; R_{1t} and R_{2t} denote daily returns of the Main market and SME market, respectively; ATV_t denotes daily aggregate traded volumes of the Main market and the SME market (in trillion shares for Thailand and 100 billion shares for other countries); JB represents Jarque-Bera statistic; Q and Q^2 are statistics of the Ljung-Box test for autocorrelation in return series and squared return series, respectively; ARCH represents the Engle's Autoregressive Conditional Heteroscedasticity statistic.

Table A1.2: Stationarity Tests of Returns and Aggregate Trading Volume

		Hong Kong			Singapore			Thailand			Malaysia		
		R_{1t}	R_{2t}	ATV_t	R_{1t}	R_{2t}	ATV_t	R_{1t}	R_{2t}	ATV_t	R_{1t}	R_{2t}	ATV_t
ADF	C	-42.41*	-25.79*	-7.13*	-40.95*	-51.03*	-4.79*	-41.50*	-39.29*	-4.76*	-37.74*	-27.24*	-7.86*
	C&T	-42.40*	-25.79*	-7.34*	-40.98*	-51.06*	-4.79*	-41.55*	-39.29*	-5.07*	-37.85*	-27.24*	-8.89*
PP	C	-42.40*	-37.19*	-28.56*	-41.22*	-50.54*	-13.46*	-41.49*	-39.41*	-9.80*	-37.81*	-40.63*	-13.65*
	C&T	-42.40*	-37.19*	-28.88*	-41.21*	-50.57*	-13.46*	-41.56*	-39.40*	-10.92*	-37.95*	-40.60*	-15.61*
NP – C	MZ_α^d	-12.01**	-14.48*	-71.36*	-15.24*	-75.64*	-130.41*	-71.22*	-26.42*	-90.39*	-20.75*	-8.28**	-215.24*
	MZ_t^d	-2.38**	-2.69*	-5.96*	-2.73*	-6.15*	-8.07*	-5.95*	-3.59*	-6.72*	-3.22*	-1.99**	-10.37*
	MSB^d	0.20**	0.19*	0.08*	0.18**	0.08*	0.06*	0.08*	0.14*	0.07*	0.16*	0.24**	0.05*
	MP_T^d	2.34**	1.70*	0.36*	1.74**	0.33*	0.19*	0.39*	1.07*	0.28*	1.18*	3.13**	0.12*
NP – C&T	MZ_α^d	-26.89*	-30.33*	-181.05*	-38.25*	-18.98**	-212.31*	-184.67*	-66.39*	-191.80*	-120.22*	-20.04**	-370.33*
	MZ_t^d	-3.66*	-3.89*	-9.50*	-4.37*	-3.07**	-10.30*	-9.61*	-5.76*	-9.78*	-7.75*	-3.16**	-13.60*
	MSB^d	0.14**	0.13*	0.05*	0.11*	0.16**	0.05*	0.05*	0.09*	0.05*	0.06*	0.16**	0.04*
	MP_T^d	3.40*	3.06*	0.53*	2.40*	4.89**	0.45*	0.50*	1.38*	0.51*	0.77*	4.58**	0.25*

*, ** indicate the test statistic is significant at 1% and 5%, respectively; R_{1t} and R_{2t} denote daily returns of the Main market and SME market, respectively; ATV_t denotes daily aggregate traded volumes of the Main market and SME market; C represents constant; C&T represents constant and trend; $MZ_\alpha^d, MZ_t^d, MSB^d$ and MP_T^d represents the four test statistics of the Ng-Perron unit root test.

Appendix 2: Descriptive Statistics and Stationarity Tests of Macroeconomic, SME Stock Market Development and Innovation Indicators

Table A2.1: Descriptive Statistics of Macroeconomic, SME Stock Market Development and Innovation Indicators

Variables	INV	SAV	ID	PG	NX	UN	SCAP	STRA	STUR	PTA	TMA	HTE
						Hong Kong						
Mean	0.14	0.27	0.42	0.04	-0.23	0.04	0.85	0.06	0.06	0.28	0.77	0.003
Median	0.14	0.26	0.41	0.04	-0.23	0.03	0.84	0.05	0.06	0.28	0.79	0.003
Maximum	0.16	0.35	0.48	0.10	-0.13	0.06	1.78	0.25	0.16	0.33	0.87	0.005
Minimum	0.12	0.23	0.38	-0.05	-0.34	0.03	0.38	0.01	0.02	0.26	0.56	0.001
Std. Dev.	0.01	0.03	0.03	0.03	0.05	0.01	0.32	0.04	0.03	0.02	0.08	0.001
Skewness	-0.58	0.92	0.57	-0.76	0.001	1.96	0.65	2.54	1.14	0.29	-0.80	0.53
Kurtosis	3.19	3.46	1.97	5.25	2.39	5.98	2.92	11.00	3.86	2.05	2.88	1.99
Jarque-Bera	5.18***	13.43*	8.84**	27.64*	1.40	91.02*	6.34**	336.87*	22.40*	4.69***	9.57*	8.14**
						Singapore						
Mean	0.17	0.54	0.34	0.03	0.25	0.02	0.25	0.02	0.10	0.25	0.48	0.47
Median	0.17	0.54	0.34	0.01	0.24	0.02	0.24	0.02	0.08	0.25	0.48	0.45
Maximum	0.19	0.55	0.39	0.17	0.30	0.03	0.35	0.09	0.31	0.26	0.53	0.55
Minimum	0.15	0.49	0.29	-0.02	0.21	0.02	0.17	0.004	0.02	0.23	0.41	0.40
Std. Dev.	0.01	0.01	0.03	0.04	0.02	0.003	0.05	0.02	0.06	0.01	0.03	0.04
Skewness	-0.66	-1.74	-0.13	1.82	0.26	3.29	0.33	1.70	1.65	0.04	-0.67	1.18
Kurtosis	3.05	6.81	1.97	5.81	2.21	16.02	1.97	6.62	5.98	2.23	3.43	3.38
Jarque-Bera	6.62**	100.06*	4.26	79.57*	3.34	797.89*	5.59***	92.67*	74.08*	2.24	7.34**	21.62*
						Thailand						
Mean	0.13	0.31	0.33	0.03	0.06	0.01	0.17	0.04	0.20	0.01	0.10	0.09
Median	0.13	0.31	0.35	0.03	0.06	0.01	0.15	0.02	0.18	0.02	0.10	0.09
Maximum	0.15	0.37	0.43	0.14	0.20	0.01	0.40	0.17	0.59	0.02	0.12	0.10
Minimum	0.12	0.28	0.18	-0.06	-0.04	0.004	0.04	0.003	0.06	0.003	0.08	0.08
Std. Dev.	0.006	0.03	0.07	0.04	0.05	0.002	0.11	0.03	0.11	0.005	0.01	0.01
Skewness	0.54	0.94	-0.40	0.50	0.26	0.21	0.43	2.08	1.36	-0.83	0.07	0.86
Kurtosis	2.89	2.85	1.88	4.74	2.79	2.68	1.69	8.31	4.86	2.14	1.72	2.54
Jarque-Bera	4.41	13.40*	7.10**	15.24*	1.19	1.04	9.28*	171.03*	40.92*	13.05*	6.27**	11.96*
						Malaysia						
Mean	0.21	0.36	0.64	0.03	0.11	0.03	0.09	0.014	0.14	0.04	0.20	0.20
Median	0.22	0.35	0.64	0.04	0.10	0.03	0.09	0.011	0.12	0.04	0.20	0.19
Maximum	0.24	0.40	0.71	0.16	0.22	0.04	0.14	0.05	0.38	0.05	0.23	0.25
Minimum	0.16	0.32	0.55	-0.19	0.05	0.03	0.07	0.002	0.03	0.04	0.17	0.17
Std. Dev.	0.02	0.03	0.03	0.06	0.04	0.002	0.02	0.01	0.08	0.002	0.01	0.02
Skewness	-0.73	0.27	-0.58	-1.05	0.74	0.06	0.84	1.14	0.80	-0.93	0.27	1.12
Kurtosis	2.23	1.71	4.29	6.56	2.46	2.33	2.64	4.04	3.05	3.95	2.82	3.14
Jarque-Bera	10.24*	7.28**	11.28*	63.99*	9.37*	1.72	11.18*	23.51*	9.61*	16.38*	1.23	19.03*

Notes: *, **, *** indicate that the test statistic is significant at 1%, 5%, and 10%, respectively; INV is investment, SAV is savings, ID is income distribution, PG is productivity growth, NX is net export, UN is unemployment, SCAP is SME stock market capitalization, STRA is SME stock market traded value, STUR is SME stock market turnover, PTA is the number of patents applications, TMA is the number of trademark applications, and HTE is high-technology exports.

Table A2.2: Stationarity Tests of Macroeconomic, SME Stock Market Development and Innovation Indicators (Hong Kong and Singapore)

Variables	INV	SAV	ID	PG	NX	UN	SCAP	STRA	STUR	PTA	TMA	HTE	INV	SAV	ID	PG	NX	UN	SCAP	STRA	STUR	PTA	TMA	HTE
	Level 0 [$I(0)$]												Level 1 [$I(1)$]											
	Hong Kong																							
ADF																								
C	-2.0	-1.7	-1.7	-2.2	-2.2	-3.5**	-0.9	-2.8***	-2.4	-1.1	-1.9	-1.0	-3.9*	-3.6*	-4.5*	-3.9*	-12.5*	-6.2*	-7.3*	-7.6*	-7.4*	-5.7*	-5.5**	-4.1*
C&T	-2.0	-1.0	-1.1	-1.8	-2.1	-2.5	-1.6	-2.8	-2.5	-1.1	1.0	-2.2	-3.9**	-3.9**	-4.7*	-3.6**	-12.5*	-7.2*	-7.3*	-7.6*	-7.4*	-5.8*	-5.6*	-5.6*
PP																								
C	-2.6	-1.1	-1.6	-5.0*	-5.8*	-4.1*	-1.0	-3.2**	-2.6***	-1.0	-2.6	-0.8	-4.3*	-14.9*	-4.4*	-5.1*	-21.4*	-11.3*	-15.3*	-7.6*	-10.5*	-5.9*	-3.2**	-5.7*
C&T	-2.6	-1.5	-1.0	-4.9*	-5.6*	-3.2***	-1.7	-3.2	-2.8	-1.0	1.0	-2.2	-4.3*	-18.7*	-4.6*	-5.0*	-21.4*	-8.1*	-15.6*	-7.5*	-10.4*	-6.0*	-5.6*	-5.7*
NP - C																								
MZ_{α}^{d}	-4.8	-1.9	-0.5	-2.5	-4.0	-1.3	-1.4	-15.6*	-3.6	-1.4	-1.2	0.4	-52.2*	-33.1*	-30.8*	-21.5*	-25.2*	-23.0*	-35.4*	-41.1*	-19.8*	-36.9*	-7.8**	-27.9*
MZ_{t}^{d}	-1.5	-1.0	-0.3	-1.0	-1.4	-0.7	-0.5	-2.8*	-1.2	-0.4	-0.7	0.3	-4.9*	-4.1*	-3.4*	-3.2*	-3.5*	-3.1*	-4.2*	-4.5*	-3.1*	-4.2*	-1.7**	-3.7*
MSB^{d}	0.3	0.5	0.6	0.4	0.4	0.5	0.4	0.2**	0.3	0.3	0.6	0.8	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.2*	0.1*	0.2**	0.1*
MP_{T}^{d}	5.2	12.7	24.3	9.0	6.1	16.1	11.8	1.6*	6.8	9.5	19.2	43.5	0.9*	0.8*	2.2**	1.5*	1.0*	2.2**	0.7*	0.6*	1.2*	0.9*	4.0**	0.9*
NP - C&T																								
MZ_{α}^{d}	-5.3	-3.1	-13.3	-12.3	-6.1	-1.1	-5.6	-16.1***	-7.7	-4.2	-7.0	-9.0	-39.6*	-34.5*	-29.7*	-31.7*	-29.4*	-36.2*	-36.8*	-41.5*	-43.6*	-40.0*	-34.7*	-34.3*
MZ_{t}^{d}	-1.6	-1.2	-2.4	-2.5	-1.6	-0.5	-1.6	-2.8***	-2.0	-1.2	-1.6	-2.1	-4.4*	-4.2*	-3.5*	-3.8*	-3.8*	-4.2*	-4.3*	-4.6*	-4.7*	-4.5*	-4.1*	-4.1*
MSB^{d}	0.3	0.4	0.2	0.2	0.3	0.5	0.3	0.2***	0.3	0.3	0.2	0.2	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*
MP_{T}^{d}	17.0	28.3	8.0	7.4	14.9	47.2	16.2	5.7***	11.8	19.9	13.4	10.3	2.6*	2.6*	4.9**	3.8**	3.1*	3.1*	2.5*	2.2*	2.1*	2.4*	2.7*	2.7*
	Singapore																							
ADF																								
C	-0.8	0.3	0.6	-3.0**	-2.1	-1.8	-1.6	-2.0	-2.0	-1.4	-0.6	-1.2	-3.2**	-3.8*	-3.9*	-3.8*	-5.8*	-5.2*	-10.2*	-9.8*	-9.7*	-7.6*	-10.3*	-4.7*
C&T	-0.8	-0.1	-4.4	-2.3	-2.1	-1.0	-1.8	-1.8	-2.0	-1.4	-2.3	-2.0	-5.2*	-5.8*	-4.3*	-4.9*	-5.9*	-5.6*	-10.1*	-9.7*	-9.7*	-7.7*	-10.5*	-6.6*
PP																								
C	-1.6	-2.1	-0.7	-2.0	-2.5	-8.0*	-1.6	-2.5	-3.6*	-1.6	-2.0	-0.6	-7.3*	-5.6*	-5.2*	-4.6*	-5.9*	-6.2*	-10.2*	-9.8*	-12.6*	-4.0*	-5.1*	-5.8*
C&T	-2.3	-1.6	-3.1	-2.6	-2.4	-5.4*	-1.8	-2.5	-3.6**	-1.8	-3.2	-2.0	-10.2*	-6.3*	-5.3*	-4.5*	-6.0*	-5.7*	-10.1*	-9.7*	-12.5*	-3.9**	-5.0*	-5.8*
NP - C																								
MZ_{α}^{d}	-3.3	-1.7	-0.9	-3.0	-1.5	-0.2	-2.6	-5.5	-4.5	-3.5	1.1	-0.5	-16.2*	-26.6*	-13.4**	-13.2*	-10.2**	-27.2*	-21.8*	-29.3*	-42.2*	-35.5*	-10.5**	-19.8*
MZ_{t}^{d}	-1.2	-0.9	-0.5	-1.2	-0.9	-0.2	-1.1	-1.6	-1.4	-1.3	0.8	-0.2	-2.8*	-3.4*	-2.5**	-2.5*	-2.2**	-3.6*	-3.2*	-3.8*	-4.6*	-4.2*	-2.3**	-3.0*
MSB^{d}	0.4	0.5	0.5	0.4	0.6	1.1	0.4	0.3	0.3	0.4	0.8	0.4	0.2*	0.1*	0.2**	0.2*	0.2**	0.1*	0.1*	0.1*	0.1*	0.1*	0.2**	0.2*
MP_{T}^{d}	7.4	13.4	16.2	8.2	16.0	60.3	9.3	4.5	5.6	7.1	44.2	13.9	1.7*	1.7*	2.3**	2.1*	2.8**	1.0*	1.3*	0.9*	0.6*	0.7*	2.3**	1.7*
NP - C&T																								
MZ_{α}^{d}	-4.8	-2.1	-2.6	-4.9	-1.7	-0.7	-7.2	-5.7	-6.1	-3.8	-7.9	-7.2	-76.3*	-33.8*	-32.5*	-31.2*	-36.7*	-33.9*	-34.1*	-38.3*	-68.5*	-58.2*	-20.5**	-29.4*
MZ_{t}^{d}	-1.5	-0.6	-1.0	-1.5	-0.7	-0.4	-1.8	-1.7	-1.7	-1.4	-2.0	-1.8	-6.2*	-4.0*	-4.0*	-3.9*	-4.2*	-4.1*	-4.1*	-4.4*	-5.9*	-5.4*	-3.1**	-3.8*
MSB^{d}	0.3	0.3	0.4	0.3	0.4	0.5	0.3	0.3	0.3	0.4	0.3	0.3	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.2**	0.1*
MP_{T}^{d}	18.5	25.1	32.7	18.2	40.1	57.8	12.9	15.9	15.0	24.1	11.6	12.7	1.3*	3.5*	2.9*	3.3*	2.8*	2.7*	2.7*	2.4*	1.3	1.6*	5.0**	3.2*

Notes: *, **, *** indicate the test statistic is significant at 1%, 5%, and 10%, respectively; INV is investment, SAV is savings, ID is income distribution, PG is productivity growth, NX is net export, UN is unemployment, SCAP is SME stock market capitalization, STRA is SME stock market traded value, STUR is SME stock market turnover, PTA is the number of patents applications, TMA is the number of trademark applications, HTE is high-technology exports; C represents constant; C&T represents constant and trend; $MZ_{\alpha}^{d}, MZ_{t}^{d}, MSB^{d}$ and MP_{T}^{d} represent the four test statistics of the Ng-Perron unit root test.

Table A2.3: Stationarity Tests of Macroeconomic, SME Stock Market Development and Innovation Indicators (Thailand and Malaysia)

Variables	INV	SAV	ID	PG	NX	UN	SCAP	STRA	STUR	PTA	TMA	HTE	INV	SAV	ID	PG	NX	UN	SCAP	STRA	STUR	PTA	TMA	HTE
	Level 0 [I(0)]												Level 1 [I(1)]											
	Thailand																							
ADF																								
C	-2.5	0.6	-1.4	-3.1**	-1.6	-2.3	-0.2	-2.1	-3.5*	-1.9	-1.3	-1.8	-5.6*	-4.7*	-8.2*	-7.3*	-3.7*	-10.2*	-8.0*	-13.4*	-13.2*	-5.5*	-9.7*	-7.1*
C&T	-2.5	-0.9	-3.0	-3.1	-2.5	-2.2	-1.8	-2.4	-3.6**	-1.6	-1.6	-1.5	-5.6*	-7.2*	-8.3*	-7.3*	-3.7**	-8.5*	-7.9*	-13.3*	-13.2*	-5.5*	-9.7*	-7.2*
PP																								
C	-2.5	0.2	-1.8	-3.4**	-1.5	-3.3**	-0.4	-2.4	-4.4*	-0.8	-1.3	-1.8	-4.0*	-6.4*	-6.2*	-7.0*	-5.9*	-18.0*	-8.0*	-14.8*	-12.9*	-5.6*	-9.7*	-6.2*
C&T	-2.5	-1.4	-3.1	-3.4***	-2.1	-3.2***	-2.0	-2.9	-4.4*	-2.1	-1.6	-1.7	-3.9**	-6.6*	-6.2*	-6.9*	-6.1*	-33.2*	-7.9*	-14.7*	-13.0*	-5.6**	-9.7*	-6.2*
NP - C																								
MZ_{α}^{d}	-2.5	0.9	0.9	-5.2	-3.5	-3.3	0.9	6.3	-2.7	-2.6	0.5	-0.4	-12.1**	-36.3*	-28.9**	-17.6*	-40.0*	-37.2*	-41.4*	-23.6*	-35.4*	-10.8**	-39.5*	-32.5*
MZ_{t}^{d}	-0.8	0.4	1.0	-1.4	-1.3	-1.3	0.7	1.7	-0.6	-1.1	0.5	-0.3	-2.3**	-4.3*	-3.8**	-2.9*	-4.4*	-4.3*	-4.5*	-3.4*	-4.2*	-2.3**	-4.4*	-4.0*
MSB^{d}	0.3	0.5	1.1	0.3	0.4	0.4	0.8	0.3	2.3	0.4	1.0	0.6	0.2**	0.1*	0.1**	0.2*	0.1*	0.1*	0.1*	0.1*	0.1*	0.2**	0.1*	0.1*
MP_{T}^{d}	8.4	20.9	75.9	5.2	7.1	7.3	45.4	5.0	6.5	9.3	67.2	24.1	2.5**	0.7*	0.9**	1.7*	0.7*	0.7*	0.7*	1.1*	0.7*	2.4**	0.7*	0.8*
NP - C&T																								
MZ_{α}^{d}	-8.2	-3.0	-1.9	-11.2	-4.5	-3.4	-7.0	-11.4	-11.5	-7.0	-7.4	-4.6	-23.5**	-39.2*	-35.8*	-22.5**	-39.2*	-36.9*	-41.6*	-38.7*	-37.7*	-21.3**	-42.9*	-35.0*
MZ_{t}^{d}	-2.0	-1.0	-0.9	-2.3	-1.5	-1.2	-1.9	-2.4	-1.3	-1.8	-1.7	-1.5	-3.2**	-4.4*	-4.2*	-3.2**	-4.4*	-4.3*	-4.5*	-4.4*	-4.3*	-3.2**	-4.6*	-4.2*
MSB^{d}	0.2	0.4	0.4	0.2	0.3	0.3	0.3	0.2	1.2	0.3	0.2	0.3	0.1*	0.1*	0.1*	0.1**	0.1*	0.1*	0.1*	0.1*	0.1*	0.2**	0.1*	0.1*
MP_{T}^{d}	11.3	26.4	40.0	8.2	20.4	24.7	13.1	8.0	7.2	13.1	12.6	19.5	5.2**	2.3*	2.6*	5.0**	2.5*	2.5*	2.3*	2.4*	2.4*	4.4**	2.1*	2.6*
	Malaysia																							
ADF																								
C	-1.5	-0.1	-2.3	-4.4*	-2.2	-2.1	-1.5	-1.4	-1.9	-0.6	-0.5	-2.3	-4.1*	-7.8*	-6.3*	-4.5*	-5.0*	-15.1*	-6.3*	-10.8*	-11.3*	-3.5**	-3.6*	-5.0*
C&T	-2.2	-3.0	-2.2	-4.3*	-3.1	-2.0	-1.9	-1.1	-1.7	-1.0	-2.4	-2.6	-4.1*	-7.9*	-6.2*	-4.5*	-5.0*	-15.2*	-6.3*	-10.7*	-11.3*	-3.6**	-3.7**	-3.9**
PP																								
C	-2.2	-0.3	-2.4	-4.2*	-2.3	-3.7*	-2.1	-1.8	-2.5	-0.5	-0.3	-2.4	-4.8*	-7.8*	-6.4*	-7.7*	-5.1*	-17.1*	-9.4*	-10.8*	-15.5*	-10.5*	-11.0*	-5.0*
C&T	-2.5	-2.4	-2.4	-4.2*	-2.7	-3.6**	-2.5	-2.0	-2.9	-1.3	-1.6	-2.2	-4.7*	-7.9*	-6.3*	-7.4*	-5.1*	-17.6*	-9.4*	-10.7*	-16.9*	-10.9*	-11.0*	-4.9*
NP - C																								
MZ_{α}^{d}	0.7	0.3	1.6	-0.1	0.2	-2.7	-4.4	-3.7	-4.5	-2.2	1.1	-1.6	-17.6*	-15.5*	-22.0*	-22.9*	-23.9*	-38.9*	-44.0*	-22.7*	-13.8*	-31.9*	-39.6*	-19.7*
MZ_{t}^{d}	0.7	0.2	1.4	-0.1	0.1	-1.2	-1.5	-1.3	-1.5	-0.8	0.5	-0.7	-2.9*	-2.8*	-3.2*	-3.4*	-3.4*	-4.4*	-4.7*	-3.4*	-2.6*	-4.0*	-4.4*	-3.1*
MSB^{d}	0.9	0.6	0.9	0.7	0.8	0.4	0.3	0.4	0.3	0.3	0.5	0.4	0.2*	0.2**	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.2**	0.1*	0.1*	0.2*
MP_{T}^{d}	58.6	26.4	59.1	29.6	40.7	9.2	5.5	6.6	5.1	9.1	22.0	11.4	1.5*	1.6*	1.6*	1.1*	1.1*	0.6*	0.6*	1.1*	1.8**	0.9*	0.6*	1.2*
NP - C&T																								
MZ_{α}^{d}	-6.1	-5.2	-1.3	-2.5	-7.0	-3.8	-12.4	-4.3	-7.2	-2.4	-7.2	-13.1	-31.7*	-38.4*	-28.4*	-33.1*	-30.9*	-36.8*	-39.8*	-33.9*	-26.7*	-40.8*	-41.5*	-28.4*
MZ_{t}^{d}	-1.7	-1.6	-0.7	-1.1	-1.8	-1.3	-2.3	-1.3	-1.8	-0.7	-1.8	-2.6	-3.9*	-4.3*	-3.5*	-4.0*	-3.9*	-4.3*	-4.5*	-4.1*	-3.6*	-4.5*	-4.5*	-3.7*
MSB^{d}	0.3	0.3	0.6	0.4	0.3	0.3	0.2	0.3	0.3	0.3	0.2	0.2	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*	0.1*
MP_{T}^{d}	14.9	17.3	62.5	36.7	13.1	22.5	8.1	19.7	12.9	25.2	12.9	7.0	3.1*	2.6*	5.0*	3.0*	3.0*	2.5*	2.3*	2.7*	3.5*	2.2*	2.3*	3.5*

Notes: *, **, *** indicate the test statistic is significant at 1%, 5%, and 10%, respectively; INV is investment, SAV is savings, ID is income distribution, PG is productivity growth, NX is net export, UN is unemployment, SCAP is SME stock market capitalization, STRA is SME stock market traded value, STUR is SME stock market turnover, PTA is the number of patents applications, TMA is the number of trademark applications, HTE is high-technology exports; C represents constant; C&T represents constant and trend; $MZ_{\alpha}^{d}, MZ_{t}^{d}, MSB^{d}$ and MP_{T}^{d} represent the four test statistics of the Ng-Perron unit root test.

Appendix 3: Lag Order Selection Criteria and Johansen Cointegration Rank Test

Table A3.1: Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
			Hong Kong			
0	1,867.87	NA	3.80E-27	-43.81	-43.64*	-43.74
1	1,935.06	123.31	1.83E-27	-44.54	-43.34	-44.06*
2	1,969.90	59.01	1.90E-27	-44.52	-42.27	-43.61
3	2,033.21	98.32	1.03E-27	-45.16	-41.88	-43.84
4	2,081.83	68.64*	8.15e-28*	-45.45*	-41.14	-43.72
			Singapore			
0	2,023.79	NA	5.50E-29	-48.04	-47.87*	-47.97
1	2,085.97	114.00	2.96E-29	-48.67	-47.45	-48.18
2	2,099.70	23.21	5.09E-29	-48.14	-45.88	-47.23
3	2,234.40	208.46	5.01E-30	-50.49	-47.19	-49.16*
4	2,274.94	56.95*	4.80e-30*	-50.59*	-46.25	-48.85
			Thailand			
0	1,911.60	NA	7.95E-28	-45.37	-45.20*	-45.30*
1	1,960.35	89.38	5.89E-28	-45.67	-44.46	-45.19
2	1,980.77	34.51	8.64E-28	-45.30	-43.05	-44.40
3	2,055.11	115.06	3.58E-28	-46.22	-42.92	-44.89
4	2,104.27	69.05*	2.79e-28*	-46.53*	-42.19	-44.79
			Malaysia			
0	1,977.41	NA	1.66E-28	-46.94	-46.76*	-46.87
1	2,050.80	134.54	6.83E-29	-47.83	-46.61	-47.34*
2	2,078.23	46.38	8.48E-29	-47.62	-45.37	-46.72
3	2,134.54	87.14*	5.41e-29*	-48.11*	-44.81	-46.78

Notes: * indicates lag order selected by the criterion; LogL is log-likelihood; LR is sequentially modified likelihood ratio test statistic (each test at 5% level); FPE is Final Prediction Error; AIC is Akaike Information Criterion; SIC is Schwarz Information Criterion; HQ is Hannan-Quinn Information Criterion.

Table A3. 2: Johansen Cointegration Rank Test

Hypothesized	Hong Kong		Singapore		Thailand		Malaysia	
No. of Cointegrating Equation(s)	Trace Statistic	Max-Eigen Statistic	Trace Statistic	Max-Eigen Statistic	Trace Statistic	Max-Eigen Statistic	Trace Statistic	Max-Eigen Statistic
None	417.55*	86.98*	438.02*	125.04*	430.93*	144.48*	375.56*	97.86*
At most 1	330.57*	74.33*	312.97*	92.66*	286.45*	78.10*	277.70*	72.50*
At most 2	256.24*	64.14**	220.31*	65.71*	208.35*	57.82*	205.20*	65.68*
At most 3	192.10*	58.75*	154.61*	51.97	150.53*	55.32*	139.53*	44.18
At most 4	133.34	37.70	102.64	33.21	95.21	35.95	95.35	40.78
At most 5	95.64	34.28	69.43	24.96	59.26	22.39	54.56	21.55
At most 6	61.36	26.80	44.46	18.46	36.87	18.06	33.01	14.70
At most 7	34.56	14.68	26.01	14.55	18.81	14.35	18.31	9.37
At most 8	19.87	14.17	11.46	11.30	4.46	3.77	8.94	5.24
At most 9	5.70	5.52	0.15	0.15	0.68	0.68	3.69	3.69
At most 10	0.18	0.18	-	-	-	-	-	-

Notes: *, ** indicate that the test statistic is significant at 1% and 5%, respectively.

Appendix 4: SVEC Matrices Estimation (Short-Run Restrictions)

Hong Kong	INV	SAV	ID	PG	NX	UN	$SCAP$	$STRA$	$STUR$	TMA	HTE
INV	0.0019	0	0	0	0	0	0	0	0	0	0
SAV	0.0015	0.0052	0	0	0	0	0	0	0	0	0
ID	0.0010	0.0006	0.0024	0	0	0	0	0	0	0	0
PG	0.0026	0.0014	0.0023	0.0053	0	0	0	0	0	0	0
NX	0.0097	−0.0041	0.0117	0.0055	0.0188	0	0	0	0	0	0
UN	0.0000	−0.0001	0.0000	0.0000	0.0002	0.0004	0	0	0	0	0
$SCAP$	0.0102	0.0161	0.0091	−0.0037	0.0076	0.0078	0.0525	0	0	0	0
$STRA$	0.0047	0.0041	0.0038	0.0002	0.0021	0.0002	0.0113	0.0094	0	0	0
$STUR$	0.0023	0.0047	−0.0016	0.0000	0.0018	−0.0004	0.0058	0.0098	0.0030	0	0
TMA	0.0000	0.0005	−0.0006	0.0004	0.0012	0.0004	0.0003	0.0014	0.0005	0.0015	0
HTE	0.00002	0.0000	0.00003	0.0000	0.0000	−0.00002	0.00002	0.0000	0.00002	0.0000	0.0001

Singapore	INV	SAV	ID	PG	NX	UN	$SCAP$	$STRA$	$STUR$	PTA
INV	0.0018	0	0	0	0	0	0	0	0	0
SAV	0.0007	0.0023	0	0	0	0	0	0	0	0
ID	0.0009	0.0000	0.0026	0	0	0	0	0	0	0
PG	0.0029	0.0028	0.0006	0.0065	0	0	0	0	0	0
NX	−0.0002	−0.0008	0.0017	−0.0005	0.0060	0	0	0	0	0
UN	−0.0001	0.0000	0.0000	−0.0001	0.0000	0.0002	0	0	0	0
$SCAP$	0.0041	0.0030	0.0031	0.0008	0.0006	−0.0021	0.0076	0	0	0
$STRA$	0.0026	−0.0004	0.0018	−0.0005	0.0000	−0.0021	0.0025	0.0044	0	0
$STUR$	0.0101	−0.0020	0.0089	−0.0024	0.0001	−0.0073	0.0058	0.0186	0.0042	0
PTA	0.0000	0.0002	0.0000	0.0001	−0.0001	−0.0001	0.0000	0.0001	0.0001	0.0003

Thailand	INV	SAV	ID	PG	NX	UN	$SCAP$	$STRA$	$STUR$	TMA
INV	0.0011	0	0	0	0	0	0	0	0	0
SAV	0.0018	0.0026	0	0	0	0	0	0	0	0
ID	0.0027	−0.0027	0.0037	0	0	0	0	0	0	0
PG	0.0060	−0.0011	0.0049	0.0105	0	0	0	0	0	0
NX	0.0017	−0.0013	0.0022	−0.0001	0.0057	0	0	0	0	0
UN	0.0001	0.0001	0.0003	0.0000	0.0001	0.0008	0	0	0	0
$SCAP$	−0.0013	−0.0002	0.0012	−0.0014	−0.0012	−0.0004	0.0087	0	0	0
$STRA$	0.0006	−0.0015	0.0001	0.0008	0.0005	−0.0012	0.0118	0.0063	0	0
$STUR$	0.0062	−0.0080	0.0062	0.0002	0.0108	−0.0092	0.0566	0.0243	0.0214	0
TMA	0.0000	0.0003	0.0001	0.0000	0.0000	−0.0001	0.0000	0.0002	0.0001	0.0010

Malaysia	INV	SAV	ID	PG	NX	UN	$STRA$	$STUR$	PTA	TMA
INV	0.0016	0	0	0	0	0	0	0	0	0
SAV	0.0007	0.0025	0	0	0	0	0	0	0	0
ID	0.0006	−0.0014	0.0042	0	0	0	0	0	0	0
PG	−0.0004	−0.0018	0.0036	0.0122	0	0	0	0	0	0
NX	−0.0002	0.0008	0.0018	0.0009	0.0039	0	0	0	0	0
UN	0.0000	−0.0002	0.0000	0.0004	0.0002	0.0012	0	0	0	0
$STRA$	0.0003	0.0009	0.0005	0.0005	0.0010	−0.0010	0.0040	0	0	0
$STUR$	0.0041	0.0076	0.0036	0.0011	0.0090	−0.0045	0.0350	0.0096	0	0
PTA	−0.0001	−0.0001	0.0001	0.0003	−0.0001	0.0000	0.0000	0.0001	0.0003	0
TMA	0.0005	−0.0003	0.0005	0.0012	0.0004	0.0002	0.0003	0.0002	0.0013	0.0006

Notes: Grey highlights indicate the parameter is statistically significant at least at 10%; INV is investment, SAV is savings, ID is income distribution, PG is productivity growth, NX is net export, UN is unemployment, SCAP is SME stock market capitalization, STRA is SME stock market traded value, STUR is SME stock market turnover, PTA is the number of patent applications, TMA is the number of trademark applications, HTE is high-technology exports.